INTERNATIONAL JOURNAL OF HYDROGEN ENERGY 39 (2014) 15215–15223

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/he

Hydrogen as a fuel in the transport sector in Algeria

R. Boudries

Division Hydrogène Energie Renouvelable, Centre de Développement des Energies Renouvelables, Algiers, Algeria

ARTICLE INFO

Article history:
Available online 30 June 2014

Keywords:
Hydrogen fuel
PV-electrolysis system
HICV
HFCV
GICV
HGICV

ABSTRACT

A number of issues related more particularly to green gases emissions and fuel availability has resulted worldwide from the transport sector expansion. Stringent regulation laws, improvement in engine efficiency and alternative fuel options have been proposed to address these issues. However, the suitability of an alternative fuel depends on its performance, cost and availability. By its versatility in use and its renewability, hydrogen, as an alternative fuel, offers the best potential for reducing greenhouse gases emission, improving engine efficiency and ensuring fuel security.

The aim of the present work is the study of hydrogen as an alternative fuel in the transport sector in Algeria.

First, a review of the Algerian transport sector is presented. Hydrogen as a fuel in vehicles is then analyzed. The needs for hydrogen to power vehicle hydrogen vehicle are estimated. Based on the techno-economic factors, a comparative of the economic viability of a hydrogen powered vehicles with a gasoline powered vehicle is carried out. The PV-electrolysis technique for hydrogen production is considered. Results show that, advancement in technology and improvement in manufacturing are going to lead to the development of a hydrogen fuel based transport sector.

Introduction

The world economy vitality relies on a strong transport sector. This requires the development of a performing transport sector. Based, since the late nineteenth century, mainly on oil fuels and internal combustion engines, the transport system is actually facing many challenges. Indeed, with the demand for fuels for the transport sector steadily increasing, concern about the depleting energy sources is increasing. Moreover, the use of hydrocarbon based fuels in engine vehicles has lead to environment degradation. This degradation is due to the emission of greenhouse gases, fine particulate matter, volatile organic compounds and nitrogen oxides. To effectively face these challenges, steps have to be taken. These steps should result not only in the use of low emission and high efficiency technologies but also the replacement of the oil based fuels. In the long run, the solution should be in the introduction of cleaner alternative fuels along with high efficiency technologies.

For Algeria, the introduction of hydrogen into the transport sector opens many opportunities. First it permits the exploitation of the huge solar energy potential. Then it alloys the country to meet the surging needs particularly in the transport sector and to contribute in the development of the isolated area of the South. It also addresses the problem of pollution that could contribute to stopping desertification.

In the present work, study is limited to an analysis of hydrogen as a fuel in the transport sector. The scope is to estimate the needs for hydrogen as a substitute to the

E-mail addresses: r_zaka@yahoo.fr, r.boudries@cder.dz.
http://dx.doi.org/10.1016/j.ijhydene.2014.06.014

conventional fuel. It is also to determine the economic viability of hydrogen as a fuel.

First, the issues of alternative fuels, more particularly vehicle technologies and hydrogen production and distribution, are addressed. The different techniques of hydrogen production, with emphasis on renewable techniques, are presented and discussed. Then, the assessment of hydrogen production cost is carried out in the case of a PV-electrolysis system. After that, the transport sector, particularly the evolution of the vehicle park and the fuel consumption, in Algeria is analyzed.

Finally hydrogen as a fuel in the transport sector is dealt with. The case of a PV-electrolysis system for hydrogen production is considered. Taking into account the local techno-economic parameters, a comparative evaluation of the economic competiveness of hydrogen as a vehicle fuel with gasoline as fuel for an internal combustion engine vehicle is carried out. Three different cases are studied. First, there is the case of hydrogen as the sole fuel to an internal combustion engine vehicle. Then the case of hydrogen–gasoline mixture as a fuel to an internal combustion engine vehicle is considered. Finally the case of pure hydrogen as fuel to a hydrogen fuel cell vehicle is examined. In each case, the cost of fuel to cover a distance of 100 km is determined and compared to the cost of gasoline for an internal combustion engine vehicle to cover the same distance.

