Challenges for the Use of Hydrogen

White paper for Task 38 – Power to X.
International Energy Agency Hydrogen Technology Partnership

Power to hydrogen (PtH)

Hydrogen production from electricity is dominated by electricity price. Further improvement in the efficiency of electrolysers is possible principally through catalyst development. A globally focused assessment is needed of the cost to market of hydrogen from potentially viable locations via heavy road vehicles, and/or pipeline and/or shipping with either PV, wind or CCS prominent in electricity production. There is capacity to improve compressor technology.

Hydrogen to power (H2P)

Feasibility is principally dependent on the marginal price of electricity, the cost and capacity of hydrogen storage, scale and type of fuel cells, the proportion of renewables mandated in the power supply and distance between generation and supply. An international inventory of storage cost and capacity of large scale underground storage sites such as salt caverns, depleted oil and gas fields, aquifers, and rock caverns will assist development. Continuing improvements are needed in catalysts, electrodes, fuel cell performance and durability, and membranes and electrolytes for PEM; alkaline; phosphoric acid; molten carbonate and solid oxide fuel cells.

Hydrogen injection in NG grid (HG-H2)

Establish safe mixing limit for hydrogen in existing gas infrastructure especially with respect to hydrogen embrittlement. Optimise grid storage for hydrogen/natural gas mixtures for low carbon grid balancing. Determining the performance characteristics of existing natural gas turbines with respect to increasing proportions of hydrogen in the gas stream is an important element in optimising use of existing infrastructure while minimising carbon emissions.

Hydrogen to Natural Gas – Methanation (HtG-M)

Improvements in reactor and catalyst technology in the methanation of carbon dioxide are needed for viable production of green methane.

Hydrogen to Fuel Cell – Vehicle (HtF-H2)

Cost reductions in fuel cells and storage tanks are needed. Fuel cell improvements are needed primarily in reducing platinum content that can account for over 40% of the fuel cell cost, while maintaining power density at improved efficiency. For storage tanks reduced cost of composite construction is needed especially in the use of carbon fibre that can constitute half of the tank cost. Further developments in metal hydrides and carbon nano-structures may also provide for alternatives to cryogenic or gaseous pressure vessels.

Hydrogen to Liquid Synfuels (HtF-S)

More analysis of the economics for the use of hydrogen in the green production of synthetic fuels is needed. These include ammonia, methanol, ethanol, dimethylether, ethylmethylether, isobutane, isopentane, ethylbenzol, toluol, and octane.

Hydrogen to Gas Fuels (HtF-G)

Need to determine optimum hydrogen and natural gas fuel mixtures for the specific ICE or diesel engine. More analysis of environmental and health benefits of reduced hydrocarbon and NOx emissions is needed.

Hydrogen to industry (HtI)

As with hydrogen to gas hydrogen embrittlement of existing infrastructure remains a constraint in the distribution of hydrogen. Impacts of lower volumetric energy delivery to industry need assessing if hydrogen is used to displace natural gas as the volumetric energy density of hydrogen is about 1/3 that of natural gas. Potential applications include replacing hydrogen production by NG reforming in refineries and replacing use of coke in metal ore reduction especially in steel production.

Hydrogen to heat (HtQ)

Microgeneration heating options using hydrogen fuel cells such as the Japan Ene-Farm producing combined heat and power still require cost reductions to be competitive with grid electricity or gas. More analysis of use of hydrogen for heat is needed including the extent of infrastructure and upgrades to heating equipment such as burners, and available CCS capacity e.g. H21 North of England project.

Hydrogen to Ammonia (H2tA)

Ammonia has good prospects as a hydrogen carrier due to its high hydrogen density, suitability for use in existing infrastructure, easy catalytic decomposition, no net CO2 emissions in the capture of hydrogen within the ammonia molecule and its release. The drawbacks with ammonia are mainly the toxicity of liquid ammonia and the problems related to trace amounts of ammonia in the hydrogen after decomposition. Ammonia has a low calorific value being about 40% of that of hydrocarbon fuels. More economic analysis is needed for use of ammonia in high-temperature solid oxide fuel cells, for combustion in turbines and internal combustion engines from ignition and as a storage medium that can use existing global infrastructure.

Hydrogen to Methanol (H2M)

More research is needed on production of methanol by green hydrogenation of carbon dioxide. CO2 capture and electricity costs are important components of green methanol production. Methanol has half the calorific value of gasoline but can be used in fuel cells and burned in existing power generation plants. Transportation costs are low. Further studies are needed weighing the advantages of methanol based octane enhancement and reduced emissions of ozone, carbon monoxide and PM against the disadvantages such as emission of formaldehyde and MTBE pollution of groundwater. Methanol can also be used as a raw material for many of the products that we currently obtain from oil, for example plastics.

Hydrogen to Chemicals (HtCh)

Opportunities exist for carbon reduction using green hydrogen in the production of a range of chemicals such as hydrogen peroxide, hydrochloric acid and vegetable oils.

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