U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

U.S. DOE Hydrogen & Fuel Cells Program Overview

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2nd Meeting - Global Technical Regulation 13 – Phase II

February 2018

DOE Hydrogen and Fuel Cells Program

Early R&D Focus

Applied research, development and innovation in emerging hydrogen and fuel cell technologies leading to:

- Energy security
- Energy resiliency
- Strong domestic economy

Early R&D Areas

Fuel Cells

- PGM- free catalysts
- Durable MEAs
- Electrode performance

Hydrogen

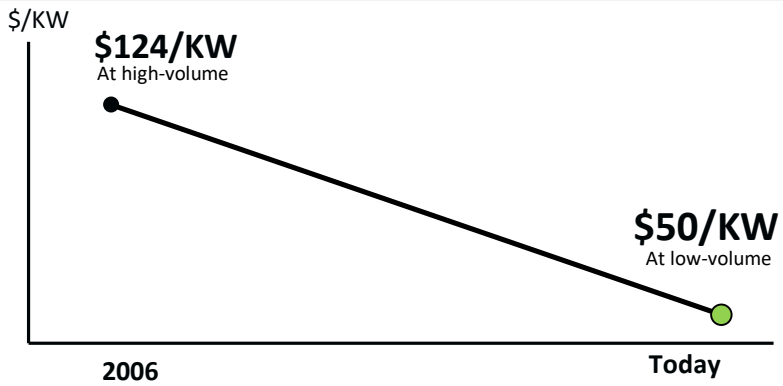
- Production pathways
- Delivery components
- Advanced materials for storage

