Hydrogen Production & Distribution

HIGHLIGHTS

PROCESS AND TECHNOLOGY STATUS – Hydrogen is currently used in a number of applications in chemical and refinery industry. It can be obtained from a variety of feedstock (i.e. water, chemicals, fossil and renewable fuels) based on a number of processes. Due to its high gravimetric energy density, hydrogen can also be used as a high-quality fuel or energy carrier, though the very low volumetric energy density poses significant storage and transportation issues. Costs and storage issues have hindered so far the use of hydrogen as a fuel. Main technologies for hydrogen production include: catalytic **steam reforming** (800-1000°C) and **partial oxidation** (600–900°C) of hydrocarbons (e.g. natural gas) or renewable fuels (e.g. bioethanol); coal or biomass **gasification; water electrolysis** (i.e. electrochemical split of water into hydrogen and oxygen); **thermo-chemical water splitting** at around 900°C; and **biological production**. It is worth noting that all processes based on fossil fuels need to be associated with a CO_2 capture and storage technology to produce carbon-free hydrogen. Hydrogen can be stored as a compressed gas (up to 700 bar), as a liquid at cryogenic temperature, as well as trapped (e.g. adsorbed) in solid materials. **Hydrogen storage** by compression and liquefaction are mature and energy-intensive processes, while solid storage is not yet a commercial option. Compressed hydrogen can be transported by either tube trailers (typically, up to 300 kg at 200 bar) and pipelines (typically, 10-20 bar, large quantities and distances), while liquid hydrogen is moved by tankers (typically, 400 to 4000 kg). The availability of cheap hydrogen could help the commercialization of **fuel-cell vehicles** as a possible clean alternative to internal combustion engines running on fossil fuels. However, further R&D is needed to reduce the fuel cell costs and solve on-board storage issues. Electrolytic hydrogen could also be used as an energy storage medium in combination with hydro, solar and wind energy. Though expensive, this is an option under consideration to exploit excess (e.g. overnight) electricity generation.

PERFORMANCE AND COSTS – Natural gas steam reforming is a mature technology with large-scale industrial plants in operation and a commercial efficiency ranging from 70 to 85% (even higher if steam is available from other sources). Coal gasification is a less used and less efficient (50-70%) process. Commercial alkaline electrolysis can meet hydrogen production demand from 1 to 1000 Nm^3/h with an electricity-to-hydrogen efficiency of 62-82%. High-temperature or high-pressure variants can reduce the electrolysis energy use. As for hydrogen storage, compression energy amounts to 10-15% of the hydrogen energy content (up to 30% for very high pressure) while liquefaction absorbs between 30% and 40% of the energy content. Hydrogen production costs depend basically on process, feedstock and production capacity. Estimated ranges given as €/Nm^3 are 0.05–0.1 for natural gas steam reforming and coal gasification and 0.16–0.3 for electrolysis, which is very sensitive to the electricity cost. In general, production from fossil fuels offers competitive prices and large-scale potential but cannot be considered a viable option for large scale production in the absence of effective carbon capture and storage. In contrast, electrolysis is costly, but involves no or negligible emissions (apart from those from electricity generation) and produces high-purity hydrogen. Hydrogen **c**ompression cost is estimated to range between €0.9 and €1.75/kg. Transportation costs range from €0.13-015/kg for liquid tankers, 0.14-0.26/kg for pipeline and €0.5-0.6/kg for tube trailers (100 km).

POTENTIAL AND BARRIERS - Hydrogen is seen as an attractive, clean and versatile energy carrier (*hydrogen economy*). If produced from primary renewable energy, it materialises a 100% carbon-free fuel. However, several technology challenges need to be overcome for this to happen such as increasing production efficiency, reducing costs, and identifying viable options for storage and transportation. At present, hydrogen is almost entirely used as a basic feedstock in refining and chemical industry. Its use as an energy storage system in association with renewable electricity generation is under investigation. Hydrogen use as fuel for fuel-cell vehicles is currently challenged by electric vehicles. However, large-size batteries for electric vehicles also face their own technical and economic issues, and fuel cell cars continue to be an option under development. Hydrogen also needs a specific distribution infrastructure to be developed. It is currently unclear in which volumes and form (gaseous, liquid, etc.) hydrogen will be used, and system cost/benefit analyses have not been fully worked out. A key question is whether hydrogen is needed to achieve a sustainable low-carbon energy system. Continued R&D and demonstration as well as a regulatory framework are needed to introduce hydrogen in the world energy system.

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