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News & Views

Hydrogen has found its way to become the fuel of the future

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The world is searching to find alternatives to fossil fuels. The main criteria for an ideal future fuel are cleanliness, inexhaustibility, and independence from foreign control. Hydrogen fuel has indicated all these characteristics and is promoted worldwide as an environmentally friendly replacement for fossil fuels in the industrial and transportation sectors.

During an interview at the Financial Times Future of the Car summit on Tuesday (10-May-2022), Tesla CEO Elon Musk called hydrogen "the most dumb thing for energy storage." He pointed out that hydrogen is a bad choice for energy storage because "gigantic tanks" are required to hold hydrogen. He also emphasized hydrogen disadvantages by bringing up "poor efficiency of electrolysis", greenhouse gas generation during hydrocarbon cracking for hydrogen production, and the enormous energy required for hydrogen liquefaction to despise hydrogen research. Previously, in June 2020, he showed his hatred for hydrogen on Twitter: "fuel cells = fool sells," adding in July of that year: "Hydrogen fool sells make no sense"[1]. However, despite Elon Musk's negative attitudes toward hydrogen, valuable breakthroughs in hydrogen production and utilization have been implemented in recent years. The same as electricity, hydrogen is not a source of energy, and it is considered a versatile energy carrier. In other words, hydrogen is not available in nature in its pure form. It should be produced through a chemical, thermal or electrical process or a combination of these processes. Hydrogen can be produced from almost all energy resources; therefore, hydrogen production is a rainbow including but not limited to black (hydrogen from black coal), grey (hydrogen from hydrocarbons without carbon capture process), blue (hydrogen from hydrocarbon with carbon capture process), green (hydrogen from renewables), pink (hydrogen from nuclear power), and turquoise (hydrogen from pyrolysis process). Hydrogen could be employed as a battery for renewable electricity. Although the direct storage of renewable electricity using chemical batteries has been widely applied to reserve electrical power, their limited capacity, lifetime, and high cost have confined their applications. Power-to-gas is an indirect method of storing renewable electricity, attracting attention by using highly efficient electrolyzers to produce hydrogen fuel. The stored hydrogen can be converted to electrical power using a gas turbine or fuel cell system or used in internal combustion engines. The same as the other fuels, hydrogen has its flaws. Hydrogen research is still in its early stage and several research in hydrogen production, storage, delivery, and utilization are undergoing to improve these issues and make hydrogen ready to become the fuel of the future. In terms of hydrogen production, recent research indicated that the solid oxide steam electrolysis (SOSE) process is a promising hydrogen production technology with high scalability, high application flexibility, pure hydrogen production, and enhanced reaction kinetics at higher temperatures with low capital costs. Besides, steam reforming of hydrocarbons, thermal decomposition of hydrocarbons, or pyrolysis, is another technique that has been recently developed for commercial hydrogen production. Although carbon is one of the products of this process, it is black carbon (pure solid carbon) that can be used in various sorts of applications, such as carbon-fiber production, and the process of capturing and utilizing solid carbon would be simpler than capturing and sequestering carbon dioxide. Due to the small size of a hydrogen molecule and its low density, the possibility of its leakage is very high. Therefore, hydrogen storage is one of the crucial factors in the hydrogen economy. The same as hydrogen production and utilization research areas, hydrogen storage and delivery are the other fields of research that so many researchers in material and mechanical engineering are working on various aspects of that. In terms of hydrogen utilization, the deployment of fuel cell systems opened a new window to hydrogen fuel success in the transportation sector. Currently, hydrogen-powered engines based on polymer exchange membrane fuel cells have been used worldwide. The main pros of the fuel cell systems are high efficiency in well-to-wheel assessment, energy-efficient drive train, and silent mode of operation. As a fuel, hydrogen yields significantly higher energy per unit weight than other fuels such as kerosene, diesel, petrol, and methanol. Therefore, several new markets have emerged for automobiles, buses, other vehicles, and industrial trucks. There is a consensus among energy researchers and governments that hydrogen will play a crucial role in the future. Hence, a huge amount of money has been flooded into hydrogen research and development. Recently, the US Department of Energy (DoE) dedicated $9.5bn to green hydrogen to commercialize innovative hydrogen production technologies. Renewable hydrogen is already the focus of the DoE's energy initiatives aiming to reduce the cost of green hydrogen production by 80% over the next decade. The European Union's energy strategy is heavily concentrated on emissions-free renewable hydrogen, with a target to install 40 gigawatts of green hydrogen electrolyzer capacity by 2030. The Russia-Ukraine war and Russian sanctions have boosted the idea of considering hydrogen as the fuel of the future. For instance, to minimize its

reliance on Russian natural gas, Germany decided to collaborate with Australia to decrease the cost of producing renewable hydrogen and speed up the innovation process in both countries [2]. In Asia, China's five-year economic plan recognizes hydrogen as one of the six industries of the future. Japan's government has set mobility targets of 800,000 hydrogen fuel cell vehicles and 900 hydrogen refueling stations by 2030. South Korea aims to provide 10% of the energy demands of its cities, counties, and towns with hydrogen by 2030, with its share boosting up to 30% by 2040 before it becomes the country's largest single energy carrier by mid-century. India's energy policy is based on the fact that green hydrogen could help India make a "quantum leap" to energy independence by 2047 [3]. Other countries such as Australia, Morocco, Oman, Saudi Arabia, and the United Arab Emirates have solid plans to develop clean hydrogen to help diversify their economies. The governments of industrial countries have truly understood that the future power will be in the hands of the countries that establish a modern hydrogen production and utilization system. Hence, there is serious competition between the developed countries to achieve a modern hydrogen economy and dedicate more funds to hydrogen research and development. Therefore, one can say that hydrogen has found its way to become the fuel of the future.

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