IEA Hydrogen: Safety and Sustainability

Mary-Rose de Valladares

ICHIS September 2017
IEA HIA Members - Executive Committee (July 2017)

21 Countries + European Commission + UN + 4 Sponsors
IEA HIA Strategic Framework

AN INTERNATIONAL ENERGY AGENCY TECHNOLOGY COLLABORATION PROGRAMME
Strategic Framework 2009–2020

Vision: A hydrogen future based on a clean sustainable energy supply of global proportions that plays a key role in all sectors of the economy

Mission: To accelerate hydrogen implementation and widespread utilization to optimize environmental protection, improve energy security and promote economic development internationally while establishing the HIA as a premier global resource for expertise in hydrogen

Strategy: To facilitate, coordinate and maintain innovative research, development and demonstration activities through international cooperation and information exchange
Themes and Portfolios

Collaborative RD&D that advances hydrogen science and technology
- Hydrogen production
- Hydrogen storage
- Integrated hydrogen systems
- Integration of hydrogen in existing infrastructure

Analysis that positions hydrogen
- Technical progress and optimization
- Market preparation and deployment
- Support in political decision-making

Understanding, Awareness and Acceptance that fosters technology diffusion and commercialization
- Information dissemination
- Safety
- Outreach
Overarching Objectives for the period 2015-2020

- Broaden the perspective on the transformative role of H2 by articulating and communicating its functions and value as a highly flexible energy vector and energy carrier capable of serving as a weapon against climate change in an integrated future multi-sector energy system.

- Focus on the development and implementation of the H2 infrastructure

  Formulate messages derived from IEA HIA technical and analytic activities guide in order to guide and inform policy making activities.

- Strengthen analysis activities

  Cultivate and deepen industry participation

  Foster productivity and progress

- Raise the profile of the IEA HIA
OECD
Organisation for Economic Co-operation and Development
(Created by treaty post war)

International Energy Agency Hydrogen Technology Program
(Created by treaty in 1977)
Operations

- Bottom-up basis for portfolio development – one member, one vote – consensus-based culture
- Strategy and portfolio (tasks and activities) self-determined
- “Task-Shared” – tasks supported by in-kind Member contribution of expertise that “pools expertise”
- Single Common Fund fee allows Member participation in any and all tasks
- Cooperation – with other scientists and research efforts – facilitates the discovery process and protects Intellectual Property
### IEA Hydrogen Task Portfolio July 2017

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**R,D&D: Production**

**Task 33: Local H2 Supply for Energy Applications**
*(2013-2016) – Applied (successor to Task 23)*
- Evaluation and harmonization of various technologies for local H2 supply for reduced costs and increased employment
- Expands research to include electrolysers as well as reformers
- Significant industry participation = INDUSTRY NETWORK
- 16 Participants from 15 organizations in 10 Member countries plus EC

### Key Findings:
- While existing HRS fueling protocols and H2 quality standards for FCEVs are strict and lead to extra costs, they are not technical barriers.
- Small-scale electrolyzers and reformer systems with hydrogen capacities in the range of 50-500Nm3/hr are commercially available. The specific cost (CAPEX) [USD /per NM3/hr] of small scale water electrolyzers and reformers are comparable.
- Both alkaline and PEM water electrolyzers are available in MW scale. While PEM is less proven and more costly (CAPEX) than alkaline, it is more compact and suitable for dynamic load following.
R,D&D: Production


- Subtask 1 - BioHydrogen production (Dark Fermentation and Bioelectrolysis; light-drive BioHydrogen production; Enzymatic and Bio-inspired Molecular Systems)

- Subtask 2 – Applied Research and Biohydrogen Production

- 11 Participants: Member Countries; Asian concentration; solid European participation; participation expected to grow (Europe, Asia, Latin America)

Key Findings:

- Key drivers for biohydrogen technology are not only the need for renewable energy demand
- Treat waste and recover water and other valuable resources such as phosphate
R,D&D: Production

Task 35 Renewable Hydrogen Production (2014-2017) - Basic

- SUPER TASK
- Subtask 1 – Renewable Electrolysis
- Subtask 2 – Photoelectrochemical Solar Water-Splitting
- Subtask 3 – Solar High Temperature Thermochemical Cycles
- 30 Participants from 10 Member countries plus EC; US concentration

Renewable Hydrogen Options
R,D&D: Production

Recent Highlights

- **Subtask 1 – Renewable Electrolysis**
  - Several Megawatt scale wind to hydrogen projects underway in the US

