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GIS-based method for future prospect of hydrogen demand in the Algerian road transport sector

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ABSTRACT

In recent years, Algeria has intensified its efforts to diversify its resources and ensure environmental sustainability by the implementation of energetic and economic policies and strategies. The integration of hydrogen into the road transportation sector as fuel can help country to meet its policy goals. Using the combination of spatial data in a Geographic Information System (GIS) with a techno-economic models, this paper presents an analysis of hydrogen demand from hydrogen vehicle in Algeria by 2045. The costs associated with hydrogen production via water electrolysis-based renewable sources, CO_2 emissions, and the environmental benefits under two scenarios are also presented. The results of this study show that the annual amount of hydrogen demand would be 945.5 thousand tons H_2 through 2045. Where the capital, Algiers represent 26% of national demands. The average levelized cost of hydrogen for the solar-based hydrogen, is in the range of 5 $/kg to 0.9 $/kg. Whereas, the average levelized cost of hydrogen for the geothermal-based hydrogen decline from 4.66 $/kg to 3.54 $/kg by 2045. A remarkable CO_2 reduction is achievable; the environmental savings is estimated at 158.8 million tons of CO_2.

Introduction

Global energy demand has increased even more rapidly, which is mainly driven by the worldwide economic growth and population development. According to the World Energy Outlook Statistics report [1], the world's primary energy supply has increased by 118% in 39 years, from about 6.1 billion toe (ton of oil equivalent) in 1973 to about 13.3 billion toe in 2012. Furthermore, the BP Energy Outlook [2], predicts that the primary energy consumption increases by 37% between 2013 and 2035, with growth averaging 1.4% p.a (per annum). This increased demand is being met largely by fossil resources which cover roughly 80%. More importantly, the fossil resources are finite, the reserve depletion times for oil, gas and coal is predicated to be about 35, 37 and 107 years respectively [3]. However, their growing use leads to increase dramatically undesirable production of greenhouse gas (GHG) emissions, as well as CO_2 resulting from the oxidation of carbon in fuels

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during combustion dominates the total GHG emissions. The global CO_2 emissions were 31.73 $GtCO_2$ emitted globally in 2012 [4]. By sector, electric power sector remains the dominant source of growth for primary energy consumption with transportation and industrial sector contributing relatively significant amounts. Residential & commercial sector made up less than 12% of the world's energy consumption [5]. Currently, the transport sector accounts for 27% of the world's primary energy use and 22% of energy-related CO_2 emissions (7.18 $GtCO_2$). Road transport taking the largest share and consumes the most of energy (about three-quarters). Additionally, it amounts to 74% of the total CO_2 emissions from transport sector, appearing for 5.37 $GtCO_2$ [4]. Moreover, the GHG emissions obviously can't capture from hundreds millions of vehicle's tailpipes. Therefore, the big challenge is: how will transport sector reduce the CO_2-intensity of fuels-based transport on a well to wheel basis by including the share of non-emitting sources, such as biofuels, hydrogen or electricity generated from renewable energies, as a solution to replace fossil-fuel resources in the future?

There are many studies in the literature that have been widely discussed the vast promise of hydrogen as future solution to address environmental and energy security problems posed by current transportation fuels which that must be defined in the coming years [6,7]. In Ref. [8], the authors highlighted the opportunities and challenges of introducing hydrogen as alternative fuel in the transport sector from economic, technical and environmental point of view. Fayaz et al. [9] reviewed the previews development and studies that have been done by another research on hydrogen as a possible major fuel of the future. Hydrogen has very special properties as a transportation fuel, including a rapid burning speed, a high effective octane number, and no toxicity or ozone-forming potential. It has many wider limits of flammability in air than methane and gasoline, and its combustion product is clean, which consists of only water vapor [6]. Hydrogen can be produced from a number of primary or secondary energy sources, depending on regional availability, moreover, by various methods and processes. Primary energy sources useful for hydrogen production include renewable sources, such as solar energy, and as well fossil fuels, such as natural gas (NG) and coal. Electricity can also be used for hydrogen generation employing electrolyzers, which are the most mature industrial technology for enabling the splitting of water into its components, hydrogen and oxygen [10].

