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Solar/Wind Energy Direct H2 Refueling Stations

Who's going to open the door for this brand new market?

Michael Song

Introduction

Despite the negative attacks on the hydrogen economy and hydrogen fuel cell vehicles (FCVs), FCV producers and their related industries have established mature technologies to provide acceptable driving ranges and energy efficient hydrogen-generation technologies. A lack of hydrogen refueling infrastructure has hindered the path in proving the role of FCVs in zero-emission vehicles (ZEVs). It is urgent for FCV related industries to provide a sufficient number of hydrogen refueling networks around the world. The industries directly related to this issue may include FCVs producers, PEM fuel cell producers, alkaline or PEM bipolar electrolyzer fabricators, H_2 dispenser providers and on.

In my previous articles, I've provided analytical data to prove that:

(a) Grid-tied battery electric vehicle (BEV) charging should be banned due to **CO_2 emission amplification**. Rather, solar/wind energy direct BEV charging should be adopted.

(b) Considering the well-to-wheel (WTW) energy efficiency, solar/wind direct BEV charging and hydrogen generation at the refueling station should be promoted. With a direct application of solar/wind energy, **the well-to-wheel (WTW) efficiency of FCVs are higher than Tesla BEVs**.

(c) Capital costs of solar/wind energy direct FCV refueling stations is **30 to 35% cheaper than Tesla Supercharger stations** for a comparable filling/charging capacity.

The decarbonization in transportation sector is an urgent issue with the question of the hour being who is going to open the door to this brand new market. Tesla's efforts to provide Supercharger networks all around the world is a prime example for FCV makers to follow. Recently, there's been news on **Toyota Motors' plan** and **Nikola motors' plan** to build H_2 generation and refueling facilities. While details have been sparse, this is an example that could open the door to H_2 refueling infrastructure. Once there's proof that H_2 refueling station businesses are profitable, funding from the private sector would flood into the H_2 refueling infrastructure expansion projects.

LCOE Multiplication factor & Profitability of Solar/Wind Direct FCV refueling stations

Electric energy is a raw material both for BEVs and FCVs. In a grid-tied EV charger, "f = 100/WTW efficiency (%)" was defined as **CO_2 emission multiplication factor**. In solar/wind direct EV charging and hydrogen refueling stations, "f_e = 100/WTW efficiency (%)" is defined as levelized cost of electricity (LCOE) multiplication factor. The profitability of FCV refueling stations will depend on the cost of solar/wind energy and LCOE multiplication factor. Namely, LCOE ($/kWh) x

f_e. It should be noted that water and water processing costs should be added to raw material costs in case of FCVs.

With the direct application of solar/wind energy for BEV charging and hydrogen generation, losses due to AC transmission, AC transformers, and AC/DC or DC/AC conversion are removed. Also, there is no need for grid connectivity and **transmission acess charge (TAC)** to reduce the cost of electricity. Distributed generation of hydrogen gas at the rural or urban refueling station removes the need for compressed gas transportation and distribution loss to increase profits to station operators. With an on-going decrease in the LCOE for solar/wind energy, these factors add up to increase the profitability of solar/wind energy direct FCV refueling and BEV charging stations.

Solar/wind energy direct FCV refueling was shown to provide **4% higher WTW energy efficiency** than solar/wind direct Tesla BEV charging. This means that 4% more energy and 4% less cost are available with FCV motors compared to BEV motors. Of course, more energy means a longer driving range with the same electric energy input. For the same energy input from solar/wind energy, the longer driving distance means a lower energy cost for FCVs. If BEVs use DC motors, FCVs and BEVs would have a comparable efficiency. If Tesla chooses to use DC motors rather than induction motors just like other EV makers including GM, Tesla EVs would have a comparable efficiency and energy cost with FCVs.

