iea hydrogen

IEA Hydrogen R,D&D and Global Outlook for Hydrogen

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M.R. De Valladares

Electrolysis Workshop
Huesca, 23rd May 2019

INTRODUCTION

- IEA Hydrogen Members - Executive Committee (December 2018)
- IEA Hydrogen TCP – Global Hub for Hydrogen R,D&D

CONTEXT & TRENDS

- CONTEXT: Industry and Markets
- TRENDS: Industry and Markets
- CONTEXT: World Governments
- TRENDS: Growth in initiative to international collaboration
- TRENDS: Mission Innovation IC#8

IEA

- CONTEXT: IEA
- MULTI-TCP activity: IEA/EC Electrofuels workshop example of multi-TCP activity

IEA Hydrogen R,D&D

- IEA Hydrogen TCP Tasks – 2015-2020
- IEA Hydrogen TCP Tasks – from 2019
- New Task proposal

IEA Hydrogen Outreach

IEA Hydrogen Members - Executive Committee (December 2018)

European Commission
Dr Beatriz Acosta-Iborra

UNIDO (UN)
Dr Federico Villatico-Campbell

Europe

Austria
Dr Theodor Zillner

Denmark
Mr Jan Jensen

Germany
Mr J.-F. Hake

Italy
Dr Alberto Giaconia

Spain
Ms M Pilar Argumosa

Finland
Dr Michael Gasik

Greece
Dr Elli Varkaraki

Lithuania
Dr R. Urbonas

Sweden
Dr Mikael Lindqvist

The Netherlands
Dr Herman Prinsen

France
Mr Paul Lucchese

Belgium
Mr Adwin Martens
Dr Joris Proost

Norway
Mr Trygve U. Riis

Switzerland
Dr Stefan Oberholzer

United Kingdom
Mr Y. Lethbridge

Hychico
Mr Sergio M. Raballo

Shell
Dr C. Patil

Middle East

Israel
Dr Zvi Tamari

NOW
Dr Klaus Bonhoff

Southern Company
Dr N. Meeks

Hydrogen Council
Mr Guillaume de Smedt

Reliance Industries Ltd
Dr Anurag Pandey

Asia - Pacific

Japan
Mr. Eiji Ohira

Korea
Dr Y. Shul
Mr. Seok-Jai Choi

PRC
Dr P. Chen &
Dr Lijun Jiang

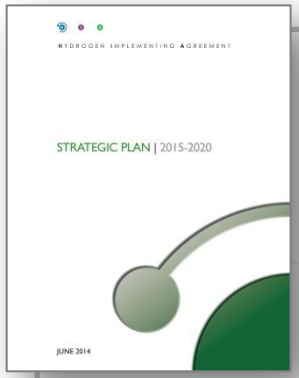
Oceania

Australia
Dr Craig Buckley

New Zealand
Dr J. Leaver

21 Countries + European Commission + UN + 6 Sponsors (Argentina in accession)

IEA Hydrogen TCP – *Global Hub for Hydrogen R,D&D*



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 – accelerate H2 implementation and utilization to optimize environmental protection, improve energy security and economic development

Overarching Objectives

- Communicate role and value of hydrogen as flexible energy carrier in future integrated multi-sector energy system
- Analysis – IEA & other
- Infrastructure
- Industry engagement

Strategic planning underway for 2020-2025

Collaborative R,D&D Portfolios
- Production
- Storage
- Integrated Systems
- Integrated Infrastructure

Analysis Portfolios
- Technical
- Market
- Political Decision-making

Awareness, Understanding & Assessment (AUA) Portfolios
- Information Dissemination
- Safety
- Outreach

