CENTER FOR

Hydrogen™ SAFETY

Connecting a Global Community

CHS Strategic Vision

Champion hydrogen safety and best practices worldwide

Empower stakeholders and the workforce

Ensure the safe and timely transition to hydrogen and fuel cell technology

The Need for Safety

Safety issues must be addressed for successful hydrogen technology deployment. It is necessary for leaders to establish a culture friendly to safety in order to be successful.

Its use as a fuel is new to many

- Users may lack experience or expertise for its safe use
- Some users have misconceptions… and may not know that they don't know

Stable foundation

- Hydrogen can be used safely… It has been for nearly a century by industry
- Safety knowledge and best practices exist

Dangerous assumptions

- "We already know how to use hydrogen safety" (apathy - established users)
- "Hydrogen is like any other flammable gas" (misconceptions - new players)
- "Hydrogen is too dangerous" (fear - general public/AHJ's)

Failing to address the knowledge gaps can result in impactful incidents.

CHS Membership Value

- **Collaborate** in a global hydrogen safety community
  - Demonstrate commitment to safety - "License to do business"
  - Participate in member meetings
  - Contribute to working groups and conferences

- Access resources to **remove barriers** and manage risk
  - Hydrogen Safety Panel
  - Hazard analysis, site evaluation, custom training
  - Outreach, incident investigation

- **Increase knowledge** and expertise
  - Training courses, credentialing, and webinars
  - Conferences and workshops
  - Best practices and incident resources
  - Technical bulletins

Membership Benefits

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MEMBERSHIP TYPE (COST)	EXECUTIVE ($50,000 USD/yr)	GOVERNMENT ($25,000 USD/yr)	INDUSTRY ($15,000 USD/yr)	STARTUP ($5,000 USD/yr)	NATIONAL LAB ($5,000 USD/yr)	UNIVERSITY ($2,000 USD/yr)
Seat on the Managing Board	●					
Direct Strategy and Influence Path of CHS	●					
Participation in Working Groups	Guaranteed	As Available	As Available	As Available	As Available	As Available
Discounted HSP Review Charges	-25%	-25%	-15%	-10%		
Discounted Credentialing	-50%	-25%	-25%	-25%	-25%	
Discounted Conferences and Workshops	Free*	●	●	●	●	●
Discounted eLearning Courses through AIChE Academy	Free**	●	●	●	●	●
Demonstrate Commitment to Safety	●	●	●	●	●	●
Newsletter and Technical Bulletins	●	●	●	●	●	●
Incident Coordination and Resources	●	●	●	●	●	●
Participation in Monthly Members Meeting	●	●	●	●	●	●

** First 5 registrations free* *** First 500 seats free. Additional seats discounted*

CENTER FOR Hydrogen SAFETY
Connecting a Global Community

EXECUTIVE MEMBERS

AIChE

AcuTech
PROCESS RISK MANAGEMENT

Air Liquide

bp

BLACK & VEATCH

STATE OF CALIFORNIA ENERGY COMMISSION

conEdison

Cummins

STRATEGIC PARTNERS

Asia-Pacific Hydrogen Association

Australian Hydrogen Council

California Fuel Cell Partnership

CGA Compressed Gas Association
The Standard For Safety Since 1913

DECHEMA Gesellschaft für Chemische Technik und Biotechnologie e.V.

