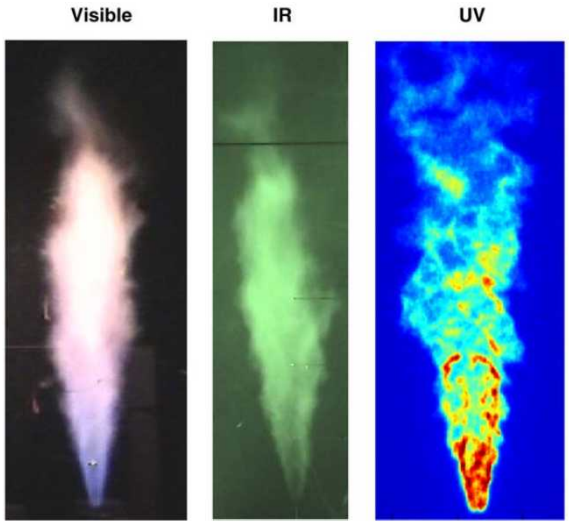
SAND2017-11166C

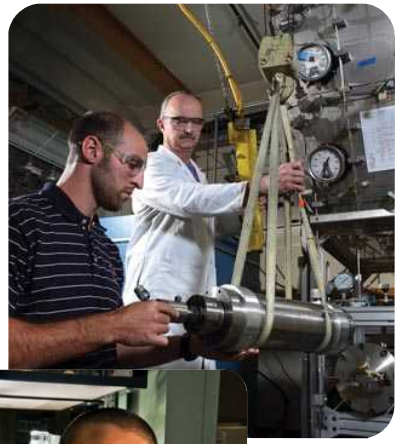
Sandia's Hydrogen and Fuel Cells (H_2FC) Program

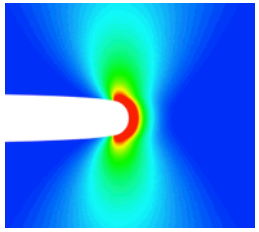
Enabling Hydrogen Technologies with Science and Engineering

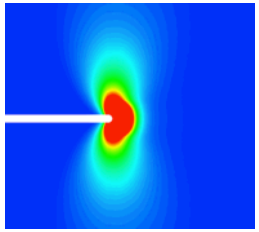
2017 Fuel Cell Seminar & Energy Exposition
November 7-9, 2017
Long Beach, CA USA

Jonathan Zimmerman









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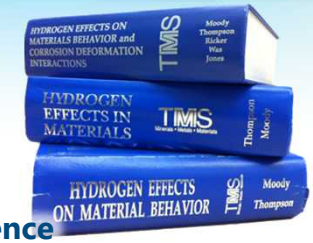
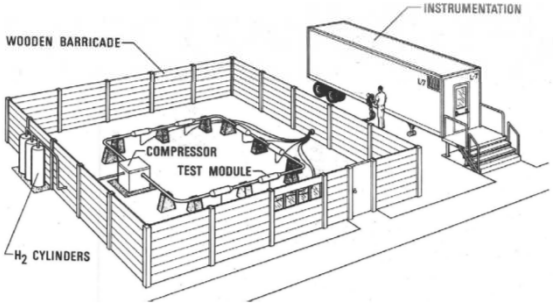
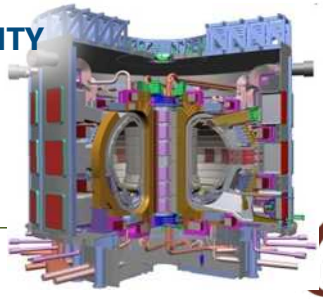
History of Hydrogen Sciences at Sandia

Sandia's core mission to support the nuclear deterrent has enabled science and engineering for energy programs



EXPERIMENTAL HYDROGEN PIPELINE FACILITY





FUSION ENERGY SCIENCES

Conference Organization

METAL HYDRIDE CENTER OF EXCELLENCE

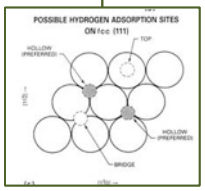
Lift-Truck Lifecycle

H2 Infrastructure

H_2FIRST

1960 1970 1980 1990 2000 2004 2008 2012 2016

METALLURGY



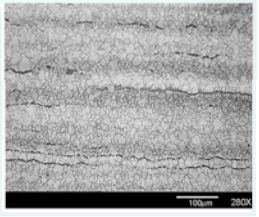
Embedded Atom Method

RATLER

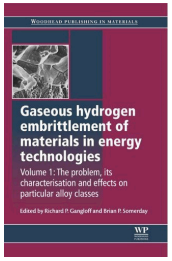
AUTOMOTIVE STORAGE

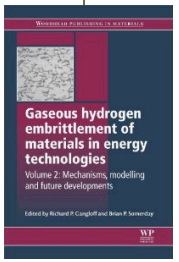
HyMARC Hydrogen Materials Advanced Research Consortium

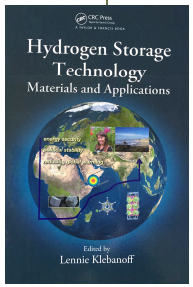
TRITIUM RESEARCH



MINING LOCOMOTIVE







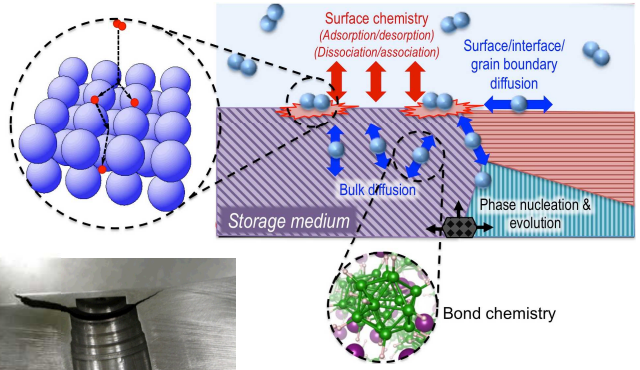
Sandia's Current Hydrogen Program

Hydrogen Production

Develop technologies that utilize concentrated solar power for large-scale, renewable production of hydrogen

Hydrogen Storage

Provide fundamental understanding of the phenomena limiting solid-state hydrogen interactions

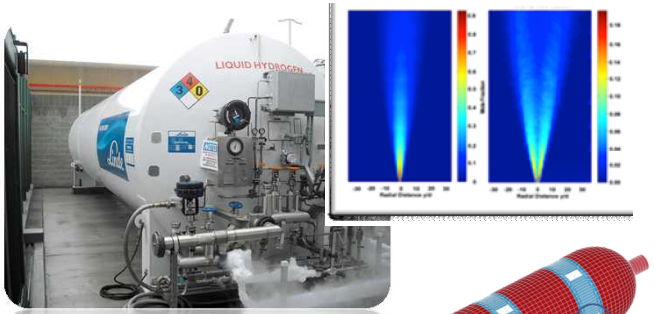


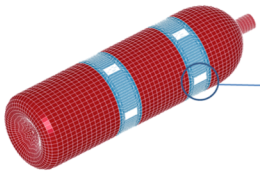
Hydrogen Delivery

Identify pathways for reducing cost of steel hydrogen pipelines without compromising reliability and integrity

