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

# HFTO Hydrogen Production Overview


## David Peterson, HFTO – Hydrogen Production Program Manager


2023 Annual Merit Review and Peer Evaluation Meeting

June 6, 2023 – Arlington, VA

# The Hydrogen and Fuel Cell Technologies Office (HFTO)

**Mission**

Support research, development and demonstration (RD&D) of hydrogen and fuel cell technologies to advance:

- Clean Energy and Emissions Reduction Across Sectors
- Job Creation and a Sustainable and Equitable Energy Future

## Office Sub-Programs

### Hydrogen Technologies

- Hydrogen Production
- Hydrogen Infrastructure

### Fuel Cell Technologies

- Materials & Components
- Systems

### Systems Development & Integration

- Transportation
- Industrial and Chemical Applications
- Grid Energy Storage and Power Generation

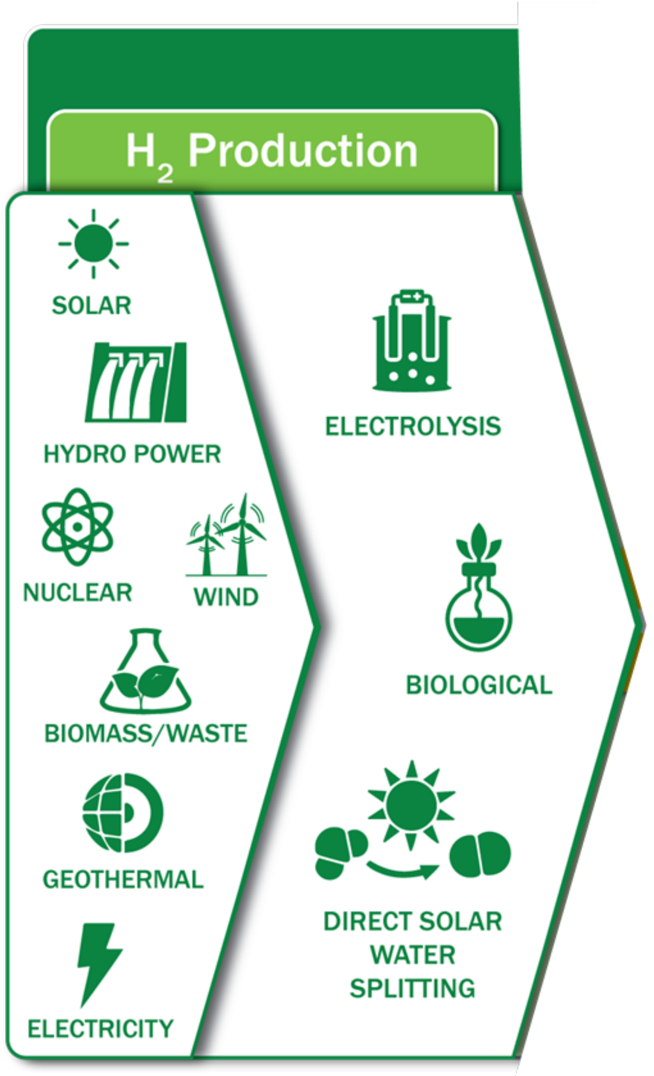
**Data, Modeling, Analysis, Safety, Codes and Standards**

***Enabling***

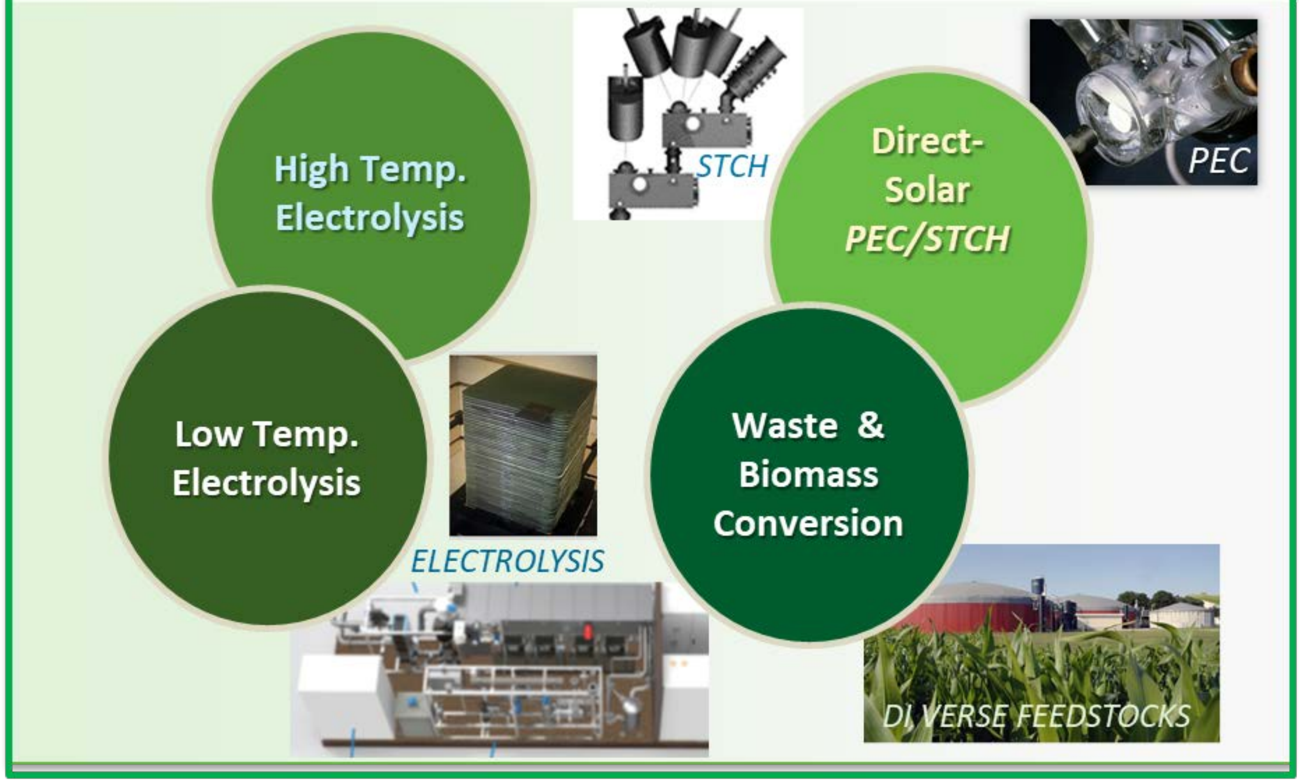
Energy earthshots U.S. Department of Energy | Hydrogen

H2@Scale U.S. Department of Energy

# Hydrogen Production Program Overview




| Near- to Mid-Term | Longer-Term |
| --- | --- |
| ▪ *Water splitting through low- and high-temperature electrolysis leveraging renewable energy resources* | ▪ *Microbial-based conversion of bio- and waste-stream feedstocks*<br>▪ *Direct solar water-splitting* |




***Focus on hydrogen production pathways that utilize renewable/clean resources***

# Alignment with DOE Draft National Strategy and Roadmap

| | 2022-2025 | | 2026-2029 | | 2030-2035 |
|---|---|---|---|---|---|
| **Clean Hydrogen Production** | Catalyze RD&D in electrolysis, thermal conversion, & new pathways to meet Hydrogen Shot | Demonstrate replicable, scalable production from renewables, nuclear, & fossil and waste with CCS | Deploy gigawatt-scale electrolyzers and develop domestic supply chains | Scale up electrolyzer manufacturing and recycling/reuse capacity | Achieve 10 MMT production capacity and $1/kg target |
| **Delivery and Storage Infrastructure** | Identify and prioritize barriers to infrastructure roll out | Initiate supporting infrastructure for regional hubs | Demonstrate advanced and efficient infrastructure components | Develop sustainable regional clean hydrogen networks | Deliver hydrogen at scale |
| **End Uses and Market Adoption** | Engage regulators to lay groundwork for strategic adoption across sectors | Initiate transition for hard to decarbonize industries | Deploy at least four regional clean hydrogen hubs | Deploy technologies that lower pollution and provide resiliency | Scale up hydrogen hubs and prepare export opportunities |
| **Enablers** | Engage stakeholders; address safety codes and standards; develop critical supply chains | Use and expand workforce, talent pools, and apprenticeship programs | Ensure 40% of benefits accrue to disadvantaged communities in hub regions | Demonstrate business cases and activate private capital | Achieve Justice 40, create good-paying jobs, and ensure public health and safety |