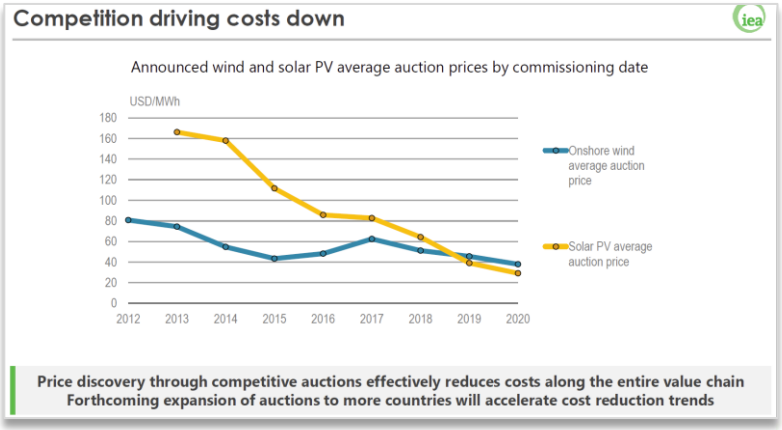
CONTEXT & TRENDS

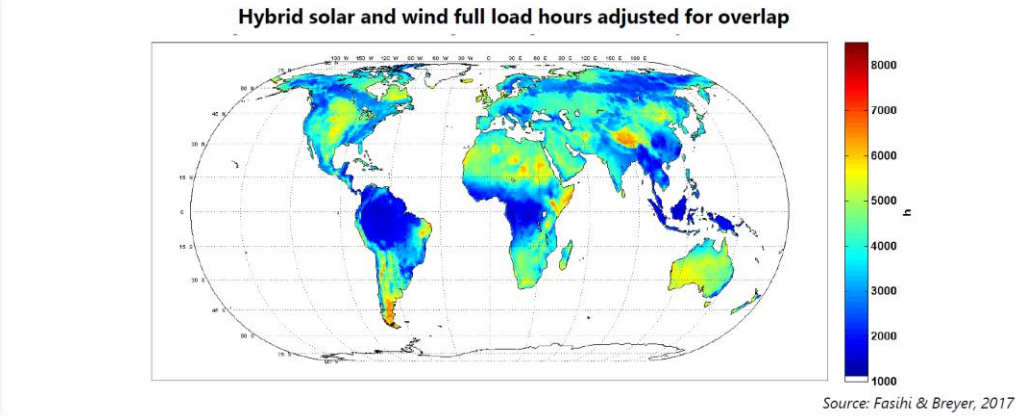
CONTEXT: Industry and Markets

Over the past five years the Landscape for Hydrogen has changed; momentum has accelerated dramatically in the last two years

- **~2015 Energy game changer**: with increasing share of renewables in electricity mix, **low cost renewable electricity (PV and wind)** in some areas enables production of hydrogen at competitive cost
- **2017 Creation of Hydrogen Council** (initially 18, now 53 companies), a global business initiative
- **~2018 Hydrogen trends globally**: 380+ **Hydrogen Refueling Stations (HRS)** open to public or fleets; close to 6,500 **FCEVs sold**; **electrolysers available** in small and large sizes (**MW scale**); **applications proliferate** – hydrogen for industry, mobility, stationary, "**smart grid**", **intermediates** and **electrofuels/synfuels**; larger demonstrations and debates about "green" hydrogen and "origin"; **sector coupling and system integration** now recognized opportunities; and **hydrogen scale-up** is a focus everywhere

The emergence of low-cost renewable power is a game-changer





TRENDS: Industry and Markets
Early markets for multiple applications show promise

Passenger Cars & Captive Fleets

Toyota Mirai | Honda Clarity | Hyundai Tucson | Hyundai Genesis

- Japanese vehicle production increases dramatically.
- FCEV registration is now being tracked in California.
- Norway anticipates application of FCEVs incentives similar to BEVs.

Buses

- **UC Transit in Oakland**, CA, USA - largest fleet in North America, with 12 fuel cell buses.
- Foshan and Yunfu – $17 million order for 300 fuel cell buses.
- European Union Coordination a national Call for order in progress for a 1000 FC Buses
- South Korea - planning to replace 27,000 CNG buses with FC buses by 2030.

Heavy Duty Trucks

Nikola Motor Company H2 powered **long range tractor trailer**

Logistics Vehicles

UPS - first hydrogen fuel cell electric class 6 delivery van. 17 vans in the U.S. by year end 2018.

Toyota a heavy duty drayage vehicle (class 8), **Amazon** buying $70 million of **fuel-cell forklifts.**

Light Rail Trains

In 2017, **Alstom** unveiled its **Coradia iLint**, which will **replace diesel trains** in the extensive, **un-electrified sections** of rail in Germany.

Airplanes & Drones

Hydrogen-powered Drone
Fuel cell technologies power drones varied applications from lightweight Hycopter to larger military based applications like the Boeing Insitu's ScanEagle drone.
HY4 Hydrogen Fuel Cell Electric Aircraft, World's first 4 seater H2 plane.
HYCARUS & FLHYSAFE EU projects to integrate auxiliary power units onboard comercial aircraft

Maritime

90% of all trade is by ship. Maritime tourism is huge global industry.

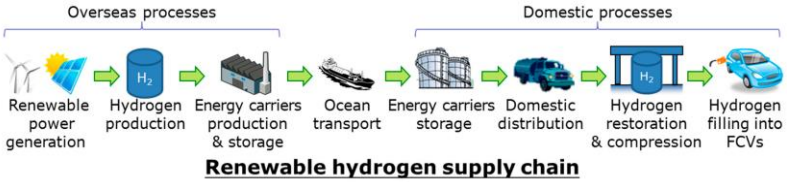
The **Red and White Ferry Company** and **Sandia National Laboratory** have teamed up on a feasibility study for designing, building and operating a high-speed hydrogen fuel cell powered passenger ferry and refueling station.

Portables

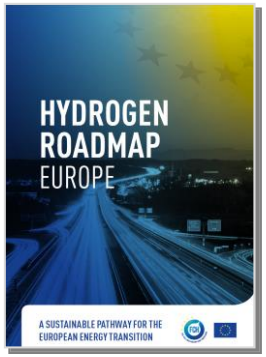
CONTEXT: World Governments

- **2015** **COP21** Paris Agreement
- **2017** Japanese Prime Minister announces **Japan's intent** to become **world's first hydrogen society**
- **2018** Hydrogen adopted as **8th MISSION INNOVATION Challenge** in May
- **2018** European Ministries – **Linz Declaration** on Hydrogen in September
- **2018** **IPCC Special Report** on Global Warming of 1.5° C in October; hydrogen workshop in October
- **2018** **Japan makes voluntary contribution to IEA** for preparation of G20 Report on Hydrogen to be delivered June 2019 at G20 Meeting
- **2018** First Hydrogen Ministerial Meeting in Japan in October produces **"Tokyo Statement"**
- **2019** **FCH2JU Study** Hydrogen Roadmap Europe – published in February
- **2019** Delivery of **IEA Hydrogen Report at G20 Meeting** in June
- **2019** 2nd Hydrogen Ministerial Meeting in fall