Safety, Codes and Standards

Facilitate safe deployment of hydrogen technologies with science-based codes and standards





Fuel Cells

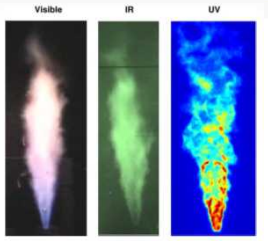
Develop new membrane systems for enhanced electrochemical performance

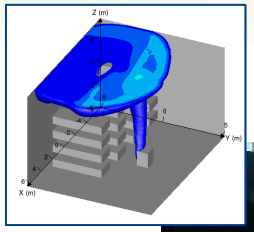
Systems Engineering

Demonstrate innovative engineering solutions to harness clean energy technologies

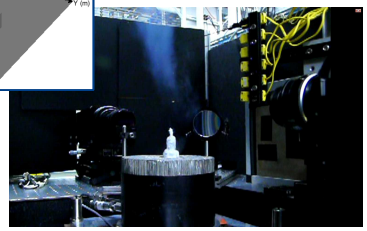
Capabilities for Hydrogen Research and Development

Risk Assessment

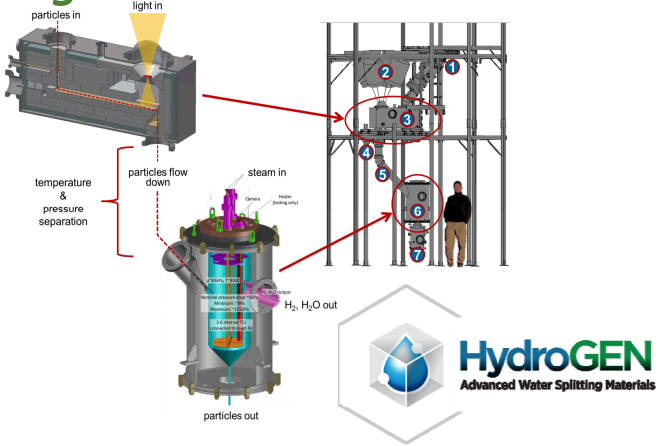




HyRAM
HYDROGEN RISK ASSESSMENT MODELS



Solar Thermochemical Hydrogen Production

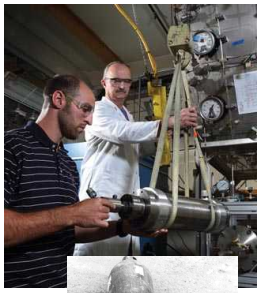


HydroGEN
Advanced Water Splitting Materials

Infrastructure Research and Station Technology

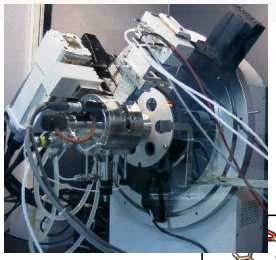
H2FIRST

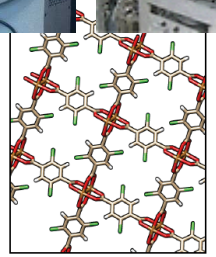
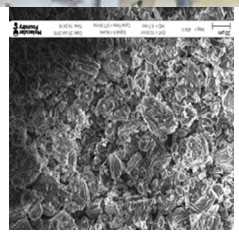
Materials Compatibility with Hydrogen



Capabilities for Hydrogen Research and Development

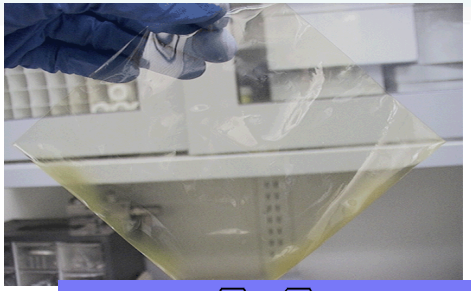
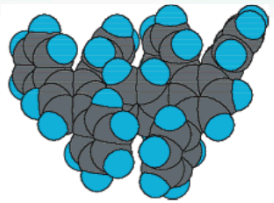
Hydrogen Storage Materials

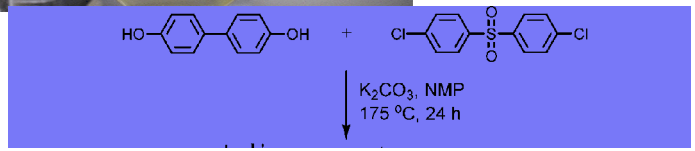



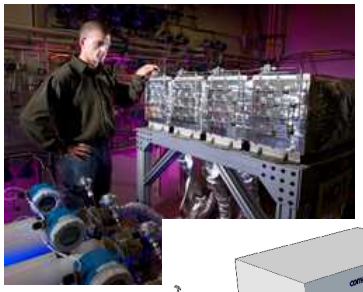
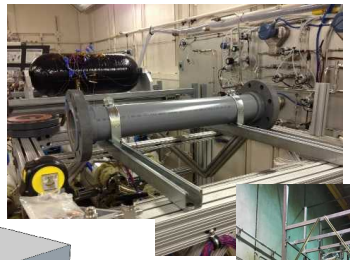
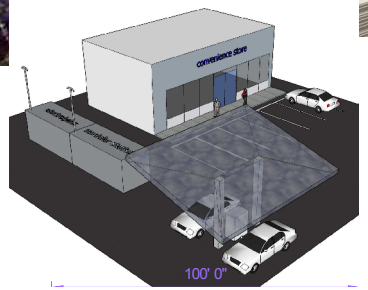
HyMARC
Hydrogen Materials Advanced Research Consortium

Fuel Cell Membranes

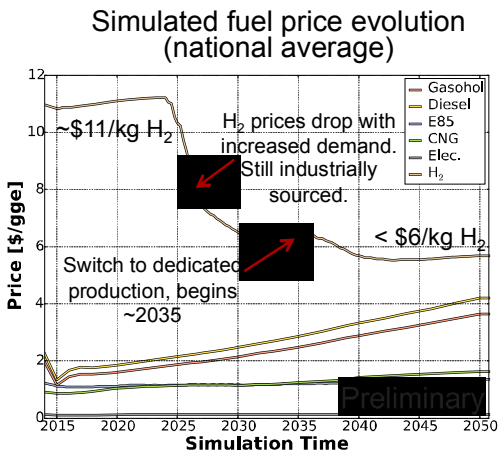



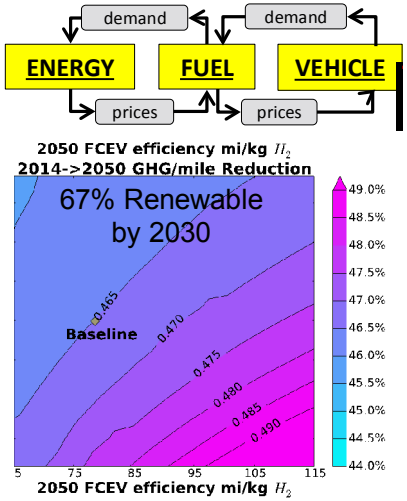


Systems Engineering

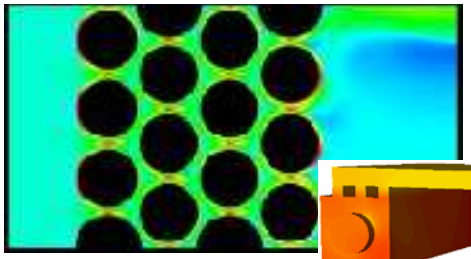
Infrastructure Scenario and Techno-economic Analysis

