Hydrogen as a transport fuel – current status and developments

by Rapha Julysses Perez[1]

Climate change is a global phenomenon that countries have to acknowledge, since its effects are felt regardless of national borders. As a result, countries are initiating efforts to combat anthropogenic climate change by abating greenhouse gas emissions. Initiatives for sectoral decarbonization are happening on a global scale. In the energy sector, the continued increase and improvement of renewable energy technologies prove to be useful in decarbonizing the electricity source. But there is still work that needs to be done to decarbonize the transport sector. This is one of the sectors where green hydrogen[2] aims to provide a decarbonization option.

Hydrogen for transport

Based on end-use applications, hydrogen produced from electrolysis can be prescribed for purposes such as for vehicle fuel and energy storage. Fossil fuels currently dominate as a transport energy source worldwide, providing an opportunity for hydrogen to replace fossil fuels as a transport fuel [1]–[4]. Hydrogen can tackle sectors which are “battery challenged”, such as heavy-duty transport, non-electrified rail, and maritime transportation. While possible, electrified transport may not always meet performance standards and the criterion of charging convenience [5]. For Example, electrified boats may have to complete a single trip before it can recharge. The charging capacity of these boats should be enough to hold energy tantamount to the time that the boat can operate at least a single trip.

All vehicle types are potential niche markets for hydrogen fuel, but long haul vehicles can truly benefit from longer ranges and fewer refuelling stops (Figure 1) [5]. Compared to battery electric vehicles, however, fuel cell vehicles are relatively new to the market. At present, large battery electric vehicles and fuel cell technologies are still expensive relative to small battery electric vehicles. Without significant improvements in battery technology, hydrogen becomes the only viable low-carbon electrification option for long haul vehicles [6]. Boats, in particular, may not be classified as long haul vehicles and may not benefit from hydrogen technology.

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[2] Hydrogen produced from purely renewable sources

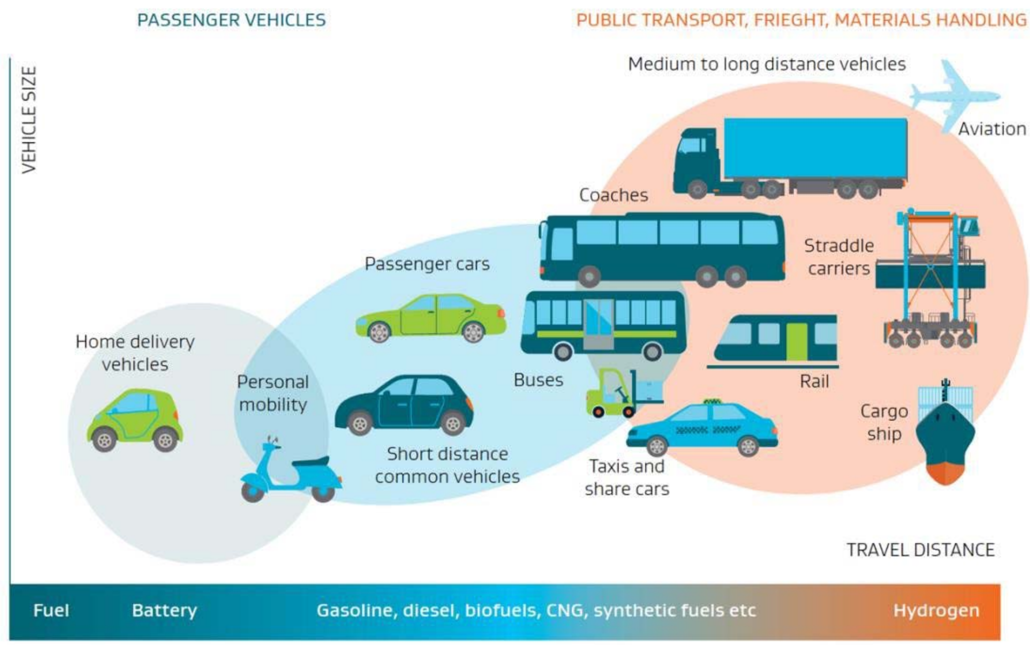

Figure 1. Complementary roles of battery electric and hydrogen fuel in the transport fleet decarbonization. From MBIE (2019, p. 50)