MISSION INNOVATION
Accelerating the Clean Energy Revolution



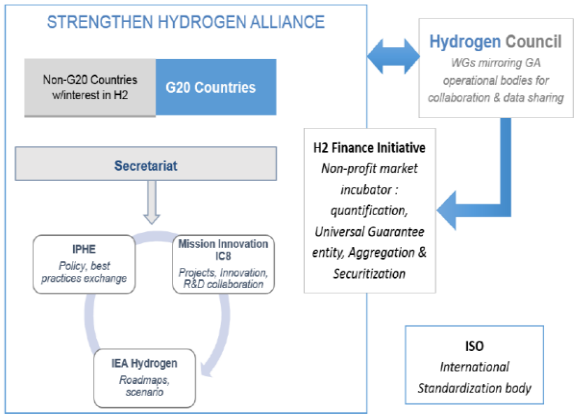
Renewable hydrogen supply chain



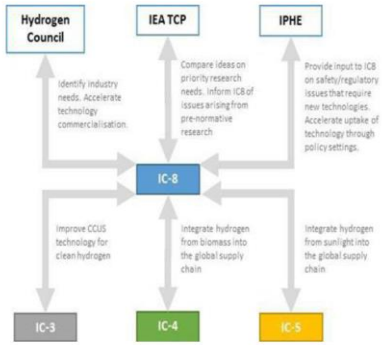
TRENDS: Growth in initiative to international collaboration

Hydrogen Council Proposal
GOVERNANCE

- **Representation of key deployment countries**
  including Japan, Korea, China, Germany, Netherlands, Belgium, France, UK, Norway, USA, Canada, Australia....
- **High-level political commitment**.
- **Regular minister-level interactions**
- **A dedicated body ?**
- **Clear governance principles**



MISSION INNOVATION
Accelerating the Clean Energy Revolution



A global hydrogen alliance[1)] could provide a platform for a high-level public-private dialogue, increasing the awareness regarding the potential impact of hydrogen in the context of global CO2-reduction targets.

Existing international organizations can support this global dialogue by providing networks, expertise and analysis:

- **IPHE** – intergovernmental exchange on policies and international standards
- **IEA TCPs** – academia and industry participation providing technical expertise (studies and research networks)
- **MI H2 Challenge** – government, academia and industry participation to accelerate deployment based on targeted R&D

[1)] as discussed at the San Francisco CEO-meeting of the Hydrogen Council (09/2018)

IEA activities related to hydrogen

Reports

Technology Network

iea Energy Technology Network

iea hydrogen

Workshop

Business Network

Energy Business Council

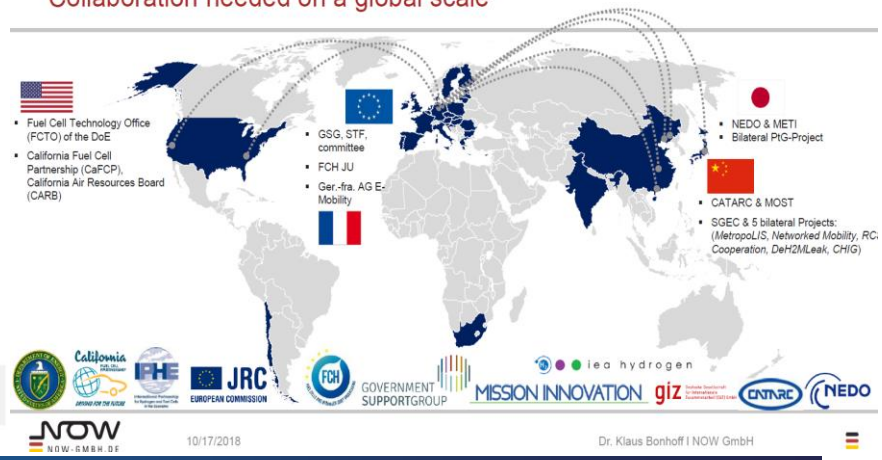
IEA Ministerial Meeting (Nov 2017)

Secretariat

CLEAN ENERGY MINISTERIAL
Advancing Clean Energy Together

IEA has been active on the analysis of hydrogen for many years; our work will expand, collaborating closely with our extensive technology and business networks