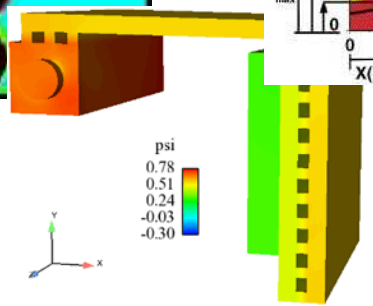


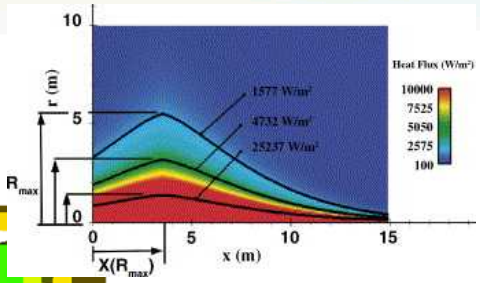


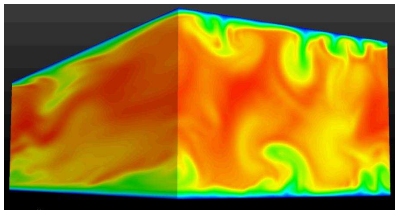
Capabilities for Hydrogen Research and Development

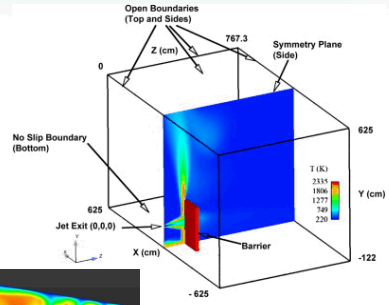
Thermal/Fluids Modeling and Simulation

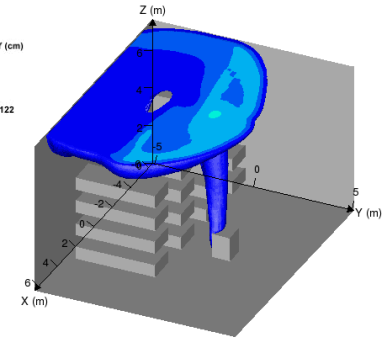




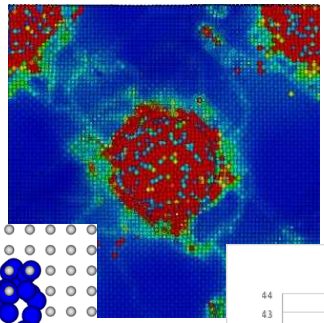


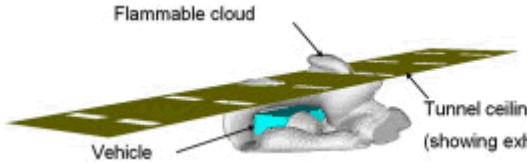


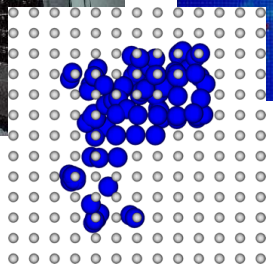


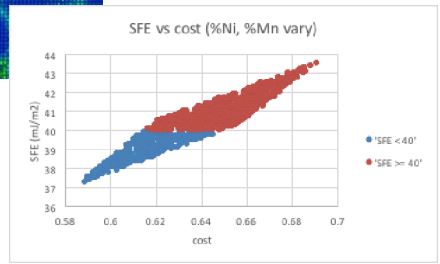


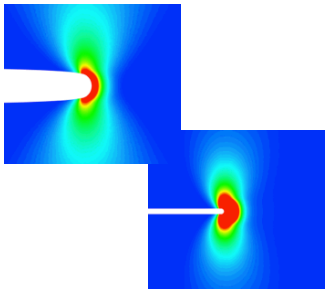
Infrastructure for High-Performance Computing





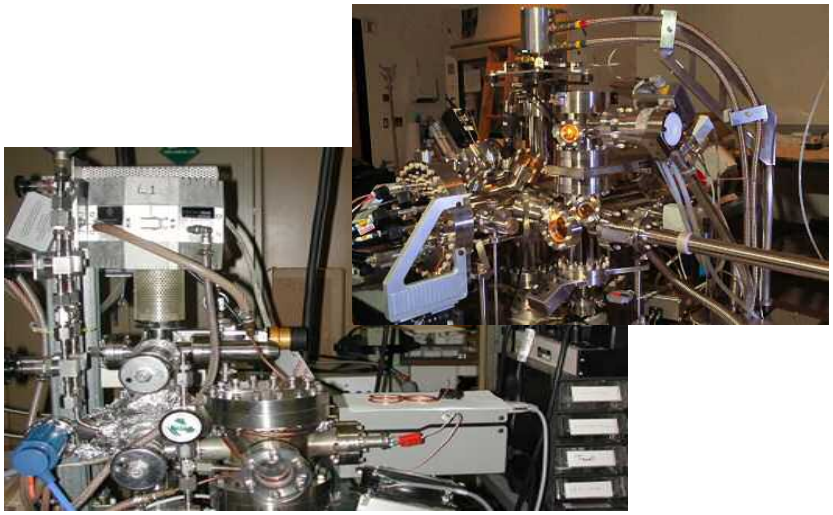




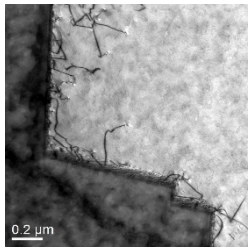


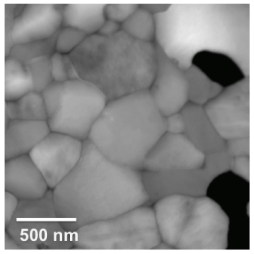
Capabilities for Hydrogen Research and Development

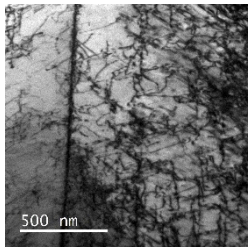
Permeation and Thermal Desorption Instruments and Expertise