- **Subtask 2 – Photoelectrochemical Solar Water-Splitting** *(24 march 2017)*:
  - Worlds largest artificial sun at DLR, Germany with 149 7-kW xenon short-arc lamps delivering
  - 11 MW/m² (max. 320 kW), used for research on hydrogen production with concentrated solar power

- **Subtask 3 – Solar Thermochemical Water Splitting**
R,D&D: Hydrogen Storage

- Further research on new and improved compounds and demonstration of solid storage systems for stationary, mobile and portable applications, as well as electrochemical storage
- World’s largest R&D collaboration in H2 Storage
- Project based participation: 52 experts from 17 Member countries organized in 6 working groups:
  - Porous materials
  - Magnesium-based H2 and energy storage materials
  - Complex and liquid hydrides
  - Electrochemical storage of energy
  - Heat storage – concentrated solar thermal using meta hydrides
  - H2 storage systems for mobile applications
- A special issue of the international journal ‘Applied Physics A’ by Springer has recently been published

Key Findings:
- Concentrating Solar-thermal power plant, heat storage tank system - Andasol 28,500 t molten salt for storage of 1,000 MWh could be replaced by 1,100 t MgH2
- Modified Sodium hydride (NaH) shown to be reversible for the first time after four cycles
## Market Readiness Assessment for “Japanese residential CHP”

**Task 29, Subtask 4 – Concept Replicability**

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<td>2 Fuel cell subsystem maturity</td>
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<td>3 Boiler subsystem maturity</td>
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<td>6 Integration between hydrogen components in the system</td>
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Overall goal is to provide knowhow on the use of hydrogen and fuel cells in the maritime:

- **Subtask 1 – Technology Overview**
  - Investigate possibilities for use of hydrogen in the maritime
- **Subtask 2 – New Concepts**
  - Contribute to new concepts, technologies and components
- **Subtask 3 – Demonstration**
  - Provide input, evaluate and link international demonstration projects
- **Subtask D – large-scale storage and greening of gas**
- **Growing Participation** - To date 11 Member countries and EC confirming (all European but clear US interest)

**Rationale:**

- Shipping is the primary means of transportation worldwide
- 90% of all trade between countries is on ships
- Ports in the UE handles 400 million passengers in 2013
- Nexus of land and sea provides infrastructure opportunities
Analysis


- Environmental challenges
- Economic Analysis
- Social Indicators and Integrative approaches for LCSA
- 2 papers published: one in Springer and one in Elsevier

Fig 1 shows the decision diagram designed for the harmonisation process. In the first block of the diagram, choices about general modelling approach, LCIA method and system boundaries are tackled.
Analysis

Task 38: Power to Hydrogen and Hydrogen-to-X: System Analysis of the techno-economic, legal and regulatory conditions

- Subtask 1: Management and Communication
- Subtask 2: Mapping and analysis of existing demo projects
- Subtask 3: Deliverables
- Subtask 4: Specific Case Studies
Task 38: Cross-Cutting - Power to Hydrogen

GREEN HYDROGEN IN POWER, GAS, TRANSPORTATION AND INDUSTRY SECTORS

22.09.2016
Hydrogen Awareness, Understanding and Acceptance (AUA): Safety

- Subtask A – Integrated Tool Kit for Hazards and Risk Assessment
- Subtask B – Accident Scenarios/Sequences Development
- Subtask C – Physical Effects
- Subtask D – Human Reliability Analysis (HRA)
- Subtask E – Materials Compatibility

Key Findings:
- Clear need to create harmonious safety codes and standards.
- (C&S) to accelerate worldwide adoption of hydrogen-based technologies.
- Insufficient technical data to revise C&S remains a challenge.
- Usage and access restrictions (for road tunnels, parking structures) are a challenge.
- Tasks 19/31 held an End of Task North American Workshop in 2013; a companion workshop will be held 14 September in Hamburg
ICHSCONFERENCE2017
International Energy Agency Hydrogen Technology Collaboration Programme

Task 37 – Hydrogen Safety
Task 37 Operating Agent:
Dr. Y. (John) Khalil, Associate Director of Research at the United Technologies Research Center (UTRC), USA, and Research Fellow at the University of Oxford, United Kingdom
Contact: khaillyf@utrc.utc.com

Announces

IEA H2 Stakeholder Workshop on Hydrogen Safety

Hydrogen Safety:
Prospects for Hydrogen Technologies and Applications

Where: Former Main Customs Office Hamburg
Alter Wandramh 20 Hamburg, Germany
(Same location as ICHS2017)

When: 14 September 2017 from 11:15-17:00
Immediately following ICHS 2017

Lunch: Lunch will be provided

No registration fee. However, space is limited.
RSVP on Eventbrite to reserve your place ASAP.

