Hydrogen: premium electrofuel & building block for all electrofuels

IEA Hydrogen - global hub for hydrogen R,D&D

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IEA Electrofuels Workshop

10 September 2018
Hydrogen – why premium electrofuel?

**The strategic Hydrogen advantages**

Hydrogen can play a transformative role as a highly flexible energy carrier during the clean energy transition and in an integrated future multi-sector energy system as follows:

- For Sector coupling - as a bridge between different types of energies
- For Storage – utilizing electrical energy that would otherwise have been lost
- For Storage – enabling use of massive quantities of renewable energy
- For Stability - balancing grid and buffering energy system
- Decouple energy and power parameters for Recharging Infrastructure
- For feedstock – using captured carbon
- For certainty – avoiding CO2 capture from air

Hydrogen is a building block of all electrofuels
Consensus on multi-sector applications for Renewable Hydrogen
Hydrogen is a bridge between different energy sector

Hydrogen  — Key to support the energy transition

Enable the renewable energy system  →  Decarbonize end uses

Enable large-scale renewables integration and power generation

Distribute energy across sectors and regions

Act as a buffer to increase system resilience

Help decarbonize transportation

Help decarbonize industrial energy use

Help decarbonize building heat and power

Serve as renewable feedstock

Source: Hydrogen Council
Hydrogen for industrial and chemical uses will remain predominant (Ammonia as Hydrogen carrier not taken into account)
**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

**Membership**
- 20 Countries + EC+ UN + 4
- Sponsors + 4 new members pending

**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
Direct Hydrogen/Fuel Cells
Usage Options
for transportation
**Passenger Cars & Captive Fleets**

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

**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.

**Maritime**

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

**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.

**Portables**

- 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.

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**AN INTERNATIONAL ENERGY AGENCY TECHNOLOGY COLLABORATION PROGRAMME**
Battery and Fuel cell: a perfect technologies wedding in the electric car family

Hydrogen as a gas like others electrofuels has unique advantage to uncouple power to energy due to storage capacity. New fuels/electricity infrastructure design will be key for massive deployment.

Different design for power train architecture

- Battery Electric Vehicle (BEV)
- Fuel Cell Range Extender (FCREEV)
- Plug-in Fuel Cell Electric Vehicle (PFCEV)
- Full Power Hydrogen Vehicle (FCEV)

Fonctionnement:
1. Le moteur électrique assure une propulsion zéro émission.
2. La pile à hydrogène produit de l’électricité à bord.
3. La batterie et la pile hydrogène alimentent le moteur.
4. La batterie se recharge sur le secteur, l’hydrogène à la station.
Hydrogen Pathways
Hydrogen Production via Electrolysis: key technology
conventional, renewable and innovative production RES technologies

Via Electrolysis

**Electrolysers** available in small and large sizes (now in MWs!)

**Electrolysers** available in low and high temperature technologies:
- **Low** – alkaline and polymer electrolyte membrane (PEM)
- **High** – solid oxide electrolyser (SOEC)

Via conventional, renewable & innovative RES technologies

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**Production method**

- **Central**
  - Natural Gas Reforming (established industrial process)
  - Low GHG Reforming (biogas, etc.)
  - Biomass Gasification
  - Electrolysis (wind)
  - Electrolysis (solar)
  - Coal Gasification (with CCUS)
  - High-temp Electrolysis
  - PEC
  - STCH
  - Photo-biological Bio Inspired Approaches

- **Mid-scale**
  - Distributed SMR
  - Grid Electrolysis
  - Bio-derived Liquids
  - Microbial Conversion
  - Hybrid & Other

- **Near-term**
  - Biomass Pathways
  - Solar Pathways

- **Mid-term**

- **Long-term**

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AN INTERNATIONAL ENERGY AGENCY TECHNOLOGY COLLABORATION PROGRAMME
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HyLYZER® - PEM: key milestones @ Hydrogenics

- Test large stack
- Field test 1.5 MW electrolyser (Reitbrock)
- 1.5 MW cell stack
- Dual cell stack design (HyBalance 2 x 0.6 MW)
- Multi MW design (with 2 x 2.5 MW building block)

1999 2004 2012 2014 2015 2017 2018 ...