# Hydrogen Eligible for $4 billion in Manufacturing Tax Credits

## What is 48C?

- Competitively-awarded Investment Tax Credit (ITC) established in 2009 with $2.3B
- Expanded by IRA with $10B available
- Projects receive up to 30% investment tax credit
- DOE will accept a first round of applications in 2023 to allocate up to $4B
- Approximately 40% of credits ($1.6B) will be allocated to projects in coal communities

- Clean Energy Manufacturing and Recycling
- Critical Materials Process, Refining, and Recycling
- Industrial GHG Emissions Reductions

## Timeline & Review

**Notice Released:** May 31

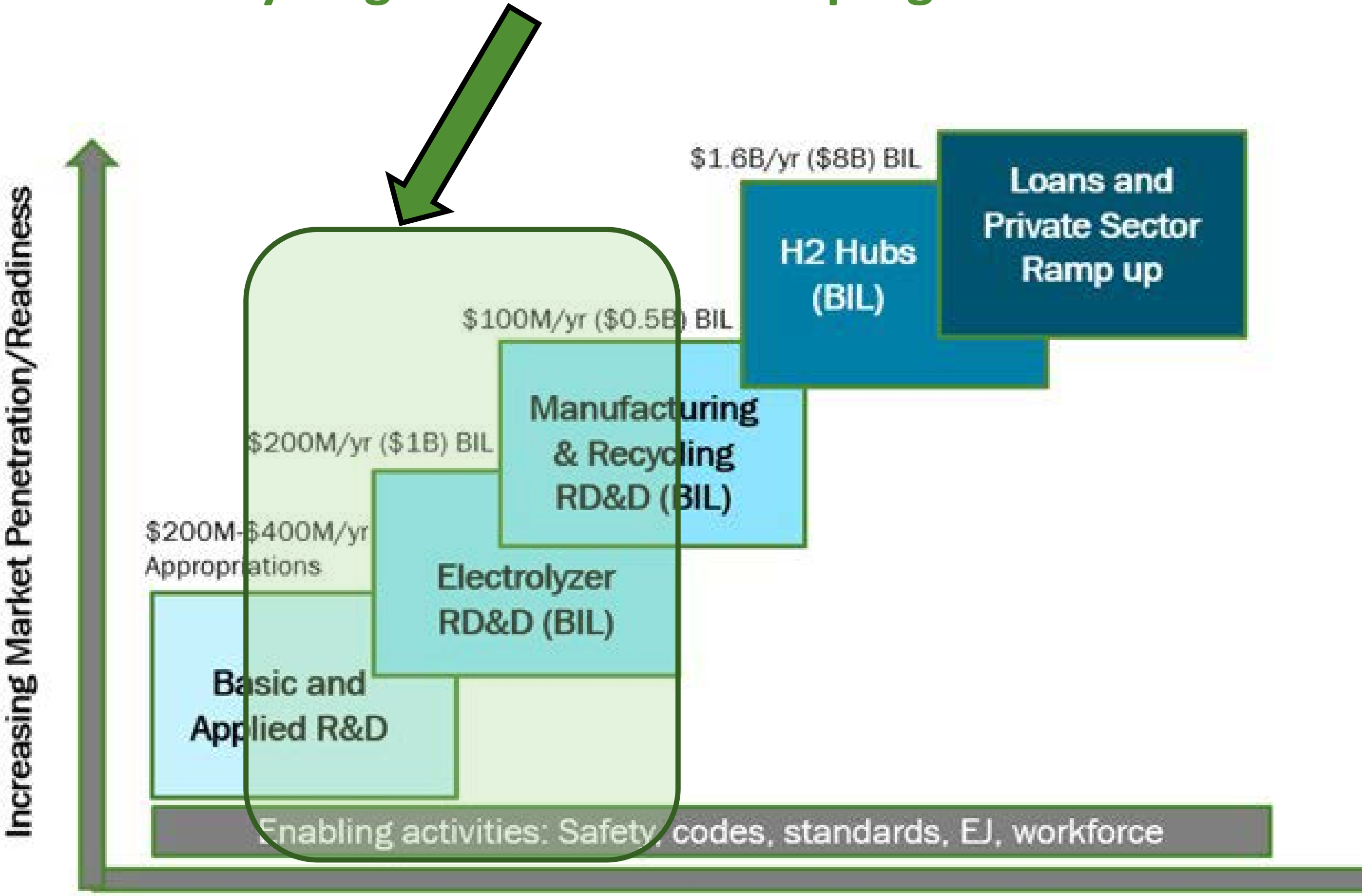
**Informational Webinar:** June 27

**Concept Papers Due:** July 31

**Full Applications Due:** Fall 2023

# Alignment with Hydrogen Program RDD&D Portfolio

## HFTO Hydrogen Production Subprogram




Funding shown is for DOE-Wide H2 Program

### Core Activities

- Advanced, clean hydrogen production pathways
- Techno-economic analysis
- Hydrogen Shot Incubator Prize
- Consortia

### BIL/IRA Activities

- Clean Hydrogen Electrolysis Program
- Clean Hydrogen Manufacturing and Recycling Program
- Consortia
- BIL FOA and Lab Call
- Multi-MW scale electrolyzer system testing and validation

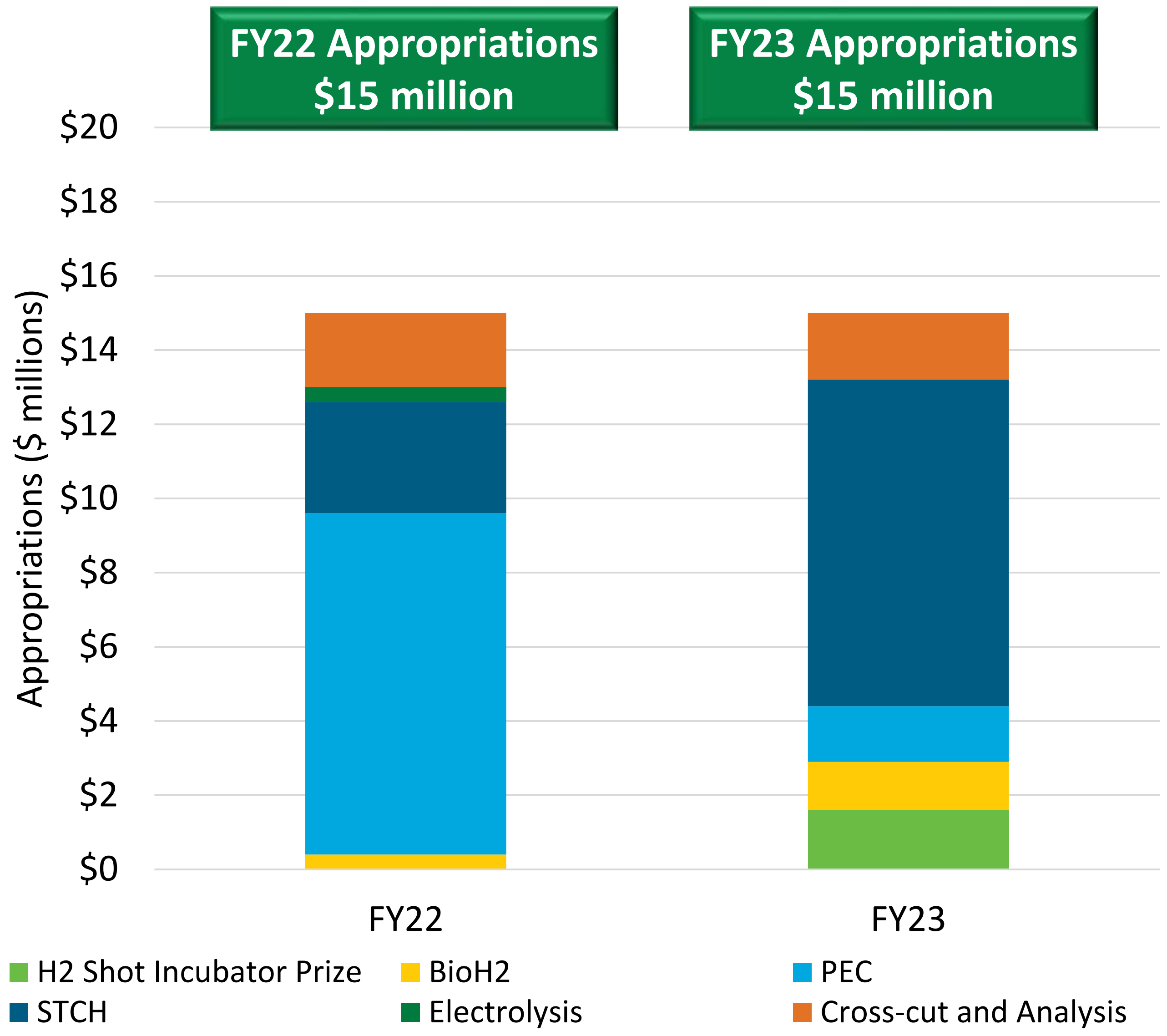
# Clean Hydrogen Electrolysis Program: BIL Sec. 40314 (EPACT Sec. 816)

**$1,000,000,000 over 5 years (fiscal years 2022 through 2026)**

| | |
|---|---|
| **Goal:** | Reduce and validate the cost of hydrogen produced using electrolyzers* to **less than $2 per kilogram** of clean hydrogen by 2026 |
| **Program Description:** | Establish a **research, development, demonstration, commercialization**, and **deployment** program<br>for purposes of commercialization to **improve the efficiency**, **increase the durability**, and **reduce the cost** of producing clean hydrogen using electrolyzers. |

*The term 'electrolyzer' means a system that produces hydrogen using electrolysis. The term 'electrolysis' means a process that uses electricity to split water into hydrogen and oxygen.

