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EIC Column

Editor in Chief's Note on the Green Hydrogen Fuel from Solar / Wind Power

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ABSTRACT

Renewable and sustainable energy has an evolving story as the ongoing trade war in the word is influencing crude oil prices. Moreover, the global warming is an inevitable consequence of the worldwide increasing rate of fossil fuel utilization which has persuaded the governments to invest on the clean and sustainable energy resources. In recent years, the cost of green energy has tumbled, making the price of renewables competitive to the fossil fuels. Although, the hydrogen fuel is still extremely expensive compared to the crude oil price, investigations about clean hydrogen fuel production and utilization has been developed significantly which demonstrate the importance of the hydrogen fuel in the future. This article aims to scrutinize the importance of green hydrogen fuel production from solar/wind energy.

1. Introduction

The global energy demand by the year 2050 is estimated to be in the range of 600–1000 EJ. Currently, about 80% of the worldwide energy demand is supplied by fossil fuel resources which the present rate of fuel consumption will conduct the reservoirs to be depleted within the next 5o years [1]. Moreover, concerns about greenhouse gases (GHG) emissions from fossil fuel powered vehicles have highlighted the need of renewable energy with minimal negative environmental effects. The share of renewable energy by the year 2025 is predicted 36% of the total worldwide energy demand with hydrogen shares of 11%. The strong support of hydrogen production technologies will drop the use of coal and crude oil to 36.7% and 40.5% respectively by 2030 [2]. Transportation sectors release about one-fifth of total global emitted Carbone dioxide (CO_2) due to fossil fuel consumption [3]. Consequently, transition to the alternative fuel powered engines in the transportation system is vital in the world's future energy scenario. In this regard, hydrogen powered engines are considered promising technologies for vehicles energy supply [4]. There are precious benefits to using hydrogen instead of fossil fuels in transportation engines. Hydrogen is an environmentally friendly fuel since it emits only H_2O when used in a fuel cell engine [5]. Using hydrogen-fueled internal combustion engine (H2ICE) systems or fuel cell (FC) propelled vehicles is promising for the transportation sectors.

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2. Solar/Wind to Hydrogen

As the lightest and simplest element on the earth, hydrogen consists of only one electron and one proton which does not exist in nature and should be produced. Hydrogen is considered as the fuel of future which will reduce the dependence on crude oil and minimize the toxic emissions from transportation system. The energy of hydrogen is approximately 122 kJ/g, which is 2.75 times more than hydrocarbon fuels. Due to the environmental issues and energy policies, using hydrogen in transportation system has extensively been developed in both electric fuel cell (FC) vehicles and combustion engines. In the current modern fossil fueled power transportation systems, air pollutants such as carbon monoxide (CO), volatile organic compounds (VOCs) and nitrogen oxides (NO_x) are unavoidable which have significant negative impacts on the people health [6]. Considering life cycle assessment of hydrogen fuel, it is obvious that various hydrogen production technologies are associated with pollutant formation [7]. However, evaluating various indicators such as sustainability, environmental impacts and economic issues, hydrogen could be considered as a clean fuel [8]. Furthermore, the efficiency of hydrogen FC engines is three times more than fossil fuel powered vehicles which highlights the importance of research on hydrogen production and utilization [9]. There are several crucial impedes in widespread use of hydrogen fuel in transportation systems which require tenacious investigations. Hydrogen is not available in nature and its production process is currently expensive. The hydrogen energy density is 10 MJ/m3 which is miniscule in comparison to propane and methane by 86.7 and 32.6 MJ/m3 respectively, and consequently a larger fuel tank is required for hydrogen powered vehicles [10]. Moreover, hydrogen can be leaked from its vessel due to the small size of its molecules.