For the development of clean fuel, economically practical large-scale industrial hydrogen, an infrastructure, from feedstock to end-use needs to be built and construct. The hydrogen infrastructure presents many obstacles that need to be surmount for a successful transition from fossil fuels to a hydrogen-based transportation system. These challenges are mainly due to the existence of many technological options. For the hydrogen supply network, national/regional planning for hydrogen infrastructure building will be necessary to optimize supply chain scenarios. This includes a choice of production technology (by steam reforming of NG, biomass gasification, renewable energy-based water electrolysis…), and transmission (pipeline, truck and on site schemes) as well as integrated hydrogen distribution networks by truck and/or pipeline [11]. The establishment of a comprehensive hydrogen fuel infrastructure was a major priority for several nations in the worldwide (Table 1). Therefore, many technical and economic studies have been reported and applied at country, region and city level. These include China, Korea, Malaysia, Netherlands, Norway, California, Ohio, Iran, Spain, Germany, and United Kingdom [12–26]. Nevertheless, without a working infrastructure, hydrogen-powered vehicles are not likely to find any traction with consumers. Fuel-cells have become an important focus for the auto industry. Many companies have begun developing fuel cell vehicles in order to comply with emission's regulations and bring clean transportation into the mainstream. Today, there are several initiative demonstration projects of Hydrogen Refueling Stations (HRS) and fuel-cell vehicles (FCVs) around the world, including the European H_2Mobility project (UK, France, Scandinavia and Germany). Actually in Europe, there are more than 72 HRS in operation, 26 of them in Germany. In Japan, government and 13 companies announced program for FCVs mass production and 100 HRS by end 2015 connecting four metropolitan areas (Tokyo, Nagoya, Osaka and Fukuoka). South Korea's government announced program to finance and deploy 100,000 FCVs and 170 HRS by 2020. Actually in Asia, there are 46 HRS, mainly in Japan. USA launched their hydrogen infrastructure project, H_2 USA. However, it has always been California the one who leads USA to develop in the field, with their automotive legislation. Demo initiatives in California and East Coast H_2 highway; partially funded by Department of Energy. California Fuel Cell Partnership announced roadmap to roll out 68 stations by 2015 [27,28].

However, despite the expanding literature on the field of the planning of a national/regional infrastructure build up, this field is not very mature in terms of research for the case of Algeria. In 2013, transport represented 32% of GHG emissions in Algeria, 37% of final energy consumption, representing 13.4 Mtoe of the final energy consumption, and 97% of oil consumption for energy uses. Road transport expends 94% of total transport energy use in Algeria, including more than 8716 ktoe of diesel fuel, 4050 ktoe of gasoline and 366 ktoe of Liquefied Petroleum Gas Fuel (LPG/F) [4,29]. As early as the beginning of the 90s, a research program was initiated to convert vehicles using diesel fuel to NG fuel. Fueling stations were developed by Sonelgaz (Algerian Company of Electricity and Gas) for the distribution of this fuel to an experimental fleet. For more energy efficiency in the transport sector, there are plans to increase by 20% the market share of LPG/F in the automobile fleet by 2020. This will be accompanied by the provision of direct financial help to people wishing to convert their vehicles to LPG/F [30]. Transition from traditional fossil fuel towards hydrogen as a transportation fuel in the next years could fundamentally transform the Algerian's transport sector, creating opportunities for exploiting the local renewable energy sources potential for hydrogen production, to diversify alternative fuels used, to meet the interest needs particularly in the transportation sector and to contribute in the development of the isolated area in the southern region while reducing the environmental impact [31]. Furthermore, Algeria has been implemented “HySolThane” project (as part of the “MedHySol” project [32], which is applied on transportation sector). This project intended for the development of Hydrogen enriched Compressed Natural Gas (HCNG) fuel