Renewable hydrogen production –
Collaboration needed on a global scale



TRENDS: Mission Innovation IC#8
Renewable and Clean Hydrogen Challenge

Objective

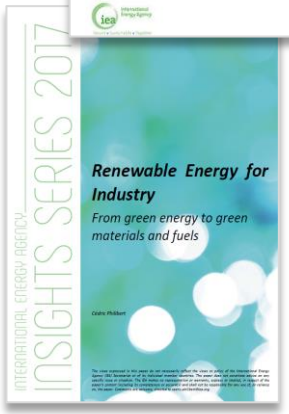
- To accelerate the development of a global hydrogen market by identifying and overcoming key technology barriers to the production, distribution, storage, and use of hydrogen at gigawatt scale.
  - Launched in May 2018
  - 14 countries
  - 3 years to make a difference
- The challenge will focus multinational research and large scale demonstration efforts from both public and private sectors on industry-directed breakthroughs which have a realistic prospect of underpinning commercial renewable and clean hydrogen industries.
  - Co-lead: Australia, Europan Commission, Germany

IEA

CONTEXT: IEA

- **2015** *Technology Roadmap: Hydrogen and Fuel Cells*
- **2017** IEA Renewables Division publishes **study on hydrogen for industry, electrofuels** and **hydrogen as an intermediate**
- **2018** **IEA EC workshop on Electrofuels** in September
- **2018** *World Energy Outlook* (WEO) – role for hydrogen
- **2018** Hydrogen topic in November Energy Business Council (EBC)
- **2019** **IEA Workshop on Hydrogen** February
- **2019** IEA preparing **G20 Hydrogen Report** for mid-June release

  Content: State of Play
  - Near Term Markets: 10 years
  - Long term potential of hydrogen
  - All applications including industry, chemicals, synfuels, biofuels, ammonia
  - Scaling up
- **~ 2017** MULTI-TCP ACTIVITIES



IEA Ministerial Meeting - EBC

G20 2019 JAPAN

MULTI-TCP activity: IEA/EC Electrofuels workshop example of multi-TCP activity

International Energy Agency
Secure Sustainable Together

European Commission

Joint workshop by the International Energy Agency and the European Commission

Electrofuels

8:30	**Registration & Welcome**
9:00	**Introduction and overview of the agenda** *Dr Kyriakos Maniatis*, Principal Administrator, DG ENER, EC *Pierpaolo Cazzola*, Transport Analyst, IEA **Opening** *Tudor Constantinescu*, Principal Adviser to Director General DG ENER, EC
9:15	**Introductory keynote speech** *Cédric Philibert*, Senior Analyst in the Renewable Energy Division, IEA
9:30-10:45	**Session 1 – Electrofuel production pathways and costs** Chair: *Dr Kyriakos Maniatis*, Principal Administrator, DG ENER, EC **Hydrogen** *Paul Lucchese*, Chair, IEA Hydrogen TCP **Ammonia** *Professor Bill David*, Professor of Chemistry, University of Oxford **Liquid hydrocarbons** *Karl Hauptmeier*, Head of Products, Sunfire **Liquid hydrocarbons** *Dr Jitka Hrbek*, Senior Scientist, Vienna University of Technology, IEA Bioenergy Task 33 **Methane** *Eelco Dekker*, Managing Director, Conker
10:45-11:15	**Session 2 – Costs and benefits: How do electrofuels compare with other options?** Chair: *Dr Kyriakos Maniatis*, Principal Administrator, DG ENER, EC *Dr Jens Perner*, Associate Director, Frontier Economics *Adrian O'Connell*, Scientific Officer, European Commission Joint Research Centre
14:00-15:00	**Session 3 – Usage of electrofuels** Chair*: Cédric Philibert*, Senior Analyst in the Renewable Energy Division, IEA Road *Dr Ilkka Hannula*, Principal Investigator, VTT Technical Research Centre of Finland Ltd Shipping *Dr Carlo Raucci*, Principal Consultant, University Maritime Advisory Services Aviation *Dr Arne Roth*, Lead of Alternative Fuels, Bauhaus Luftfahrt Power and Industry *Andreas ten Cate*, Director International Business Development, ISPT
15:00-16:00	**Q&A for session 3** Chair*: Cédric Philibert*, Senior Analyst in the Renewable Energy Division, IEA
16:00-16:30	**Coffee break**
16:30-17:30	**Panel – What's next?** Chair**:** *Pierpaolo Cazzola*, Transport Analyst, IEA *Denis Thomas,* Board Member, Hydrogen Europe *Laura Buffet*, Manager Clean Fuels, Transport & Environment *Dr Magnus Lindgren*, Chair, IEA Advanced Motor Fuels TCP *Morna Cannon*, Head of Maritime 2050 Environment Strategy, UK Department for Transport *Paula Abreu Marques*, Head of Unit, DG ENER, EC

IEA Hydrogen R,D&D

IEA Hydrogen TCP Tasks – 2015-2020

Created 6 October 1977

41 tasks approved in whole or part to date – production is most frequent task topic