Currently, approximately 95% of the worldwide hydrogen is produced from fossil fuels such as oil, coal and natural gas following by 4% by electrolysis process and 1% from biomass utilization [11]. As a long-term goal, production of green hydrogen from renewables such as solar and wind energy (intermittent renewables), biomass, hydro, geothermal (non-intermittent renewables) and nuclear energy has been noticed by hydrogen researchers [12]. Although, mining and collection of renewables is exorbitant due to their decentralized characteristic, the recent exponential growth in green energy generation technologies have made the renewables commercially competitive to the non-renewable resources [13]. Renewables can produce hydrogen locally; however, they are not adequate sources to supply sufficient hydrogen to meet the global demand [14]. This is because there are currently inadequate storage solutions for hydrogen that are inexpensive.

Solar is most likely the only source of renewable energy that could generate enough hydrogen to develop the hydrogen economy [15]. Solar is the largest source of energy, however just 0.06% of the worldwide electrical power demand is generated by solar [16]. Nevertheless, solar is projected to supply a widespread energy demand of future, hence several affordable solar energy storage technologies have been proposed to tackle the intermittency characteristic of solar energy to cover the mismatch of the supply and demand of solar power [17]. To tackle global warming and mitigate the world's dependence to fossil fuel, splitting water by solar electricity and solar-to-hydrogen technology was emerged [18]. Several solar-to-hydrogen production technologies such as thermochemical water splitting, photovoltaic-based hydrogen production, solar thermolysis, solar thermal hydrogen via electrolysis, and fossil fuels decarbonization have been proposed with special focus on the near-term sustainable methods. Concentrated photovoltaic (CPV) systems are found as one of the most affordable near-term technologies for hydrogen production with efficiency around 25% [19]. In this context, the electrolysis systems including polymer electrolyte membrane (PEM) electrolysis, alkaline water electrolysis (AWE) and solid oxide electrolysis for integrating to the solar systems for H_2 production are deployed. Among these methods, AWE has been found the most mature technique to couple with the CPV system for hydrogen production. Although, noticeable progresses have been made in solar-to-hydrogen systems, these systems need further maturation to emulate the produced grid-based hydrogen.

Compared to the other renewables, electrical power generation by wind energy has shown minimum negative impacts on the environment [20]. Approximately, 2% of global electricity demand is supplied by wind energy where USA, China, Germany, Spain, and India produce around 73% of overal worldwide wind electricity [21]. Wind-to-hydrogen using water electrolysis is another clean hydrogen production method considered by the energy policy makers. The generated electricity could be stored as hydrogen and transformed to electrical power later in times of low wind potential or when grid congestion has stopped [22]. Integrating the wind power plants to hydrogen production systems has introduced hydrogen a buffer mechanism for wind power plants to abate the intermittent characteristic of wind power [23]. Investigations about life cycle assessment of wind-to-hydrogen and hydrogen production from natural (NG) and gasoline indicate that although the cost of renewable hydrogen is

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higher than non-renewable-based hydrogen production methods, using hydrogen produced by wind energy in hydrogen fuel cell vehicles instead of gasoline can lead to an economically effective mitigation of GHG emissions because the efficiency of fuel cell engines is two times more than that of an internal combustion vehicle [24]. The high cost of wind-to-hydrogen technology is due to the high initial cost of the installed equipment and inefficiencies in the energy conversion processes [25]. By integrating wind electricity to PEM, the price of hydrogen has been reported $5.50/ kg. This price is projected to drop using advanced wind turbines and the cost target is $2/kg [26].

3. Conclusion

Solar-to-hydrogen and wind-to-hydrogen offer precious benefits as a green energy carrier which made from sustainable resources of energy. Intermittency of solar / wind power is an unavoidable characteristic of these resources which could be managed by hydrogen production instead of using conventional chemical batteries. The cost of solar / wind hydrogen is dependent on the cost of solar / wind electricity. The commercialization of solar / wind-to-hydrogen is conceivable using inexpensive and robust technologies. A strong link between economy / mechanical / chemical / material sciences is needed to deploy solar / wind-to-hydrogen technologies. To expedite the commercialization of solar / wind-to-hydrogen technologies, more studies required on the wind turbines in wind electricity and the semiconductor materials in solar electricity. AWE is one of the most promising electrolysis techniques for efficient and the near-term large-scale solar / wind hydrogen production processes.

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