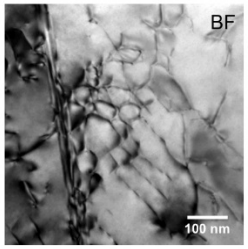


Electron Microscopy-Based Expertise in Interface Science and Material Defects

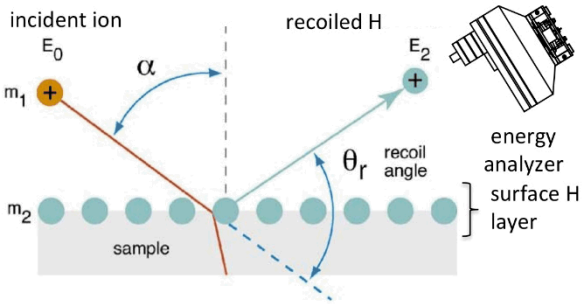


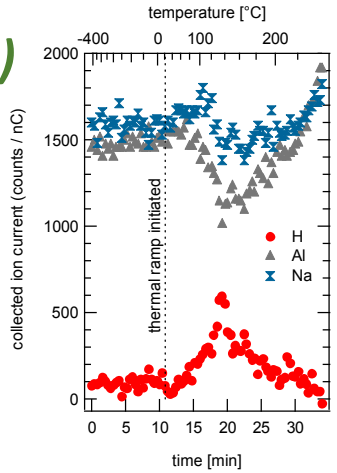






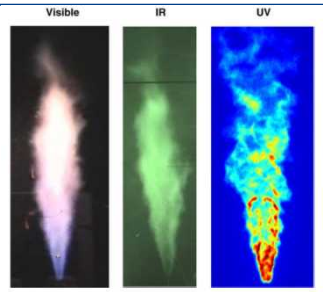
Angle-Resolved Ion Energy Spectrometery (ARIES)





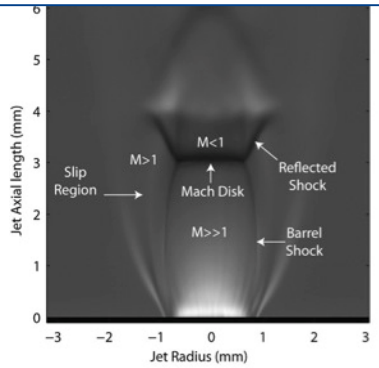
Hydrogen Science is Key to Developing Predictive Engineering Tools for Safety, Codes and Standards

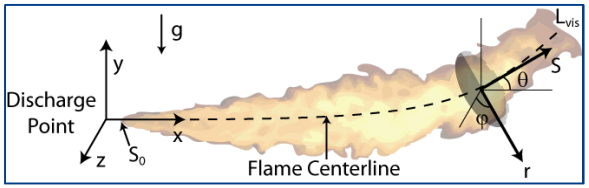
Radiative properties of H2 flames quantified



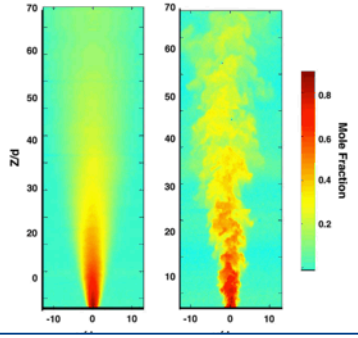
Barrier walls for risk reduction

Ignition of under-expanded H2 jets



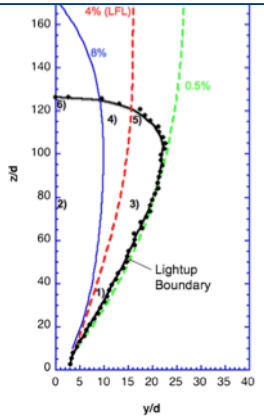


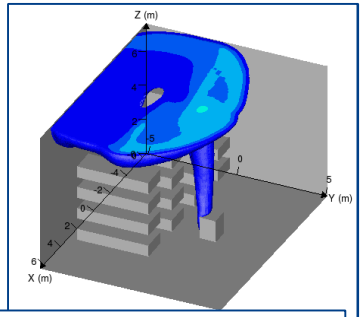
Buoyant jet flame model with multi-source radiation



Advanced laser diagnostics applied to turbulent H2 combustion

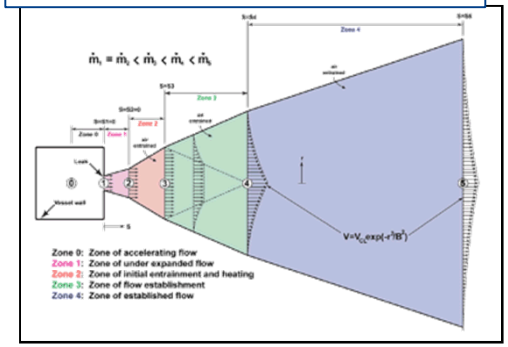
Ignition limits of turbulent H2 flows





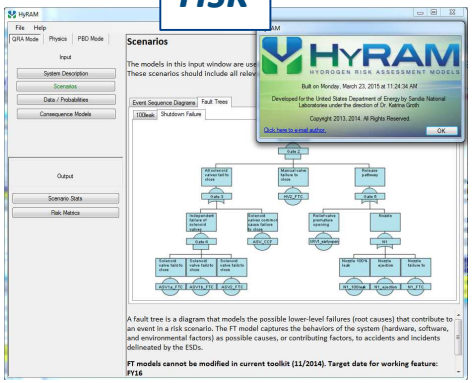
Experiment and simulation of indoor H2 releases

Laboratory-scale characterization of LH2 plumes and jets



Making Science Accessible through Integrated Tools

risk



Develop integrated methods and algorithms

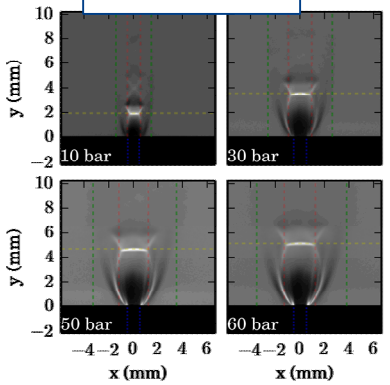
for enabling consistent, logical and defensible QRA

application

Apply quantitative risk assessment techniques

in real hydrogen infrastructure and emerging technology

behavior



Develop and validate scientific models

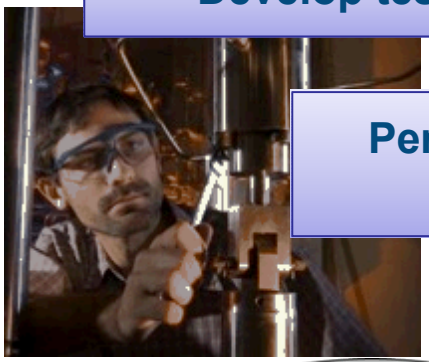
to accurately predict hazards and harm from liquid releases, flames, etc.

