

# IEA Hydrogen Energy Technology Roadmap North America Stakeholder Engagement Workshop Workshop Summary 27-28 January 2014 Bethesda, MD

On 28-29 of January, 2014 the IEA hosted its second stakeholder engagement workshop in support of the development of the Hydrogen Technology Roadmap. The workshop was organized together with the US Department of Energy (US DOE) and Industry Canada as well as with the help of the Hydrogen Implementing Agreement. Participants included experts from government, industry and academia.

The objectives of this workshop were to:

- Discuss the scope of the roadmap
  - Technologies covered
  - Possible inter-sectoral synergies
  - Regional characteristics/developments;
- Identify and prioritize technical/market/policy related developments, opportunities and barriers in mobile, stationary, industrial and energy storage applications of H2 technologies in the North American context;
- Discuss H2 Transmission and Distribution (T&D)and refueling infrastructure along with related developments, opportunities and barriers; and
- Identification of possible actions and milestones as well as policy instruments to develop the broader application and adoption of H2 technologies.

This document reflects key points that emerged from the discussions held at this workshop. The views expressed in this paper do not represent those of the IEA or IEA policy nor do they represent consensus among the discussants.

#### Background

The IEA roadmaps provide guidance to stakeholders on the technology pathways needed to achieve energy security, economic growth, and environmental goals. The roadmaps include a vision guided by the IEA Energy Technology Perspectives 2-Degree Scenario (2DS). Each roadmap represents international consensus on milestones for technology development, legal and regulatory needs, investment requirements, public engagement and outreach, and international collaboration.

The goal of the hydrogen roadmap is to:

- Provide a vision for hydrogen's role in a low carbon energy system
- Outline current status of hydrogen technology development
- Identify barriers and actions needed to accelerate the development and deployment of hydrogen technologies to meet the roadmap vision
- Identify and share lessons learned and best practices in hydrogen roll out
- Discuss policy measures to support the development and broader application of hydrogen technologies that facilitate the low carbon energy system

#### Group discussion introduction session: Scope of hydrogen roadmap

- The roadmap should carefully examine the relation between impacts on the environment, energy security and economic growth for H2 technologies.
- The roadmap needs to find a good balance between quantitative and qualitative analysis.
- The participants agreed with having a broad scope across all energy sectors aiming to discuss inter-sectoral synergies, and even stressed the need to provide a "universal picture" of hydrogen applications highlighting its flexible use across the energy system.
- H2 generation and possible energy resources needs to be discussed in the roadmap.
- Developing the global picture for the roadmap can be based on a detailed analysis for the US, EU G4 and Japan.
- Regional specifications need to be discussed including: the impact of low cost gas in the US and Canada; the relatively low cost of renewable energy in Canada; the integration of variable renewables in the EU; and, energy imports in Japan.
- Existing regional roadmaps and technology roll-out plans such as those for FC transport in California, Japan, Canada and Germany should be included.
- The roadmap needs a clear definition of technologies and processes (e.g. power-togas equals H2 blending not methanization). The term hydrogen energy storage also needs to be clearly defined (power-to-power vs. power-to-gas vs. power-tofuel/feedstock).
- Efficiency is an important argument but should not be discussed in isolation. Wider energy system benefits should also be considered.
- The trend towards more integration within industrial sites and in fleets should be highlighted.

# Group discussion session 2: Market drivers – Transportation

- Clustering of stations is essential to achieve high coverage at minimal cost while economics for refuelling infrastructure needs to be analysed both from network and station owner perspective. Investment costs at the station need to be minimised.
- A positive cash-flow at the station can only be reached within acceptable time if there is a rapid fuel cell electric vehicle market uptake, or if regulatory support is provided during the slower uptake period.

