HYDROGEN IMPLEMENTING AGREEMENT

IEA Hydrogen Implementing Agreement (HIA)

A Model R,D&D Collaboration in An Interdependent World

Nick Beck, Yoshiteru Sato, Antonio García-Conde, Mary-Rose de Valladares

20th World Energy Congress

Rome 07

IEA HIA Presentation

- ❑ IEA HIA Fundamentals
- ❑ Overview of IEA HIA Portfolio
- ❑ Gaps and Priorities in Hydrogen R&D
- ❑ Outreach and Collaboration
- ❑ IEA HIA Value Proposition

The HYDROGEN Opportunity

Offers promise as an energy carrier and a fuel

clean, abundant, sustainable!

- **H_2 production based on separation of H_2 from feedstocks**
  - H_2 found in carbon containing materials (fossil energy and biomass)
  - Diverse array of primary sources (renewables, nuclear and fossil) can also be used to extract H_2 from water (H_20)
- **Global diversity of production options enhances hydrogen's appeal**

International Energy Agency

Germany
Australia
Austria
Belgium
Canada
EC
Korea
Denmark
Spain
United States

Finland
France

Autonomous body within the Organization of Economic Cooperation and Development (OECD), founded in 1974 to foster energy cooperation among member countries.

Greece
Netherlands
Hungary
Ireland
Italy
Japan

Luxembourg
Norway
New Zealand
Portugal
United Kingdom
Czech Republic
Sweden
Switzerland
Turkey

Hydrogen Implementing Agreement (HIA)

A collaborative research and development (R&D) program
Created in 1977 on a task-shared, "bottom-up" basis

Strategic Framework

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

Strategy

To facilitate, coordinate and maintain innovative research, development and demonstration (RD&D) activities through international cooperation and information exchange

Annex / Task

Basic unit of organization; Next level is sub-task;

Operating Agent manages Annex; Experts do work

IEA HIA Members

IEA HIA July 2007

Canada
Mr Nick Beck (Chairman)

Australia
Dr John Wright

Norway
Ms Line Amlund Hagen

European Commission
Dr Stathis Peteves

Germany
Mr J.-F. Hake

Spain
Dr Antonio Garcia-Condé

Japan
Dr Yoshiteru Sato

Sweden
Dr Lars Vallander

Italy
Dr Agostino Iacobazzi

Greece
Dr Eli Varkaraki

Switzerland
Dr Andreas Gut

Iceland
Dr Agusta Loftsdottir

United Kingdom
Dr Ray Eaton

Lithuania
Dr Jurgis Vilemas

Turkey
Dr Alper Sarioglan

United States
Dr Carole Read

The Netherlands
Mr Frank Denys

Korea Dr Young-Sam Kim

Denmark
Mr Jan Jensen

France
Dr Paul Lucchese

Finland
Dr Heikki Kotila

New Zealand Dr Steven Pearce

HIA Goals

Science & Technology Goal

Advancement of Science via Pre-Commercial Collaborative RD&D

- Hydrogen Production
- Hydrogen Storage
- Hydrogen Systems

Market Environment Goal

Assessment of Market Environment, including Non-Energy Sector

- Non-Energy and Industrial Processes
- Foundation for Codes & Standard
- Infrastructure

Outreach Program Goal

Increasing Knowledge and Comfort with Hydrogen

- Membership and Participation
- Information Dissemination
- Synchronization worldwide

HIA Annexes Since 1977

1. Thermochemical Production
2. High-Temperature Reactors
3. Potential Future Markets
4. Electrolytic Production
5. Solid Oxide Water Electrolysis
6. Photocatalytic Water Electrolysis
7. Storage, Conversion and Safety
8. Techno-Economic Assessment
9. Hydrogen Production
10. Photoproduction of Hydrogen
11. Integrated Systems
12. Metal-Hydride for H_2 Storage
13. Design and Optimization of Integrated Systems
14. Photoelectrolytic Production
15. Photobiological Production
16. H2 from Carbon-Containing Materials
17. Solid & Liquid State Storage Materials

Current Portfolio

18. Integrated Systems - II
19. Hydrogen Safety
20. Hydrogen from Waterphotolysis
21. BioHydrogen
22. Fundamental and Applied H2 Storage Materials Development
23. Small-Scale Reformers for On-Site H2 Supply (SSR for H2)
24. Wind Energy and H2 Integration
25. High Temperature Processes for H2 Production

