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A preliminary assessment of wind generated hydrogen production potential to reduce the gasoline fuel used in road transport sector of Sweden

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ABSTRACT

Hydrogen produced with the help of local wind energy resource can be considered as a key energy carrier, which can play a major role in switching the transport fuels from fossil to renewable. In this paper, we preliminary assessed the wind generated hydrogen production potential in order to provide the environmentally clean, renewable and cheap fuel to the road transport sector of Sweden. Vestas-112 wind turbine (V-112) and proton exchange membrane (PEM) electrolyzer were used as main components. Land use restrictions related to wind to hydrogen energy installation were also taken into account. Geographic Information System (GIS) tool was used for this study. We estimated that in Sweden, 25,580 ktons/year of hydrogen can be produced by using local wind energy resource, which is equivalent to 860 TWh of energy. Moreover, by using per capita gasoline consumption of Sweden, it was also estimated that during year 2011, 2900 ktons of imported gasoline was used in transport sector, which emitted 8700 ktons of CO_2 into the local atmosphere of country. It was also estimated that in Sweden, gasoline consumption and CO_2 emission can be reduced to 50% by using only 530 ktons i.e. (2%) of total local wind generated hydrogen production.

Introduction

Background

Production and utilization of renewable energy resources have gained a reasonable momentum owing to nonstop exhaustion of local fossil fuel assets and worldwide plans related to the climate change and energy security [1]. In this regard, modern and encouraging developments in the exploitation of local renewable energy sources all around the globe have shown that renewable fuels can be considered as promising alternatives. Though renewable energy resources are environmental friendly and have no fuel cost but their

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irregular nature is still of great concern while considering the large scale penetration into national energy system. Mostly in the world, wind energy is generally used for direct electricity production and very slight progress has been seen in the storage of wind energy to reduce the intermittency level. As estimated by some authors of this paper, Sweden possesses 1274 TWh of yearly onshore wind energy generation potential with an average capacity factor of 28% [2]. Most of high potential areas are located in southern part of country, but the restrictions to wind energy are also high in southern region of country as most of Swedish population is living in this region, whereas northern region of country offers lesser restrictions to wind energy [2]. Despite of enormous wind energy potential, up to year 2013, total yearly wind energy generation of 11 TWh was achieved in the country [2]. Therefore, keeping in view the available wind energy potential in Sweden, option of renewable hydrogen production and its storage with the help of local wind energy resource may be considered as a better option to increase the integration of intermittent wind energy into the national energy systems [3–5]. Furthermore, stored and compressed form of hydrogen can also be used as fuel in the road transport sector, which can help in the reduction of fossil fuel imports and also can contribute in the avoidance of harmful emissions into local environment of country. Renewable energy resources can play important role in the replacement of fossil fuels and reduction of CO_2 emissions to meet the energy and environment targets in the world [6]. Wind generated hydrogen also can be supplied to the local and remote populated areas with the help of piping network, where it can be used for the production of electricity, refueling of the road transport and heating sectors [7]. As an end result, it can be said that wind generated hydrogen as energy carrier can be considered as excellent alternative, which can be used later on when wind is not blowing.

Modern renewable hydrogen as energy carrier also can offer the broad variety of economical and social benefits just like energy security, rural development and reduction of green house gas emission and fossil energy imports. Despite of theses mentioned advantages, at present most of hydrogen produced in world is generally used for industrial processes rather than electricity and transport sectors. According to a report by Clean Energy States Alliance [8], in United States about 10–11 million metric tons per year of hydrogen are prepared, which can fuel the 20 to 30 million of cars. On global scale, the hydrogen production is around 41 million tons, and it was expected to increase at the rate of 3.5% yearly during 2013. At present, commercially produced hydrogen is used in oil refineries for the treatment of crude oil, in food industry for hydrogenation process, in metal industry for metal treatment and in fertilizer industry for producing ammonia.

The burning of fossil fuels remained the main reason behind the emission of green house gases (GHG) in to local environment of countries [9]. Therefore, as transport fuel, hydrogen has also received a reasonable attention in many countries around the globe, which can be used for the deep decarbonization of the transport sector [10]. According to a report by US Department of Energy [11], about 140 hydrogen fueling pumps are in operation in 19 countries around the globe, which can refuel approximately 1 million hydrogen vehicles. In Italy, 05 hydrogen refueling stations are in operation since recent past [4]. While talking about the thermal efficiency of hydrogen fueled vehicles, it is very important to mention here that, Ford Motor Company has introduced a car fueled by hydrogen having thermal efficiency of 38%, which is approximately 25% more than gasoline fueled vehicle and have almost zero emissions [12]. The normal thermal efficiency of gasoline fueled vehicle is around 30%, whereas thermal efficiency of most efficient hydrogen fueled car is around 45% [13].

Fuel imports of Sweden

Sweden does not have local oil and gas reserves and heavily depends on the fossil energy imports from neighboring countries. According to a report by International Energy Agency (IEA), 100% of natural gas used in Sweden is imported from Denmark. Additionally during 2011, nearly 18.8 Mt of crude oil, or an average of roughly 330 kb/d was imported in Sweden, i.e. 51% from Russia, 20% from Norway, 16% from Denmark and 7.4% from United Kingdom. During the past decade the oil import share from Russia has increased drastically from 10% of total crude imports in 2000 to 50% in year 2011 [14].

Final energy consumption in Sweden

Total final energy consumption of Sweden was 395 TWh during 2012. According to the data provided by Swedish Energy Agency (SEA) [15], total final energy consumption was shared by industry, transport, residential & services by share of 148 TWh, 91 TWh and 156 TWh respectively. Break up of each energy source used in each sector is shown in Figs. 1–3. It is very important to mention here that, in transport sector 83 TWh came out of oil products, where as in residential & service sector, 15 TWh and 2 TWh came out from oil and gas respectively. As per new Swedish energy policy, use of fossil fuels has to be eliminated in heating sector by year 2020 and in transport sector vehicles have to be free from fossil fuels use by year 2030 [16].

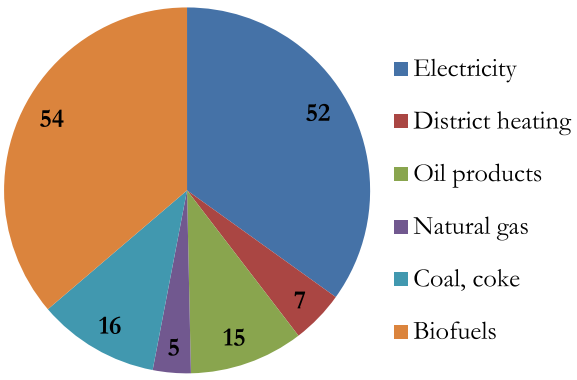

Fig. 1 – Distribution of energy use by type in industrial sector, total 148 TWh.