NR	NAME	15	16	17	18	19	20	21	22	23	STATUS
28	Large Scale Hydrogen Delivery Infrastructure										completed
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32	H2Based Energy Storage										completed
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35	Renewable Hydrogen (Super Task)										completing
36	Life Cycle Sustainability Assessment (LCSA) (Successor Task 30)										completed
37	Safety (Successor to Task 31; extended 3 years through 2021)										current
38	Power-to-Hydrogen and Hydrogen to X										current
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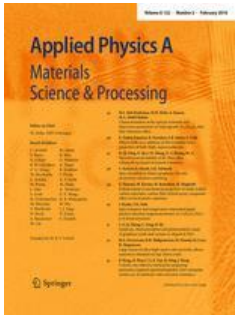
41	Analysis and modeling – a reference database (likely to become a “standing task”)										ST C approved others in definition
i	Market Deployment and Pathways to Scale										In definition
ii	Biological production & conversion of H2 for energy and chemicals (Successor Task 34)										In definition
iii	Hydrogen Export Supply Chains										In definition
iv	Hydrogen Applications In Primary Sectors (agriculture, mining and resource)										In definition
v	Successor tasks for renewable electrolysis, photoelectrochemical water-splitting (PEC), and solar thermochemical hydrogen production										In definition
vi	Industrial Use of Hydrogen in Middle Income Developing countries										Proposed new

R,D&D: Task 32 - Hydrogen-Based Energy Storage (2013-2018) – basic
Task 40 – Energy Storage and Conversion Based on Hydrogen

- 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 was published
- Part 1 of final report is special issue in IJHE with 7 peer reviewed articles
- *Successor Task 40 to include working group on ammonia and reversible liquid hydrogen carriers, catalysis, and electrochemical storage of energy – first task meeting May 2019*



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: Task 34 - BioH2 for Energy & Environment (2014-2018) - Basic

- 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)

Bio-inspired

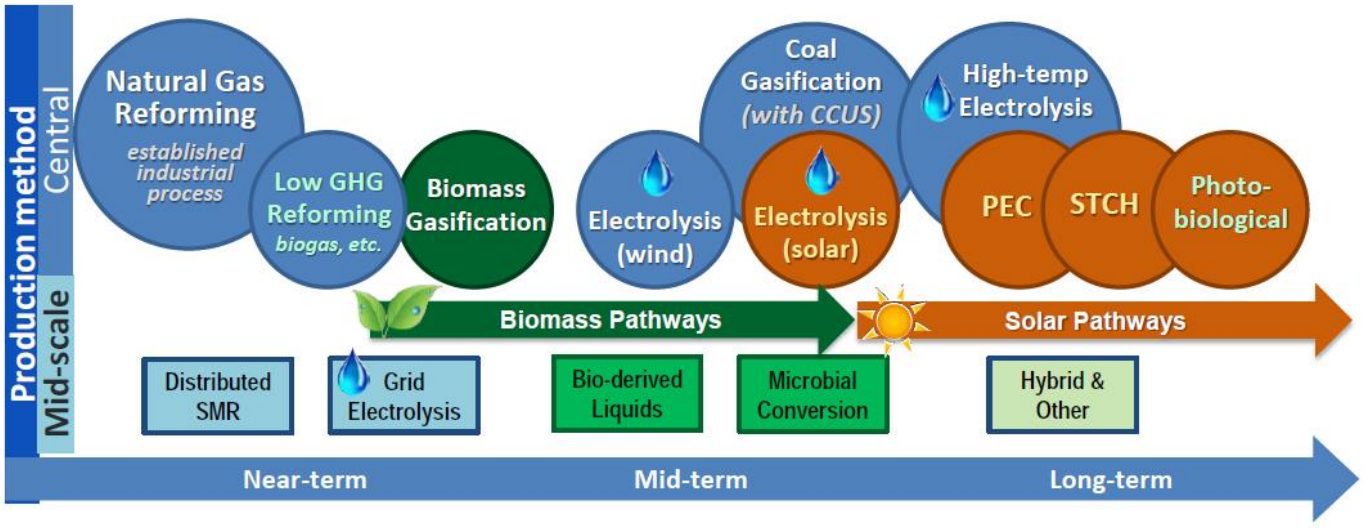
Key Findings:

- Key drivers for biohydrogen technology include not only the renewable energy demand but also waste treatment, water recovery and recovery of other valuable resources such as phosphate

R,D&D: Task 35 - Renewable Hydrogen Production (2014-2017) - Basic

- *SUPER TASK* - final report will be posted soon!
- 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 and network of U.S. experts

Renewable Hydrogen Options



R,D&D: Task 39 - Hydrogen in Maritime Transport (2016-2019)

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 15 Member countries and EC confirming (all European but clear US interest)

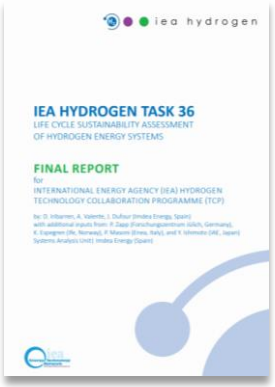
Rationale and Output:

- 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
- **3 white papers in development**: H2 supply in ports; H2 safety; Hydrogen experience and knowledge gaps

Analysis: Task 36 – Life Cycle Sustainability Assessment (LCSA)

- **Subtask A:** Addressing environmental challenges in LCA of hydrogen energy systems
- **Subtask B**: Economic analysis of hydrogen energy systems
- **Subtask C**: Social indicators for the assessment of hydrogen energy systems and integrative approaches for LCSA
- **Subtask D**: Collaboration with IEA HQ analysts