Planning

For a target country or state, FCV manufacturers should set up strategic locations of H_2 refueling stations considering population density, volume of traffic, driving ranges of FCVs, and other factors both for rural and urban version of stations. The availability of water resources should be considered because water is the primary raw material used in hydrogen generation. Most FCVs have driving range over 500 km. The distance between San Diego and San Francisco is around 800 km (I-5). 3 to 4 refueling stations on both sides of I-5 may cover south-to-north FCV traffic in California. Increasing the number of refueling stations, a band of coverage for west-to-east traffic would be established. According to Nikola motors, the Nikola One truck's driving range is 1920 km. The driving distance from New York City to San Francisco is 4662 km (I-8). 3 to 4 H_2 refueling stations on both side of I-8 will cover east-to-west freight traffic. As on the I-5, a band of coverage for north-to-south coverage band would be established with increasing the number of refueling stations.

Standardization of Rural and Urban H_2 Refueling Station in Size

It will be important to standardize the scale of refueling stations based on H_2 generation capacity. NERL classified 5 different sizes of H_2 refueling stations based on **H_2 generation capacity** (H_2 kg/day). Rather than large-capacity central H_2 generation, small capacity distributed stations would perform better. Specific station sizes would be determined on a per-site basis both in rural and urban areas. Rural refueling stations are free from connectivity requirement to the grid. The availability of water and good insolation would be the prime requirements. Based on traffic volume and other factors, proper sizes of refueling station may be determined.

It would be desirable for FCV makers to establish a standardized dispensing and hose connection system in advance. Rated H_2 tank pressure may differ depending on the vehicle. In this context, FCV makers may establish standardized tank pressures. In BEV charging, a variety of charge plugs, terminologies, and compatibility created a **complexity in charging EVs**. A standardized universal refueling system would be advantageous to all FCV makers.

It will be desirable for FCV makers to develop front-end-engineering-design (FEED) for standard rural and urban stations and establish EPC companies specialized in developing H_2 refueling stations.

Who Will be Interested in H2 Refueling Station Business?

Funds from the private sector would flood into the construction of rural and urban H_2 refueling infrastructures once FCV makers prove that H_2 refueling stations are profitable. Investment pattern may be similar to predicted **investment pattern in EV charging network**. Some of interested parties are considered below:

1) **Electric Utility Companies** will be very much interested in an H_2 refueling infrastructure. A rural version would include a solar power plant and customer at one site with no additional costs related to electric power transmission infrastructure. In an urban setting, they can create a utility of absorbed excess renewables and a spinning reserve with dissipative nature. Through rural and urban H_2 refueling stations, utilities can create new sources of revenue. It should be noted that urban stations could acted as real-time adjustable loads toward the grid operator. For example, the **French utility giant Engie** and the **Swedish power company Vattenfall** have been super-active in renewables. I am sure that Engie would be interested in an H_2 refueling infrastructure.
2) **Solar/wind energy developers** may be interested in this emerging industry. Siting of solar and wind farm requires favorable grid connectivity. Without the requirement of grid connectivity, rural H_2 refueling stations would be an exciting new market for them. It would be easy for them to develop their own version of FEED and EPCs with their specialty in solar or wind energy.
3) **Fossil Fuel industries** around the world are ramping up their investments in renewables. **Royal Dutch Shell** continues a renewable investment spree including high power EV charging stations. Shell would be very much interested in rural and urban hydrogen refueling infrastructure with its extensive gasoline and diesel pumping infrastructure. The infrastructure includes real estate and underground tanks that could be useful to build H_2 refueling stations. Shell is not the only one seeking renewable investment, **Equinor (formerly StatOil)**, **Exxon Mobil**, **BP**, and other oil giants are extending their investment

to renewables to be prepared for their future in energy transition.

Conclusion

With a higher WTW efficiency of FCVs than BEVs, and more than 30% lower capital cost of H_2 refueling stations than BEVs charging stations, it is evident that FCVs will lead carbon free transportation in the near future. I firmly believe that it is time for FCV makers to show their initiative to prove profitability of solar/wind direct H_2 refueling infrastructure.