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Preliminary estimation of electrolytic hydrogen production potential from renewable energies in Ecuador

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ABSTRACT

An initial assessment of the production potential of H_2 by electrolysis is performed in Ecuador with electricity from renewable sources. The renewable energies considered are: solar photovoltaic, wind, geothermal and hydropower. The information about their potential is based on maps of solar and wind resources, geothermal surveys, as well as estimates on mini-hydro and spilled turbinable energy from hydroelectric plants with reservoir. The amount of H_2 is obtained by considering a PEM electrolizer, with an efficiency of 75%, reaching a production of 4.55×10^8 kg/year in a likely scenario. Two different uses of H_2 are presented: 1) automotive transportation, replacing gasoline and diesel and, 2) rural energy, replacing firewood for cooking in rural households in the country. As a result, H_2 is able to replace 65% and 44% of the volumes of imported gasoline and diesel, respectively and the overall replacement of gasoline in 9 out of 23 provinces. Also, it is possible the total replacement of firewood in rural households in 20 provinces, and, under certain conditions, the H_2 surplus could be used to completely cover the electricity needs in the same rural households in 20 provinces. It is concluded that, there are certain opportunities in Ecuador to include H_2 in its energy matrix, contributing to improve the supply of secondary energy, raising the life quality in rural areas, mitigation of environmental pollution and strengthening the national economy. All this makes necessary to conduct more detailed technical and economic studies.

Introduction

The use of hydrogen, H_2, as a way of energy storage and transportation is considered frequently as a good alternative to fossil fuels, whose massive utilization creates dangerous environmental consequences. Moreover, the eventual collapse of oil and gas reserves in the medium term makes the current energy system unsustainable [1]. The interest in H_2 as an energy carrier is based on its unique properties, the

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Nomenclature

Acronyms

CELEC EP	Electric Corporation from Ecuador, Public Sector
CDM	Clean Development Mechanism
CIE	Corporación para la Investigación Energética
RE	Renewable energies
FC	Fuel cells
GDP	Gross Domestic Product
GHG	Green house gasses
GIS	Geographic Information Systems.
HHV	Higher Heat Value
LHV	Lower Heat value
MMBOE	Million barrels of oil equivalent
NREL	National Laboratory of Renewables Energies
PEM	Proton Exchange Membrane
PV	Photovoltaic
SHES	System Hydrogen Energy Systems
STE	Spilled Turbinable Energy
MEER	Ministry of Electricity and Renewable Energy

Parameters

A_P	Province area, km^2
F_{AP}	Available area factor by province, adimensional
F_{AE}	Availability factor (electrolysis), adimensional
F_{AG}	Availability factor (geothermal), adimensional
F_C	Capacity factor, adimensional
F_p	Plant factor, adimensional
g	Gravity acceleration, m/s^2
H_2 HHV	H_2 Higher Heat Value, kWh/kg
η_e	PEM electrolyzer efficiency, adimensionañ
η_{fv}	PV conversion efficiency, adimensional
ρ_{H20}	Water density, kg/m

Variables

I_{PA}	Mean annual global insolation by province, kWh/m^2 day
E_{PV}	Annual PV energy by province, GWh/year
P_G	Geothermal potential, MWe
E_{EG}	Geothermal electric energy, MWh
E_{MHYDRO}	Minihydro electric energy, MWh
P_{MHYDRO}	H_2 minihydro annual production, kg/year
H	Water head, m
V	Spilled volume, m^3
P_{H2H}	H_2 hydro annual production, kg/year
E_{EXC}	Excess energy, J
P_{H2R}	H_2 Net annual production, kg/year

possibilities to obtain it from different sources and processes, and the capacity to satisfy the basic energy requirements in every society sector for different applications such as mobile, static or portable [2,3].

However, to constitute H_2 as the basis of a sustainable and distributed energy system, it is mandatory its production from primary renewable sources, creating the Solar Hydrogen Energy System, SHES, where the primary source is any type of renewable energy, RE, and the secondary source is H_2. Also, the use of H_2 constitutes an important mechanism to overcome the difficulties of RE approaching, related to its intermittence and its low storage capacity in a larger scale [4]. Thus, the SHES is having an important technological and scientific development in all the stages of the structure and performance [5]. Subsequently, it is proposed the slow incorporation of H_2 in energy systems in several countries to expand the energy supply and to reduce the dependence on fossil fuels [6].

In this context, a previous key stage to SHES implantation in a region or country is the estimation of the H_2 amount that potentially could be obtained through RE that assure its production continuously. The results of such estimation could guide and define the realization of specific studies about the technical and economic feasibility of SHES implementation. This requirement has motivated researches in several countries to evaluate the potential production of H_2 from RE, which is considered in the next section.

Theoretical background

USA

The USA is one of the countries with the largest number of studies on the amount of H_2 that could be obtained from fossil primary sources -natural gas and coal- and renewables energies -wind, solar, biomass and nuclear hydropower-, all led by NREL [7–11]. In the case of RE, they estimated annual production of 1 billion ton H_2 when solar PV, wind onshore and biomass are the primary sources with water electrolysis and biomass gasification as production process. The results are expressed in maps of H_2 potential production normalized by the area of the counties of the country and obtained by techniques of geographic information systems, GIS.

When the studies per renewable source are specified, for the case of wind power, it has been quantified the wind potential for the production of H_2 in two studies by NREL. In the first study, it is presented a map output in every county in the country, for a total production of H_2 of 2.74×10^{11} ton [8]. In the second one, more accurate wind resource estimates are achieved, resulting in a H_2 production of 1.1×10^{12} ton/year for the whole country [10]. For its part, the use of the PV power in the H_2 production by electrolysis has been evaluated in the US based on records from insolation in geographical cells 40 km side, with a conversion efficiency of 10%. Under certain environmental restrictions and land use, an amount of 7.2×10^8 ton/year of H_2 is obtained [8]. This value increases after more accurate estimates of the PV usable potential, reaching the amount of 8.7×10^9 ton/year for the same previous conditions [10]. Finally, NREL has estimated the production potential of H_2 from Spilled Turbinable Energy, STE, assuming that 30% of the annual production of 1321 plants in the country of this kind, reaching a H_2 production of 1×10^6 ton for 2006 [9].

Argentina

In this country, it has been determined the production potential of H_2 with solar PV, wind and biomass as primary