PGM = Platinum group metals

MEA = Membrane Electrode Assembly

Early R&D Impact

60% Lower Fuel Cell Cost



Greater Fuel Cell Durability

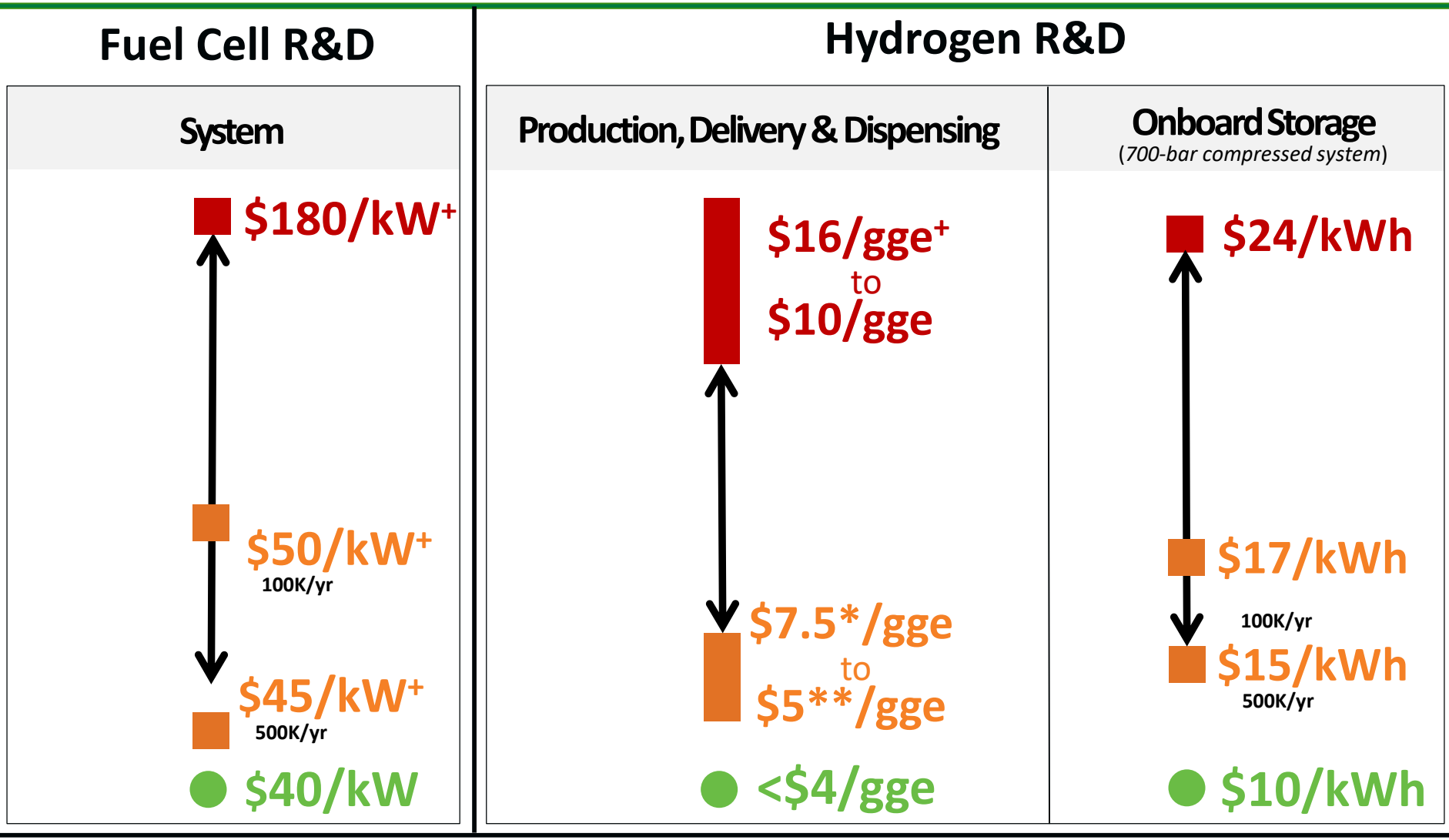
4X more hours

of fuel cell lifetime since 2006

80% Lower Electrolyzer Cost

for H_2 production since 2002

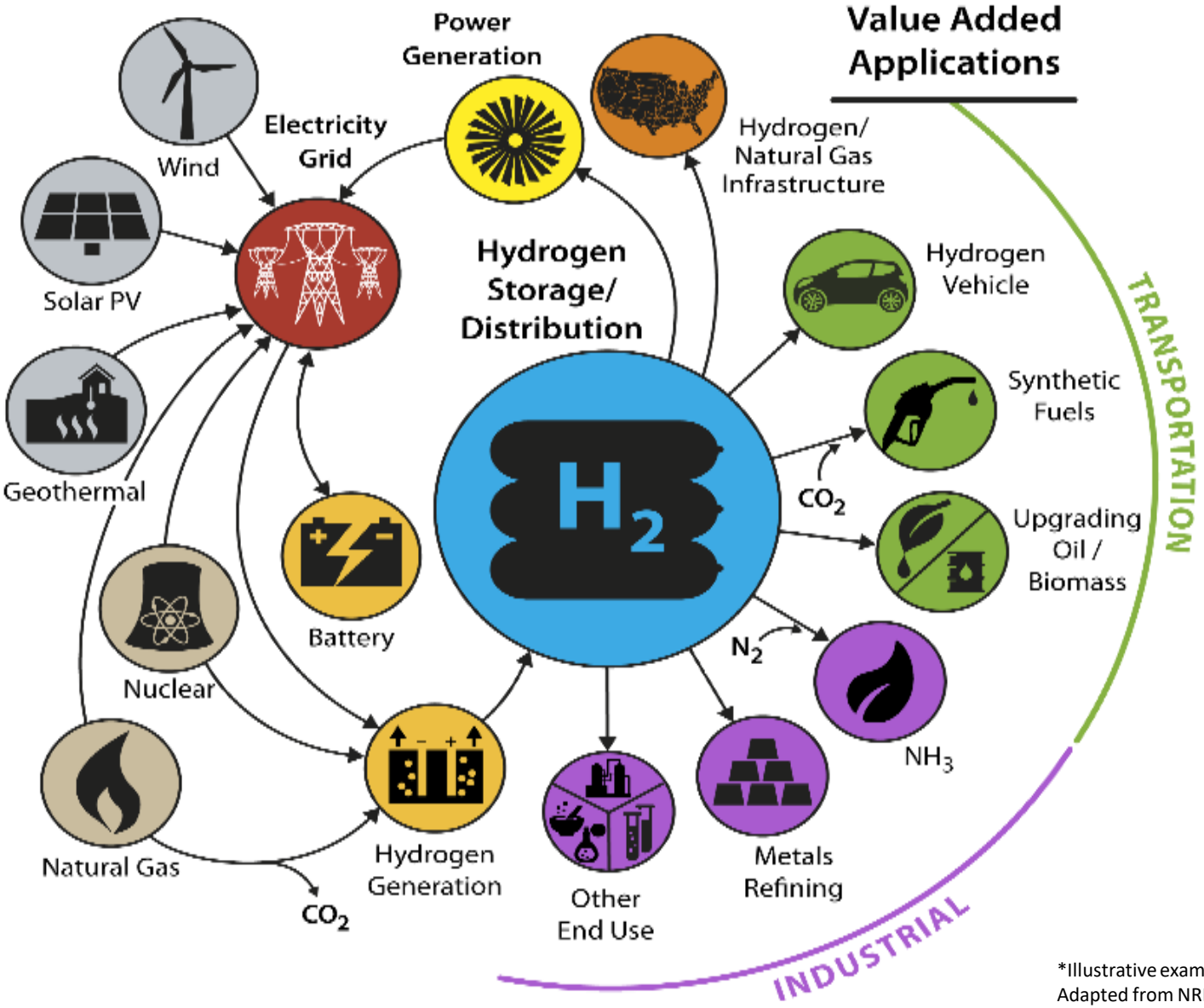
DOE Cost Status and Targets



*Based on Electrolysis **Based on NG SMR + Preliminary, updates underway
Onboard storage cost status from DOE Program Record 15013

Note: Graphs not drawn to scale and are for illustration purposes only.

H2@Scale Energy System



*Illustrative example, not comprehensive
Adapted from NREL, Lab Big Idea Team

Safety, Codes & Standards Goals & Objectives

Funding R&D needed to develop science-based codes and standards, thereby enabling the safe deployment of H_2 and fuel cell technologies

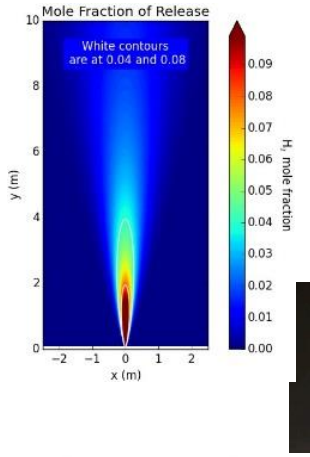
Codes & Standards

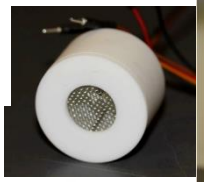
- Conduct **R&D to provide critical data** and information needed to define requirements in developing codes and standards.
- Support and facilitate development of **essential codes and standards** to **enable widespread deployment** of hydrogen and fuel cell technologies and completion of essential regulations, codes and standards (RCS).