Internationally recognized hydrogen safety experts will present their latest research activities in this 2017 European IEA H2 Workshop. The experts’ presentations will discuss deterministic phenomenological studies and probabilistic methods and tools related to hydrogen safety and applications. Insights on market readiness and challenges to global-scale penetration of hydrogen technologies and recent accomplishments of safety codes & standards will be part of the panel discussion in this European IEA H2 Workshop.

IEA Hydrogen (www.ieahydrogen.org) is an international collaboration with a long-standing commitment to hydrogen safety research that enhances hydrogen awareness, understanding and acceptance.

For more information please contact: khaillyf@utrc.utc.com
Hydrogen AUA: Information Dissemination and Outreach
Global Automotive Executive Survey 2017
http://kpmg.com/GAES

- Opinions of 1,000 executives from 42 countries:
- «Evolutionary, revolutionary and disruptive key trends?»
- «Battery e-vehicles #1 key trend in 2017, fuel cell e-vehicles #3 key trend»
- «Battery e-vehicles (BEVs) will fail due to infrastructure challenges, while fuel cell e-vehicles (FCEVs) are seen as the real breakthrough for e-mobility»

62% of executives absolutely or partly agree that BEVs will fail due to infrastructure challenges.

Executive opinion

78% of executives absolutely or partly agree that FCEVs will be the real breakthrough for electric mobility.

Executive opinion

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FCHJU Region and City Initiative:
Potential use of Fuel Cell and H2 Based Products

There are bankable business cases for PtoH in Europe already today

- By 2025, the European market for PtoH is estimated at a cumulative 2.8 GW, representing a market value of 4.2B€ and 400 ktons H2 per year.
- Bankability can be achieved by complementing hydrogen sales with electricity grid flexibility services
- Combining PtoH for mobility/industry applications and gas grid injection is more cost-effective than stand-alone injection
- Gas grid injection is a risk mitigation instrument until H2 demand picks up
- The Clean Energy package is a unique opportunity to create a market for PtoH in oil refineries
- PtoH is a practical and system-beneficial way to value excess of RES but requires a long-term view on grid fees, taxes and levies to enable bankability
Industry Outreach in Hydrogen

New Hydrogen Council launched at WEF in Davos, January 2017

13 leading energy, transport and industry companies have launched a global initiative to voice a united vision and long-term ambition to help achieve the ambitious goal of reaching the 2 degrees Celsius target.

- Hydrogen Council members plan to invest at least EUR 1.9 billion per year in hydrogen technology for the coming 5 years.
- Investments in market introduction and deployment are growing and are showing the acceleration of commercialization.

«How hydrogen empowers the energy transition»
www.hydrogencouncil.com, January 2017
Market development & technology trends

- Continuous improvements along the entire hydrogen and fuel cell value chain

1 Extrapolating the growth to 20 MW in 2017/2016 from outstanding projects, 2 Assuming 20k units production per year, 3 Assuming 100k units production per year in 2025

Source: IEA, E4Tech, US DOE, PwC research

«How hydrogen empowers the energy transition»

www.hydrogencouncil.com, January 2017
Leading Western and Asian Countries H2 Infrastructure Plans

**US**
- 2016: 60
- 2020: 130
- 2025: 600

**Europe**
- 2016: 100
- 2020: 520
- 2025: (Up to 2,000) (3)

**Asia**
- 2016: 103
- 2020: 340
- 2025: 830

Notes:
1. Publicly available HRS from countries with a significant HRS network development
2. Countries or states with no major HRS outlook as of today
3. Depending on the number of FCEVs on the road

Source: H₂ Mobility, US DOE, Hydrogen Europe, Air Liquide

*How hydrogen empowers the energy transition*
www.hydrogencouncil.com
January 2017
AN INTERNATIONAL ENERGY AGENCY TECHNOLOGY COLLABORATION PROGRAMME

Analysis and Budget

- **Analysis**
- **Budget Adoption**
- **Support R&D, Private Investment**
- **Budget Development**
- **Policy Making**
- **Policy Decisions**
- **Results and Outcomes**
- **Information and Conclusions**
# Safety Agenda