Final Task 36 Report available at ieahydrogen.org



Findings and Output

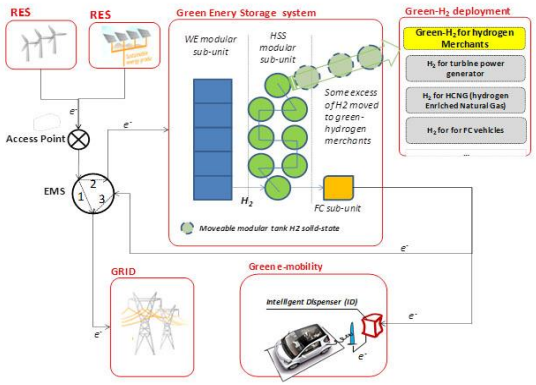
-LCSA concludes that different calculations associated with conventional LCC and LCC with externalities influence levelized cost of H2. Use of LCSA is convenient methodological solution to evaluate the performance of hydrogen energy systems.

- See **Spring/Summer 2019 IEA Hydrogen NEWS Technology Spotlight article featuring Task 36 and Dr. Javier Dufour of IMDEA** at http://ieahydrogen.org/pdfs/2019-Spring_Summer_Newsletter.aspx

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 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



ingrid

High-capacity hydrogen-based green-energy storage solutions for grid balancing

CEN CENELEC

McPhy energy

Inside

Capitalize on surplus electricity produced by a 200 MW windfarm that is under construction

Power to Gas with 2 H_2 production and storage lines

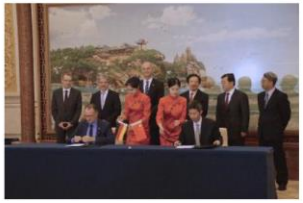
- Latest generation McLyzer 2MW electrolyzer producing H_2 @30 bar
- Transportable solid storage unit used alongside traditional reservoirs

Timeline

- Contact effective end July
- Delivery in July 2016
- Commissioning in January 2017

Hebei province in China

Contract officially signed on June 3, 2015



Hydrogen in the Energy System, extension of Smart Grid?

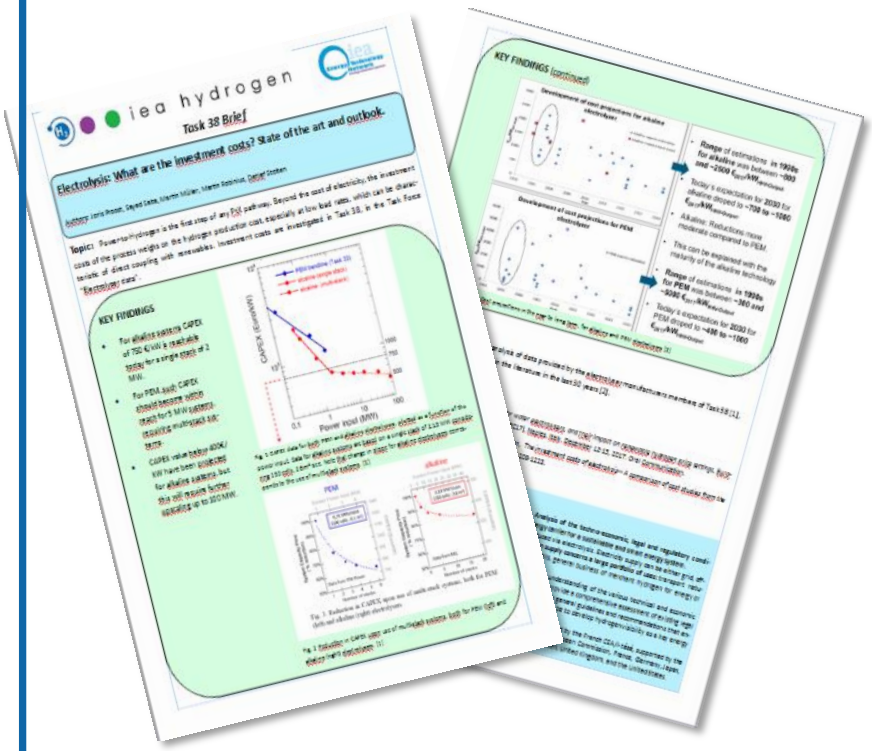
A major Challenge

Task 38 - Extensive publications: journal papers, conference presentations, briefs

- 1 article published by TF Electrolyzer data in IJHE: **State-of-the art CAPEX data for water electrolysers, and their impact on renewable hydrogen price settings, J. Proost**
- Technology briefs – two published and another in preparation on **Services to the Grid**