HyRAM
HYDROGEN RISK ASSESSMENT MODELS

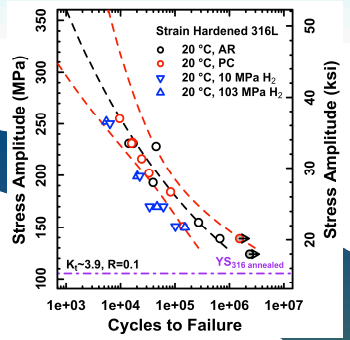
hyram.sandia.gov

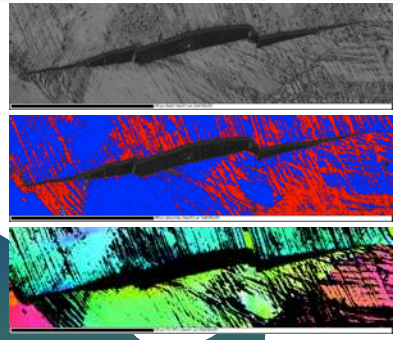
International Leadership in Materials Compatibility Enables Innovation of Hydrogen Technologies

Develop test methods

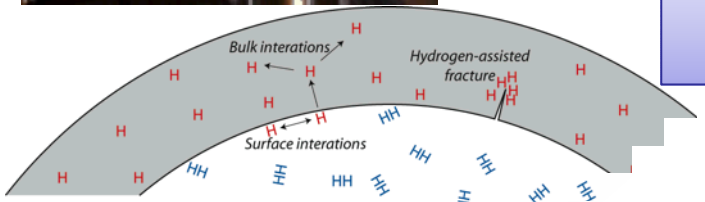


Performance-based testing (compatibility)

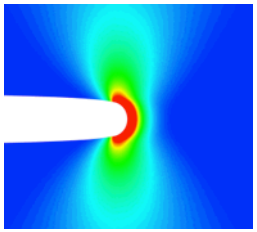




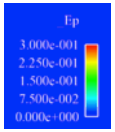
Understanding physics of hydrogen embrittlement

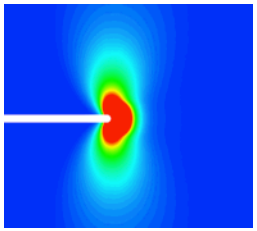


Predictive models

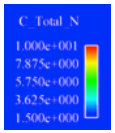


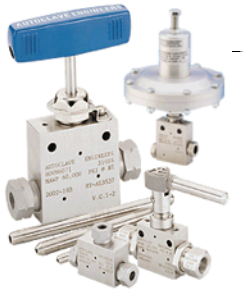
Transport

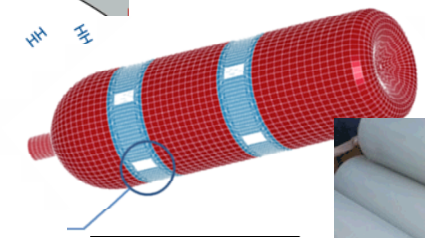




Mechanics

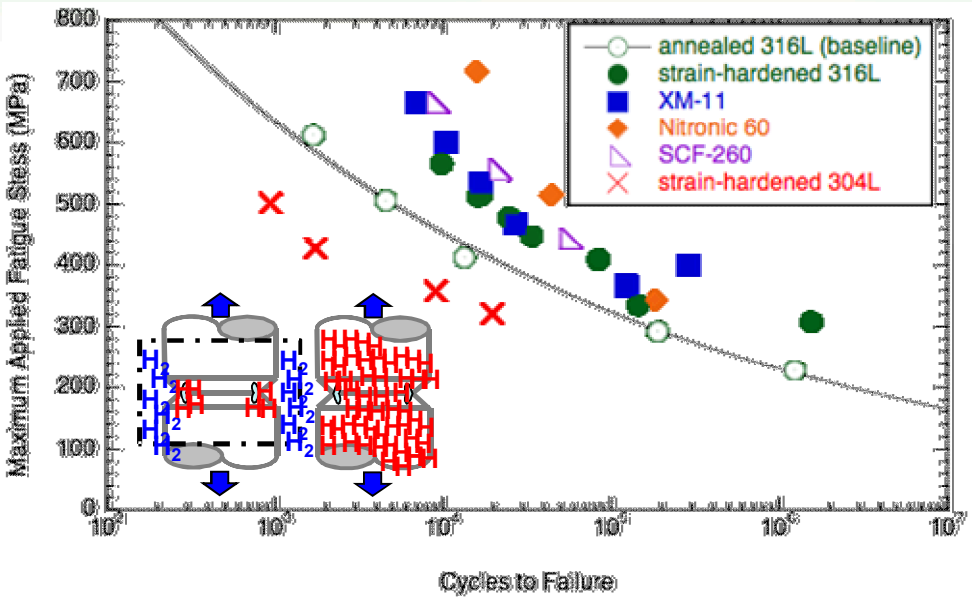




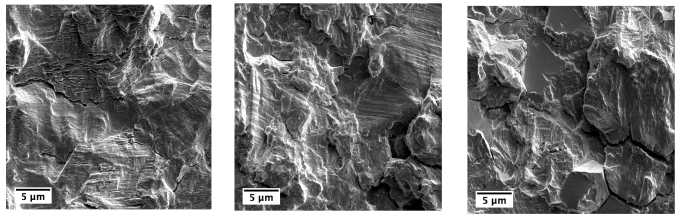


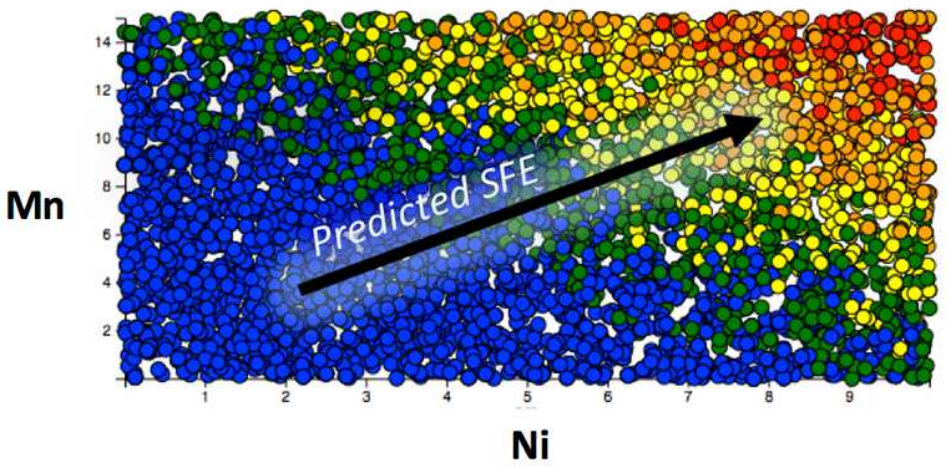
System validation (suitability)

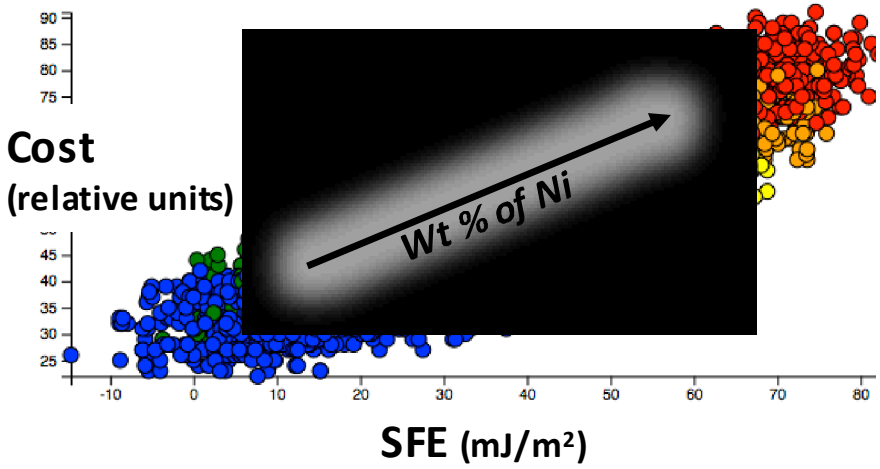
Evaluating Materials Options and their Hydrogen Compatibility Using Experiments and Modeling