Hydrogen produced from renewable energy

Green hydrogen systems can operate in small-scale or large-scale applications. Identifying a clear scale of hydrogen production is important as it can affect both the component choices and economic performance of a green hydrogen system [6]. In order to make a profit, maximizing hydrogen production potential from renewable electricity via electrolysis must therefore be in balance with economies of scale. Both small-scale and large-scale systems can be prescribed for decentralized operation. A decentralized electrolyser operation, which consumes dedicated power from renewables, can avoid delivery risks [7], [8]. Decentralised systems also have greater flexibility in terms of design and scalability by being installed in multiple sites where they can be produced at the point of service and/or near to where they can take advantage of a rich renewable electricity source. Location of hydrogen production points is also important from the perspective of commercial vehicle operators. Production points are more beneficial if placed near the point of consumption [9]. Electrolysers can also be increased in capacity in a strategic place in order to serve higher transport demand volumes and provide greater flexibility and autonomy for vehicle operators [8]. In the case of boat operation, hydrogen production can take place where the boats are docked.

Some studies have considered off-grid green hydrogen systems, in which either a dedicated or a hybrid dedicated renewable electricity source is solely powering the electrolytic hydrogen production. An advantage of off-grid systems is that they are able to exploit places with rich renewable energy resources [10], [11]. One disadvantage of off-grid systems is that the utilisation factor is limited by the capacity factor of the RE source itself [12]. The largest problem concerning green hydrogen systems in general is the intermittency of renewable electricity, thereby resulting in electrolyser power variations and variable hydrogen production [13], [14]. However, a diversified RE electricity supply (e.g. solar and wind) is more reliable than a single type of RE source [15]. A key takeaway for the prospect of hydrogen production in Romblon is that the production can happen off-grid, but it will have to be limited by the available renewable energy resources in the island.

Economics

Hydrogen cost is directly sensitive to changes in electricity source, regardless of whether electricity is sourced from renewable or non-renewable sources, grid-connected or off-grid (Genç et al., 2012; Greiner et al., 2007; Levene et al., 2007; Linnemann & Steinberger-Wilckens, 2007; Loisel et al., 2015; Manage et al., 2011; Parra et al., 2019; Rahil & Gammon, 2017). For instance, considering a variable electricity source in the techno-economic analysis (which is the case for most renewable sources), will affect how green hydrogen systems operate and how volatile hydrogen costs will become [2], [19], [21]. Fluctuating operation imposes high investment costs, because fluctuating electricity reduces the lifetime of electrolyser equipment [21]. However, hydrogen produced using renewable electricity is expected to be economically competitive in the future as technology [13] and economies of scale in renewable energy [10] improve over time, even when electricity from grids with a high share of renewables will not necessarily offer the cheapest electricity feedstock for grid-connected configurations [21]. This implies that if the cost of renewable energy source in a particular area will go down, hydrogen prices at point-of-sale can also be as competitive.

The second most influential factor is capital cost (CAPEX), for both electrolyser and fuel cell equipment. Hydrogen systems are still expensive owing to the fact that the technology readiness is still on its early stages. System optimization is necessary to avoid incorrect sizing of system components in the green hydrogen system [13], [17], [22]. However, optimization cannot further reduce unit capital costs in electrolysers that depend on rare materials, such as PEM electrolysers [13]. This implies that materials used in the hydrogen system should be sustainable. Apart from optimization, economies of scale [4] and technology learning rates will also likely have an effect on capital costs and their expected reductions in the future.

Sources

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