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Hydrogen production research in Mexico: A review

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ABSTRACT

Today, there is a great opportunity for alternative energies and specifically for hydrogen technologies to flourish within Mexico. The opportunity for the hydrogen production research to contribute to the advance and viable application of the related technologies is today of paramount importance. The present paper is aimed to present a review of research activities in the field of hydrogen production in Mexico. Main research activities are reflected in journal publications and conference proceedings within the last seven years. These resulted in the following topics and contributions: Hydrogen production (HP) from biological processes and wastes 40.4%, followed by HP through conventional and non-conventional fuels (CO_2 capture and Catalysis) 22.4%, HP by photocatalysis and photo-electrocatalysis 14.1%, HP systems and controls 12.2%, theoretical and thermodynamic studies for HP 7.7%, and HP by electrolysis 3.2%. A wide variety of potential applications can be followed by these contributions, while the spread of this research can be a key for future national or international collaborations that may strengthen this important area to take advantage of the upcoming opportunities in the country and worldwide.

Introduction

Energy is the engine of economic and social development of the world, therefore continuous supply of all forms of energy is of crucial importance to every nation, and Mexico as a country is no exception. Hydrogen has become one of the most promising alternative energy carriers in the country, this in view to decentralize the energy production based on oil. The versatility of its new applications, its high calorific value, and the fact that it can be used as a clean fuel are some examples of the high potential in new processes and developments. That is the reason why in several European nations as well as in Japan hydrogen use in transportation is currently taking place. However, hydrogen, the most abundant element on our planet is not found in its elemental form, but in molecular form (as in oil or water) and consequently in order to be utilized this must be extracted.

At present, there are different methods for producing hydrogen, and these are characterized by their primary source. Among the primary sources are fossil fuels like natural gas and coal as well as renewable sources such as biomass, solar, wind, hydro and nuclear. Additionally, in production technologies there is also many alternatives, such as chemical, biological, electrolytic, photolytic, and thermo-chemical processes. The choice of the primary energy source and the technology to produce hydrogen are strongly linked to parameters such as fuel costs as well as environmental and social impacts. Fig. 1 shows the most employed current technologies to produce hydrogen.

In general, electrical and thermal energy can be produced from fossil fuels, nuclear, or recovered energy and renewable

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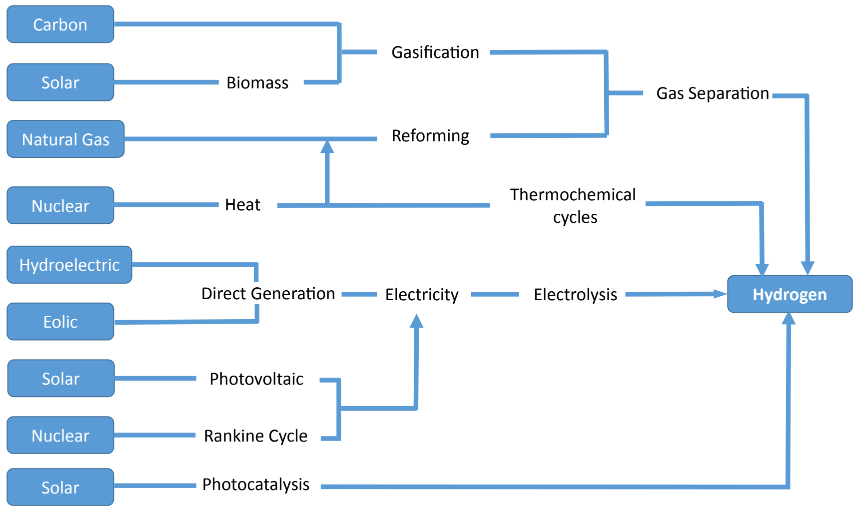

Fig. 1 – Most employed current technologies to produce hydrogen [1].

energies such as solar, wind, hydro, thermal and biomass. Photonic energy originates from solar irradiation, while biochemical energy is recovered from organic matter. Carbon and biomass (with solar energy as a source) can be gasified to produce syngas (a mixture of H_2 and CO) followed by gas processing and separation to obtain pure hydrogen. Furthermore, natural gas reforming is a mature technology used in many refineries and chemical industries in Mexico for large-scale H_2 production. In some countries small-scale reformers are currently used in demonstration H_2 refueling stations (decentralized production). Reforming options include catalytic steam methane reforming (SMR), partial oxidation (PO) and other variants under development (i.e. CO_2 capture). In SMR, methane reacts with steam at 700°C–950 °C to produce syngas, CO is then converted into CO_2, producing additional H_2 by the water-gas shift reaction (WGS). In the PO_X process, methane reacts initially with pure O_2 to generate syngas [2]. Further purification or gas separation is needed from these processes to obtain pure hydrogen for different needs such as fuel cells in transportation applications.

Hydrogen can be produced using nuclear energy as a source of primary energy, through thermal splitting of the water molecule, electrolysis and thermochemical processes, the three alternatives are free of carbon emissions. The heat obtained from the nuclear reactor is used to achieve the splitting of the water molecule, thus producing hydrogen. Thermochemical cycles were developed already since the 1970's and 1980's when the search for new sources of production of alternative fuels were needed during the petroleum crisis. In thermochemical water splitting, also called thermolysis, heat alone is used to decompose water to hydrogen and oxygen [3]. It is believed that overall efficiencies close to 50% can be achieved using these processes [4]. However, the temperature required for this process is 850 °C; these temperatures are reached only by high temperature reactors [5].

Hydroelectric power has the advantage of being a clean resource that is perpetually renewable and hydrogen production can be carried out by electrolysis. Essentially, this practice is performed to increase the efficiency of hydropower plants through the conversion of water to hydrogen through electrolysis by using the excess energy or wasted energy not yet utilized, and then conversion of hydrogen to electricity via a gas turbine or fuel cells. The electricity produced in the off-peak or no-demand time, or at the time of huge river flows in the spring can be stored in the form of hydrogen, and later, when the peak energy is needed, the hydrogen converted to electricity. One of the advantages of the proposed system is that the resource for production of hydrogen (the water) is available directly at the site. It appears that the conversion of electricity at hydro-power plants to hydrogen, and its utilization via a gas turbine, is technically and economically feasible [6].

Moreover, eolic energy is constantly growing worldwide. In some locations today, wind is cost competitive with conventional, fossil fuel, or nuclear generated electricity. It is the fastest growing renewable energy sector with annual growth of 27%, which means doubling the installed capacity every three years [7]. Direct coupling of an electrolyzer with a wind turbine to produce H_2 implies intermittent operation with a highly variable power output. One particular issue deals with alkaline electrolyzers, when at very low loads the rate at which hydrogen and oxygen are produced (which is proportional to current density) may be lower than the rate at which these gases permeate through the electrolyte, and mix with each other and this may create a hazardous condition inside the electrolyzer [8]. Due to present high costs of electrolyzers and fuel cells, the cost of delivered electricity would be several times higher than the cost of wind-generated electricity [9].

Furthermore, hydrogen production by solar technology can be produced by two methods. Solar energy is converted to electricity in a photovoltaic cell (PV) and hydrogen is generated by electrolysis of water, while the alternative method is carried out in photoelectrochemical cells directly produce hydrogen. Approximately 85% of commercial PV cell technology are based on polycrystalline silicon. Other cells are based on thin plates of amorphous and crystal compounds of

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