## IEA H2 European Workshop

### Hydrogen Safety: Prospects for Hydrogen Technologies & Applications

**Hamburg, Germany**

**11:30-17:00**

<table>
<thead>
<tr>
<th>Time</th>
<th>Presentation Topic</th>
<th>Speakers and Affiliation</th>
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</thead>
<tbody>
<tr>
<td>11:00-11:10</td>
<td>Introduction and opening remarks</td>
<td>Jani Jornes, Former Chair, IEA Hydrogen</td>
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<tr>
<td>11:10-11:30</td>
<td>IEA H2 Overview</td>
<td>Mary Rose de Valdarees, IEA Hydrogen General Manager</td>
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<tr>
<td>11:30-11:45</td>
<td>IEA Task 37 Overview</td>
<td>John Khali, IEA H2 Operating Agent, Task 37</td>
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<tr>
<td>11:45-12:00</td>
<td>Safety of Hydrogen in the Energy System</td>
<td>Stuart Hawkesworth, HSE, Boston, UK</td>
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<tr>
<td>12:00-12:30</td>
<td>Recent advances in hydrogen safety research at Ulsan - Part I</td>
<td>Vladimir Miskev, University of Ulsan, UK</td>
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<tr>
<td>12:30-13:00</td>
<td>Lunchtime speaker - Ulsan Part II 13:15-13:30</td>
<td>University of Ulsan, UK</td>
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<tr>
<td>13:30-14:15</td>
<td>The new version of the Hydrogen Incident Accident Database (HIAAD)</td>
<td>Dario MeleDeo JRC, Directorate C - Energy, Transport and Climate Energy, Stringer Unit</td>
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<tr>
<td>14:10-14:35</td>
<td>DTU - Current work related to hydrogen safety in infrastructure</td>
<td>Frank Marquet, DTU</td>
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<td>14:40-14:55</td>
<td>Numerical modelling of vented lean hydrogen-air deflagrations using HyFOAM</td>
<td>Venkata C. Madhav Rao, Jennifer X. Wen, University of Warwick, UK</td>
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<tr>
<td>14:55-15:10</td>
<td>Evaluation of engineering models for vented lean hydrogen deflagrations</td>
<td>Anubhav Saha, Venkata Chandru and Jennifer X. Wen, University of Warwick, UK</td>
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<td>15:10-15:20</td>
<td>Break</td>
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<td>15:20-15:45</td>
<td>Flame propagation (deflagration, DDT, and detonation) in hydrogen-air</td>
<td>Knut Vogtenher, USN, Norway</td>
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<tr>
<td>15:45-16:10</td>
<td>Prospects for improved consequence modelling and risk assessment for hydrogen applications</td>
<td>Tryggve Skjold, Gazco AS, Norway</td>
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<td>16:10-16:50</td>
<td>What are the main challenges to mass adoption of hydrogen-based technologies and how do we address them?</td>
<td>Panel Discussion, Thomas Jordam at KIT’s Perspective, John Khali, Panel Moderator</td>
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<tr>
<td>16:50-17:00</td>
<td>Closing</td>
<td>John Khali</td>
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Thank you from the IEA HIA
A premier global resource for technical expertise in H2 RD&D

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Most promising market segments were modelled in detail: light Duty Vehicles (LDV), buses and city delivery trucks.
Market development & technology trends: Fuel Cells and Hydrogen in Transport

- Heavy/materials handling vehicles: emerging market opportunity with global potential
Market development & technology trends:
Fuel Cells and Hydrogen in Transport

- **Heavy fuel cells vehicles as emerging market opportunity with global potential**
  - FC buses: city fleets around the world moving from demonstrating fuel cell buses to long term order schedules.
    - China: adding several hundred FC buses
    - South Korea: replacing 27,000 CNG buses with FC buses until 2030.
    - Europe: 3EMotion-project
  - Logistics and duty vehicles: Pollution rises pressure to shift to alternative fuels or powertrains. H2-trucks in operation in Norway, Switzerland, Netherlands.
  - Light rail: Trams and light rail as markets where fuel cells can exhibit significant performance and cost improvement against traditional powertrains and infrastructure (new infrastructure in China, US, replacement of stock in Europe)
    - €50 million exclusive deal between Alstom and Hydrogenics
    - Framework agreement between Ballard Power and
    - Tangshan Railway Vehicle Company