U.S. Department of Energy
Energy Efficiency & Renewable Energy

Hydrogen Council

hySafe International Association for Hydrogen Safety

HySUT

INERC BV
Quality Services for Operations

IPHE

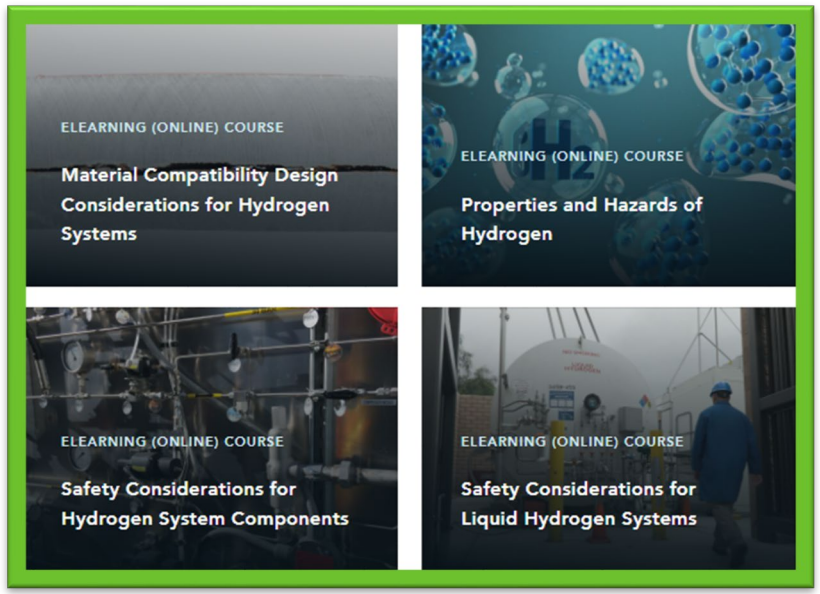
RHA Renewable Hydrogen Alliance

SCEJ The Society of Chemical Engineers, Japan

MEMBERS

AcuTech PROCESS RISK MANAGEMENT
Rocket Company ASTRA
Air Liquide
AIR PRODUCTS
Atura Power
bp
BAKERRISK
BayoTech
BLACK & VEATCH
Bloomenergy
BrainDrip Patently True Innovations
Brookhaven National Laboratory
STATE OF CALIFORNIA ENERGY COMMISSION
CATERPILLAR
Pacific Northwest Center of Excellence for Clean Energy
CF
Chevron
Chevron Phillips Chemical Company LP
ENERGY INSTITUTE COLORADO STATE UNIVERSITY
conEdison
Constellation
CSA GROUP
CSIRO
Cummins
DOUGLAS COUNTY P.U.D.
Dräger
ELECTRIC HYDROGEN
EPRI ELECTRIC POWER RESEARCH INSTITUTE
EMCARA
ENEOS
ENGIE
equinor
EVERSOURCE
ExxonMobil
TRUE ZERO
FuelPositive Fuel For A Mindful World
GEXCON
GTI ENERGY
HTEC FUELING THE DRIVE TO HYDROGEN
HYSTOR ENERGY
HAVRAND Hydro
HYDROGEN RESEARCH INSTITUTE UQTR
HYUNDAI
IH Independence Hydrogen
intertek
Iwatani Group Iwatani Corporation of America
JGC
Kawasaki
Kiewit
한국가스안전공사 KOREA GAS SAFETY CORPORATION
LIFTE H2
Linde Making our world more productive
MACQUARIE University SYDNEY·AUSTRALIA
MITSUBISHI HEAVY INDUSTRIES
MOLLO HYDROGEN (PTY) LTD GREEN IS THE FUTURE!
MYONGJI UNIVERSITY
nationalgrid
NREL NATIONAL RENEWABLE ENERGY LABORATORY
Nebraska Public Power District Always there when you need us
nel
NIKOLA
HySA Infrastructure Hydrogen South Africa
NOVO HYDROGEN
NW Natural
NEW YORK STATE OF OPPORTUNITY. NYSERDA
OAK RIDGE National Laboratory
ohmium
origin
Pacific Northwest NATIONAL LABORATORY
plug
RENEWABLE INNOVATIONS renewable-innovations.com Clean Scalable Power
SAN JUAN COLLEGE School of Energy
Sandia National Laboratories
SAPPHIRE GAS SOLUTIONS
aramco
Savannah River National Laboratory
Shell
SoCalGas A Sempra Energy utility
Southern Company
STAR SCIENTIFIC
TC Energy
tenova
Chemours
PILOT COMPANY
TOYOTA
UL
UNIVERSITY of HOUSTON
UNIVERSITY OF MARYLAND
MISSISSIPPI POLYMER INSTITUTE
WASHINGTON STATE UNIVERSITY
WHA
Williams
Woodside
WOODWARD
Xcel Energy
ZHEJIANG UNIVERSITY 1897