Material	Raw Material Cost	Yield Strength (MPa)	Weight Savings (%)	Relative Material Cost (%)
316L (A)	*1.0*	*170*	*0*	*100*
316L (CW)	1.2	570	**70**	**36**
21Cr-6Ni-9Mn (XM-11)	0.8	540	**69**	**33**
304L (CW)	1.0	540	**68**	**26**
Nitronic 60	1.0	415	**59**	**48**
SCF 260	1.1	965	**82**	**23**





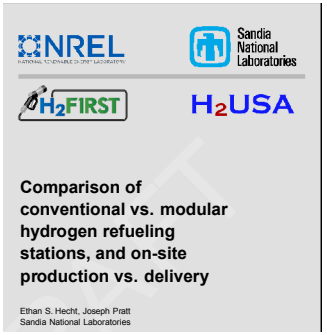


Hydrogen Fueling Infrastructure Research and Station Technology (H_2FIRST)

Goal: Leverage capabilities and expertise of national laboratories to address challenges for hydrogen fueling station deployment.

Key areas focused on include:

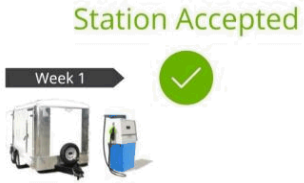
- Station Design, Status and Requirements
- System Cost and Reliability Engineering
- Station Acceptance and Qualification
- Fuel Containment Detection



Hydrogen Station Equipment Performance (HySTEP) – *Accelerate commercial hydrogen station acceptance by developing and validating a prototype device to measure hydrogen dispenser performance.*

Fill safely
Follow standards:
SAE J2601-2014 (fueling protocol)
CSA HGV 4.3 (dispenser test method)
Test stations

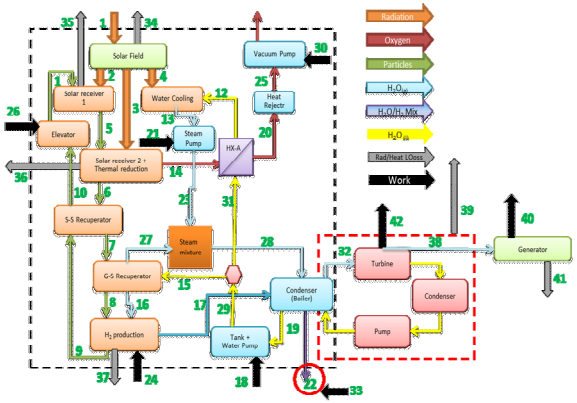
HyStEP acts as FCEV surrogate; operated by testing agency

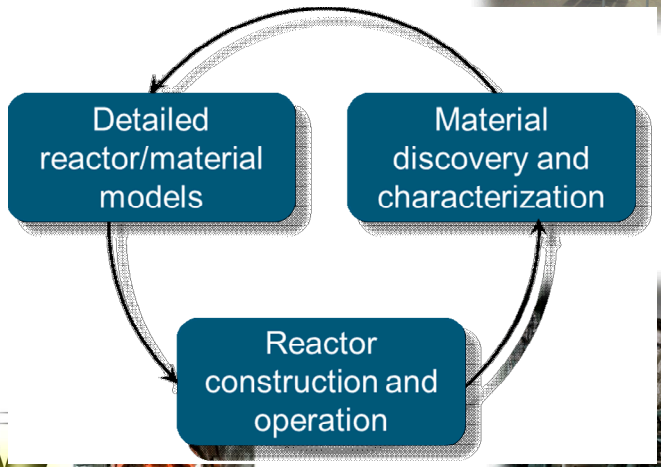


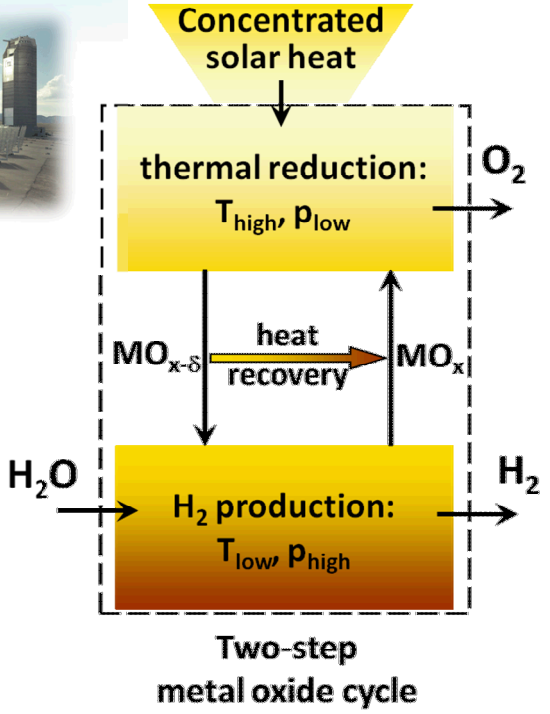
Large-Scale Renewable Hydrogen Production using Solar Power Leads to a Sustainable Energy Future

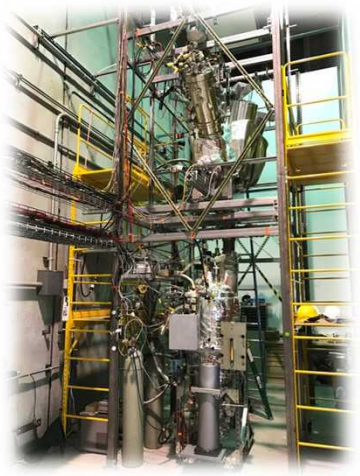
MW scale concentrating solar power provides heat for

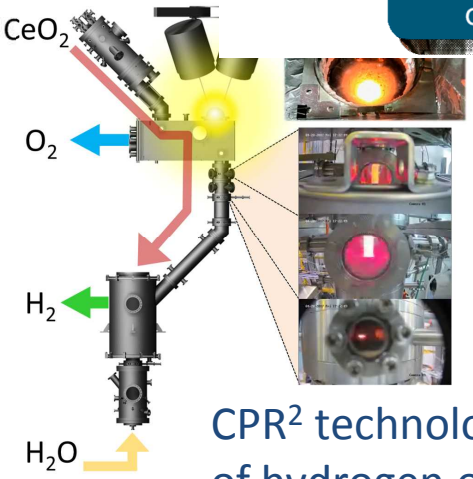
1. Metal oxide reduction
2. Oxidation with water ***producing H_2***











The challenge is to develop efficient and scalable solar-powered reactors up to 100,000 kg/day

CPR² technology produced 2 liters of hydrogen on simulated sun.