# Hydrogen Production Core Budget*




## Program Direction

**H2 Production**

- Direct Water Splitting
  - PEC and STCH
- Biological hydrogen production
- H2 Shot Incubator Prize
- All electrolysis work is being supported under the BIL Sect. 816 Clean Hydrogen Electrolysis Program as well as Sect. 815 Clean Hydrogen Manufacturing and Recycling Program

**FY24 Request**
**$15 million**

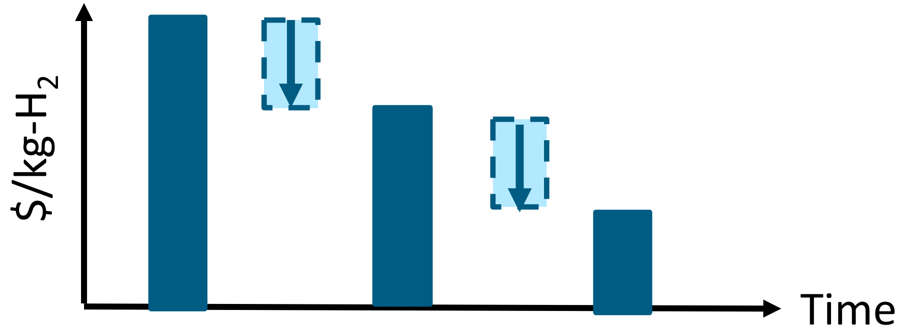
**Clean $H_2$ Electrolysis Program**
**$200 M/yr over 5 yrs**

**Core budget complements BIL funding*

# $H_2$ Production: RD&D Strategy/Approach

## Metrics-Driven RDD&D Approach

*Technoeconomic analyses to guide priorities, track progress, & set targets*




| *Example: H2NEW Electrolyzer Stack Goals (2026)* | | |
|---|---|---|
| | PEM | HTE |
| Capital Cost | $100/kW | $125/kW |
| Performance | 3 A/cm$^2$ @ 1.8 V | 1.2 A/cm$^2$ @ 1.28 V |
| Lifetime | 80,000 hr | 40,000 hr |

*https://www.energy.gov/eere/fuelcells/hydrogen-production-related-links#targets*

**Stakeholder Engagement:** *Provides feedback to inform strategy; Includes Workshops, RFIs, Consortia Stakeholder Advisory Boards*

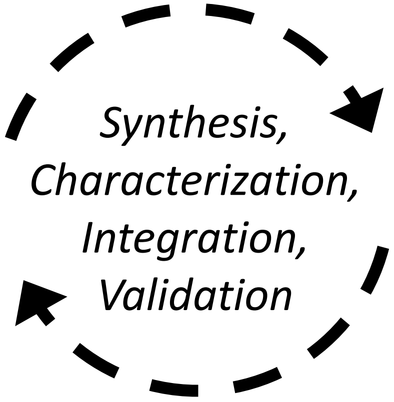
## Consortia Model for Enhanced Collaboration

*Leverage world-class national lab expertise & facilities with…*

H2NEW U.S. DEPARTMENT OF ENERGY

ElectroCat Electrocatalysis Consortium

HydroGEN Advanced Water Splitting Materials




Industry
Universities
(FOAs)

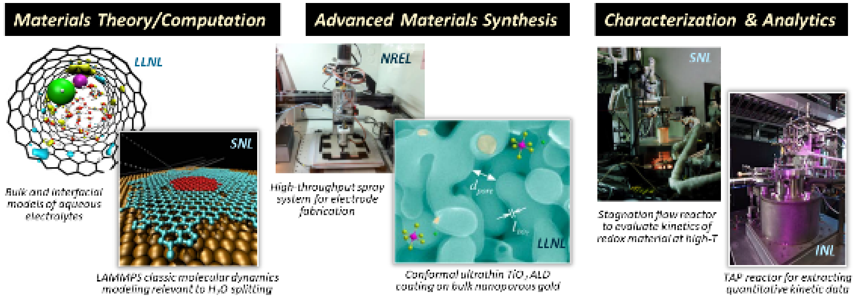
*…an influx of new ideas and partners*

# $H_2$ Production: Consortia-Supported RD&D

HydroGEN
Advanced Water Splitting Materials

**Materials development for:**

- Photoelectrochemical (PEC)
- Solar thermochemical (STCH)
- High-temperature electrolysis (HTE)
- Low-temperature electrolysis (LTE)

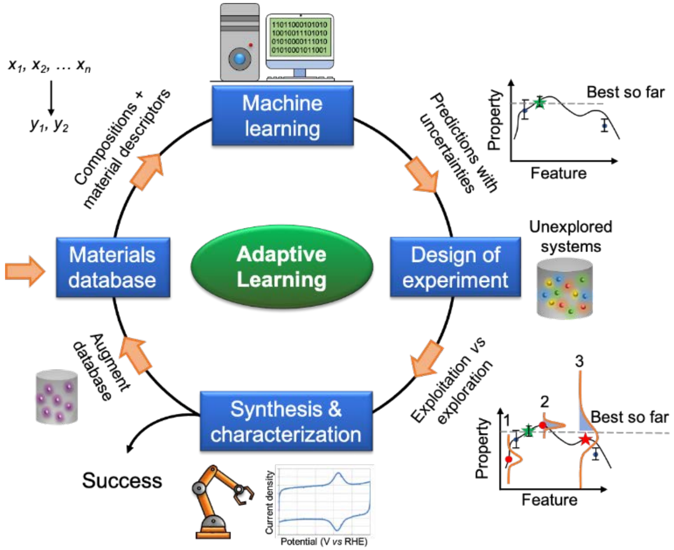



**https://h2awsm.org/**

Presentation: P148 (Tuesday, 9:30am)
Posters: P148A-E (Tuesday)

ElectroCat
Electrocatalysis Consortium

**PGM-free catalyst development for LTE**



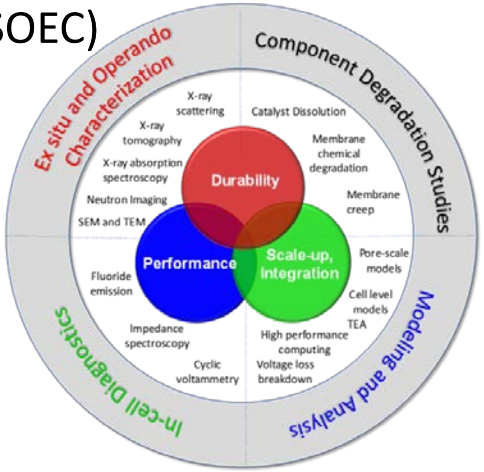

**http://www.electrocat.org**

Presentation: FC160 (Tues., 9:30 am)

H2NEW
U.S. DEPARTMENT OF ENERGY

**Component integration, accelerated stress test development for:**

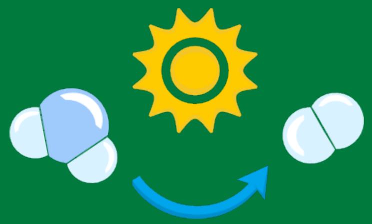
- Proton exchange membrane (PEM)
- Liquid alkaline (LA)
- Oxide ion-conducting solid oxide (O-SOEC)




**https://h2new.energy.gov/**

Presentation: P196 (Tuesday, 1:45pm)
Posters: P196A-H (Tuesday)

