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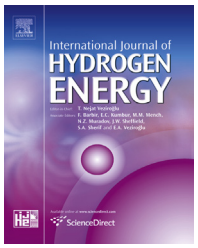

Estimation of electrolytic hydrogen production potential in Venezuela from renewable energies

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ABSTRACT

An initial estimation of the potential for hydrogen (H_2) production in Venezuela is made, obtained by water electrolysis using electricity from renewable sources, taking advantage of the great potential of the country for solar, wind and mini hydro energies. For the first two, its potential maps is obtained from insolation and wind speed maps, respectively, prepared from satellite data, and for mini-hydro, the potential is obtained from documentary information. To calculate the amount of H_2 to produce is used the Higher Heating Value, considering the electrolytic system overall efficiency of 75%, including power requirements of the electrolyzer, auxiliary equipment, and system losses. In addition, in the calculation of usable renewable potential are excluded land areas under special administration, marine, lake and urban areas, and other limitations are considered concerning energy conversion efficiencies and useful areas available for the location of the different renewable technologies.

The results give a total production of 2.073×10^{10} kg of H_2/year, with a contribution of 95% of solar photovoltaic energy. The H_2 produced covers entirely the energy requirements of rural population without energy service, and the remainder could be used as a chemical feedstock in industrial processes such as oil refining or petrochemical, whose demand in not entirely satisfied with the annual production of H_2 from the country, or even for export. It is concluded that the results are the initial point of a detailed research, with more accurate estimation of the potentials that include economic and social topics related with the production on H_2, on the way to determine the feasibility of developing of the Solar-H_2 system, in its different forms in Venezuela.

Introduction

The Solar-Hydrogen Energetic System (SHES), can be defined as an energetic system in which the primary source is any type of solar energy, direct or indirect; and the H_2 is the secondary source or energetic vector. It is a clean, self-sufficient and appropriate system to overcome the drawbacks of intermittency and storage related with electric generation from renewable energy (RE), and therefore, able to motorize the

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sustainable development of a country or region [1]. A crucial stage for the development of the SHES is the H_2 production with numerous studies that demonstrates its feasibility [2,3], while working intensely to achieve in the medium term, production costs competitive with the conventional production process by reforming of natural gas, with the lowest cost currently [4]. In Latin America, Brazil is a leader in R&D on H_2 production from RE, especially hydropower [5,6], In turn, although Venezuela exhibits great potential of these primary sources, its development is minimal, and, except for large-scale hydro, without an effect on the energy balance of the country. Although country's degree of electrification is close to 96%, an important sector of rural population, about 25%, has no permanent energy services, for this reason is difficult, expensive, and therefore improbable, its satisfaction with the traditional energy system [7]. Since these rural communities are disseminated throughout the country, probably located in areas with exploitable potential of solar energy, its energy needs could be met by SESH in its various forms, thus overcoming the situation of energy deprivation. Complementarity and synergy between electricity and H_2 would allow the energy autonomy to these isolated and depressed areas, improving their quality of life, stimulating the local economy to be employment-intensive, preserving the culture and sustainable endogenous development. Moreover, it is also recognized that any action or project that proposes the SESH implantation, requires a primary estimation of potential H_2 production because it would be an appropriate starting point for more comprehensive studies on the feasibility of a specific SESH. In this context, the principal objective of this paper is to make a preliminary estimate of the production potential of electrolytic H_2 in Venezuela from those forms of solar energy with potential of a significant magnitude in the country, considering its use as an energy vector in the rural areas of the country, and eventually as an input in improvement processes of heavy crudes, refining and petrochemical.

An important contribution associated to the purpose of this paper is the free access software, HYDRA (H_2 Demand and Resource Analysis) developed by the National Renewable Energy Laboratory (NREL), that provides information about demand, sources, production, costs, infrastructure and distribution of H_2 for a determined country [8]. About the H_2 production potential, it includes different fossil and renewable sources, and presents the results in different potential maps with different detail level, thus, for the US, the software shows the production potential for states and counties, while for Latin America it does not show results, maybe for the lack of information about renewable resource in the region. In fact, there is not documental evidence about the renewable H_2 production in these countries, but are available estimations for specific regions in several countries and for some RE, then some essential cases are presented.

In the Córdoba province from Argentina the production potential of H_2 obtained by electrolysis for the automotive sector has been evaluated using the wind energy as electric source. The wind energy is evaluated based on wind maps of the province, and are selected whose regions with levels above Class 4, a capacity factor of 0.39 is considered, excluding natural areas and those with gradients above 20%, for the electrolysis system an efficiency of 75% is assumed. The yearly total amount of H_2 generated in 10 departments of the Province is 3.734×10^7 Ton H_2/year, enough for providing until 10 times the energy required for the automotive sector of the entire province [9].

A prospective study about the viability of H_2 production considering the wind potential of La Patagonia, this energy is accounted with the use of seven weather station located at southern Chilean lands, using meteorological and statistical models, getting a capacity factor of 0.55 for wind source. The H_2 is produced by electrolysis with unsalted sea water, after that, the liquid H_2 is transported by ship to the central region for its use. The H_2 production is equivalent to substitute 7.1% of oil consumption it is around 380,000 kg H_2/year [10].

In Ecuador the potential of H_2 production from hydroelectricity is evaluated, the study considers that certain turbinable spilled water in several hydroelectric plants over the country could be used to additional generation oriented to H_2 production by electrolysis. The hydroelectric plant HidroPaute is selected for the study; it has an installed capacity of 1100 MW, contributing with 32% of total generation of the country, with a capacity factor of 62% in 2011. Two scenarios of H_2 production are considered: in the first one is assumed that is available a 30% of water spilled in 2011; in the second situation this amount is duplicated. Considering an electrolysis process efficiency of 75%, it has obtained for the first scenario 5400.8 Ton H_2/year and 10,801.7 Ton H_2/year for the second one, which is used for chemical and energy requirements [11].

In Brazil [3] have studied the H_2 production from solar photovoltaic (PV), wind, and hydroelectricity energies, the same sources considered in this paper. The study evaluates the technical and economic performance of a hypothetical production plant of electrolytic H_2 with a capacity of 30 MW located at northeast Brazil. The evaluation of the potential of generation of solar PV and wind energies is based on the Solar Atlas and Brazilian Wind Potential Atlas, the hydroelectric energy is provided by a Hydroelectrical Central located at northeast of the country and it is able to deliver the required energy to surpass the electrical requirements of the electrolysis plant. It is considered an availability factor of 95%, conversion efficiency of 80%. The overall annual production is 56.26×10^6 m^3 H_2/year, for export only.

In other ambit [2], have estimated the amount of H_2 from renewable energies available in the US, with the use of solar PV and wind energies, with the aim to provide the automotive sector. The potential from both sources is estimated with software based on GIS. For the solar option, the radiation data corresponds to monthly means for 40 km^2 cells, considering 3% of this area for solar photoelectric conversion, excluding forest parks, marine and lake areas, assuming 10% of solar PV efficiency. For the wind case, are considered the winds Class 3 or higher, and placing in every cell turbines of 5 MW and also considering the mentioned exclusions. The efficiency for the electrolysis process is 75% and the results are expressed with a potential map of the country, organized by counties, obtaining an overall annual potential of 1.110×10^{12} kg H_2/year for 2010.

From this revision, is clear that methodology used to calculate the production potential of H_2 by electrolysis, has the following characteristics: a. the use of potential maps of the renewable resources, generated thought different models