HydroGEN
Advanced Water Splitting Materials

Sandia National Laboratories

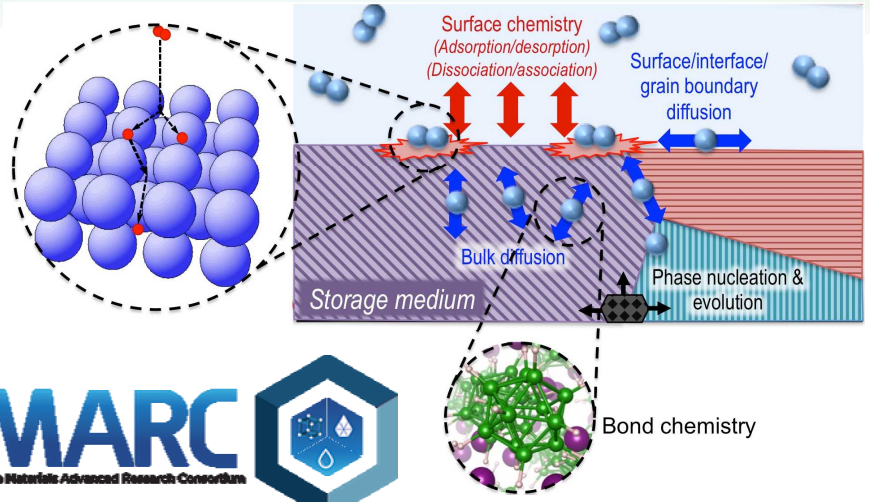
H_2FC Hydrogen and Fuel Cells Program

Hydrogen Storage – Advancing solutions for materials

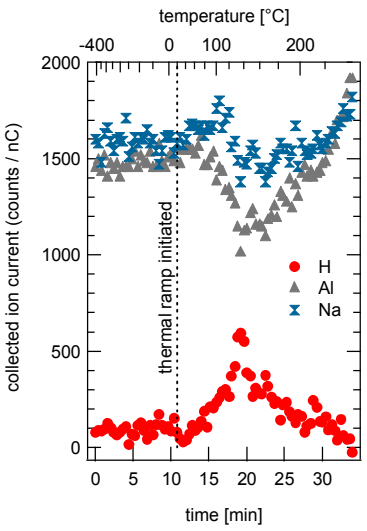
https://hymarc.org

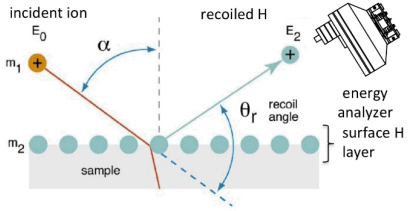
Sandia National Laboratories | Lawrence Livermore National Laboratory | Berkeley Lab

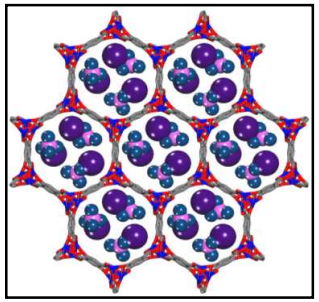
Hydrogen Materials Advanced Research Consortium (HyMARC) – Develop fundamental understanding of the underlying phenomena limiting solid-state hydrogen storage materials, thereby enabling breakthroughs to new materials meeting all DOE targets.

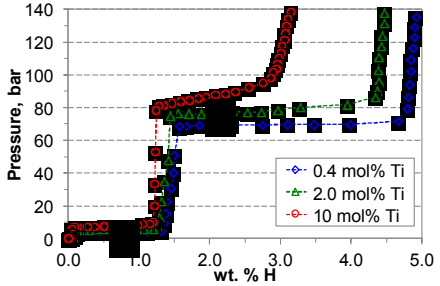


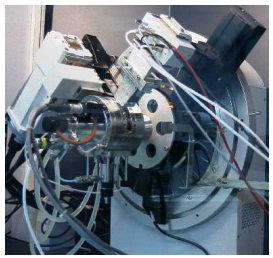
HyMARC
Hydrogen Materials Advanced Research Consortium

