Lowering energy spending and costs for hydrogen transportation and distribution

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Future prospects of hydrogen fuel cell vehicles will allow an important decrease in the spent final energy, and in greenhouse gas and pollutant emissions for transportation. Nevertheless, care has to be taken so that this decrease in the final energy does not induce a too large increase in the energy spent in the intermediate steps of hydrogen production, storage, transportation and distribution. This is a clear issue to be addressed as the energy for hydrogen liquefaction or compression is high, as pointed out in [1].

Many studies have been realized during the last 2 decades concerning the most secure way to fill hydrogen car tanks and reported, during NHA congresses for example, as by Schneider & al. [2]. They resulted in the release in July 2014 of a last version of the SAE-J6201 standard for fueling protocols for gaseous hydrogen vehicles under 35 or 70 MPa pressures.

The present paper is dedicated to cost and energy consumption optimisation of compression, transportation and distribution of hydrogen. It considers 2 cases: the case of a refuelling station on the site of the hydrogen production and the case of a production unit providing hydrogen to several distant refuelling stations. It is a part of the VABHYOGAZ3 project supported by the French Programme "Investissements d'Avenir", led by HERA France and its subsidiary ALBHYON, with TRIFYL, RAPSODEE, HP Systems and EMTA (VEOLIA Group) as partners. VABHYOGAZ3 considers hydrogen production from biogas with production units of 100 to 800 kg/day to deliver hydrogen to several distribution units of 20 to 200 kg/day located within a distance of 100 km of the production unit.

In the case where production and distribution are located on the same site, no transportation has to be considered and the energy consumption is mainly due to hydrogen compression and cooling. The study calculates an energy need at **3,6 or 4,4 kWh per kg** of hydrogen transferred to the car tank at 35 or 70 MPa in a reference case corresponding to current practices. It then shows that this need can be reduced by **more than 21%, 25 or 27%** when judiciously using **3, 4 or 5 stages** of buffers organised in a pressure cascade for the filling of a tank at 35 MPa (and **2**

to 3% more for a filling at 70 MPa). Whereas the total volume of the staged buffers is higher the volume of an only very high pressure buffer (VHPB), the investment cost is not higher; then the energy savings result in **net savings**.

In the case where a production unit supplies hydrogen to several distant hydrogen refuelling stations, energy for transportation by truck and for re-compression on the distribution site must be added. The off-site distribution reference case considers the transportation of hydrogen steel frames or trailer tubes and the re-compression of all the hydrogen to the VHPB.

To lower the energy spending, small containers of 30 MPa light composite bottles are designed. These containers can then also be used instead of intermediate pressure buffers on the distribution site; just a small VHPB has to be kept and only a small part of the hydrogen has to be compressed to this VHPB. The study shows that, even if the investment in composite bottles is higher than in steel bottles or tubes, the resulting overall cost is always lower: the use of up to 4 containers on the distribution site generates global cost reduction of 13 to 20%, according to the size, for a distribution at 35 MPa (and 9 to 14% at 70 MPa). The energy savings are high (12 to 39%); the overall energy expenditure can be **lower than 4 kWh/kg H2** for a 35 MPa distribution (4,7 kWh/kg H2 for 70 MPa) and the green gas emission lower than **0,40 t CO2 / t H2**.

When higher pressure composite containers are available (52 MPa), then for a distribution at 35 MPa, VHPB and compressor are useless and this results in **significant supplementary reductions** of investment cost, global cost and energy needs; while for a distribution at 70 MPa, 52 MPa containers give similar results to 30 MPa containers.

References

[1] Klell M., Kindermann H., Christian J. "Thermodynamics of gaseous and liquid hydrogen storage" Proceedings International Hydrogen Energy Congress and Exhibition IHEC 2007, Istanbul, Turkey 13-15 July 2007

[2] Schneider J., Ward J. et al. "Optimizing Hydrogen Vehicle Fueling", NHA 2005