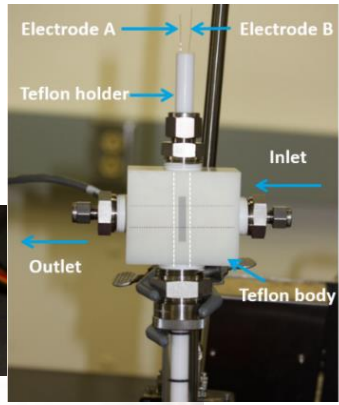
Safety

- Ensure that **best safety practices** underlie activities supported through DOE-funded projects.
- Enable **widespread sharing** of **safety-related information resources** and lessons learned with key stakeholders.

HyRAM
HYDROGEN RISK ASSESSMENT MODELS







Current Strategy and Barriers

Focus areas	Barriers*	Objectives
Hydrogen Behavior	Insufficient data for code revision (e.g.-large station footprints)	R&D model development and verification to establish scientific basis for codes and standards revisions.
Risk Assessment	Usage and access restrictions; Limited reliability data	Develop tools on a scientific foundation which can be used for various hydrogen applications.
Materials Compatibility	Lack of information on new materials compatibility with H_2	Establish a foundational materials understanding, which will enable and support the C&S development.
Detection & Sensors	High cost and limited commercial availability of products	Develop H_2 contaminant detectors for fuel quality at H_2 station.
Outreach & Support	Limited access and understanding of safety data and information	Support critical stakeholders in understanding hydrogen safety best practices.