Task 16: H_2 from Carbon-Containing Materials

April 2002 – December 2005 – **recently completed**

- **Three Subtasks:**
  - ***Subtask A* – Large Scale Integrated H2 Production**
  - ***Subtask B* – Hydrogen from Biomass**
  - ***Subtask C* – Small Stationary Reformers for Distributed H2 Production**
- **Final Reports or all subtasks may be accessed at**

  http://www.ieahia.org/page.php?s=static&p=task16
- **Significant industry participation**
- **Two successor annexes: Task 23 (reformer technology) and Biomas**

OA: Elisabet Fjermestad-Hagen (Hydro, Norway)

Task 17: Liquid & Solid Hydrogen Storage

June 2001 – May 2006 **recently completed**

- **World's largest collaboration in H2 Storage is succeeded by Task 22**
- **Joint R&D on 20 metal hydride, 12 combined hydride/carbon and 4 carbon projects.**
- **Final Report with all project summaries accessible at**
  http://www.ieahia.org/page.php?s=static&p=task17
  800 publications, presentations and patents. Global database created: http://hydpark/ca.sandia.gov
- **Metal hydride storage material with 5 wt% @ 150ºC confirmed**

OA: Dr Gary Sandrock (USA)

Task 18: Integrated Systems Evaluation

January 2004 – January 2009 **recently extended**

- **Comprehensive information datasets** and **summary compilation** of **integrated hydrogen demonstration systems and development plans** - www.port-h2.com/IEA-Annex-18/
- **Modeling and existing analysis tools** used to **evaluate hydrogen demonstration projects.**
- Case Studies (http://www.ieahia.org/case_studies.html)
- **Phase 1** had **two Subtasks, A and B**. **Phase 2 will include Subtask C – Synthesis and Learning** to bridge Subtask A and B experience and provide lessons learned, benchmark assessments and trend analysis

OA: Dr Susan Schoenung (Longitude 122 West, Inc, USA

Task 18 Demonstration Sites – Phase 1 and 2

CANADA	Pacific Spirit Station (H2 filling station)
DENMARK	Island Power
FRANCE	Review lessons learned from fuel cell evaluation **(EPACOP)**
GERMANY	Hydrogen Filling Station
GREECE	RES2H2
ICELAND	Hydrogen bus/refueling project **(ECTOS)**
ITALY	**BEAM** project: System efficiency; Control strategy
JAPAN	Regenerative PEM FC power system (grid)
NEW ZEALAND	Renewable hydrogen at remote site
SPAIN	The Fuel Cell Innovative Remote Systems for Telecommunications (**FIRST**) project
SWEDEN	Malmö filling station and hythane-fueled buses
UK	Hydrogen and Renewables Integration **(HARI)** Project
USA	Las Vegas Energy Station
USA	Hydrogen Power Park

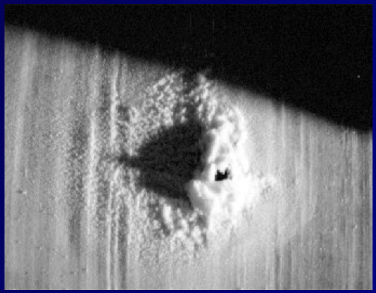
Task 19: Safety

October 2004 – January 2008

Bonfire test

Grenade test

Hydraulic burst test



Gunfire test

Drop test

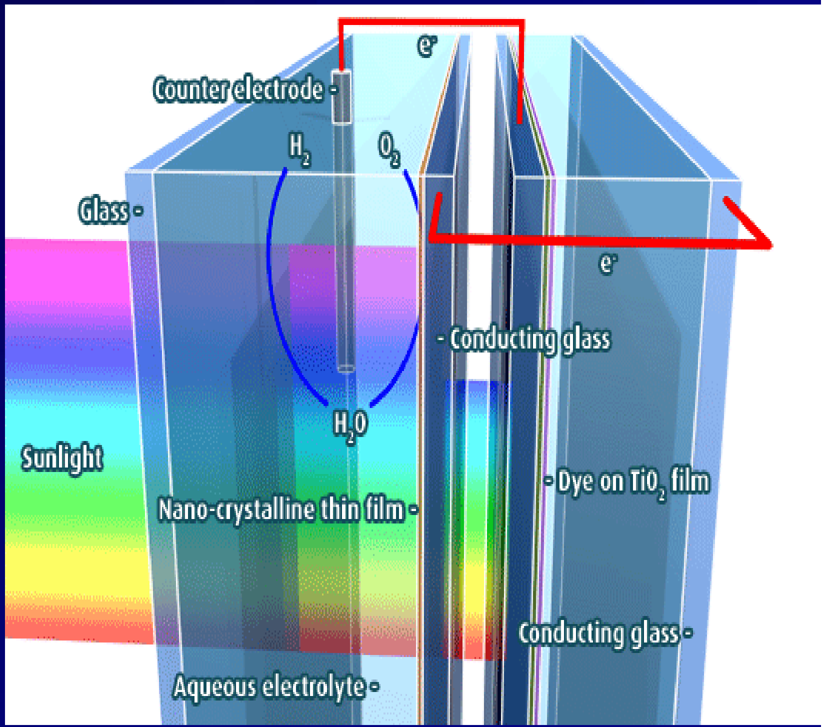
- Survey of Quantitative Risk Assessment (**QRA**) methodologies and testing methodologies **(public report October 2007)**
- **Testing and Experimental Program:** will evaluate the effects of equipment, product and/or system failures under a range of real-life scenarios, environments or mitigation measures
- **Targeted information packages for stakeholder groups such as:** permitting officials, insurance providers, system developers, manufacturers, early adoptors