- Any anticipated decrease of total costs of driving for FCEVs over time is very dependent on H2 costs at the pump over time.
- While there is research evidence that the long-run H2 prices can decline to competitive levels, the initial market launch will be critical in terms of setting expectations.
- Integration of FC drivetrains within a conventional passenger light duty vehicle chassis is a major step towards getting FCEV costs down whilst the high cost of on-board storage systems are still a challenge.
- In order to command higher initial premiums for expensive, new technology, it is essential that FCEVs appeal to consumers as an exclusive, high-tech product. This is not necessarily in line with the use of FCEVs in fleets to expand early markets (fleets have a negative, low-tech image in US Markets).
- FCEVs can replace conventional cars with respect to range, size and refuelling time. However, this promise is constrained by the H2 infrastructure. In contrast battery electric vehicles provide the feeling of cars with "essentially free or very low cost fuel," and the fuel is available everywhere.
- Renewable H2 can be psychologically important for first movers and might also attract states to invest, but can be risky if a mandatory requirement is imposed too early.
- Air pollution can be an interesting argument for FC buses as they could reduce emissions significantly for transit authorities in heavily populated regions. FCs do have hard times with long distance heavy freight trucks as current engines work already close to optimal efficiency.
- 20,000 to 50,000 FCEVs (stock) in North America can be a reasonable target by 2020

# Group discussion session 3: Market drivers – Stationary power

- FC applications, such as telecommunications back-up systems and commercial fork lift fleets, are considered to be early market drivers with reasonable returns on investment (ROI).
- Power-to-gas can be an attractive energy storage solution if renewable H2 is blended at very low shares in the gas grid due to existing large storage capacity in the natural gas pipelines and natural gas underground storage facilities. It offers the possibility of integrating excess variable renewable energy within the natural gas networks and/or onto electrical grids.
- Larger scale FC projects often lack policy framework and public support.
- There are many synergies in PEM FC for transportation and stationary applications, and increased volumes overall will result in cost reductions for both sectors; however, the applications have different characteristics which ultimately limit the achievable cost targets at different levels (e.g. energy density vs. efficiency).
- If blast furnace top gas recovery and H2 separation is applied for steel making processes, the captured H2 might not be re-injected but could be used in higher value applications. However, costly purification of the H2 gas is necessary to meet

the purity requirements for fuel in FCEVs and additional natural gas would be needed to replace the hydrogen being used as fuel elsewhere in the process.

- Levellized costs of energy can only give a hint at technology competitiveness and should not be seen as the single deciding argument. Caution needs to be used when referring to LCOE in the context of renewable power because of its intermittency.
- Higher temperature FCs can deal with lower purity H2 but show limitations in terms of flexibility (ramp-up/down) which may be a serious hurdle in energy systems with very high shares of variable renewables.

#### Group discussion session 4: Supply/Demand for Hydrogen

- Hydrogen generation pathways need to be discussed in the roadmap as region specific resource endowment has major impacts. A wide variety of hydrogen generation technologies are already included within the IEA ETP TIMES model. Furthermore, studies from US DOE as well as the H2 Resource Study currently developed within the Hydrogen Implementing Agreement can provide useful input.
- In general the US DOE has extensive material on H2/FC technology, which should be incorporated into the roadmap.
- Natural gas needs to play a role as a transition fuel to H2 generated from renewable energy sources. Biogas, especially from waste water treatment, needs to be considered as there is often a good correlation between resource and demand centres.
- H2 transport, distribution and retail infrastructure initially installed for H2 from natural gas can lead to a low carbon energy system in the more distant future if hydrogen generation is gradually decarbonized over time. Early calls for renewable H2 raise the cost and complexity of the first stations.
- The final H2 generation and T&D infrastructure will neither be purely centralized nor purely decentralized, the market will shape the supply side.
- Small scale natural gas steam reformation can play an important role. Also, liquefied merchant H2 can play a bigger role for early market supply in the US.
- The role of renewable H2 should not be overly stressed in the early phase though Non-Governmental Organisations (NGOs) fear lock-in, if fossil H2 is used in the beginning.
- Current H2 generation infrastructure needs to be used during FCEV roll-out but *excess hydrogen* from the refining industry might be limited as steam reformers are operated at high load (~96%) and refiners might not be willing to give up their margins of operation. Nonetheless, a 1-2% share of current H2 generation might be available for other use under optimistic assumptions.
- By-product H2 from chlor-alkali production or ethane cracking might be more promising sources in the early market though there may be issues of purity and hence cost of cleaning.
- A theoretic stock of 50,000 FCEVs by 2017 might be already challenging to refuel with current hydrogen generation capacity in North America.