* From Safety, Codes and Standards MYRD&D (June 2015)

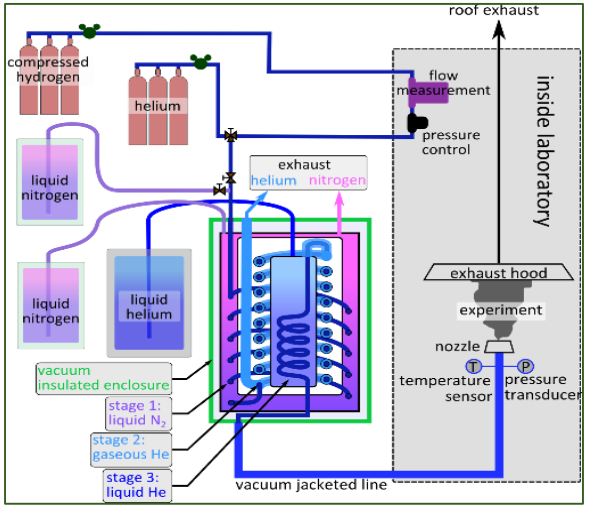
Hydrogen Behavior & Modeling

Leveraging science to enable infrastructure through understanding hydrogen behavior, analyzing risk, and implementing inherently safe design options

R&D to inform codes & standards development for both gaseous and liquid hydrogen.

- **NFPA-2:** Draft revised setback distances for **bulk gaseous hydrogen storage** systems with reductions that would have a significant impact on the number of potential sites for hydrogen fueling, focusing on three parameters:
    1. ***Maximum release area:*** currently, this value is 3%
    2. ***Heat flux harm criteria***
    3. ***Lower flammability percentage for hydrogen in air:*** currently 4%

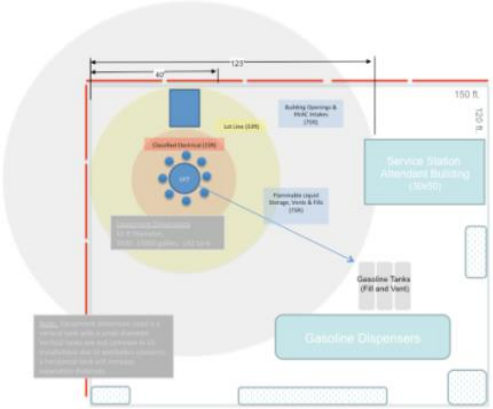
- **Science-based approach for liquid hydrogen:** Developed cryo-temperature laboratory to validate liquid hydrogen models to enable risk assessment tools.

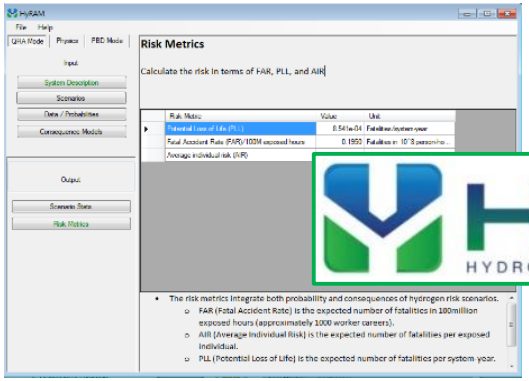


Risk Assessment for performance-based design

Leveraging science to enable infrastructure through understanding hydrogen behavior, analyzing risk, and implementing inherently safe design options

- **Quantitative risk assessment (QRA)** utilizes engineering models to produce risk metrics which enable performance-based design.
  - The HyRAM (Hydrogen Risk Assessment Models) tool integrates models and data to quantify risk. This QRA tool is a critical enabler for code committees to pursue data-driven decisions to provide an objective basis for code requirements.
- **Performance-based design** is a risk-enabled (via QRA), NFPA 2 - compliant option for station design.
  - Developed a template, which guides the user through the PBD process
  - Connecting materials compatibility to risk assessment to enable alternative materials not currently used in hydrogen service



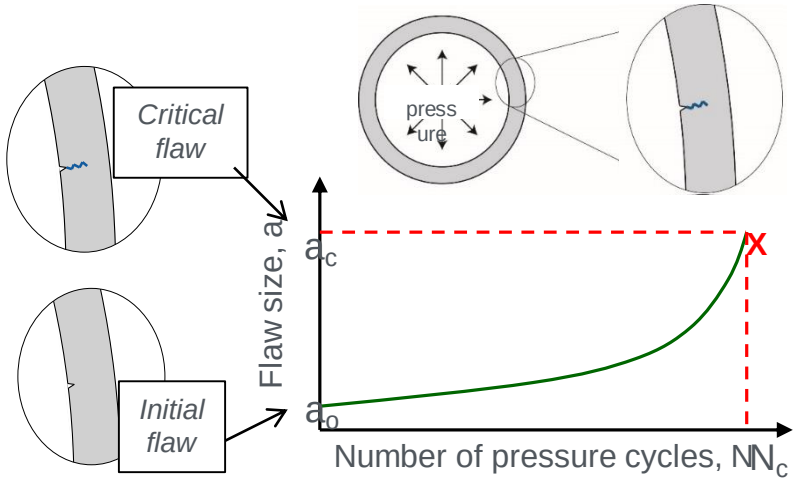


Hydrogen Compatibility of Materials

Performing critical materials R&D to understand material behavior in high pressure hydrogen to enable RCS in support of infrastructure deployment