Overview of hydrogen as an alternative fuel

Actually there are various alternative fuels competing to be tomorrow vehicle fuel. By definition, alternative fuels are non hydrocarbon based fuels. They rely for their production on different feedstocks and different energy sources [1]. Among these alternative fuels, there are hydrogen, natural gas, methanol, ethanol, LGP, biodiesel and electricity both plug-in and fuel cell [2].

There exist also different vehicle technologies. These technologies include internal combustion engine vehicles, electrical vehicles, fuel cell vehicles and hybrid vehicles.

Of all the alternative fuels under consideration, hydrogen, especially renewable hydrogen, as a fuel for the transport sector has been receiving a lot of attention. Though suffering from some drawbacks in a number of issues, such as storage capacity, combustion control and distribution infrastructure, hydrogen is still looked at as one of the leading alternative fuels. Hydrogen is an appealing and versatile fuel. Indeed, it is a carbon free fuel and it offers sustainability if produced from renewable sources. Moreover, it can be used in fuel cell vehicle or in internal combustion vehicle as sole fuel or mixed with other fuels such gasoline or natural gas. The use of hydrogen, as a vehicle fuel, has been the subject of various studies. Technological and economical benefits as well as hurdles arising from hydrogen implementation as an alternative fuel have been identified, analyzed and discussed [3,4].

A set of issues must be addressed before an effective penetration of hydrogen as alternative fuel in the transport sector is possible. Besides the safety concerns, these issues include the hydrogen-dedicated infrastructure implementation, the consumers' acceptance and the competiveness of hydrogen as a fuel with other alternative fuels. Cost effective hydrogen infrastructure lay out is important from both the technological and the economic point of view for hydrogen fuel penetration in the transport sector. The hydrogen infrastructure includes systems for the different activities, i.e., production, transportation, storage and dispensing. Due to the multiple options that are available, the infrastructure implementation remains though a complex issue. Indeed, different technology options are conceivable for each one of these activities. Various infrastructures can be devised depending on the feedstock nature, the process and the energy used for the production, the transportation, the storage and the refueling methods.

Addressing hydrogen safety issues is critical for hydrogen penetration as a fuel in the transport sector. Hydrogen, as a fuel, should be handled with care. However, it is hard to say if it is more or less dangerous than conventional fuel, more particularly gasoline and diesel. Taking into account its lower buoyancy, its high auto-ignition temperature, its high specific heat and its diffusivity, it has been argued [5,6] that hydrogen is a much safer fuel. Experiences carried out on hydrogen leak in moving vehicles [7] have shown that, because of dispersion, the risk of explosion is minimal. It has also been demonstrated [8] that a hydrogen fire causes less damage to a vehicle than a conventional fuel. Some have even argued that in the case of a crash, hydrogen fuel is no more dangerous than conventional fuels [9].

On the other hand, because of its wide range of flammability in air and its low ignition energy, hydrogen as fuel sets new challenges for safety in storage and in use. Effort is undertaken to evaluate safety aspects related to hydrogen as a fuel in the transport sector [10–12]. Extensive work on modeling and simulating as well as on testing safety issues is underway [13]. Indeed, sufficient knowledge for securing hydrogen systems safety is necessary on critical safety issues [11]. These issues include material embrittlement, hydrogen leakage, and broad range flammability and low energy ignition. High pressure hydrogen storage, collision and flame propagation are also important issues for risk assessment and system design. Techniques are set up on one hand to identify and eliminate potential component failures and system errors and to measure the impact of these failures on the other hand. Data are also necessary for regulations and standards formulation. Indications are that the control of these safety issues is well underway, helping in the successful transport sector market penetration of the hydrogen fuel vehicles.

There are various techniques for producing hydrogen for fueling vehicles [14]. Each technique is characterized by its location and its method of production. For the location, three options are possible. First, there is the centralized option where hydrogen is produced at large facilities; then dispatched to refueling stations. Heavy infrastructures for distribution are though required in this option. There is then the decentralized option where hydrogen is produced at smaller size facilities, at refueling stations. Finally there is the option where hydrogen is produced on board, i.e., on the vehicle. Concerning hydrogen production, there are various possibilities concerning the feedstocks, the energy used for the production and the processes [2]. It is though only with renewable feedstock and renewable energy that hydrogen can be clean and sustainable.