Fundamental Hydrogen Safety Courses



Fundamental Hydrogen Safety E-Courses

- Hydrogen as an Energy Carrier
- Properties and Hazards
- Safety Planning
- Facility Design
- Equipment and Components
- Liquid Systems
- Material Compatibility
- System Operation
- Inspection & Maintenance

- CHS's Fundamental Hydrogen Safety Courses have been developed to help the industry build the safety skills needed to meet the demands of the growing hydrogen marketplace.
- 9 courses covering the fundamentals of hydrogen safety
- Take at your own pace, purchase ala carte or as a package for the credential
- $69 for non-members, $34.50 for members

Fundamental Hydrogen Safety Credential

Credential Pricing	Exam Fee/Renewal Fee	Retake Fee	Packaged Program*
CHS Member	$180.00	$80.00	$490.50
CHS Executive Member	$120.00	$80.00	$430.50*
CHS University Member	$240.00	$80.00	$550.50
All Others	$240.00	$80.00	$861.00

- CHS's Fundamental Hydrogen Safety Credential demonstrates an employee's understanding of hydrogen's properties and best practices for handling it safely.
  - 3 year renewal cycle
  - Requires you to have taken and passed all 9 fundamental hydrogen safety courses
  - Requires you to pass the Hydrogen Safety Credential Exam with 80% or greater

Free: Hydrogen Laboratory Safety Course

- CHS's Hydrogen Laboratory Safety Course is intended to help the learner understand the hazards of hydrogen and apply best practices for creating and maintaining safe laboratories and safe experiments.
  - Two hour course
  - Free for all comers
  - Learn about…
    - General laboratory safety culture
    - Identification, prevention, and mitigation of hydrogen hazards
    - Specific design considerations for hydrogen laboratories and experimental equipment
    - Safety and Emergency planning

Free: First Responder Hydrogen Safety Training

Free First Responder Hydrogen Safety E-Courses

- Introduction to Hydrogen Safety for First Responders
- CHS First Responders Micro Training Learning Plan
  - First Responders Micro Training Learning Plan
  - Introduction to Hydrogen Fuel Cell Vehicles for Incident Response
  - Fire Response & Extrication of a Hydrogen Fuel Cell Vehicle
  - Transport of Hydrogen Fuel
  - Hydrogen Fueling Station Incident Response

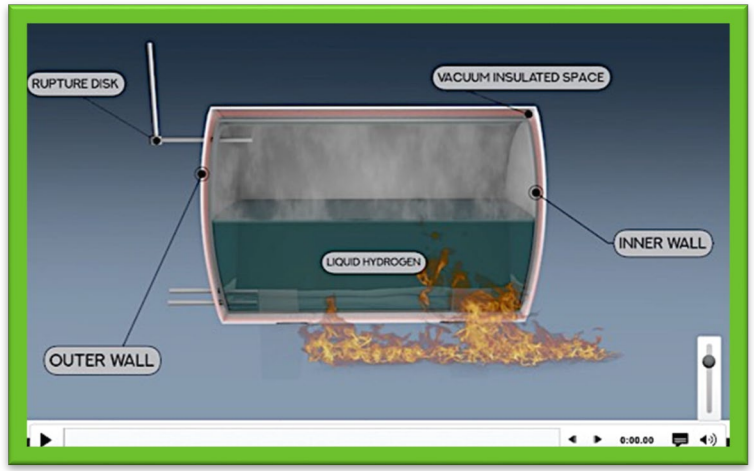
- The Center for Hydrogen Safety (CHS) has developed training to better equip first responders with technical knowledge and aid in their preparedness for mitigating potential risk associated with hydrogen, Fuel Cell Electric Vehicles, and fueling stations.

