IEA Hydrogen Vision and R,D&D: Current perspectives, future prospects

Mary-Rose de Valladares, Paul Lucchese

EFC 13 December 2017
### IEA Hydrogen Members - Executive Committee (December 2017)

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21 Countries + European Commission + UN + 4 Sponsors
OECD
Organisation for Economic Co-operation and Development
(Created by treaty post war)

IEA
(Created by treaty in 1974, enabling Implementing Agreements)

International Energy Agency Hydrogen Technology Program
(Created by treaty in 1977)
Shared Community Vision

“Never doubt that a small group of thoughtful, committed citizens can change the world. Indeed, it is the only thing that ever has.”

Margaret Mead, Anthropologist
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 labor”
- Single Common Fund fee allows Member participation in any and all tasks
- Cooperation – with other scientists and research efforts – facilitates the research and discovery process
- Process to protect Intellectual Property
IEA Hydrogen Strategic Plan 2015-2020
IEA Technology Roadmap for Hydrogen and Fuel Cells 2015

- A Strategic Plan is developed for every five year cycle. Current SP is for period 2015-2020. 

- IEA Technology Roadmap – Hydrogen and Fuel Cells
  http://ieahydrogen.org/PUBLICATIONS,-REPORTS-
  PRESENTATIONS/Special-Reports.aspx
IEA Hydrogen Strategic Framework

- Vision
- Mission
- Strategy
- Technical Portfolio
- Market Portfolio
- Policy Support and Political Will Portfolio
- H₂ Storage Portfolio
- Integrated H₂ Systems Portfolio
- H₂ Production Portfolio
- H₂ Integration in Existing Infrastructure Portfolio
- H₂ Awareness, Understanding & Acceptance Portfolio
- Outreach Portfolio
- Safety Portfolio
- Information Dissemination Portfolio

AN INTERNATIONAL ENERGY AGENCY TECHNOLOGY COLLABORATION PROGRAMME
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.
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
Climate Change – Catalyst for Sustainability and Choice of Hydrogen

COP 22 - 2016
Train to Marrakech
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

Focus on the development and implementation of the H2 infrastructure

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.

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
Collaborative RD&D

**PRIORITY**
- Investigate development, deployment and delivery challenges and risks pertinent to hydrogen safety and infrastructure
- Pursue research on hydrogen production from renewable energy
- Explore power to hydrogen (P2H; power to gas - P2G; power to fuel), examining the potential for storage of intermittent renewable power sources in the natural gas grid for energy balancing
- Continue research on solid storage of hydrogen
- Research hydrogen production via reforming and gasification

**PORTFOLIOS**
- Hydrogen Production
- Hydrogen Storage
- Integrated Hydrogen Systems
- Hydrogen Integration in Existing Infrastructure

That advances hydrogen science and technology.
Analysis

**PRIORITIES**

- Explore the role of H2 in the energy mix of the future, assessing the maturity and state of the art of hydrogen technologies
- Perform techno-economic and life-cycle sustainability analysis (LCSA) of H2 systems
- Perform competitive technology and stakeholder analyses, highlighting the roles of business and innovation
- Elaborate the interaction with IEA analysis, particularly as regards ETP and WEO activities and publications
- Address the issue of social acceptance of hydrogen

**PORTFOLIOS**

- Technical
- Market
- Support for Political Decision-Making

For technical progress and optimization
For market preparation and deployment
For support in political decision-making
Hydrogen Awareness, Understanding & Acceptance

**Priorities**
- Convey the state of the art and maturity of hydrogen technologies and also report on competitive and stakeholder analyses
- Research and communicate the regulatory, code and standards (RCS) framework
- Conduct hazard assessment and develop quantitative risk assessment (QRA) tools related to safety
- Increase the visibility and media exposure of hydrogen via IEA HIA activities
- Influence IEA policy development through messaging derived from IEA HIA R&D and analytic activities as well as cooperation with other organizations

**Portfolios**
- Information Dissemination
- Safety
- Outreach

That fosters technology diffusion and commercialization.
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Hydrogen & Fuel Cells