OA: William Hoagland (W. Hoagland & Associates, USA)

Task 20: Hydrogen from Waterphotolysis

October 2004 – June 2008

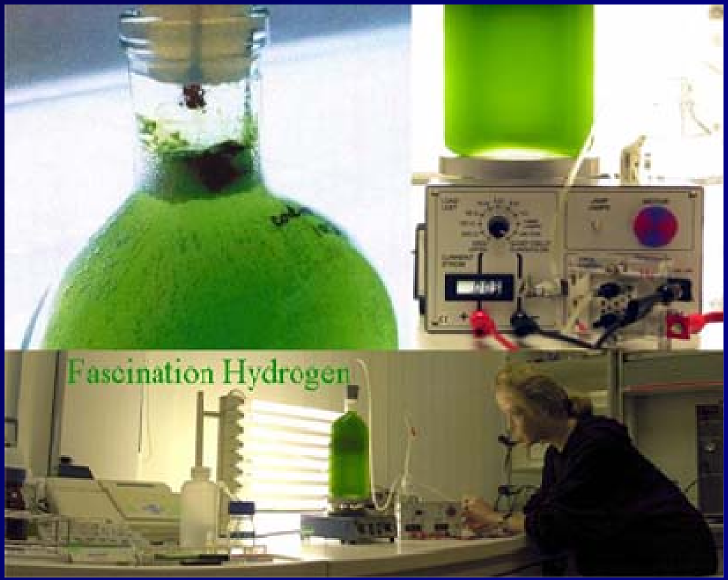
- Continuation and expansion of Task-14 (up to 14 countries and 37 research groups)
- Aim: Net solar-to-hydrogen conversion efficiency of 10%
- Objectives: Intensification of international collaboration, advancement of PEC materials science, development of engineering solutions, demonstration of leading concepts, promotion of photolysis of water



OA: Dr Andreas Luzzi (University of Applied Sciences Rapperswil, Switzerland)

Task 21: BioHydrogen

October 2005-October 2008



- ❑ **Evolved from Task 15**
- ❑ **Includes four areas of investigation:**
  - ❑ **Hydrogen dark fermentations**
  - ❑ **Photobiological hydrogen production systems**
  - ❑ **Bio-inspired systems**
  - ❑ **Overall analysis**

OA: Dr. Jun Miyake

Task 22: Fundamental and Applied Hydrogen Storage Materials Development

December 2006-December 2009

- **3 Targets:**
  - Reversible or regenerative storage media
  - Fundamental & engineering understanding
  - Storage materials for stationary apps

- **15 HIA countries, 43 experts, 39 projects**
- **Project types**: experimental, engineering, theoretical, safety
- **Classes of Materials:** reversible metal hydrides
  regenerative hydrogen storage materials
  chemical hydrides
  nanoporous materials
  rechargeable organic liquids and solids

OA: Dr. Bjørn C. Hauback

Task 23: Small-Scale Reformers for On-Site H2 Supply

December 2006-December 2009 NEW!