CHS Conferences

- CHS Conferences are designed to connect the global hydrogen community
  - Focused on applied hydrogen safety topics
  - Built in panel Q&A for each session
  - Conferences hosted once a year
  - Conferences are hosted in the Americas, Europe, or Asia Pacific
  - Conferences cover all areas of the world in a 3 year rolling manner

CHS Custom Training

- Can be done **virtually or onsite**
- Available for a wide variety of audiences
  - Code officials, fire prevention officers and inspectors
  - Academia and laboratories
  - OEMs and equipment producers
  - Military organizations
- Topics can be tailored to specific needs
- Materials include slides, videos and animations
- Led by members of the Hydrogen Safety Panel

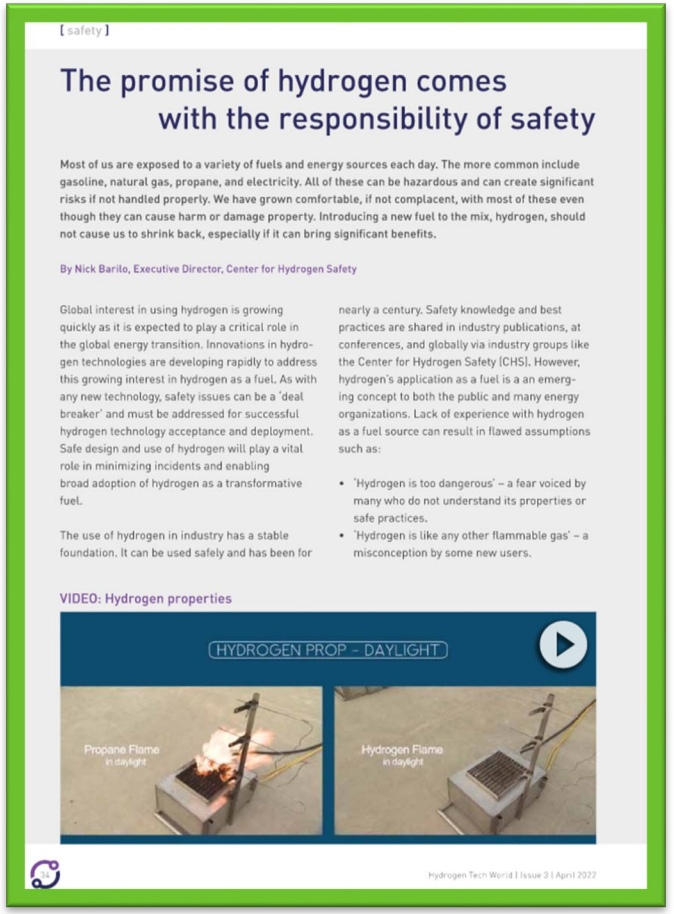


CHS Webinar Series

- [CHS's Hydrogen Safety Webinar Series] covers discrete hydrogen safety topics
  - Live webinars free to all
  - 60 min of deep content, 30 min of Q&A with the presenter/presenters
  - Questions not answered during live Q&A answered afterwards and provided as PDF
  - Archive of past webinars
    - Free to members
    - Available for purchase for non-members

Publications and Podcasts

- CHS engages with outside magazines and podcasts to spread the word about hydrogen safety.
- Explore the back catalog of articles and e-content
  - Magazine articles
  - External podcasts
  - CHS LinkedIn Lives
  - External webinars



[safety]

The promise of hydrogen comes with the responsibility of safety

Most of us are exposed to a variety of fuels and energy sources each day. The more common include gasoline, natural gas, propane, and electricity. All of these can be hazardous and can create significant risks if not handled properly. We have grown comfortable, if not complacent, with most of these even though they can cause harm or damage property. Introducing a new fuel to the mix, hydrogen, should not cause us to shrink back, especially if it can bring significant benefits.

By Nick Barilo, Executive Director, Center for Hydrogen Safety

Global interest in using hydrogen is growing quickly as it is expected to play a critical role in the global energy transition. Innovations in hydrogen technologies are developing rapidly to address this growing interest in hydrogen as a fuel. As with any new technology, safety issues can be a 'deal breaker' and must be addressed for successful hydrogen technology acceptance and deployment. Safe design and use of hydrogen will play a vital role in minimizing incidents and enabling broad adoption of hydrogen as a transformative fuel.

