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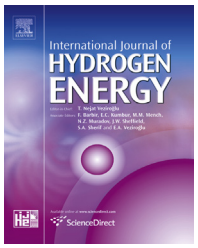

Hydrogen transportation fuel in Croatia: Road map strategy

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ABSTRACT

In the past 15 years worlds and Croatian economy is faced with the transition from classic primary energy sources to renewable energy sources. It is widely assumed that renewable energy can be stored in the form of hydrogen. Hence, world is faced with roll out of the commercial generation hydrogen fuel cell electric vehicles on the road. Anticipating estimated development there is a question when and how will Croatia keep along with this global scenario?! One of the possible answers, derived from Croatia position as EU country that draws 13% of its GDP mostly from tourists flooding during two summer months, was discussed in this paper. The number of hydrogen fuel cell electric vehicles that could be running by foreign tourists in Croatia up to 2030 was estimated. It was proposed hydrogen infrastructure based on photovoltaic technology of solar energy conversion and water electrolysis as adopted hydrogen production technology. Installed hydrogen infrastructure should be incorporated into national grid power system as renewable energy production, energy consumption, and energy storage subsystem.

Introduction

The exponential growth of industrial production and transport in the past 150 years was possible made by the utilization of fossil fuels, coal, and oil particularly. At the same time, the exponential consumption of fossil fuels is followed by menacing side effects such as the increasing of global climate changes and pollution of air, water and soil, especially within major industrial zones. Since these natural resources are spent at the rate much faster than their natural renewal cycle, a decrease in established reserves is inevitable. Considering the fact that the world's largest states are just entering the period of economic expansion (e.g. China and India), it is expected that the resulting rise of oil prices occur in such a manner. Hence, this is going to endanger political and economic stability, not only individual states but worldwide [1]. In an attempt to timely avoid, or at least scale down the effects of such a scenario, in the most developed countries the solution that is looked for is in the implementation of new ways of utilization of those energy resources. It should be used those energy resources available at the level of particular area, state or region under assumption that their utilization does not have harmful impacts to either humans or the environment. These resources are designated as renewable energy sources (RES). Among RES usually counts solar energy, wind energy, energy of biomass, energy of free water flows, wave energy, energy of tides, and ocean heat energy. It is obvious that each

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spot on the Earth disposes with certain quantity of RES in which mentioned energy forms have certain shares.

The size of a particular share and the stage of development of appropriate technology dominantly determine which form of RES will be the most used one locally. There are a large number of various conversion technologies available for the purpose of transforming RES from the primary form to the useful form of energy. Some of these technologies are very simple, while others are highly complex. Due to this diversity, the use of RES requires larger number of highly educated and much better organized and connected people working in this area. At the same time, this diversity of conversion forms at the end works down to heat, mechanical, and electrical energy that are all intermittent in nature and which are difficult to store, especially for longer periods of time. Energy storage is an unavoidable requirement, being the consequence of the intermittence of primary RES and the intermittence of needs of the final user [2]. This is particularly important for those means of transportation that requires the autonomy of travel on beforehand undefined routes, therefore being compelled to store necessary energy within them. Regarding to that, a demand for a fuel as a form of stored energy or an energy carrier is unquestionable. It should be capable of reducing all forms of RES to a common denominator on one side while enabling standardization that would ensure mass application itself and thereby the economics of primary RES usage on the other side. The solution around which the major world powers look for is hydrogen as the fuel [3] and fuel cell as the device that uses hydrogen with larger efficiency without harmful effects on the environment [4]. When talking about hydrogen and its role as a fuel, it should be kept on mind four important moments: First, the latest news is talking about hydrogen in the free form existing on the Earth. That discovery of natural hydrogen presents scientific boom in hydrogen community but also in the energy sector worldwide in general [5]. Second, although hydrogen makes 90% of the space matter, on the Earth it is largely a part of chemical compounds such as water or hydrocarbons. It means that additional energy is needed in order to produce it [6]. Regarding to this, it follows that the hydrogen production is clean and socially acceptable as much as it is clean and socially acceptable technology used for that purpose. These conditions are also related to the chemical compounds used for hydrogen production regarding to the by-products such as carbon or nitrogen oxides, solid particles, etc. Third, once it is produced in a clean way, hydrogen remains a clean fuel [7]. Chemical combustion of hydrogen produces only water and heat. It is technically possible to induce hydrogen combustion in an open-air burner, in an internal combustion engine, and in the gas turbines. Fourth is hydrogen utilization in the fuel cells. Should one compare outputs of electricity generated from the same quantity of hydrogen by means of a classical system and a fuel cell system, the unconventional system would prove significantly more efficient. Although hydrogen was already omnipresent in the industrial use for a long time, all previously mentioned elements point to the fact that hydrogen production and its utilization became the focal issue in energy management.

Hydrogen is not just an industrial gas in the chemical industry anymore but grown into the energy vector, i.e. the energy link between RES and the final user. And finally, the expression of Hydrogen Economy was created: a phrase designating global world economy based on hydrogen as the fuel of choice [8]. Hydrogen-based economy is widely considered to be the heir of the economy based on fossil fuels nowadays. The major problem in the introduction of hydrogen into road traffic is the size of the bite. In order to hydrogen fuel cell electric vehicle (FCEV) become a mass-used product, the infrastructure for production, storage, and transportation of large hydrogen volumes comparable to the current infrastructure for fossil fuels has to be put into place. At the same time, hydrogen infrastructure will fail to materialize if there would be insufficient number of hydrogen FCEVs on the roads. It means that the development of infrastructure and vehicle production has to take place simultaneously – a task requiring enormous financial investments. All major world countries are engaged in organized research of RES technologies coupled to the technologies of hydrogen production and its utilization in households, industry, and transportation [9]. In EU there are currently 93 hydrogen refueling stations (HRS) in operation and public accessible. Just in Germany *H2 Mobility* initiative plans network of 115 HRS to be operational until 2017, and 400 until 2023. Even 1180 HRS and 1.8 million hydrogen FCEVs are planned in Germany for 2030 [10]. For example, action plans for that purpose in the USA are systematized in the documents of *A National Vision of America's Transition to a Hydrogen Economy – to 2030 and beyond*, *National Hydrogen Energy Roadmap* and *Hydrogen Posture Plan*. Similar plans for the EU can be found in the reference [11].

In this sense there are not existing corresponding documents of strategy in Croatia yet but legislations for hydrogen FCEVs homologation were set in 2013. However, scientific and development research is continuously in progress from what and where it should be. Since nothing of importance would be achieved by purely declarative drafting of such documents, especially without representatives of the industry and scientific institutions, it is of paramount importance to present within their frame a series of complex and far-reaching projects. These could have long-term positive effects on science, technological development and production. A strategy for such a project is presented in this paper concerning the introduction of solar-hydrogen technology in the road traffic, nautical tourism, and ferry traffic in Croatia.

Main motivation

Transition to low carbon development became increasingly important since climate change, economic, energy, food, and other crises in last decade. Due to that energy and transportation sectors are the most important in terms of new investments, potential of greenhouse gases (GHGs) reduction, and urgency to act – since business as usual means locking in to old technologies that are unable for efficient shift to low emission economy. Transportation sector could make even more pressure on electricity generation, since fuel switch towards electricity means more electricity needed. If this electricity is generated in coal power plants, it could lead to even more GHGs emissions than if fossil fuels are used in transportation. This work contributes to more flexibility in power system network to offset production peaks to energy that can be utilized for later use. The year 2014/15 is going to