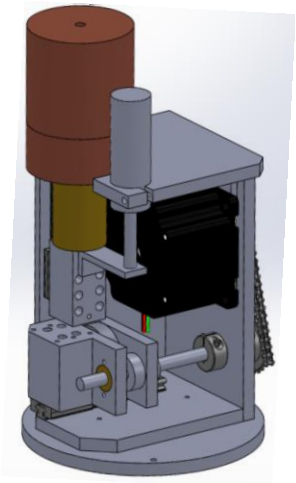
Metallic Materials Compatibility

- Establish coordinated fatigue life testing and data sharing with international stakeholders
- High-hardenability steels (Ni-Cr-Mo) show similar fatigue crack growth rates as common PV steels (Cr-Mo) in gaseous hydrogen



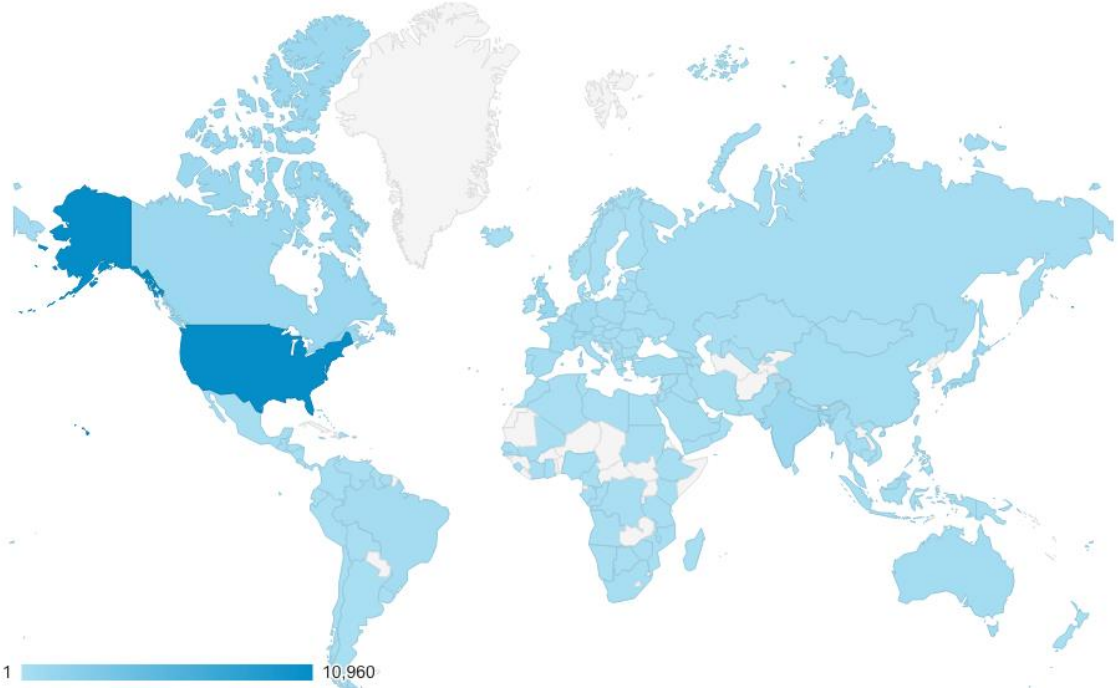
Polymer Compatibility

- Filling the critical knowledge gap for polymer performance in H2 environments
- Initiated testing program of critical materials to understand behavior (e.g.- Tribology in 500 bar H2



Planned upgrade with vertical LVDT for in-situ wear track measurement

H2Tools: One-stop for H2 safety knowledge



- Includes resources on **safety** best practices, **first responder training**, and **H_2 codes & standards**

- Site visit tracking shows a **global reach: 50%** of visits are **international!**
- Over **300,000 site visits**
- Training resource **translated into Japanese**

Thank You

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