# Hydrogen Production
# Advanced Pathways



# New Direct Solar Water Splitting PEC & STCH Projects

HydroGEN Advanced Water Splitting Materials

## DE-FOA-0002792 "Funding Opportunity in Support of the Hydrogen Shot and a University Research Consortium on Grid Resilience"
## Topic 1: HydroGEN: Solar Fuels from Photoelectrochemical and Solar Thermochemical Water Splitting

| | Selectee | Project Title | PI | Total Award Amount | Total DOE Share | Recipient Cost Share |
|---|---|---|---|---|---|---|
| PEC | **University of Michigan** | Gallium Nitride (GaN) Protected Tandem Photoelectrodes for High Efficiency, Low cost, and Stable Solar Water Splitting | Zetian Mi | $1,250,000 | $1,000,000 | $250,000 |
| PEC | **Yale University** | >200 cm2 Type-3 PEC Water Splitting Prototype Using Bandgap-Tunable Perovskite Tandem and Molecular-Scale Designer Coatings | Shu Hu | $1,250,086 | $1,000,000 | $250,086 |
| PEC | **California Institute of Technology** | Demonstration of a Robust, Compact Photoelectrochemical (PEC) Hydrogen Generator | Joel A. Haber | $1,250,000 | $1,000,000 | $250,000 |
| PEC | **University of Hawaii** | Semi-Monolithic Devices for Photoelectrochemical Hydrogen Production | Nicolas Gaillard | $1,250,000 | $1,000,000 | $250,000 |
| PEC | **Rice University** | Scalable halide perovskite photoelectrochemical cell mini modules with 20% solar-to-hydrogen efficiency and 1000 hours of diurnal durability | Aditya D. Mohite | $1,180,307 | $937,242 | $243,065 |
| PEC | **The University of Toledo** | All-Perovskite Tandem Photoelectrodes for Low-Cost Solar Hydrogen Fuel Production from Water Splitting | Yanfa Yan | $1,250,000 | $1,000,000 | $250,000 |
| STCH | **University of Colorado** | Non-intermittent, Solar-thermal Processing to Split Water Continuously via a Near-isothermal, Pressure-Swing Redox Cycle | Alan W. Weimer | $1,250,000 | $1,000,000 | $250,000 |
| STCH | **University of Colorado** | Accelerated Discovery and Development of Perovskites for Solar | Charles Musgrave | $1,250,000 | $1,000,000 | $250,000 |
| STCH | **Arizona Sate University** | Inverse Design of Perovskite Materials for Solar Thermochemical Water | Christopher Muhich | $1,250,000 | $1,000,000 | $250,000 |
| STCH | **The Washington University** | Ca-Ce-Ti-Mn-O-Based Perovskites for Two-Step Solar Thermochemical Hydrogen Production Cycles | Robert B. Wexler | $1,248,860 | $998,860 | $250,000 |
| STCH | **Saint-Gobain** | Scalable Solar Fuels Production in A Reactor Train System by Thermochemical Redox Cycling of Novel Nonstoichiometric Perovskites | Xin Qian | $1,250,079 | $999,997 | $250,082 |

***Projects will be part of the HydroGEN Consortium and have access to national lab expertise***

# New Awards in PGM-free Catalyst & Electrodes for Electrolyzers & Fuel Cells

**DE-FOA-0002598 FOA (Joint with FECM), "University Training and Research for Fossil Energy and Carbon Management – Minority Serving Institutions (MSIs). AOI 6 – PGM-free Catalyst and Electrodes for Fuel Cells and Electrolyzers**

| Selectee | Project Title | PI | Total Award Amount | Total DOE Share | Recipient Cost Share |
|---|---|---|---|---|---|
| **University of Texas, El Paso** | Metal-Organic Framework-Based Heterostructure Electrocatalysts With Tailored Electron Density Distribution For Cost-Effective And Durable Fuel Cells And Electrolyzers | Sreeprasad Sreenivasan | $300,000 | $300,000 | $0 |
| **University of California, Riverside** | Single-Walled Carbon Nanotubes with Confined Chalcogens as the Catalysts and Electrodes for Oxygen Reduction Reaction in Fuel Cells | Juchen Guo | $300,000 | $300,000 | $0 |

ElectroCat
Electrocatalysis Consortium

***Projects will be part of the ElectroCat Consortium and have access to national lab expertise***

# Hydrogen Shot Incubator Prize


Prize winners from the Propose! Phase are working on their innovative technologies and applications for the Prove! Phase are due August 1st

Incentivize development of **innovative off-roadmap technologies** with the potential to produce clean hydrogen at **$1/kg in one decade**

Break down barriers for inventors and researchers and accelerate progress by complementing traditional FOA process

Provide access to the national labs through vouchers

## For more information on the winners visit: www.herox.com/HydrogenShotPrize

# Benchmarking and Protocol Development for AWS Technologies

**P170**
**Wed. 4:45**

***Goal:* Develop best practices in materials characterization and benchmarking: Critical to accelerate materials discovery, development, validation, and adoption**

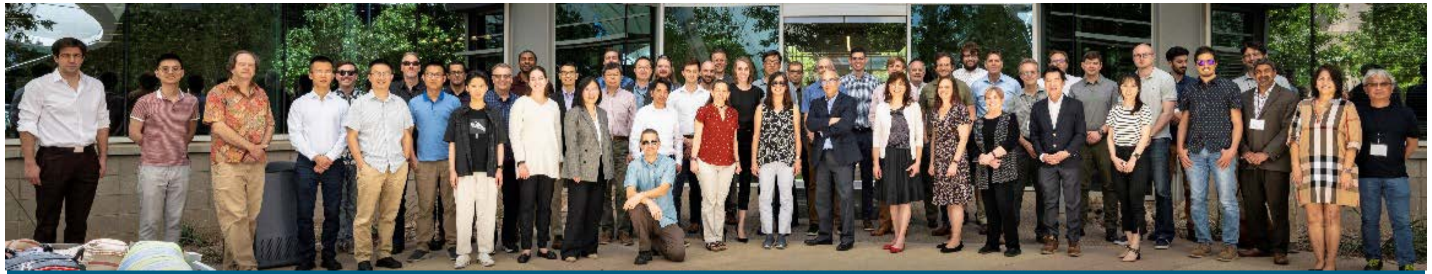
## Best Practices in Materials Characterization

Kathy Ayers, Nel Hydrogen (LTE)
Ellen B. Stechel, ASU (STCH)
Olga Marina, PNNL (HTE)
CX Xiang, Caltech (PEC)
Consultant: Karl Gross, George Roberts

- Strong community engagement and participation, nationally and internationally
  - Participation from both HydroGEN and H2NEW consortia
- Disseminated information to AWS community via HydroGEN Data Hub, website, SharePoint site, email, quarterly newsletters, workshops

## 5th Annual HydroGEN Advanced Water Splitting Technology Pathways Benchmarking and Protocols Workshop

**Date:** Thursday September 21 - Friday September 22, 2023
**Location:** ASU Scottsdale Innovation Center Scottsdale, AZ USA

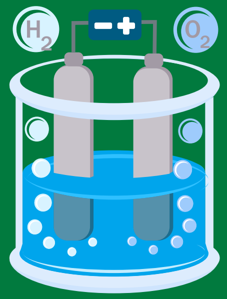


## Accomplishments:

- **19 standardized measurement protocols and benchmarks published in open-access journal Frontiers in Energy Research special issue: free to download: https://www.frontiersin.org/research-topics/16823/advanced-water-splitting-technologies-development-best-practices-and-protocols#articles**
  - **7 LTE, 4 HTE, 5 PEC, 3 STCH**
  - **4,912 total downloads and 36,000 views**
- **4 Annual AWS community-wide benchmarking workshop**
- **Developed high-level roadmaps by AWS technology**