Power-to-to-Fuels

PEM Electrolyser Scaling Up

Power-to-Fuel

- 50 MW
- 100 MW
- 200 MW
- 400 MW

- Hydrogen
- Synthetic fuels / gases (H₂ + CO₂)
- Power-to-Refinery

Workshop: “The future of e-Fuels in Europe” | Herentals, BE | 27.08.2018

Deal! New 32% renewables target for 2030. Renewables are good for Europe, and today, Europe is good at renewables. This deal is a hard-won victory in our efforts to unlock the true potential of Europe’s clean energy transition. Thank you all! #REDII #ParisAgreement #CleanEnergyEU
Transport and Distribution – Renewable Supply Chain

Renewable hydrogen supply chain

- Overseas processes:
  - Renewable power generation
  - Hydrogen production
  - Energy carriers production & storage
  - Ocean transport
- Domestic processes:
  - Energy carriers storage
  - Domestic distribution
  - Hydrogen restoration & compression
  - Hydrogen filling into FCVs

NG reforming hydrogen supply chain

- Overseas processes:
  - NG production
  - LNG production
  - Ocean transport
- Domestic processes:
  - Hydrogen production & compression
  - Domestic distribution
  - Hydrogen compression
  - Hydrogen filling into FCVs

To be newly installed inside the Hama Wing site

- Yokohama City Wind Power Plant (Hama Wing) (1,980 kW)
- Receiving/transferring/distribution panels, storage facility
- Power storage system (150 kWh)

Hydrogen manufacturing system

- Receiving/transferring/distribution panels
- Low-pressure hydrogen storage tank (800 Nm³)
- Hydrogen storage and compression system
- Hydrogen manufacturing system
- Water electrolysise system (10 Nm³/h)

Transport

- Fuel cell forklifts (Total 12 vehicles)
  - Vegetable and fruit markets
  - Refrigerated warehouses
  - Distribution warehouses, etc.

Utilization

- Keihin Waterfront Area
  - Hydrogen (H₂) 35 MPa
  - Hydrogen filling into truck (45 MPa: 270 Nm³)
  - Supplying hydrogen using simple fueling trucks
    (Optimum transport that addresses operational situations and needs)

Renewable energy

- Water (H₂O)
IEA Hydrogen Technology Collaboration Program (TCP)

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

Time Frame: 2016 - 2019

Production Pathways: Power-to-Hydrogen and Hydrogen-to-X: all sectors, applications & pathways
The new « Hydrogen » Roads?
Work in progress in Task 38: definition of new business cases

- Etude FZJ*: Possible and feasible production of possible de produire 9Mt/year from wind in Patagonia (Santa Cruz) (3cts/kWh) To Japan at a cost of 5 US $/Kg H2
- Different options for supply chain
- Renewables but also fossils+CCS
- Japanese government: ambitious goal and R&D programme
- International trade framework to be adapted

* P.Heuser, M. Reuss, T.Grube, M.Robinius, D.Stolten, FZJ, IK3
Whec 2018, Rio de Janeiro
Cost
New 2017 Study from IEA Renewable Division - Renewable Hydrogen (for industrial applications) is now an option! Scale up (competition, volume) is driving costs down

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

Hybrid solar and wind full load hours adjusted for overlap

Capacity factors of combined wind and solar power exceed 50% in vast areas, often remote from large consumption centers, potentially delivering huge amounts of power at less than $30/MWh

Producing hydrogen from cheap solar and wind power

At USD 30/MWh or less, and with high capacity factors, solar and wind power in best resources areas can now generate hydrogen at competitive costs.