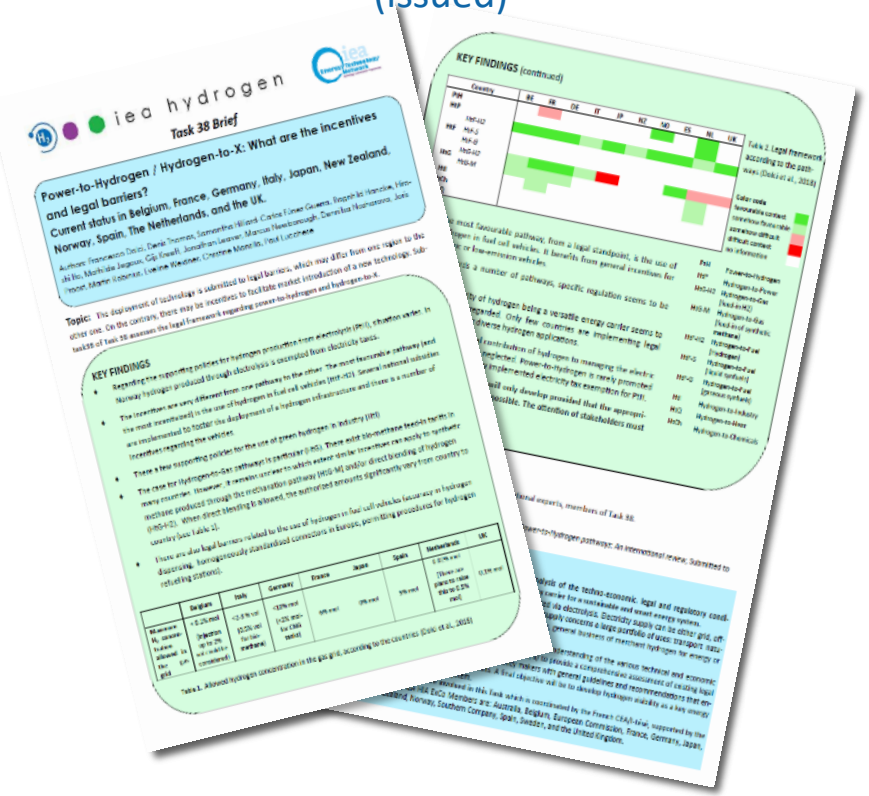
Electrolyzer Data

(issued)



Regulation and Incenives

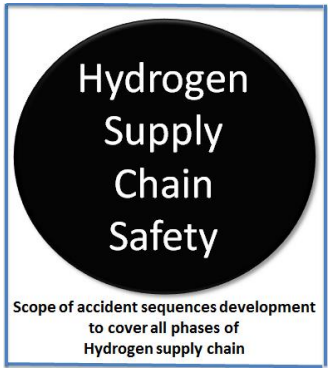
(issued)



Task 37: Safety (2015-2021)

IEA Hydrogen Safety Journal >> view/submit

- 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



Safety is crucial

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
- ***Hydrogen Safety Journal*** launched!

IEA Hydrogen TCP Tasks – from 2019

Task in definition

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New Task proposal: Industrial Use of Hydrogen in Middle Income Developing countries (led by UNIDO)

UNIDO can support an industrial development expert and identify suitable industries in selected developing countries for direct application or replication purpose

1. **H2 to industry de-carbonisation: need for partnership with industrial players, H2 suppliers (i.e. electrolyser manufacturers)**
2. **H2 roadmapping**

- **Contribution to the new Analysis Task: industrial database, how to incorporate the analysis to developing countries' case study**

New Task proposals: Planning

i 41 – Data and modeling

- Subtask 41c will meet with ETSAP 5 June in Paris
- Another task definition meeting likely in the end of August timeframe
- Ideally, the final scope of work will be presented in the fall for ExCo approval

Ii Biological production & conversion of H2 for energy and chemicals

- No task definition schedule yet

iii Hydrogen export supply chain

- Task definition meeting likely around time of G20 meeting; to be held in Osaka, Japan
- Task definition meeting at ICHS in Adelaide, Australia in September

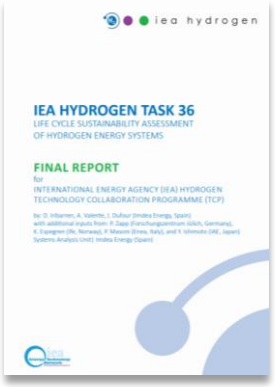
Iv Hydrogen applications in primary sectors (ag, mining and resources)

V renewable production successor – webinar soon, followed by in-person meeting in early fall

Vi industrial use – to be defined.

IEA Hydrogen Outreach

OUTREACH PRODUCTS & ACTIVITIES



- End of Task Workshops
- External Conference Participation
- IEA Conferences and Events
- IEA Hydrogen Awareness-Building Events
- Social media campaign (growing Twitter following)

IEA H2 newsletter

IEA H2 Website

IEA H2 Executive Summary

CONNECT WITH IEA HYDROGEN

IEA Hydrogen is an IEA Technology Collaboration Programme (TCP)

