Comparative life cycle assessment of hydrogen-fuelled passenger cars

***D. Candelaresi*[1], *A. Valente*[2,3], *D. Iribarren*[2], *J. Dufour*[2,3], *and G. Spazzafumo*[1]**

[1] *University of Cassino and Southern Lazio, DICeM, Cassino, Italy*

[2] *IMDEA Energy, Systems Analysis Unit, Móstoles, Spain*

[3] *Rey Juan Carlos University, Chemical and Environmental Engineering Group, Móstoles, Spain*

daniele.candelaresi@unicas.it

Hydrogen is set to play a strategic role in the decarbonisation of the transportation sector. However, comprehensive analyses from a life-cycle perspective are required to check the environmental suitability of hydrogen energy systems. In this regard, the standardised methodology of life cycle assessment (LCA) is widely applied. In a previous article [1], the role played by hydrogen as the fuel in the life-cycle environmental performance of a fuel cell passenger car was explored for three different hydrogen production technologies. The results showed that the choice of hydrogen production technology significantly affects the whole life-cycle performance of vehicles. Renewable-based hydrogen –especially when produced through wind power electrolysis (WPE)– was identified as the preferred fuel option. When using hydrogen from WPE, the ratio hydrogen impact to total impact of the whole system dropped to values around 20% or less, shifting the main contribution from the fuel to the vehicle infrastructure. Considering this result as the background, the aim of this conference contribution is to identify the environmentally preferred hydrogen-fuelled vehicle among different alternatives. For this goal, the environmental life-cycle performance of five passenger vehicles employing hydrogen from WPE (solely or as an additional fuel) was assessed. The comparative study was performed using a compressed natural gas (CNG) vehicle and its hybrid version (HEV CNG) as the benchmarks. Hybrid electric vehicles (HEV) are partially electrified vehicles, consisting mainly of an internal combustion engine, an electric motor, and a small battery. Three car options fuelled only by hydrogen were considered: (i) a fuel cell electric vehicle (FCEV), (ii) a hydrogen car equipped with an internal combustion engine (H2ICE), and (iii) a hybrid car fuelled with hydrogen (HEV H2ICE). Besides, two additional vehicles using hydrogen as an additional fuel were evaluated: (iv) a hythane vehicle equipped with an internal combustion engine fed with a gaseous mixture of 20%$_{vol}$ H_2 and 80%$_{vol}$ natural gas (Hythane), and (v) a dual-fuel hydrogen-gasoline vehicle equipped with an internal combustion engine (H2-Gasoline), with an energy ratio of the mixture equal to that of hythane. The LCA involves the vehicle life-cycle stages of production, operation, and maintenance within the system's boundaries, using 1 km travelled by each vehicle as the functional unit. Global warming (GWP), cumulative non-renewable energy demand (CED) and acidification (AP) were selected as the environmental life-cycle indicators for this analysis.

PF-07

Overall, regarding GWP and CED, the fuel cell vehicle showed the best performance, while an unfavourable performance was identified for the CNG car. The situation was found to be different in terms of AP, for which the fuel cell vehicle arose as the worst option due to infrastructure impact. Major contributors are steel-based car frame, carbon fibre for the tank, components of the vehicle's electrical system and, to a lesser extent, platinum group metals and other components of the stack. Looking only at the vehicle infrastructure, the fuel cell vehicle is outperformed in all impact categories (especially in AP) by vehicles with an internal combustion engine, which is closely linked to the lower construction complexity of the latter. Finally, the advantage of fuel cell vehicles of having no exhaust emissions was appreciable only under the GWP category, penalising vehicles with internal combustion engines.

References

[1] Valente A., Iribarren D., Candelaresi D., Spazzafumo G. and Dufour J. "Using harmonised life-cycle indicators to explore the role of hydrogen in the environmental performance of fuel cell electric vehicles", Int. J. Hydrogen Energy, *in press*, doi: 10.1016/j.ijhydene.2019.09.059.