Source: Fasihi & Breyer, 2017
KEY FINDINGS

- For alkaline systems CAPEX of 750 €/kW is reachable today for a single stack of 2 MW.
- For PEM, such CAPEX should become within reach for 5 MW systems, but currently still require the use of multi-stack systems.
- CAPEX value below 400€/kW have been projected for alkaline systems, but this will require further upscaling up to 100 MW.

Fig. 2 Reduction in CAPEX upon use of multi-stack systems, both for PEM (left) and alkaline (right) electrolyzers. [1]

Fig. 1 CAPEX data for both PEM and alkaline electrolyzers, plotted as a function of the power input. Data for alkaline systems are based on a single stack of 2.13 MW considering 230 cells, 2.6m² size. Note that change in slope for alkaline electrolyzers corresponds to the use of multi-stack systems. [1]

KEY FINDINGS (continued)

- Range of estimations in 1990s for alkaline was between ~600 and ~2500 €2017/kWHRV/Output.
- Today’s expectation for 2030 for alkaline dropped to ~700 to ~1000 €2017/kWHRV/Output.
- Alkaline: reductions more moderate compared to PEM.
- This can be explained with the maturity of the alkaline technology.
- Range of estimations in 1990s for PEM was between ~300 and ~5000 €2017/kWHRV/Output.
- Today’s expectation for 2030 for PEM dropped to ~400 to ~1000 €2017/kWHRV/Output.

Fig. 3 Cost projections in the near to long term, for alkaline and PEM electrolyzers [2]
Desired cost reductions require investment in electrolysers like other new energy technology. PV requires more than 400GW to reduce costs as it is today.

Scale and learning effects are critical for cost reduction, but uncertain (e.g. CO₂ from air).

International 100-gigawatts-challenge.

Investments are not to be expected without political intervention or high CO₂ price due to high cost of synthetic fuels.

Installed electrolysis capacity for PtG/PtL in scenarios for Germany in GW.
Hydrogen Infrastructure for Mobility: new comparative analysis dispels tale of H2 infrastructure cost barrier
Land and water demand

Task 36 – LCSA concludes that different calculations associated with conventional LCC and LCC with externalities influences levelized cost of hydrogen. The use of LCSA arises as a convenient methodological solution to thoroughly evaluate the performance of hydrogen energy systems.

Comparison of gross area-specific yields of PtL fuels from photovoltaic and wind power and biofuels.

- Netwater demand of energy crops is subject to local conditions and yieldexpectations.
- The water footprint of PtL fuel is by a factor of 400 to 15,000 lower than biofuels.
- Bulk PtXplants are still significant local consumers (seawater treatment, watercycling).
IEA Hydrogen Task 38
Workshop on Power to Gas
Demonstration projects analysis in the world

Towards an International PtG demo projects Road Map

20th November 2018, Aix en Provence, France
(on invitation only)

Objectives of the workshop:
IEA Hydrogen Task 38 gathers data from near 200 Power to Gas demonstration project at the world level and analyse each project through more than 25 parameters (technical, economics, projects characteristics ...).
The aim of the workshop is to present the result of this meta-analysis, to give the floor to a panel of a few demonstration projects representative of the variety of situation and to present and discuss a International PtG demo projects road map.
Conclusions and recommendations

- Electrolysis technologies ready to scale up
- New promising technologies are not far behind, R&D (Mission Innovation IC#8)
- « Green » Hydrogen markets are increasing, huge and diverse in any case
- ... proven incentives and regulatory framework will be in place

Perspectives for our TCP work:
- Developing energy system analysis is key
- Reliable database important
- Compare different routes and pathways (Ammonia, biofuels ...) and combination of routes in different applications (heavy transport, industry ...)
- Work on financial and regulatory framework, derisking strategies for investment

Cooperation with others TCP, IEA analyst and other organization
IEA Hydrogen: global hub for hydrogen R,D&D

IEA
Cooperation with IEA Headquarters
Cooperation with Sister TCPs

Center Lane
IEA Hydrogen R,D&D
Analysis
Outreach

International
Cooperation with Organizations/Initiatives
Cooperation with Industry

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