The use of hydrogen in industry has a stable foundation. It can be used safely and has been for nearly a century. Safety knowledge and best practices are shared in industry publications, at conferences, and globally via industry groups like the Center for Hydrogen Safety (CHS). However, hydrogen's application as a fuel is a an emerging concept to both the public and many energy organizations. Lack of experience with hydrogen as a fuel source can result in flawed assumptions such as:

- 'Hydrogen is too dangerous' – a fear voiced by many who do not understand its properties or safe practices.
- 'Hydrogen is like any other flammable gas' – a misconception by some new users.

VIDEO: Hydrogen properties

CHS Hydrogen Incident Response Activities

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Hydrogen Incident Occurs

CHS reaches out through established channels to gather all relevant information

CHS Holds Member Meeting

CHS convenes members to discuss incident and share information

CHS-HSP Participates in Fact Finding

HYDROGEN Safety Panel

CHS and the Hydrogen Safety Panel are available to help determine cause

CHS Develops Incident Record

CHS creates members-only incident report to track latest information and lessons learned

CHS Publishes Lessons Learned

HydrogenTools

CHS translates information into public lessons learned and publishes on H2Tools.org

Other resources CHS may use for responding to an incident:

- Education Materials – new courses, revised course content, etc.
- Technical Bulletins – members only and public safety bulletins developed and disseminated
- Working Groups – to address important safety issues and develop learnings for community and industry
- Conferences & Workshops – share incident information and learnings
- Incident Management Guide

Update on CHS Working Groups

The Center convenes groups of CHS members around topics of shared interest to facilitate collaboration. Specific objectives and deliverables set by individual groups.

- **Introducing H_2 into Natural Gas Infrastructure**
  - Answering key H2 safety questions related to blending H2 & NG
- **Hydrogen Equipment and Component Failure Rates**
  - Developed a process for collecting failure rate data for specific components
  - Developing a document that contains recommended failure rate data for H2 specific equipment & components
- **Academia**
  - New working group aimed at university and research institutes.
- **Hydrogen Safety Culture**
  - New working group putting together safety culture information.

H2 to NG Working Group

This working group was initiated to identify safety considerations for projects related to introducing hydrogen into existing natural gas pipelines. This group will share best practices and identify safety topics that need further consideration.

Key Deliverables

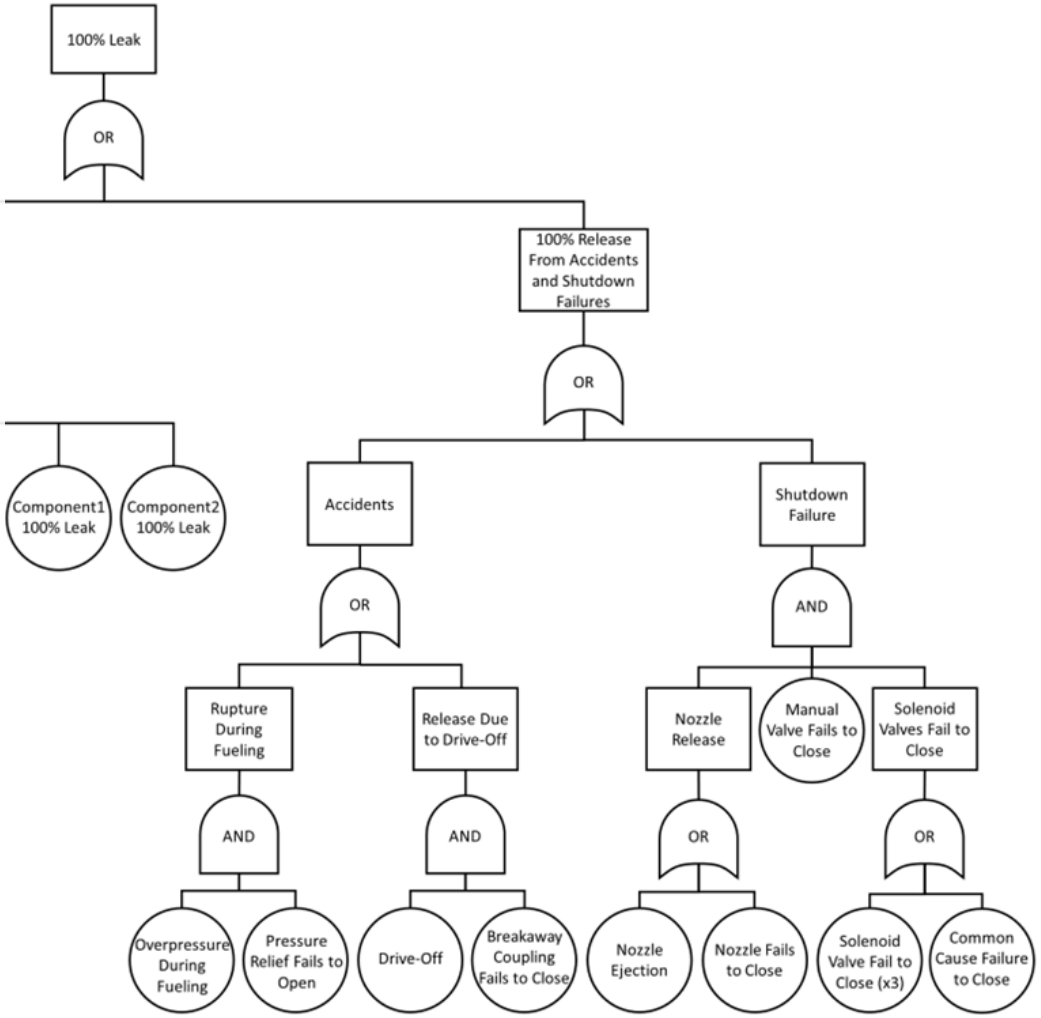
- Living Document that identifies the following:
  - Existing information and safety practices across the supply chain
  - Areas with conflicting information/best practices
  - Areas of importance where no information exists
- Prioritize "gaps" and Identify Solutions:
  - Which gaps in existing information are most important to solve first?
  - Identify potential solutions for closing this gap
- Create and publish Best Practices