- H2 adoption might be aided if it were to qualify for biofuel in accordance with Renewable Fuel Standard 2.
- It is important to note that the carbon footprint of electrolysis vs. steam reforming of natural gas is quite similar, even at higher shares of renewables in the electricity mix (~30%). This is due to differences in efficiencies and the number of transformation steps.
- Integration of excess variable renewables is an issue in high variable renewable energy scenarios. The capacity factor of variable renewable energies can be increased if otherwise curtailed energy can be used.
- Satisfying power demand at no renewable energy availability is a problem which leads to assets with very low load factors. Synergies with other sectors (e.g. inherent storage of H2 refuelling station network in the transport sector) can open new opportunities.

#### Group discussion session 5: Hydrogen infrastructure

- For infrastructure roll-out, the inclusion and education of decision makers on all administrative levels is an important factor.
- California is the most developed state with respect to H2 T&D and refuelling infrastructure. There are another 10 states with zero emission vehicle (ZEV) mandates (Connecticut, Maine, Maryland, Massachusetts, New Jersey, New Mexico, New York, Oregon, Rhode Island, and Vermont) of which 7 states do already have a memorandum of understanding to promote ZEVs.
- H2 infrastructure should be showcased in prominent positions and lessons learned from other jurisdictions should be applied.
- Combined hydrogen, heat and power and the use of power from excess renewables could help shorten the valley of death for H2 refuelling infrastructure due to underutilisation during FCEV roll-out.
- There's no chicken and egg question, infrastructure roll-out definitely needs to be in place prior to FCEV deployment.
- A fast FCEV ramp-up rate is crucial for H2 infrastructure development. The high uncertainty around ramp-up rates for FCEVs imposes a crucial problem for H2 infrastructure development.
- Putting much of the compression work up-stream reduces CAPEX of refuelling stations. As many station in the US are run by small entrepreneurs this can be crucial since the compressor can be the single biggest investment for refuelling stations. Both gaseous and liquid H2 have several pros and cons in this context for early market development.
- Impact of fleets on public hydrogen refuelling station HRS network development might be limited as locations for fleets and public refuelling can be rarely co-located.
- USD 10/kg (including margin of the retailer) seems to be an acceptable H2 price at station for early market deployment. In earlier demonstration projects the

cars/buses and the H2 fuel where packaged together. The prices quoted during the workshop were directly taken from independent studies.

- Synergies between H2 refuelling infrastructure and electricity/energy storage are possible. In the summer, transport fuel demand is on average 10% higher than in the winter. Hence, a 10% share on total inherent HRS storage capacity could be used as long-term, large scale energy storage to be which could be charged in summer and used during winter.
- H2 T&D and HRS scenarios are very region specific but lessons from the California example can work as a blue print if HRS coverage turns out to be robust.
- Even in the early market HRS network needs to be in place for long-distance driving.
- 700 bar on-board H2 storage is becoming the standard for FCV OEMs although 500 bar might be closer to the optimum between minimal CAPEX at the refuelling station and, the space and range requirements for FCEVs.

# Group discussion session 6: Industry and policy makers – expectations and requirements

- Fork lifts are an example of successful early market development with direct government intervention. Centralized fuelling, space savings within warehouses and productivity gains are amongst the primary ROI drivers.
- Waste-water biogas to H2, power, heat is considered to be an attractive early market development and offers a good match between H2 source and FCEV H2 demand if costs are competitive.
- Hawaii is an interesting case study for FCEV early market as well as HRS infrastructure development. The project also includes the integration of renewable H2 generation as well as energy storage and grid balancing. The high level of integration of different sectors can serve as illustrative example incorporating different case studies.
- Tax credits seem to be less effective than direct subsidies as the consumer has a preference to see the cash in his pocket immediately and not all buyers can monetize the tax credits.
- The next 3 to 5 years are crucial for harmonization of codes and standards.
- Problems emerge with big gas turbines and inconsistent natural gas quality. Nonetheless this issue might be less important as big gas turbines are usually connected to high pressure transmission lines. Hence, higher blend shares might be acceptable in the distribution network.
- Acceptable H2 blend shares of  $\sim 5\%$  are more of an educated guess than based on scientific evidence. In the EU higher blend shares of 5-10% are deemed to be acceptable.
- An interesting trade-off might be examined: Efficiency penalties due to more flexibility with respect to gas quality at big gas turbines might significantly decrease carbon reduction when renewable H2 is blended into the gas grid.
- Shale gas in the US has no significant impact on natural gas quality.

