



Energy Materials Network
U.S. Department of Energy



HydroGEN
Advanced Water Splitting Materials

A New Generation of Innovation

Huyen Dinh, Director of HydroGEN, NREL

9/1/2021, Virtual

Hydrogen Energy Earthshot Summit

Advanced Pathways Panel

NREL/PR-5900-81046

DOE Strategy for Green Hydrogen Challenges



Make



Move



Store



Use

Consortium Approach



Crosscutting:

- Analysis
- Manufacturing
- Codes & Standards
- Prog. Mgmt



HydroGEN is advancing Hydrogen Shot

Website: <https://www.h2awsm.org/>

Goal: Accelerating R&D of innovative advance water splitting (AWS) materials and technologies for clean, sustainable and low-cost hydrogen production.

Challenges

- Cost
- Efficiency
- Durability



Water



Low-Temperature Electrolysis (LTE)



High-Temperature Electrolysis (HTE)



Photoelectrochemical (PEC)



Solar Thermochemical (STCH)

National Lab Consortium Team

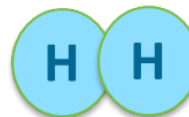


Sandia National Laboratories



Lawrence Livermore National Laboratory

H₂ Production target <\$2/kg



Hydrogen

HydroGEN is advancing Hydrogen Shot goals by fostering cross-cutting innovation using theory-guided applied materials R&D to advance all emerging water-splitting pathways for hydrogen production



HydroGEN Materials Capability Network (*Materials Theory, Synthesis, Characterization & Analytics*)

HydroGEN 2.0

(Early-Stage Materials R&D Projects, started in FY 21,
\$4 M/year for 3 years)

Cross-Cutting Activities

Director
Huyen Dinh
(NREL)

Data Hub

Technology Transfer

Website, SharePoint Site, Zotero Library

Research

LTE Technology Lead
Bryan Pivovar/
Shaun Alia
(NREL)

HTE Technology Lead
Gary Groenewold/
Dong Ding
(INL)

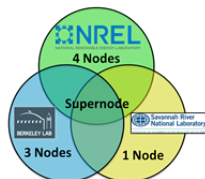
PEC Technology Lead
Francesca Toma/
Adam Weber
(LBL)

STCH Technology Lead
Tony McDaniel/
Andrea Ambrosini
(SNL)

Cross-Cutting Modeling Lead
Tadashi Ogitsu/
Brandon Wood
(LLNL)



5 Lab-led R&D: Supernode (cross-lab collaboration)



31 Lab – FOA Projects



Support through:
Personnel
Equipment
Expertise
Capability
Materials
Data



4 Multi-Agency Projects



Support through:
Personnel
Equipment
Expertise
Capability
Materials
Data



Best Practices in Materials
Characterization and Benchmarking

Data Hub

AWS Research Community



Diverse HydroGEN Leadership and Community



Director
Huyen Dinh
(NREL)



Research

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Bryan Pivovar/
Shaun Alia
(NREL)

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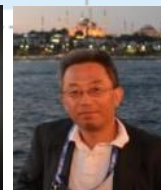
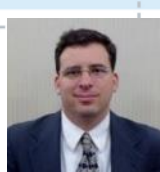
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Adam Weber
(LBNL)

STCH Technology Lead

Tony McDaniel/
Andrea Ambrosini
(SNL)

Cross-Cutting Modeling Lead

Tadashi Ogitsu/
Brandon Wood
(LLNL)





Ecosystem Enables Collaboration, R&D Acceleration, and Diversity, Equity, and Inclusivity (DEI)

11 Labs 10 Companies 39 Universities 2 Funding Agencies

STEM Work Force Development Example

NSF DMREF – DOE EERE HydroGEN Inter-agency

Collaboration: PSU – NREL PEC Project

Experimental Validation of Designed Photocatalysts For Solar Water Splitting

Catherine Badding,¹ Ismaila Dabo,²

Raymond E. Schaak,³ Héctor D. Abruña¹

¹Chemistry and Chemical Biology, Cornell, ²Materials Science, Penn State, ³Chemistry, Penn State



Cathy Badding

DOE SULI Awardee (2018)

Goldwater Scholar (2019)



Collaboration enabled development of a screening procedure (with co-validation between experiment and theory) to expedite the synthesis, characterization, and testing of the computationally predicted, most attractive materials.

HydroGEN is a nationwide, inter-agency, collaborative consortium working to advance early-stage materials R&D and build a DEI community

Community Approach to Benchmarking and Protocol Development for AWS Technologies



Kathy Ayers, Proton OnSite (LTE)



Ellen B. Stechel, ASU (STCH);



Olga Marina, PNNL (HTE);



CX Xiang, Caltech (PEC)

Accomplishments:

- 3 Annual AWS community-wide benchmarking workshops
- 36 test protocols drafted and reviewed
- 40 additional protocols in drafting process
- Engaged with new HydroGEN projects and lab experts
- Disseminated info to AWS community



*Development of best practices in materials characterization and benchmarking:
critical to accelerate materials discovery and development*



“Energy Material Network Data Hubs: Software Platforms for Advancing Collaborative Energy Materials Research”

NREL Authors: Robert White, Kris Munch, Nicholas Wunder, Nalinrat Guba, Kurt Van Allsburg, Huyen Dinh, and collaborators.