Risk Assessment/Failure Rates Working Group

This working group was initiated based on the need to identify global uniform failure rates for hydrogen for the purpose of conducting risk assessments.

Key Deliverables

- Short Term Goal – Identify what data is currently out there and what are the common risk assessment processes
- Long Term Goal- Compiling living document or database available for CHS Members, which can be updated with incident data



Hydrogen Safety Culture Working Group

CHS convened this working group to help craft best safety culture practices for the industry which will ensure consistency and help create trust in the ability of the hydrogen energy industry to deliver safe, reliable, and high-quality products and services. This working group also supports an International Energy Agency - Hydrogen Safety Task that is being conducted in collaboration with the Hydrogen Council.

Key Deliverables

- Materials that can be used by companies to promote safety culture within their organization.

Academia Working Group

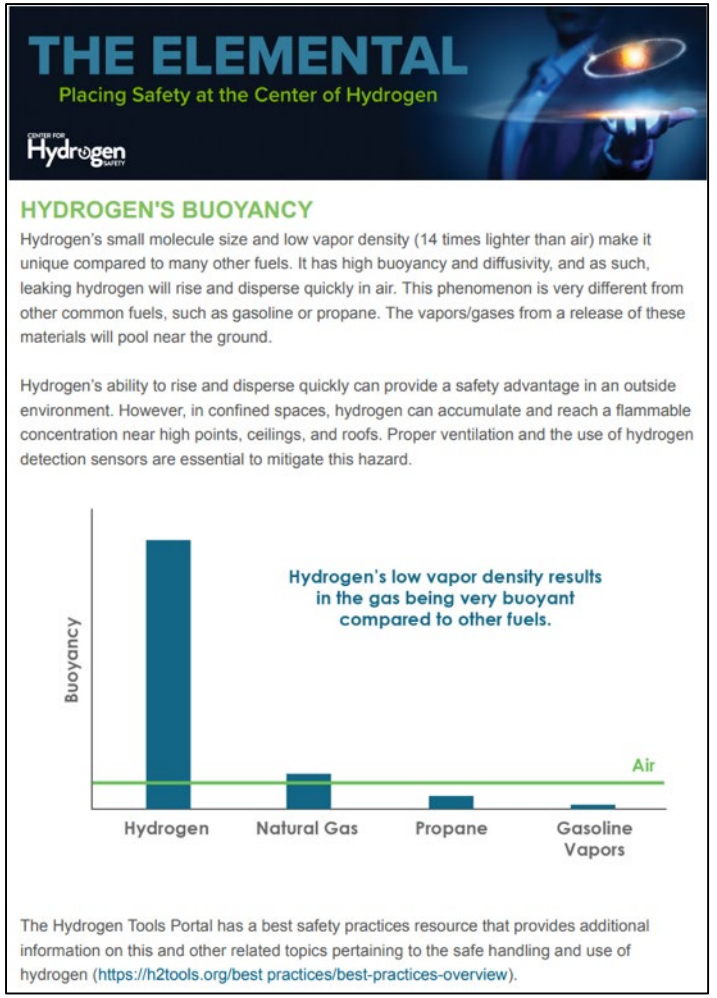
This working group was initiated by university and research groups within CHS membership to address hydrogen safety needs within academia.

