Renewable and Sustainable Energy Reviews 30 (2014) 743–757

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

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

Renewable hydrogen economy in Asia – Opportunities and challenges: An overview

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ARTICLE INFO

Article history:
Received 1 April 2013
Received in revised form
21 September 2013
Accepted 12 November 2013
Available online 1 December 2013

Keywords:
Renewable hydrogen economy
Asian countries
Government incentives
Hydrogen infrastructure

ABSTRACT

Renewable alternative energy sources are getting more attention due to the depleting nature of non-renewable fossil fuels. Increasing global warming, caused by the combustion of fossil fuels, triggered the intense research in finding out better energy options with low emission. Among the potential energy options, hydrogen is a clean fuel candidate as it simply produces water as byproducts when burning. Hydrogen can be generated from different renewable sources and Asia is one of the continents which is rich in renewable energy resources. The resources, safety parameters, public acceptability, and proper government incentives are the major factors affecting the implementation of hydrogen as an economical energy source in Asian countries. The present review deals with the necessity of employing hydrogen as an alternative fuel, its production paths, storage issues, transportation and the available sources. Special emphasis has been given to the discussion of renewable hydrogen economy in some Asian countries like, Japan, Korea, China, India and Malaysia. The challenges in the execution of hydrogen as an economical fuel in Asia are also highlighted.

Contents

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http://dx.doi.org/10.1016/j.rser.2013.11.015

1. Introduction

The primary difficulty faced by the modern world is the scarceness of fossil fuels because of the concomitant use of fuels for daily life [1]. Therefore, it is essential to develop an alternative fuel that can replace non-renewable fossil fuels [2,3]. Substituting hydrogen for fossil fuels in ultimate energy uses could bring this key environmental welfare [4] into accordance with the technical, green and cost challenges, and it is easy to overcome the difficulties in, for instance, production, storage and transport of hydrogen [5–7]. Hydrogen is considered to be the clean fuel of future because it acts as an energy carrier and because only hydrogen provides a method for the storage and transport of energy. The energy storage capacity of hydrogen is excellent because calculations show that one kilogram of hydrogen contains approximately 33 kWh of energy [8]. Hydrogen can be considered to be a secondary energy source, i.e., an energy carrier, because it can be converted to energy in the form of heat or electricity through either combustion or electrochemical reactions. (Secondary energy sources are termed energy carriers.)

Because of the weakness of our gravitational field, pure hydrogen gas is not currently available for use; therefore, hydrogen fuel must be produced from a variety of sources. Because water and natural gas are abundant sources of hydrogen in the universe, the scope is considerable. However, the simultaneous generation of unwanted oxygen with hydrogen limits the scope of large scale hydrogen production through the electrolysis of water [9]. The least expensive method for the production of hydrogen is spraying steam on white-hot coals, but the generation of huge amounts of poisonous carbon monoxide lowers the demand for this method [10]. Therefore, an appropriate substituent for the generation of high hydrogen content should be developed. In 1870, Jules Verne remarked that hydrogen would be a virtuous substitute for coal. Coal gas is another source of hydrogen; the combustion of coal gas produces water gas [11], a mixture of CO and hydrogen, and water gas is highly recommended for the so-called Fischer–Tropsch process, which converts CO and hydrogen to synthetic gasoline and alcohols [12]. In 1920, a huge underground reserve of methane (natural gas) was discovered, and it provided an inexpensive substitute for coal gas [13]. In the modern world, methane can be considered to be the cheapest source of hydrogen. In the production of hydrogen from natural gas, smaller amounts of carbon oxides are produced relative to coal gas. A wide variety of studies are now on-going in the field of the production of hydrogen from natural gas and in lowering the percentages of CO emissions. Many countries in Asia use natural gas as a renewable hydrogen source in industrial scale production of hydrogen by steam reforming or by partial oxidation methods with natural gas and some other hydrocarbons [14].

The main drawback associated with other hydrocarbons is the emission of airborne pollutants and greenhouse gases [15]. Usually, hydrogen is generated by the steam reforming process (SR) of hydrocarbons such as methane, naphtha oil, and alcohols. However, for industrial scale production of hydrogen, more than 85% can be produced from steam reforming of natural gas in conventional fixed bed reactors, and for lab scale applications, partial oxidation reactions and autothermal reactions are applied. Although the mentioned reactions are conducted in the same reactors, the efficiency for the production of hydrogen is different/lower than the efficiency of the steam reforming process [16]. However, by conventional steam reforming reactions, impure hydrogen gas with a high yield was obtained. Among the various technologies connected to the separation and purification of H_2, membrane reactors play an extraordinary role compared to conventional systems and can avoid the thermodynamic constrains associated with the out-dated reactors [17]. The application of membrane reactors for the production and purification of hydrogen was reported by Prof. Gryaznov in the 1960s [18]. Membrane reactors attracted increased attention for the efficient production of hydrogen in subsequent years.

Moving the global energy system onto a viable path is gradually becoming a key concern and strategy objective of the modern world [19,20]. The concept of a shift to hydrogen fuel has been proposed by scientists for more than 50 years [21]. However, there is a concern that hydrogen is a dangerous explosive fuel, but this objection is not true in many respects; hydrogen can explode under some careless conditions, but gasoline and natural gas can explode as well. In 1981, Hoffmann reported that if we handle hydrogen more carefully or properly, use of hydrogen is safer than use of current conventional fuels [22,23]. Midilli et al. [24] reviewed the basic and fundamental knowledge that everyone should know about hydrogen as a fuel, and the importance of hydrogen to the development of a sustainable future. Barreta et al. [25] reported that hydrogen-based fuel cells and technologies that use hydrogen have vital power in the extensive transformation to a diverse energy system with a cleaner and efficient process. This basic transformation in the world energy system brings considerable enhancements in energy systems and hastens decarbonisation of the mix of energy produced to reduce impact on the climate. These criterions for the protection of the climate can be achieved by hydrogen-based technologies, and hydrogen-based technologies satisfy this task. Wide studies have investigated the outlook and possible strategies for a transition toward a hydrogen-based energy system, the “hydrogen economy” [26–29]. It takes a long time to change the basic structure of the energy system, but a transition to a fully established “hydrogen economy” would span several decades. Hence, acceptable quantifications of structural changes and long-term trends for hydrogen technologies are essential for successful implementation. The production and utilisation of hydrogen must be renewed to inspire a hydrogen economy that is expected to enlarge beyond the few initial applications [30–32].

Renewable hydrogen can improve energy confidence throughout the world and can considerably support the basis for global harmony and fortune. Ohi et al. [33] proposed that to achieve victory in the renewable-hydrogen economy, we must consider several factors. These factors mainly consist of good renewable energy resources and how we utilise these resources for the production of hydrogen and electricity in an economically favourable manner. Other factors include the social and ecological benefits from the use of renewable energy; the provisions of domestic policies, which make renewable hydrogen more favourable; extensive public and private support; good international cooperation on hydrogen research for the development in other countries and so on. In this review, circumstantial information on renewable hydrogen pathways is reviewed, especially the economic treatment of hydrogen energy in various Asian countries. Additionally the impact of the hydrogen economy on the situation in Asian countries was outlined. Special attention is given to the challenges that we must overcome to commercialise hydrogen gas