- **Development of reformer technologies and distributed on-site reformer based H2 supply systems**
- **Three Subtasks:**
  1) Harmonized Industrialization
  2) Sustainability and Renewable Sources
  3) Market Studies

OA: Dr. Ingrid Schjølberg of Sintef

H I A

Task 24: Wind Energy and H2 Integration

December 2006-December 2009 **NEW!**

- **Mid-term R&D for entire wind to hydrogen production chain**
- **Subtask A –** State of the Art
- **Subtask B –** Needed Improvements and System Integration
- **Subtask C -** Business Concept Development
- **Subtask D -** Applications with Emphasis on wind energy management

OAs: Dr. Luis Correas and Mr. Fernando Tamaya-Madurga

Task 25: High Temperature Processes for H2 Production

May 2007 **NEW!**

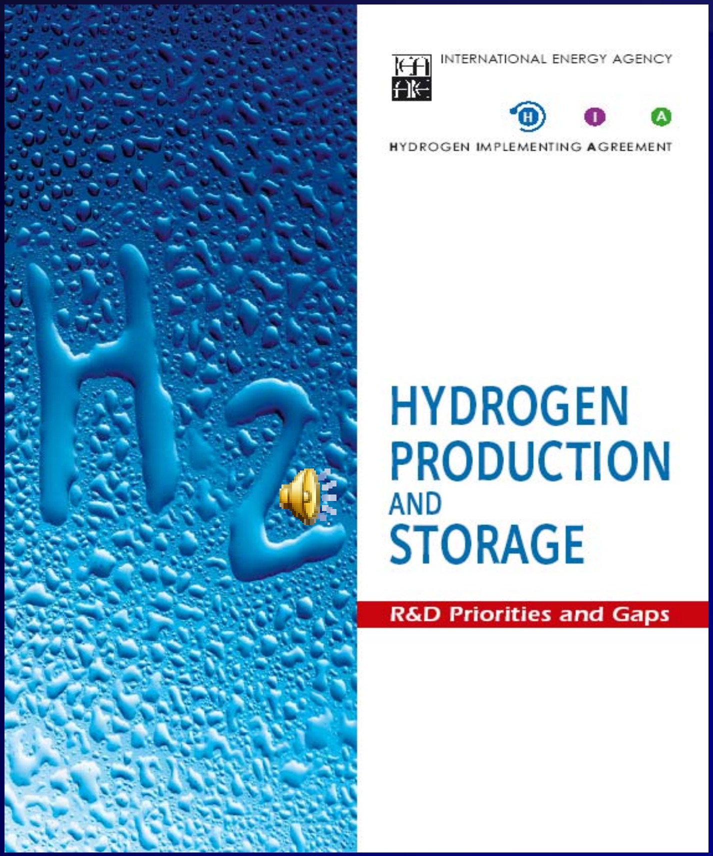
- Will Support production of massive quantities of zero-emission H2 through use of high temperature processes (> 500 ° C) coupled with nuclear and solar heat sources
- **Three process families**: thermochemical cycles: steam electrolysis: and innovative water splitting
- **Four Subtasks**:
  - **Subtask A** – State of the Art
  - **Subtask B** – Methodology approach of HTPs
  - **Subtask C** – HTP R&D and future industrial development
  - **Subtask D** – Information Dissemination

OA: Mr. Gilles Rodriquez of CEA

Other Tasks: Now in Definition or Proposed

- Near Term Market Routes to Hydrogen by Co-Utilization of Biomass as a Renewable Source with Fossil Fuels
- Hydrogen Distribution Infrastructure and Mass Storage

R&D Priorities and Gaps in H2 Production and Storage



Available for downloading at
http://www.ieahia.org/page.php?s=d&p=special

Summary

Production Processes – Research Needs

For all hydrogen production processes – Significant improvement needs for:

- Increased plant **efficiency**
- Reduction of capital **costs**
- **Reliability** and operating **flexibility**

Summary

Production Processes – Research Needs

Current/near term production options:

- **Electrolysis** – proven technology to be used in the early phases of building a hydrogen infrastructure for the transport sector

Hydro Berlin

- **Small scale natural gas reformers** limited proven/commercial availability – several demonstration cases

NG reformer station Madrid

Summary

Production Processes – Research Needs

Medium to long term production options:

- **Central fossil based production w/CO_2 capture and storage:** capture of CO_2 for storage purposes are not fully technically and commercially proven and requires R&D on absorption or separation processes and process line-up
- **Biomass to hydrogen processes:** More focus on feed preparation. Logistics is a challenge, production only economical at large scale.
- **Photo-electrolysis:** Early stage of development – material cost and practical issues to be solved.
- **Biological processes:** Very early stage of development - low conversion efficiencies.
- **High temperature processes:** Materials development, HT membranes, heat exchangers, etc.