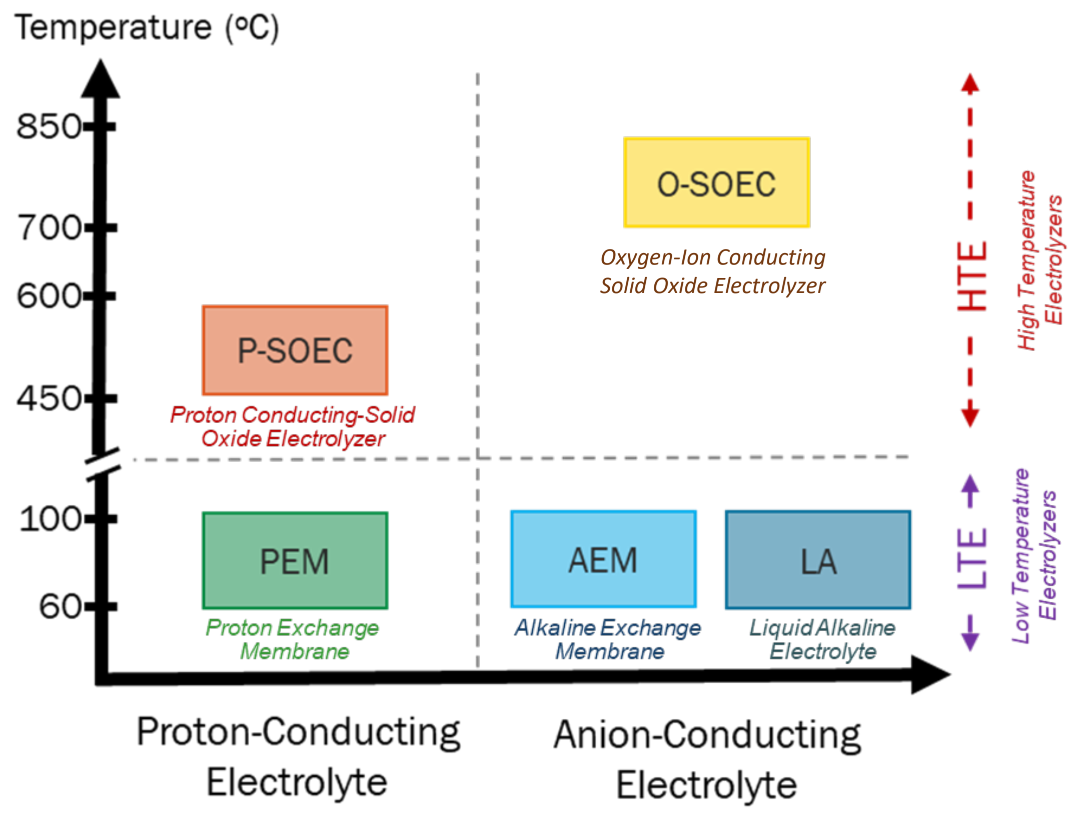
# Hydrogen Production

# Electrolysis



# Support of Diverse Electrolyzer Types

- Multiple electrolyzer types have potential to meet cost and technical targets
- Each technology has advantages and drawbacks with unique benefits and pathways to achieve $H_2$ production cost goals
- Electrolyzers are at different TRLs and supported accordingly
- To meet cost targets, need combination of close integration of electrolyzers with low-cost, clean electricity sources; high-volume manufacturing; and technology advancements




**BIL 815/816 FOA is addressing this overall approach**

# A Multi-Staged Approach to Electrolyzer Technology Progression

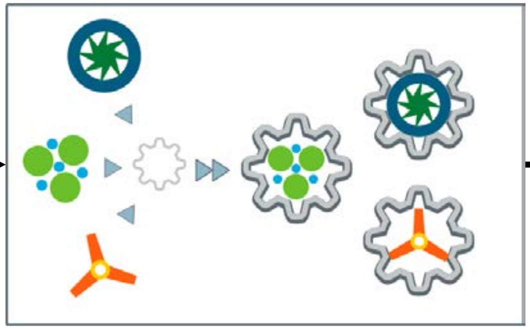
**Recycling & Reuse**

*Section 815: PGM, ionomer reclamation and recycling*

Advanced **Materials**

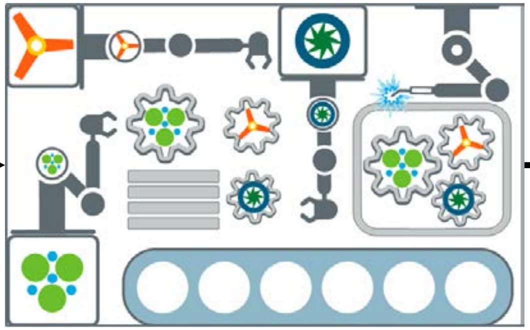
*Improved electrocatalysts, catalyst supports, electrolytes, etc.*

Advanced **Components**



*Overcome performance/durability barriers through components and integration*

**Manufacturing** Scale-up



*High-volume production of MW-scale electrolyzers and components*

**System Development, Demonstration**

*Optimized BOP components, electrolyzer validation*

HydroGEN Advanced Water Splitting Materials

ElectroCat Electrocatalysis Consortium

H2NEW Hydrogen from Next-generation Electrolyzers of Water
U.S. DEPARTMENT OF ENERGY

**Industry-led Activities**

**Leverages established R&D Consortia & includes development across complete lifecycle of electrolyzers**

# Analysis Efforts Identify Cost Reduction Strategies and Pathways to Achieve Cost Targets

## Hydrogen Production Cost Targets

| | | |
|---|---|---|
| Clean $H_2$ Electrolysis Program | 2026 | \$2/kg $H_2$ |
| Hydrogen Shot | 2031 | \$1/kg $H_2$ |

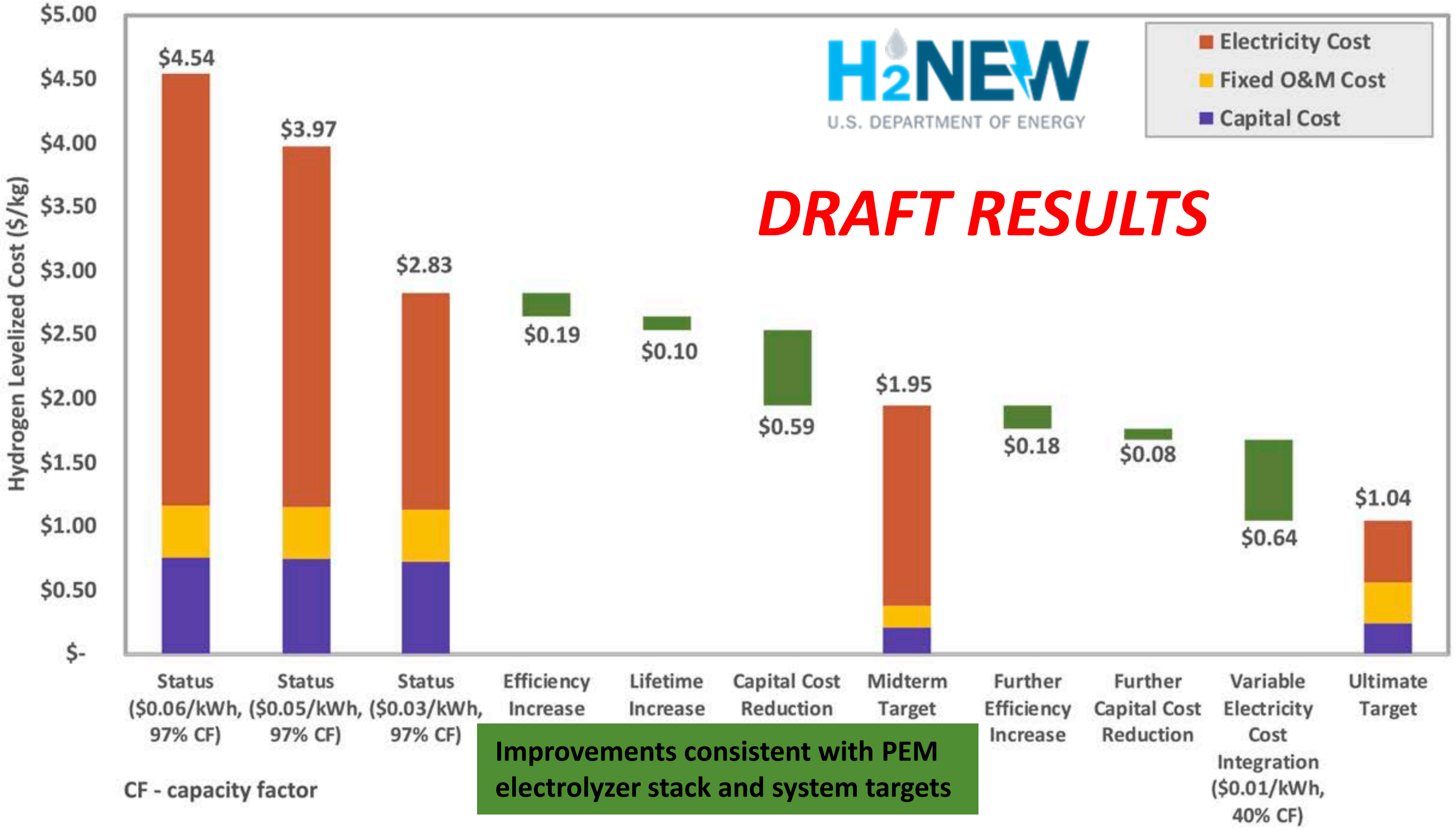
### Key Cost Drivers for Clean Hydrogen Production