Key Deliverables

- To address hydrogen safety knowledge gaps in academia.
- To help define the role of academia in promoting hydrogen safety in the energy transition

The Elemental

- The Elemental is a one-page safety message for those working with, or supporting the use of, hydrogen and fuel cell technologies.This bulletin provides a means to learn about and share hydrogen in an easy-to-access format.
- Free for both members and non-members
- Access The Elemental back catalog here.
- Sign up to receive The Elemental in your inbox
- Let us know if you have suggestions for The Elemental? Email chs@aiche.org



THE ELEMENTAL

Placing Safety at the Center of Hydrogen

HYDROGEN'S BUOYANCY

Hydrogen's small molecule size and low vapor density (14 times lighter than air) make it unique compared to many other fuels. It has high buoyancy and diffusivity, and as such, leaking hydrogen will rise and disperse quickly in air. This phenomenon is very different from other common fuels, such as gasoline or propane. The vapors/gases from a release of these materials will pool near the ground.

Hydrogen's ability to rise and disperse quickly can provide a safety advantage in an outside environment. However, in confined spaces, hydrogen can accumulate and reach a flammable concentration near high points, ceilings, and roofs. Proper ventilation and the use of hydrogen detection sensors are essential to mitigate this hazard.

The Hydrogen Tools Portal has a best safety practices resource that provides additional information on this and other related topics pertaining to the safe handling and use of hydrogen (https://h2tools.org/best practices/best-practices-overview).

Hydrogen Safety Panel (HSP)

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THE HSP PROMOTES SAFE OPERATION, HANDLING, AND USE OF HYDROGEN

Background

- Formed in 2003
- 22 members with 600+ yrs combined experience
- Hydrogen safety reviews – hydrogen fueling, auxiliary power, backup power, CHP, portable power, and lab R&D
- White papers, reports, and guides
- Provides support on the application of hydrogen codes and standards
- H_2 safety knowledge shared through the H_2 Tools Portal (h2tools.org)

19 Years

593 Reviews

423 Projects

200+ Presentations

15 Guides

Impact

- Non-regulatory, objective, and neutral
- Helps reduce costs
  - Costs from over-engineering
  - Delayed approvals
  - Missed safety considerations/features
- Provides a balanced solution to questions and problems
- Helps projects avoid safety incidents
- Helps establish stakeholder and public confidence