Published in: *International Journal of Advanced Computer Science and Applications*, 12(6), 2021. <http://dx.doi.org/10.14569/IJACSA.2021.0120677>



HydroGEN
Advanced Water Splitting Materials



DuraMAT
Durable Module Materials Consortium



ChemCatBio
Chemical Catalysts for Bioenergy



HyMARC
Hydrogen Materials Research Consortium



ElectroCat
Electrocatalysis Consortium



H-Mat
Hydrogen Materials Compatibility Consortium



LightMAT
Lightweight Materials Consortium



Simple data interface developed

HydroGEN Data Hub

The submission point for data collected from research conducted by the Advanced Water Splitting Materials National Laboratory Consortium



Register

Request a HydroGEN account.



Discover

Search the repository.

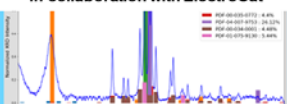


Submit Data

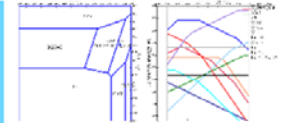
Upload and archive your data.
Share data with others.

Materials properties

Structural information: XRD interface in collaboration with ElectroCat

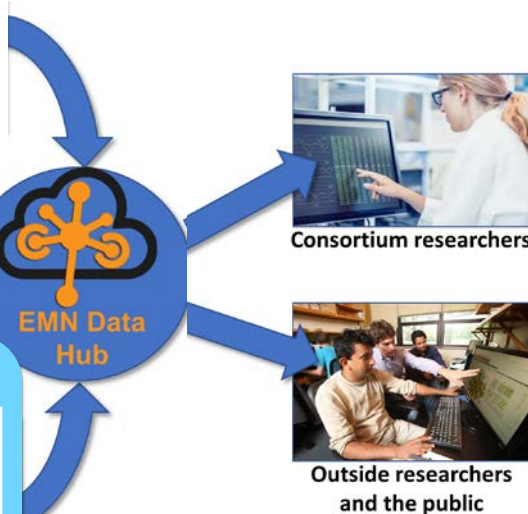
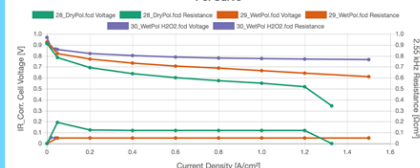


Phase stability & Defect properties



Device performance

Pot Curve



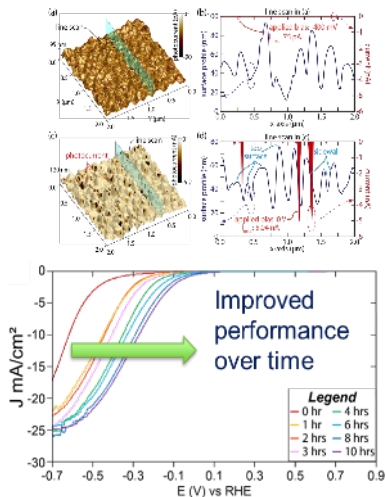
- Have proven capable of effectively leveraging geographically dispersed equipment resources and scientific expertise
- Enabled consortium in making significant advancements in their research and disseminate them the community.



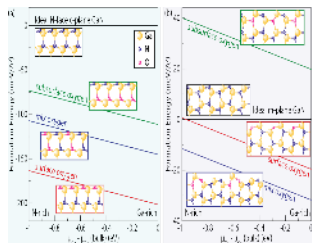
Collaboration Results in High Impact Publication and Accelerates All AWS Technologies

G Zheng, TA Pham, S Vanka, G Liu, C Song, J Cooper, Z Mi, T Ogitsu, FM Toma Development of a photoelectrochemically self-improving Si/GaN photocathode for efficient and durable H_2 production. *Nat. Mater.* **20**, 1130–1135 (2021). <https://doi.org/10.1038/s41563-021-00965-w>

Experiments



Theory



Highlight

Understanding the observed exceptional stability (> 3000 hr) is crucial for a commercial use of PEC hydrogen production.

Key Technical Accomplishments:



- Achieved 70% PEM electrolyzer cell efficiency while improving durability & reducing cost



- Scaled up baseline cell by 8X with 9% STH efficiency & 100 h stability integrated PV-PEC system



- Discovered new STCH compounds with H_2 production capacities > state of the art at lower temperatures



- Demonstrated a metal-supported o-SOEC cell with dramatically improved stability





Acknowledgements

This work was fully supported by the U.S. Department of Energy (DOE), Office of Energy Efficiency and Renewable Energy (EERE), Hydrogen and Fuel Cell Technologies Office (HFTO).



Ned Stetson



Katie Randolph



David Peterson



James Vickers



William Gibbons



Eric Miller

**Interagency collaboration between NSF–DMREF projects and HFTO HydroGEN EMN
John Schlueter, Program Director, NSF–DMREF, Divisions of Materials Research**