**Manufacturing Throughput**
- Automation
- Increased line speed
- Quality assurance/ quality control

**Electrolyzer Properties**
- System lifetime
- System efficiency
- Material and equipment costs

**Energy System Integration**
- Integration with clean energy sources
- Electricity price
- Capacity factor
- Installation costs

### <u>One</u> pathway to achieve cost targets via PEM electrolysis

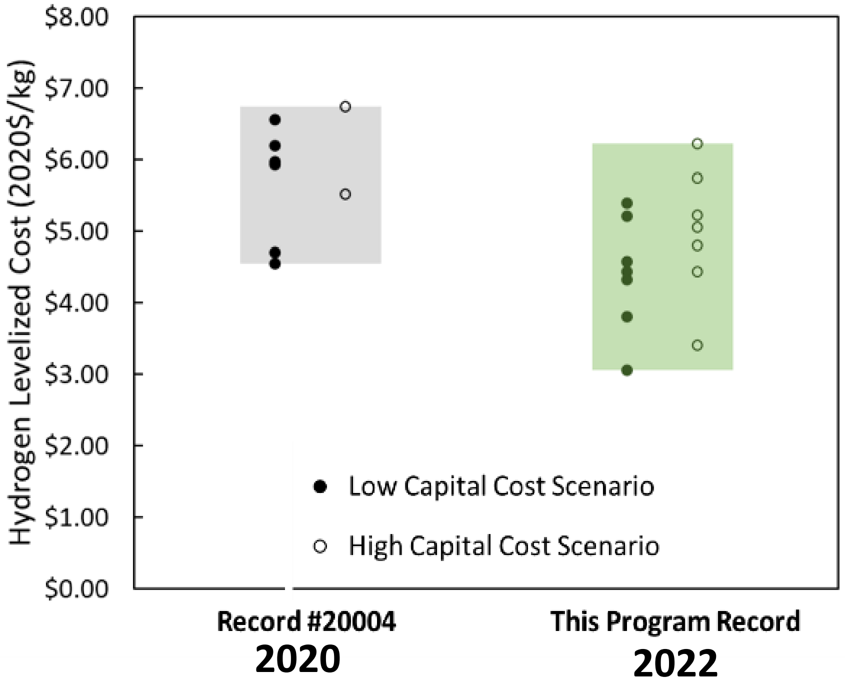



**Achieving economies-of-scale will not alone meet cost targets - RD&D of next-generation, advanced technologies and integrated systems with low-cost, clean electricity are also needed**

# Tracking Progress in Clean $H_2$ Production Cost

- Continual tracking of key parameters (capital cost, lifetime, performance/efficiency, and O&M costs)
- Vetted by electrolyzer OEMs
- Current cost of $H_2$ from PEM electrolyzers is ~$4 – 6/kg* for a range of renewable energy scenarios
- Ongoing efforts to document cost of $H_2$ from other electrolyzer types (LA, AEM, O-SOEC, P-SOEC)

| Scenario | Electricity Price[c] (¢/kWh) | Capacity Factor[d] (%) | $H_2$ Cost[e] ($/kg) Electrolyzer Capital Cost[f] $1,000/kW | $1,300/kW |
|---|---|---|---|---|
| **U.S. Grid Electricity** | | | | |
| Grid – Low Case | 5.5 | 97% | 4.44 | 4.81 |
| Grid – Average Case | 7.2 | 97% | 5.39 | 5.75 |
| **Regional Clean Electricity** | | | | |
| Utility-Scale PV, Class 1 | 2.6 | 30% | 5.21 | 6.23 |
| Land-based Wind, Class 1 | 2.5 | 49% | 3.80 | 4.44 |
| Hydropower | 4.0 | 50% | 4.58 | 5.22 |
| Nuclear Power *fully amortized* | 3.0 | 97% | 3.05 | 3.41 |




*DOE Hydrogen Program Record #23001, "Hydrogen Production Cost with Current PEM Electrolyzer Technology – 2022",*
*To be published at* [https://www.hydrogen.energy.gov/program_records.html](https://www.hydrogen.energy.gov/program_records.html)

**as low as $3/kg for some nuclear cases*

# Updated Electrolyzer Technical Targets

**Technical targets for stack and system for PEM,LA, and HTE:**

https://www.energy.gov/eere/fuelcells/hydrogen-production-related-links#targets

## PEM Electrolyzer Stacks & Systems

| CHARACTERISTIC | UNITS | 2022 STATUS[c] | 2026 TARGETS | ULTIMATE TARGETS |
|---|---|---|---|---|
| **Stack** | | | | |
| Total Platinum Group Metal Content (both electrodes combined)[d] | mg/cm$^2$ | 3.0 | 0.5 | 0.125 |
| | g/kW | 0.8 | 0.1 | 0.03 |
| Performance | | 2.0 A/cm2 @ 1.9 V/cell | 3.0 A/cm2 @ 1.8 V/cell | 3.0 A/cm2 @ 1.6 V/cell |
| Electrical Efficiency[e] | kWh/kg $H_2$ (% LHV) | 51 (65%) | 48 (69%) | 43 (77%) |
| Average Degradation Rate[f] | mV/kh (%/1,000 h) | 4.8 (0.25) | 2.3 (0.13) | 2.0 (0.13) |
| Lifetime[g] | Operation h | 40,000 | 80,000 | 80,000 |
| Capital Cost[h] | $/kW | 450 | 100 | 50 |
| **System** | | | | |
| Energy Efficiency | kWh/kg $H_2$ (% LHV) | 55 (61%) | 51 (65%) | 46 (72%) |
| Uninstalled Capital Cost[h] | $/kW | 1,000 | 250 | 150 |
| $H_2$ Production Cost[i] | $/kg $H_2$ | >3 | 2.00 | 1.00 |

## High-T Electrolyzer Stacks & Systems

| CHARACTERISTIC | UNITS | 2022 STATUS[c] | 2026 TARGETS | ULTIMATE TARGETS |
|---|---|---|---|---|
| **Stack** | | | | |
| Performance | A/cm$^2$ @ 1.28 V/cell | 0.6 | 1.2 | 2.0 |
| Electrical Efficiency[d] | kWh/kg $H_2$ (% LHV) | 34 (98%) | 34 (98%) | 34 (98%) |
| Average Degradation Rate[e] | mV/kH (%/1,000 h) | 6.4 (0.50) | 3.2 (0.25) | 1.6 (0.12) |
| Lifetime[f] | Operation h | 20,000 | 40,000 | 80,000 |
| Capital Cost[g] | $/kW | 300 | 125 | 50 |
| **System** | | | | |
| Electrical Efficiency | kWh/kg $H_2$ (% LHV) | 38 (88%) | 36 (93%) | 35 (95%) |
| Energy Efficiency[h] | kWh/kg $H_2$ (% LHV) | 47 (71%) | 44 (76%) | 42 (79%) |
| Uninstalled Capital Cost[g] | $/kW | 2,500 | 500 | 200 |
| $H_2$ Production Cost[i] | $/kg $H_2$ | >4 | 2.00 | 1.00 |

*see published targets for additional details*

# Upcoming Activities

## Electrolyzer Data Collection Effort

- Planned new initiative to collect cost, performance, and reliability data from deployed/ installed electrolyzers which will be securely stored, aggregated, and anonymized
- Data will help refine assumptions & track progress in $/kg cost reductions to validate achieving $2/kg $H_2$ by 2026
- Data contributors may also receive detailed analytics of their submitted confidential data

## Electrolyzer Installation Costs Workshop

**When:** September 2023

Stay tuned to the HFTO newsletter for the official announcement later this summer!