- Discussion of policy drivers is essential. Regulation and long term targets (e.g. climate targets, fuel economy standards), direct financial incentives, taxation as well as "soft" measures should be covered.
- The policy narrative is different in North America as major drivers (e.g. compared to EU/Japan) are not the same. Some participants nonetheless felt that if the climate change argument cannot be developed then FCEVs will have difficulties to succeed in North America.

#### Group Discussion 7: Near-term pathways toward renewable hydrogen

- Low cost electricity is crucial for renewable H2 generation.
- NREL Electricity Futures Study curtailment results do already include certain storage technologies (thermal, CAES, EVs, no H2 storage) and transmission expansion using a grid cell modelling approach.
- NRELs Energy Transportation Futures study can be relevant as it includes geographical distribution of curtailment as well as H2 transmission (power-to-gas is not included).
- H2 has higher transmission costs than electricity if pure H2 is transported. This may not be the case for H2 natural gas blend. Furthermore, the natural gas network has much higher transport capacities than power grid. Nonetheless, additional investments might be necessary to adapt the grid.
- The value of power-to-gas can lie in its ability to increase the load factor of existing infrastructure. Some claimed it to be the lowest cost measure to integrate high shares of variable renewables to the energy system. In some cases costs of H2 blended natural gas were compared to electricity costs going through direct electricity storage applications, which raises issues with comparability.
- Power-to-gas can help during periods of underutilized H2 refuelling infrastructure. Policy incentives like renewable gas certificates would be needed, which raises the issue of double incentives (under the assumption that renewable electricity generation is incentivized as well).
- Support for power-to-gas can include measures like green gas tariffs or ways of remuneration for provision of ancillary services.
- Renewable energy portfolio standard (RPS) definition needs to focus more on flexibility mechanisms within the entire energy system.

# Group Discussion 8: Transport break-out

- Early insistence on renewable H2 could hinder the industry e.g. California obligation for 1/3 of all H2 to be from renewable sources. H2 from natural gas will drive the early market in the US and should not be hindered by a requirement for CO2 free H2.
- Participants felt that the fuel source of early H2 production does not lead to "lock in" of sources, as it would apply to a relatively small number of cars in the short run.

- The transport sector will lead deployment of H2 in the US and ZEV mandate might be a trigger for deployment of FCEV. By 2015/2018 certain states will require sales of ZEVs.
- In Canada, there has been a stronger apparent need for H2 to come from a "clean source". The situation of the FC bus fleet showed that bad press with respect to CO2 content associated with the transportation of H2 using diesel trucks had negative impact on roll out of FC buses.
- Technology neutral, performance based support metric might be favourable e.g. WTW CO2 performance based.
- NG makes most sense with trucks, currently there is only little push for compressed natural gas passenger cars in North America.
- 1000-1500kgH2/d seems to be good station size in developed markets and 200kgH2/d in early markets.
- International harmonization with respect to H2 codes/standards for refuelling, onboard storage etc. is important to minimize development costs.
- Soft support measures like use of high occupancy vehicle (HOV) lanes; free use of toll roads/bridges; and, free parking can important to support FCEV market introduction.
- In early markets the high-tech image of FCEVs can be an important driver for early adopters.
- The examination of commercial tipping points might be of interest for the roadmap.
- Participants highlighted the relevance of support of early FC market applications. This will lead to greater acceptance of hydrogen by the public, provides experience and iterations on fuel cell and BOP components under real conditions and will bring technology cost down.

# Next Steps

- A 3<sup>rd</sup> roadmap workshop focused on hydrogen development in Asia will be held in Japan in June.
- A draft of the H2RM will be circulated for stakeholder review in Q4 2014.