HSP Members

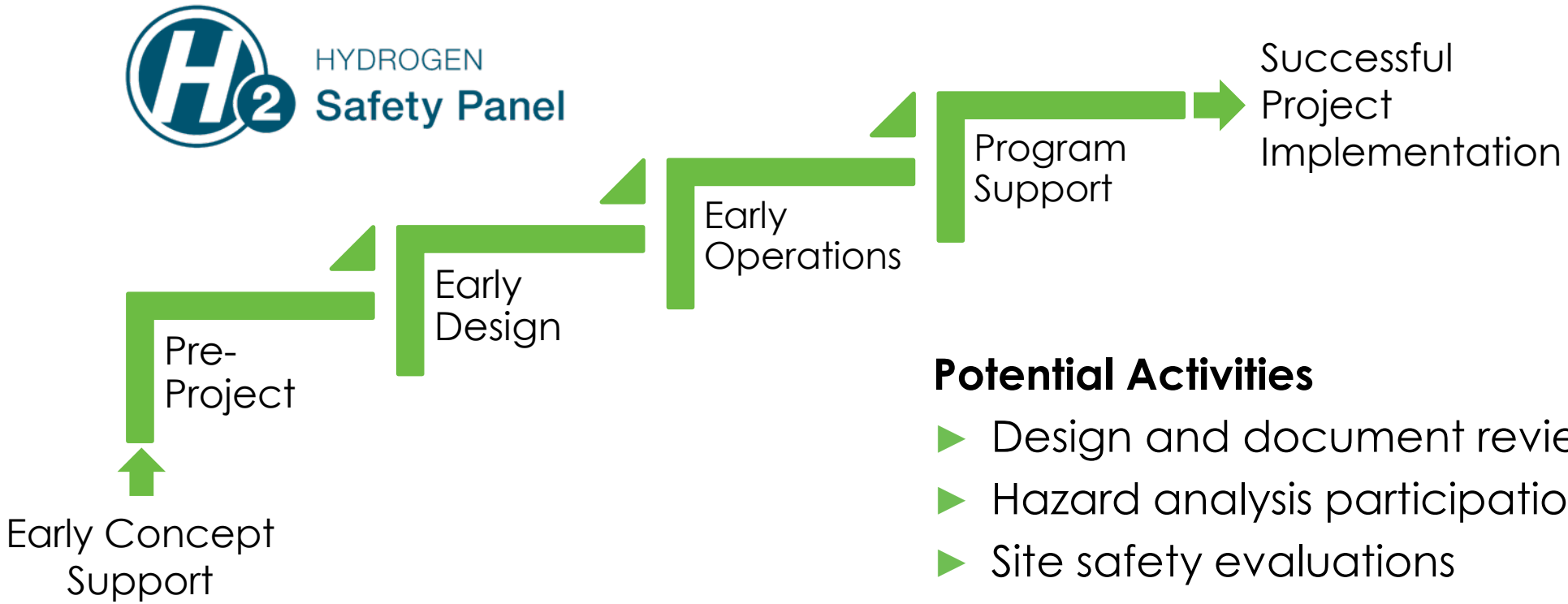
The HSP is a multidisciplinary team of engineers, code officials, safety professionals, equipment providers, and testing and certification experts.

The Panel provides guidance for hydrogen projects and facilities, including design and process safety reviews, support/review of risk analyses, onsite safety presentations, and training.

Members of the HSP at 2022 Meeting

Name	Affiliation
Nick Barilo, Manager	Pacific Northwest National Laboratory
Rick Tedeschi, Chair	Tedeschi Consulting Solutions, LLC
Ilse Alcantara	NASA-JSC White Sands Test Facility
Harold Beeson	WHA International, Inc
Ken Boyce	UL, LLC
Bud Bucci	TradeWind Services, LLC
Tom Drube	Chart Industries
David Farese	Air Products and Chemicals
Donald Frikken	Becht Engineering
Livio Gambone	Nikola Motors
Aaron Harris	Air Liquide
Brian Ladds	Calgary Fire Department
Chris LaFleur	Sandia National Laboratories
Larry Moulthrop	Proton Onsite (retired)
Dani Murphy	WHA International, Inc.
Annemarie Purmer	OCI
Spencer Quong	Quong & Associates
Brian Somerday	Somerday Consulting, LLC
Gary Stottler	Stottler Development, LLC
Kelly Thomas	Baker Risk
Tom Witte	Witte Engineered Gases and Cryogenics
Robert Zalosh	Firexplo

CHS Use of the Hydrogen Safety Panel



Potential Activities

- Design and document reviews
- Hazard analysis participation/review
- Site safety evaluations
- Safety training and webinars
- Outreach
- Incident investigation

Follow Us on LinkedIn

CHS Showcase Page

- Follow us at www.linkedin.com/showcase/center-for-hydrogen-safety/
- Posts will include member highlights and news, h2tools resources, upcoming events, conference promotion and snapshots, among others
- Let us know if you have news for us to cross-post

Questions?

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