Summary

Onboard H_2 Storage – Research Needs

Compressed Gas

- commercially available, costly (mainly due to transportation cost)
- best option: C-fibre composite vessels (6-10% H_2 at 350 –700 bar)
- R&D issues: fracture mechanics, safety, compression energy, volume

Liquid Hydrogen

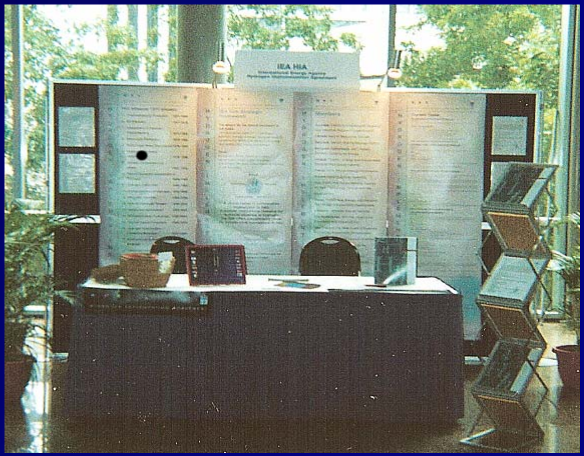
- commercially available, costly (mainly due to liquefaction cost)
- best option – cryogenic insulated dewars (20wt%H_2 at 1 bar and –253^{o}C)
- R&D issues: more efficient liquefaction, lower cost/better insulated containers, automated boil off capture (e.g., via hydrides) and re-liquefaction

Onboard H_2 storage – Research Needs

Solid State Storage

- very developmental
- **potential advantages**: lower volume,lower pressure (greater energy efficiency) higher purity H2 output
- **R&D issues**: (many) weight, lower desorption temperatures, higher desorption kinetics, recharge time & pressure, heat management, cost, pyrophoricity, cyclic life, container compatibility and optimization
- **most developed option**: probably **metal hydrides** – potential for >8wt% gravimetric and >90kg/m3 volumetric system capacities at 10-60 bars.

Outreach and Collaboration



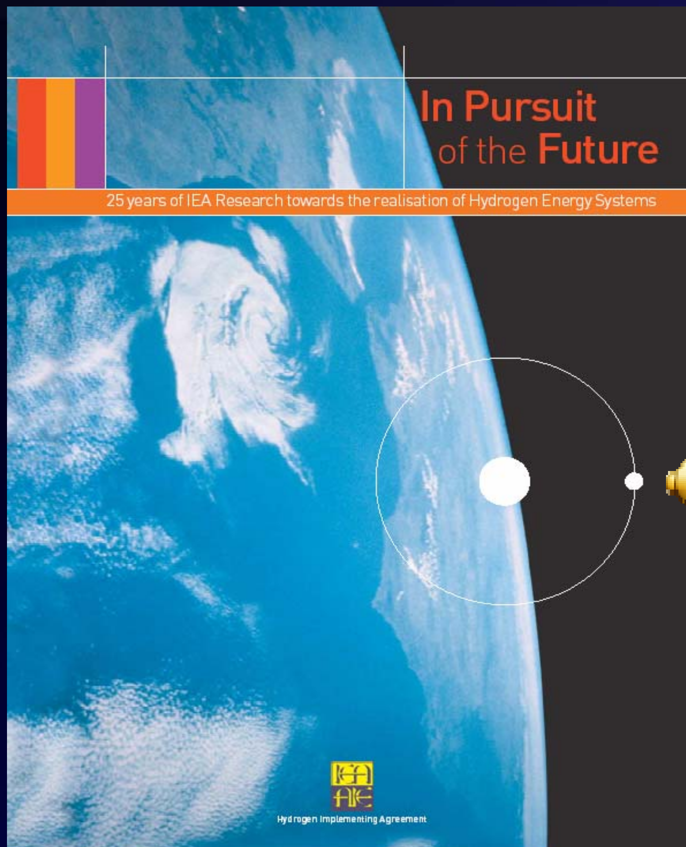
Objectives

1) Increasing Membership
   and Participation
2) Information Dissemination
3) Synchronization Worldwide

Collaboration: Means and End

Information Dissemination:

Download free at www.ieahia.org



25th Anniversary Report: In Pursuit of the Future

Luzzi / Bonadio / McCann

Released at the National Press Club, Washington DC, 7-Sep-04

Task 14 Final Report

Photoelectrolytic Production of Hydrgoen

IEA Value Proposition

Provides a neutral international profile

- Knowledgeable, reliable, unbiased
- Access to technical experts
- Global reach (government, academia, industry)

Leverages resources

- Focus includes science & technology, market analyses and outreach
- Portfolio includes shorter term and long-term, pre-competitive activities
- Careful intellectual property (IP) treatment
- Established network of researchers

Offers assurance based on track record

- Collaborative research tasks completed over 25 years
- Growing Membership

International Energy Agency Hydrogen Implementing Agreement . . .

www.ieahia.org

. . . A Model R,D&D Collaboration in an interdependent world