**Who:** Anyone interested in the details of large-scale electrolyzer installations

Virtual and open to the public

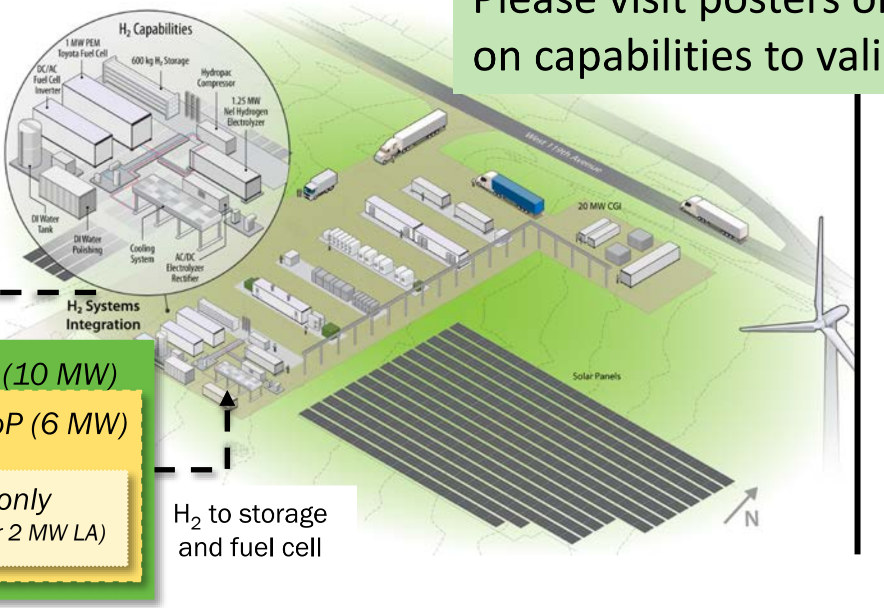
**Goals:** Understand challenges, cost drivers, and lessons learned for large-scale electrolyzer installations and opportunities for DOE to reduce the cost/timeline

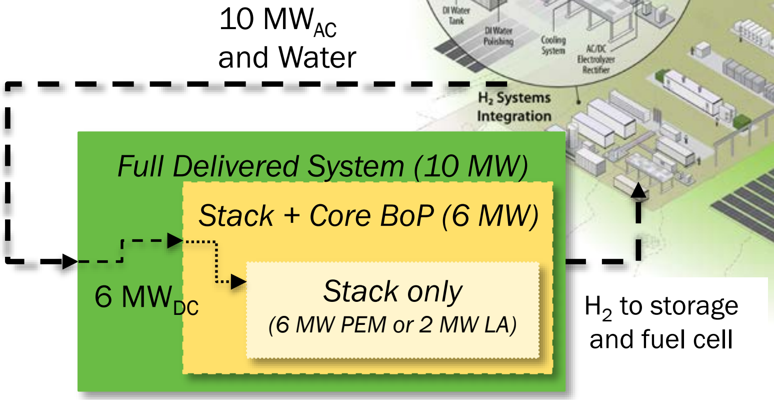
# Expansion to Multi-MW Electrolyzer Stack and System Testing

## Low-Temperature Electrolyzers – NREL *(P207)*

- Expansion of NREL's Flatirons Campus ARIES capability to support industry
- **Full LTE system testing up to 10 MW**
- **Parallel stack testing up to 6 MW** in aggregate for PEM and/or LA
- Grid integration with renewable energy production and other ARIES assets

**Coming online in 2026!**



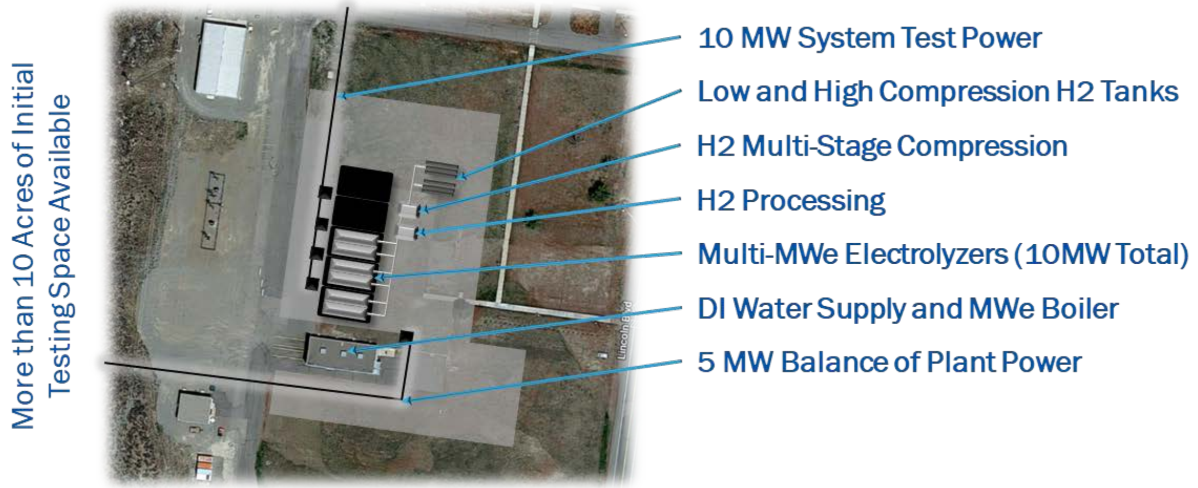




## High-Temperature Electrolyzers – INL *(SDI006)*

- Development at INL's Energy Technology Proving Ground
- **Full, multiple HTE system testing up to 10 MW** in aggregate
- Simulated nuclear integration / future physical integration with advanced nuclear reactors

Please visit posters on Wed. for more details on capabilities to validate your technology

**Coming online in 2024!**



# Milestones, Collaborations, Team

# $H_2$ Production Program Highlights and Milestones Summary

| FY2022 | FY2023 | FY2024 |
|---|---|---|
| BIL signed into law | BIL Sections 815 & 816 FOA released | BIL 815 & 816 FOA projects selected, and work commences |
| Power Electronics and Liquid Alkaline Electrolyzer Experts Meetings | Updated $H_2$ Production Cost Record Posted | Electrolyzer Installation Costs Workshop |
| Request for Information for BIL Sections 815 & 816 | BIL Section 816 Lab Call released, and selections to be made | Commission/start operation of HTE validation center |
| HTE Manufacturing and PEM Materials Electrolyzer Workshops | 5th Annual AWS benchmarking workshop | Electrolyzer real-world data collection underway |
| BIL Section 816 strategy developed | Announce FY22 direct solar water splitting FOA awards and complete negotiations | BIL Lab Call projects commence |
| H2 Shot Incubator Prize launched | Expand H2NEW, HydroGEN, and ElectroCat Consortia | $H_2$ Shot Incubator Prize “Prove!” Phase winners announced |
| FY22 FOA topic on direct solar water splitting (PEC and STCH) | Electrolyzer stack and system technical targets released | LA Electrolysis Cost Record published |
| 4th Annual AWS benchmarking workshop | Kick-off multi-MW electrolyzer validation/ test centers effort | All H2 Shot Technology Assessments Released |

# $H_2$ Production: Collaboration Network

## Fostering technical excellence, economic growth and environmental justice

| *Efforts Support Over:* |
|---|
| 10 national laboratories |
| 24 universities |
| 15 companies |

| DOE $H_2$ Program Collaborations | | |
|---|---|---|
| Collaboration across $H_2$ through Joint Strategy Teams (JST) | | |
| AMMTO | VTO | BETO |
| SETO | OCED | ARPA-E |
| SC | FECM | NE |
| **DOE Cross-Cutting Initiatives** | | |
| Advanced Materials | AI/ML | Advanced Manufacturing |
| Decarbonization of Agriculture/Buildings/Electricity/Industry/Transportation | | |

| Cross-Agency Collaborations | | | |
|---|---|---|---|
| DOC-NIST | NASA | EPA | NSF |

| *Industry Engagements* |
|---|
| Workshops |
| Requests for Information |
| AWS Benchmarking and Protocol Development |
| H2NEW |
| HydroGEN |
| ElectroCat |

| *Regional and International Collaborations* | | | |
|---|---|---|---|
| IEA $H_2$ TCP | IEA AFC TCP | AWS Benchmarking and Protocol Dev. | Bilateral Collaborations |

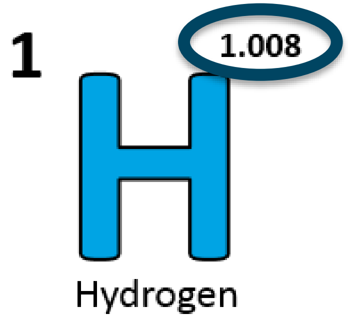
# Resources and Opportunities for Engagement

## Save the date!

**2024 DOE Annual Merit Review and Peer Evaluation Meeting**
**May 6-9, 2024**

## Hydrogen and Fuel Cells Day
## October 8

- Held on hydrogen's very own atomic weight-day

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# HFTO is Hiring!

We have **multiple federal and contractor positions**, including to support the *Clean Hydrogen Electrolysis Program*

## Federal Position

- Please submit resumes to **https://www.energy.gov/CleanEnergyCorps**
- Email **HFTOhiring@ee.doe.gov** to let us know you have submitted your resume. Include **"Clean Energy Corps Applicant"** in the subject line of the email.
- See more: https://www.energy.gov/eere/fuelcells/hydrogen-and-fuel-cell-technologies-office-careers

## Hydrogen Shot Fellowship

ENERGY earthshots U.S. DEPARTMENT OF ENERGY | Hydrogen

The U.S. Department of Energy (DOE) is looking for talented, bright, early career professionals to partner with DOE Hydrogen Program Managers working to achieve the Hydrogen Energy Earthshot goal of $1 per 1 kilogram in 1 decade ("1 1 1").