Megawatts shipped by application 2011 - 2016

Annual FC vehicle shipments; 2017 estimate
Positive trend with continued growth in sales – 40% by total power ratings

- FCEVs upward - ~25%
- Stationary sales up - ~10%
- Diversity of applications – cars, delivery trucks, buses, heavy duty trucks, trams, trains
- Fuel cell categories: PEM at top; SOFC strengthening; PAFC growing; MCFC (down in 2017 but looking good going forward)
- China is key driver for many applications
- Market capitalization for dedicated fuel cell companies increasing (78% 2017 over 2016)
- Unit shipments: Growth in Asia (led by Ene-Farm); North American car demand good; large stationary strong in Korea, followed by U.S.; Europe still lags
- Japanese, Korean and California policy is industry mover
- Assessment: industry achieved some “traction” in 2017
R,D&D: Production

electrolysers and reformers

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: final report coming soon

- 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 electrolysers 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 electrolysers and reformers are comparable
- Both alkaline and PEM water electrolysers 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

- 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
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**
- Cooperation with IEA SolarPACES
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
R,D&D: Infrastructure and Integration Portfolios

Market Readiness Assessment for “Japanese residential CHP”
Task 29, Subtask 4 – Concept Replicability

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<td>Economic validation – case studies, documentation</td>
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<td>Potential impact of technology learning on costs</td>
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<td>Multiplicity of suppliers and market standardisation</td>
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<td>Market transformation potential</td>
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<td><strong>Community/User</strong></td>
<td>MAA MAA MAA MAA MAA MAA MAA MAA MAA</td>
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<td>Industry capacity for installation and maintenance</td>
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<tr>
<td>Does it meet stakeholder use expectations?</td>
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<tr>
<td>Service support and training</td>
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<td>Insurance and indemnity</td>
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<td>Social, education value</td>
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<tr>
<td><strong>Regulatory: RCS, policy and law</strong></td>
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<td>Application performance standards</td>
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<td>Application safety standards</td>
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<tr>
<td>Regulatory consents and permissions</td>
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AN INTERNATIONAL ENERGY AGENCY TECHNOLOGY COLLABORATION PROGRAMME

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: Life Cycle Sustainability Assessment**


- 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.
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
Analysis: Power to Hydrogen and Hydrogen to X

- Power to Hydrogen: low cost decarbonized electricity (not only « surplus »)
- Hydrogen to X (Industry, Mobility, Stationary, Power)
- Injection into gas grid: H2 or Synthetic methane?
- More than 50 demonstrations project around the world, some at scale

Hydrogen in the Energy System, extension of Smart Grid?

A major Challenge
Hydrogen Awareness, Understanding & 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 European workshop held in 14 September in Hamburg
Awareness, Understanding & Acceptance: ICHS Safety Conference

INTERNATIONAL CONFERENCE ON HYDROGEN SAFETY
September 11-13 2017 - Hamburg (Germany)
Awareness, Understanding & Acceptance: Information and Outreach

Successful Social Media: Facebook and Twitter

Launching this month: Global Trends and Outlook for Hydrogen
Some opportunities now under Consideration

**General**
- Leeds Project related activity
- Storage

**Analysis and Modeling efforts**
- Reference data
- Cooperation with IEA Analysts and other TCPs

- Renewable hydrogen options
  - Renewable Electrolysis
  - Photoelectrochemical Solar Water-Splitting
  - Solar High Temperature Thermochemical Cycles
Hydrogen: the Value Choice

Hydrogen

is a highly flexible energy vector and energy carrier capable of serving as a climate change solution in an integrated future multi-sector energy system.

Join us, per favore!
Thank you from IEA Hydrogen
A premier global resource for technical expertise in H2 RD&D

Contact:

Paul Lucchesed
IEA H2 Hydrogen Chairman
Paul.lucchese@capenergies.fr

Mary-Rose de Valladares
IEA Hydrogen General Manager
mvalladares@ieahia.org
+1 301 634 7423