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A short-term analysis of hydrogen demand and refueling station cost in Shenzhen China

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Abstract

The deployment of fuel cell vehicles in Shenzhen, China is far behind electric vehicles. In order to promote the application of fuel cell vehicles, significant efforts are required to construct hydrogen stations in the near future. The present study focused on the estimation of hydrogen demand and refueling station cost in Shenzhen between 2016 and 2025. Three scenarios of fuel cell vehicle penetration rate in the new car market were employed to predict the fuel cell vehicle number and daily hydrogen demand. Capital investment and operation and maintenance cost of on-site steam methane reforming hydrogen fueling stations were studied. The capital cost of a 1000 kg H_2/day hydrogen refueling station was calculated as $ 7.84 million. Hydrogen fuel price of different size fueling stations at various years of return on investment were also compared. The lowest H_2 price can be reached is $6.78/kg.

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1. Introduction

Fuel cell vehicles (FCVs) are considered as promising alternative vehicles in our future society along with electrical vehicles (EVs). Due to the clean and energy efficient nature, FCVs are expected to significantly reduce fossil fuel consumption and greenhouse gas (GHG) emissions compared to traditional internal combustion engine vehicles (ICEVs) [1]. Toyota has released the world's first commercial FCV - Toyota Mirai - into the market in December 2014 in Japan and August 2015 in USA [2]. However, one major obstacle which limits the commercialization of FCVs is the lack of existing H_2 refueling infrastructures [3]. Without sufficient H_2 refueling stations, customers are less likely to purchase FCVs. In the other hand, it is not economically viable to construct H_2 refueling stations without an adequate number

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of FCVs running on the road [4]. It is the chicken and egg problem for FCV penetration into the market and H_2 refueling station construction [5,6].

Although hydrogen element on earth is always in water, hydrocarbons, hydrides or other forms, gaseous H_2 can be obtained from multiple sources through various technologies. Generally, H_2 can be produced either from fossil fuels through methods such as steam methane reforming (SMR) and coal gasification, or from water through ways including electrolysis, photolysis and thermolysis [4,7]. Water splitting methods consumed power from wind, solar, or nuclear are still in an early development phase [8-10]. To date the most mature H_2 production technologies are based on fossil fuels. 90% of currently used H_2 (45 billion kg) is from fossil fuel sources [11]. Among these methods, coal gasification produces the highest GHG emissions and SMR emits the least [4,12]. Moreover, SMR with a shorter payback time and a higher return on investment (ROI) is more cost effective compared to water splitting methods [4,13]. Besides, natural gas is a more easily accessed raw material for H_2 production in the short-term. In the last but not the least, failure risks in SMR stations are relatively lower compared to that in electrolysis stations [14].

Centralized H_2 production followed by pipe or truck delivery to stations and decentralized on-site H_2 production are two basic types of H_2 refueling stations [8]. It is well accepted that on-site H_2 production is the most technologically feasible option [13]. Transportation of natural gas is also safer than H_2 because natural gas has a much higher boiling point and a lower compression pressure [15,16]. By 2009, more than 70 refueling stations have been built in USA, Germany and Japan [13]. By 2013, 224 H_2 refueling stations has been constructed in over 28 countries and areas, 43% of which locates in north and south America, 34% is in Europe, and 23% is in Asia. 42 out of the 224 stations are based on the SMR technology [4]. The largest existing on-site SMR H_2 refueling station locates in Oakland, CA. It started to operate in 2006 with the capacity to generate and store 150 kg H_2/day [17].

Government and policy support significantly influence the construction of H_2 refueling stations. For instance, the California Fuel Cell Partnership Members planned the H_2 station network in CA, USA [18]. The HyWays Project set the aim of H_2 station construction in Europe [19]. The Fuel Cell Commercialization Conference proposed the plan to build H_2 stations in Japan [20]. H_2 refueling station construction is still in a very early stage in China due to the lack of strong government and policy support. By 2015, totally 6 stations (3 in Beijing, 2 in Shanghai, 1 in Guangzhou, 1 in Hong Kong) are already in operation in China [21], yet none hydrogen station has been built in Shenzhen .

As the fourth economically most developed city in China mainland, Shenzhen was selected by the central government in 2009 as one of the 13 national pilot cities for new energy vehicles, and it has grown to a world EV leader by now [22,23]. However, the deployment of FCVs in Shenzhen is far behind in the new energy vehicle market, and the construction of H_2 stations in Shenzhen needs to be promoted. In this context, the present study employed three scenarios to model the possible FCV growth trend and calculated the H_2 fuel demand in Shenzhen. Capital investment and operation and maintenance (O&M) cost of an on-site SMR H_2 refueling station in Shenzhen was also evaluated. H_2 fuel price from stations with different capacities was studied as well.

2. FCV number and H_2 demand

Three different scenarios were used to estimate the FCV market growth trend in Shenzhen in the near future. The cautious, moderate and optimistic scenarios were developed based on the published analysis for USA and Ontario, Canada [6,24]. The assumed FCV share of each scenario in the new vehicle sales market in Shenzhen between 2016-2055 is (a) cautious scenario: 0.1% in 2016, 4% in 2025 and 20% in 2055; (b) moderate scenario: 0.6% in 2016, 5% in 2025 and 40% in 2055; and (c) optimistic scenario: 0.8% in 2016, 15% in 2025 and 57% in 2055. The Logistic model shown in Eq. (1) was applied to