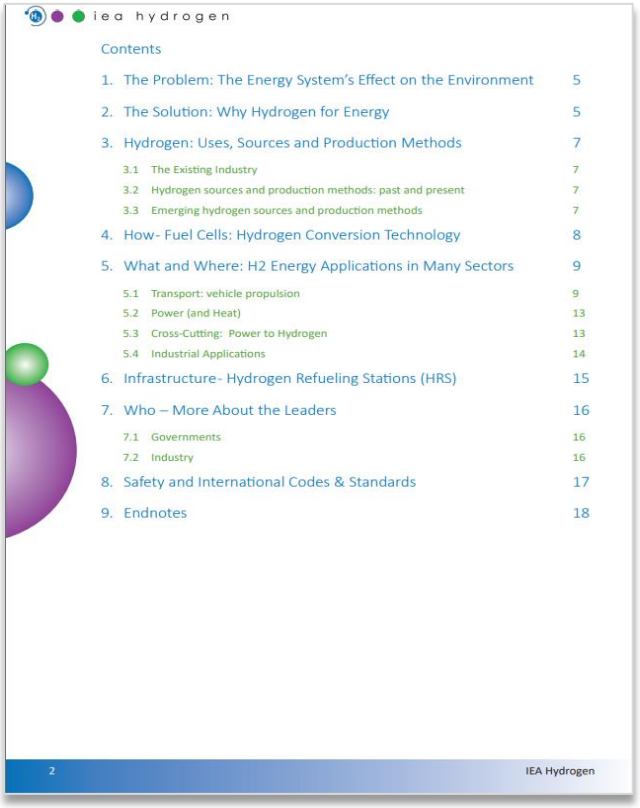
iea hydrogen

Follow us on Twitter @IEA_hydrogen

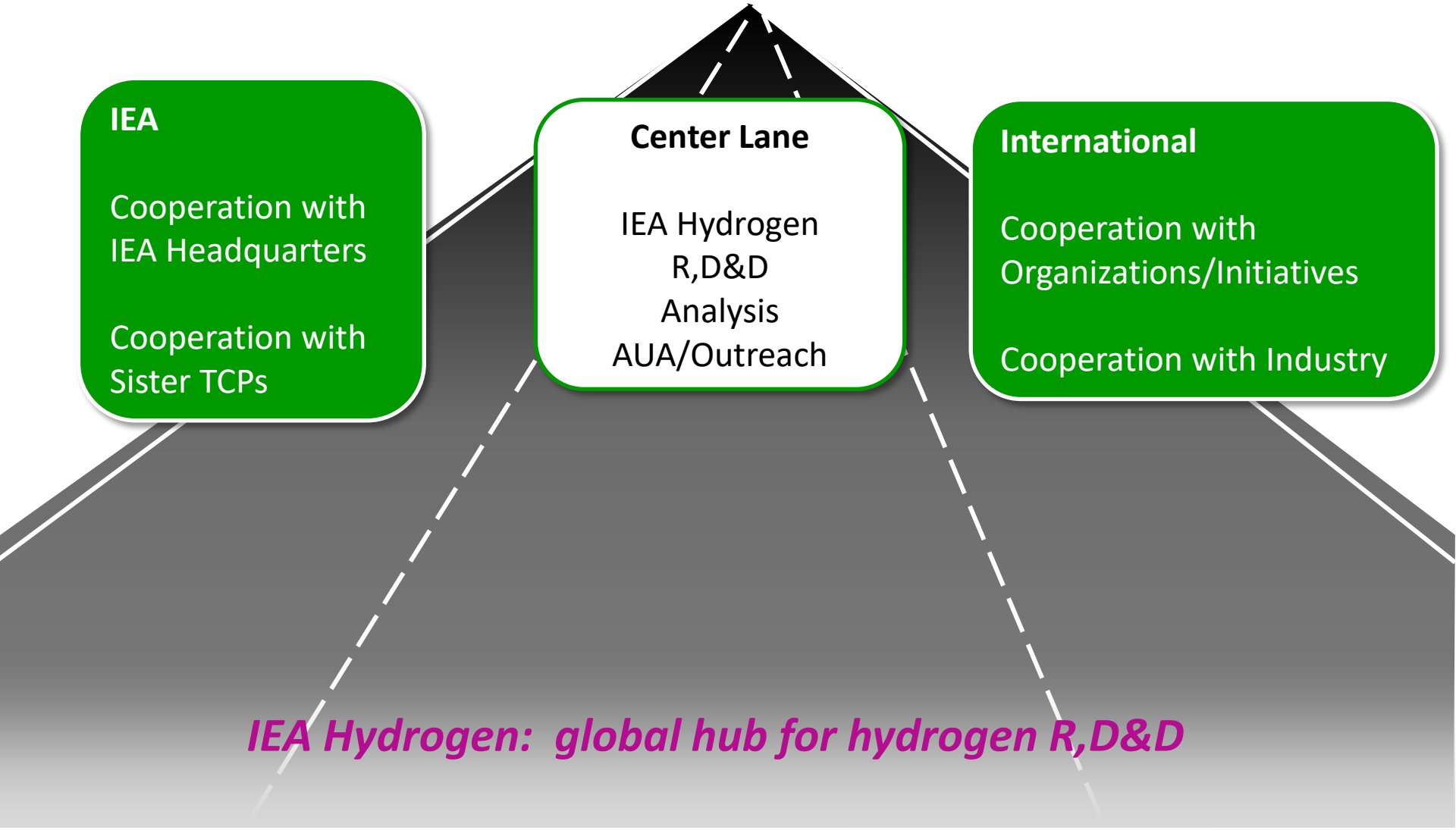
GLOBAL TRENDS AND OUTLOOK FOR HYDROGEN

2017 IEA Hydrogen Secretariat Report

http://ieahydrogen.org/PUBLICATIONS,-REPORTS-PRESENTATIONS/Special-Reports.aspx



IEA Hydrogen ROADMAP Forward



Thank you from IEA Hydrogen
IEA Hydrogen: global hub for hydrogen R,D&D

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