**Apply today at: www.zintellect.com**
**Keyword: Hydrogen Shot**

# The Hydrogen Production Team

## Acting Program Manager

David Peterson

## Technology Managers

McKenzie Hubert

Anne Marie Esposito

Open Position

James Vickers

Will Gibbons

Open Position

## Support Contractors

Leah Mcgovern

Open Position

Open Position

## Technical Project Officer

Kim Cierpik-Gold

## Fellows

Rachel Mow

Open Position

# Thank You

**Dr. David Peterson**

**Acting Program Manager, Hydrogen Production, HFTO**

**David.Peterson@ee.doe.gov**

**hydrogenandfuelcells.energy.gov**

# Session Schedule – Hydrogen Production Oral Presentations

| | Tuesday, June 6 Oral Presentations | Wednesday, June 7th Oral Presentations | Thursday, June 8th Oral Presentations |
|---|---|---|---|
| 8:00 AM | Continental Breakfast | | |
| 9:00 AM | P000 Hydrogen Production Technologies Subprogram Overview (David Peterson, HFTO) | P191 Perovskite/Perovskite Tandem Photoelectrodes for Low-Cost Unassisted Photoelectrochemical Water Splitting (Yanfa Yan, The University of Toledo) | P183 Extremely Durable Concrete Using Methane Decarbonization Nanofiber Co-Products with Hydrogen (Alan Weimer, University of Colorado, Boulder) |
| 9:30 AM | P148 HydroGEN Overview: A Consortium on Advanced Water Splitting Materials (Huyen Dinh, NREL) | P192 Development of Composite Photocatalyst Materials That Are Highly Selective for Solar Hydrogen Production and Their Evaluation in Z-Scheme Reactor Designs (Shane Ardo, University of California, Irvine) | P179 BioHydrogen (BioH2) Consortium to Advance Fermentative Hydrogen Production (Katherine Chou, NREL) |
| 10:00 AM | | P193 Highly Efficient Solar Water Splitting Using 3D/2D Hydrophobic Perovskites with Corrosion Resistant Barriers (Aditya D. Mohite, William Marsh Rice University) | P184 Scalable and Highly Efficient Microbial Electrochemical Reactor for Hydrogen Generation from Lignocellulosic Biomass and Waste (Hong Liu, Oregon State University) |
| 10:30 AM | Break | | |
| 11:00 AM | P197 Advanced Manufacturing Processes for Gigawatt-Scale Proton Exchange Membrane Water Electrolyzers (Andrew Steinbach, 3M) | P190 A Multifunctional Isostructural Bilayer Oxygen Evolution Electrode for Durable Intermediate-Temperature Electrochemical Water Splitting (Kevin Huang, University of South Carolina) | P203 Novel Microbial Electrolysis System for Conversion of Biowastes into Low-Cost Renewable Hydrogen (Noah Meeks, Southern Company Services, Inc.) |
| 11:30 AM | P198 Enabling Low Cost PEM Electrolysis at Scale Through Optimization of Transport Components and Electrode Interfaces (Chris Capuano, Nel Hydrogen) | P176 Development of Durable Materials for Cost Effective Advanced Water Splitting Utilizing All Ceramic Solid Oxide Electrolyzer Stack Technology (Brian Oistad, Saint-Gobain) | P202 Novel Microbial Electrolysis Cell Design for Efficient Hydrogen Generation from Wastewaters (Bruce Logan, Pennsylvania State University) |
| 12:00 PM | P199 Integrated Membrane Anode Assembly & Scale-Up (Adam Paxson, Plug Power) | P188 Advanced Coatings to Enhance the Durability of SOEC Stacks (Sergio Ibanez, Nexceris, LLC) | |
| 12:30 PM | Lunch | | |
| 1:45 PM | P196 H2NEW Consortium: Hydrogen from Next-Generation of Electrolyzers of Water (Bryan Pivovar, NREL & Richard Boardman, INL) | P204 Hydrogen Production Cost and Performance Analysis (Brian James, Strategic Analysis, Inc.) | |
| 2:15 PM | | P186 Performance and Durability Investigation of Thin, Low Crossover Proton Exchange Membranes for Water Electrolyzers (Andrew Park, The Chemours Company FC, LLC) | |
| 2:45 PM | | P185 High-Performance AEM LTE with Advanced Membranes, Ionomers and PGM-Free Electrodes (Paul Kohl, Georgia Institute of Technology) | |
| 3:15 PM | Break | | |
| 3:45 PM | P200 Low-Cost Manufacturing of High Temperature Electrolysis Stacks (Scott Swartz, Nextech Materials, Ltd.) | P195 A New Paradigm for Materials Discovery and Development for Lower Temperature and Isothermal Thermochemical Hydrogen Production (Jonathan Scheffe, University of Florida) | |
| 4:15 PM | P201 Automation of Solid Oxyde Electrolyzer Cell (SOEC) & Stack Assembly (Todd Striker, Cummins Inc.) | P194 New High-Entropy Perovskite Oxides with Increased Reducibility and Stability for Thermochemical Hydrogen Generation (Jian Luo, University of California, San Diego) | |
| 4:45 PM | | P170 Benchmarking Advanced Water Splitting Technologies: Best Practices in Materials Characterization (Olga Marina, PNNL) | |

# Session Schedule – Hydrogen Production Poster Presentations

| Tuesday, June 6 Poster Presentations, 5:30–7:00 p.m. | | |
|---|---|---|
| Hydrogen Production Technologies | | |
| P148A | HydroGEN: Low Temperature Electrolysis | Shaun Alia, NREL |
| P148B | HydroGEN: High Temperature Electrolysis | Dong Ding, INL |
| P148C | HydroGEN: Photoelectrochemical (PEC) Water Splitting | Joel Ager, LBNL |
| P148D | HydroGEN: Solar Thermochemical Hydrogen (STCH) Water Splitting | Anthony McDaniel, SNL |
| P148E | HydroGEN: Cross-Cut Modeling | Tadashi Ogitsu, LLNL |
| P154 | Thin-Film, Metal-Supported High-Performance and Durable Proton-Solid Oxide Electrolyzer Cell | Tianli Zhu, Raytheon Technologies Research Center |
| P175 | Intermediate Temperature Proton-Conducting Solid Oxide Electrolysis Cells with Improved Performance and Durability | Xingbo Liu, West Virginia University |
| P187 | Pure Hydrogen Production through Precious-Metal-Free Membrane Electrolysis of Dirty Water | Shannon Boettcher, University of Oregon |
| P196a | H2NEW LTE: Durability and AST Development | Rangachary Mukundan, LBNL |
| P196b | H2NEW LTE: Benchmarking and Performance | Deborah Myers, ANL |
| P196c | H2NEW LTE: Manufacturing, Scale-Up, and Integration | Scott Mauger, NREL |
| P196d | H2NEW LTE: System and Techno-Economic Analysis -- Hydrogen from Next-Generation Electrolyzers | Alex Badgett, NREL |
| P196e | H2NEW HTE: Durability and AST Development | Olga Marina, PNNL |
| P196f | H2NEW HTE: Cell Characterization | David Ginley, NREL |
| P196g | H2NEW HTE: Multiscale Degradation Modeling | Brandon Wood, LLNL |
| P196h | H2NEW LTE: Liquid Alkaline Water Electrolysis | Meital Shviro, NREL |
| P205* | Metal-Organic Framework-Based Heterostructure Electrocatalysts with Tailored Electron Density Distribution for Cost-Effective and | Sreeprasad Sreenivasan, University of Texas, El Paso |
| P206 | Single-Walled Carbon Nanotubes with Confined Chalcogens as the Catalysts and Electrodes for Oxygen Reduction Reaction in Fuel Cells | Juchen Guo, University of California, Riverside |

**Tonight from 5:30-7:00pm**

# Session Logistics

# General Information

- This meeting is a review, not a conference
  - **Questions will be taken first from reviewers**, and then from other audience members as time allows
  - Remote reviewers are reminded to enter their questions in CHAT
  - Remote general attendees can enter questions or comments into Q&A
- The schedule will be strictly followed so that reviewers can move between sessions
- Presentations are 20 minutes followed by 10 minutes Q&A

# Thank You, Reviewers!

Your input on our Program and subprograms helps guide our decisions.

Thank you for your thoughtful, objective, and timely feedback!