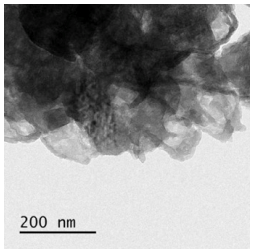


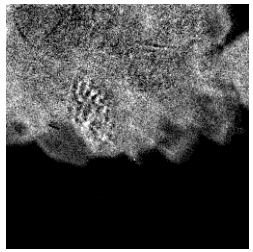


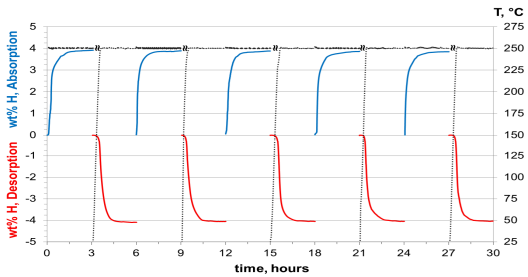












Early-Market Demonstrations of Hydrogen Tech

Hydrogen Fuel Cell Mobile Light Tower

- Zero emissions
- Quiet alternative to mobile diesel power

Hydrogen Fuel Cell Generator for Maritime/Ports

YOUNG BROTHERS

- Quiet, deployable power
- Containerized, clean power

Zero Emission Hydrogen Passenger Ferry *(feasibility study)*

- Green transportation over water
- Multi-use hydrogen station

High-speed hydrogen fuel cell ferry

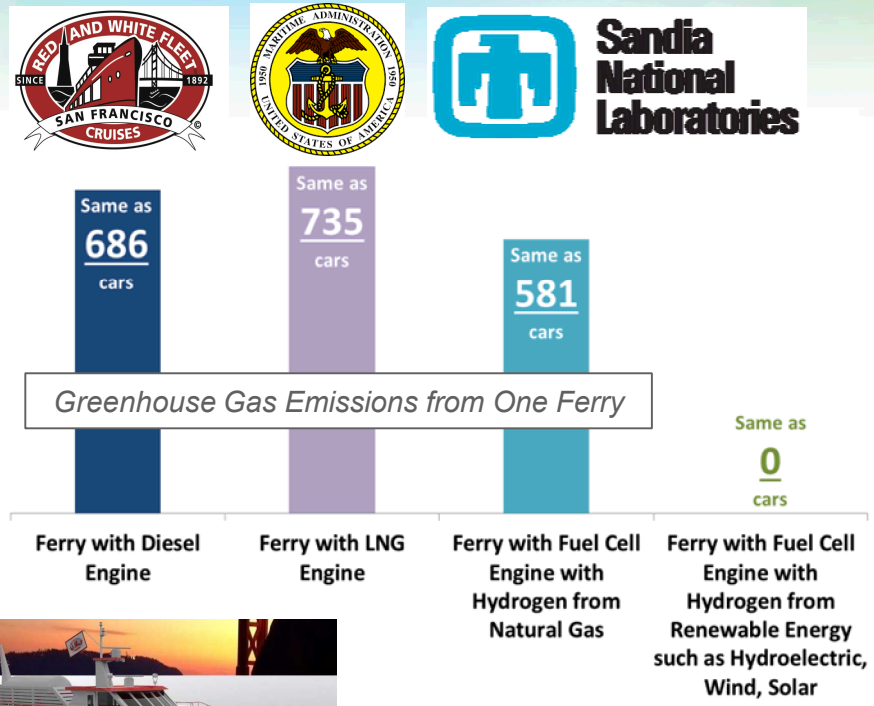
Ferry concept

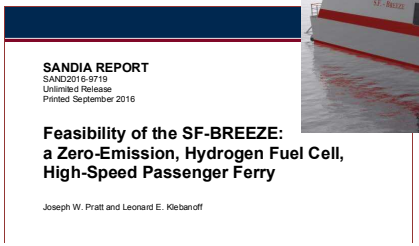
- Quiet, zero-emissions
- ~150 passenger, >25 kts
- 1,000 kg/day hydrogen demand

Enables deployment of large-scale hydrogen station

- > 1,200 kg/day capacity
- Cost-effective fuel for vessels, cars, buses, and trucks

Feasibility study funded by DOT/MARAD

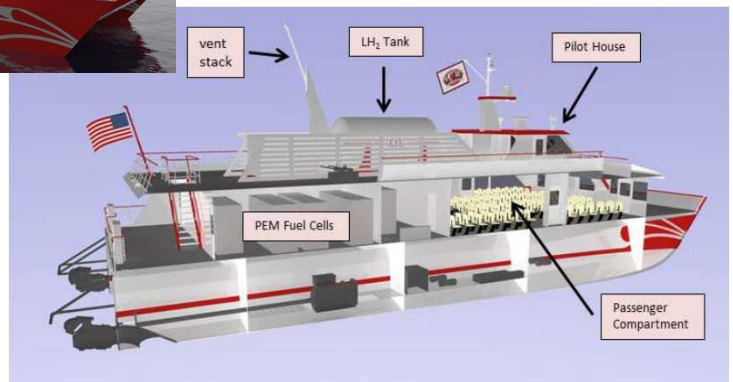



SANDIA REPORT
SAND2016-9719
Unlimited Release
Printed September 2016

Feasibility of the SF-BREEZE: a Zero-Emission, Hydrogen Fuel Cell, High-Speed Passenger Ferry

Joseph W. Pratt and Leonard E. Klebanoff

Passenger ferry



These vessels "have the potential to provide the Bay Area and the country with an entirely new green industry."
– letter from Monique Moyer, Director, San Francisco Port

Customers and Partners

Hawaii Hydrogen Carriers, LLC

Hydrogen could enable robust integration of energy sectors

H_2 Transportation

Gas/H_2 to Trans.

Heat

Trans. to Power

Heat to Gas/H_2

Managed as an integrated energy system H_2 production and storage enables:

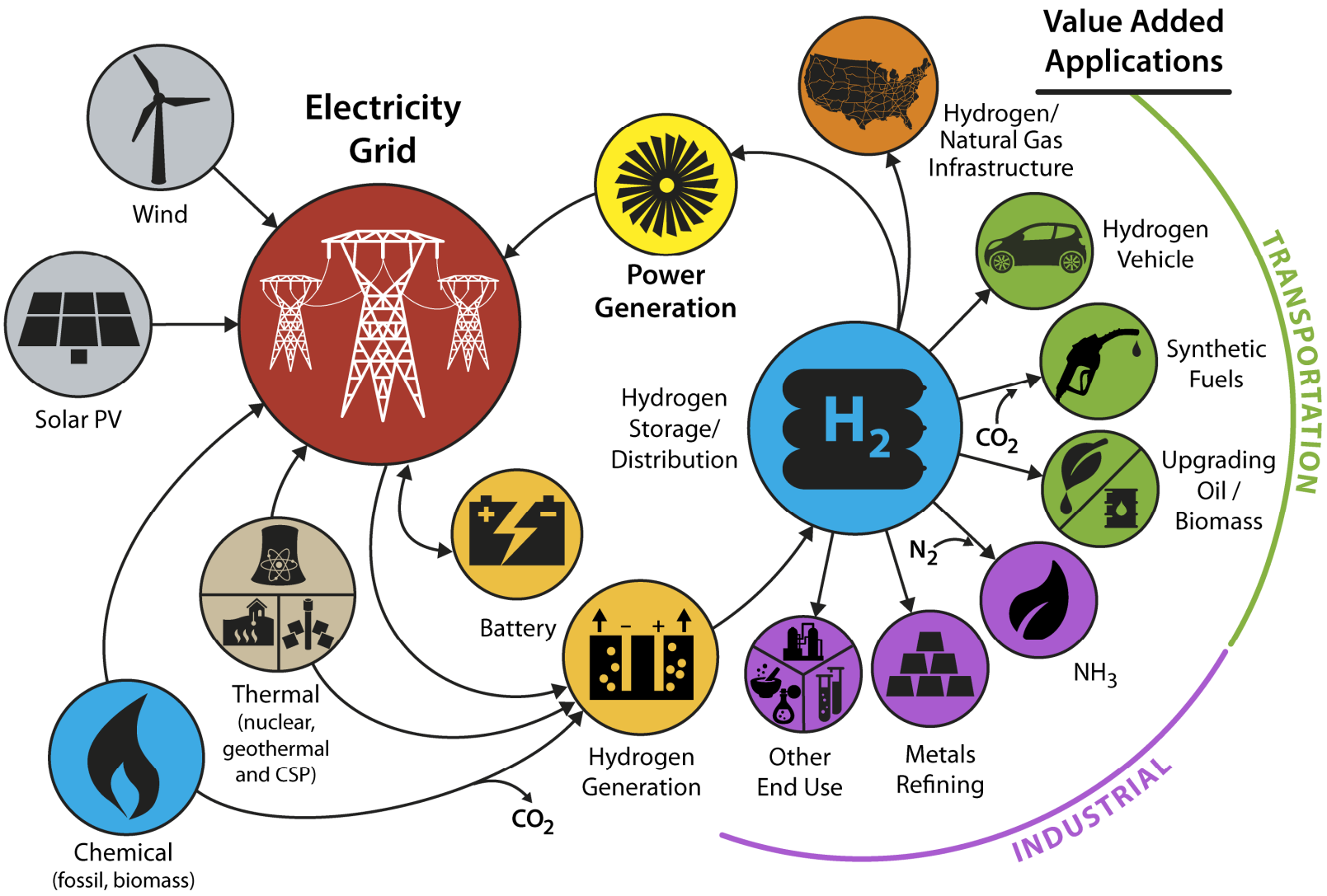
- Sustainability (clean energy)
- Resiliency
- Reliability
- Flexibility

Power

Power to Gas/H_2

Gas / H_2

H2@Scale: Conceptual Low-Carbon Energy System*



*Illustrative example, not comprehensive; from H2@Scale Big Idea Concept, Pivovar et al