RENEWABLE ENERGY SYSTEMS FOR HYDROGEN PRODUCTION IN SUB-SAHARAN AFRICA: A COMPARATIVE STUDY BASED ON A TECHNO-ECONOMIC ANALYSIS

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This paper focused on the production of the hydrogen via water electrolysis using renewable energy systems including PV and Wind. The hydrogen production capacity of ten different localities of Cameroon has been evaluated. The economic analysis reveals that, the levelized cost of energy (LCOE) to produce green hydrogen via PV/Wind/Electrolysis in Cameroon ranges from 0.138 $/kWh to 0.251 $/kWh. The corresponding levelized cost of hydrogen (LCOH) ranges from 8.409 $/kg to 14.070 $/kg. It has been demonstrated that the energy provided by the PV generator ranges from 71 to 89.46 % of the total energy supplied by the PV/Wind system. Thus PV/Electrolysis is technically more suitable for hydrogen production in Cameroon than Wind/Electrolysis and PV/Wind/Electrolysis. However, the PV/Wind/Electrolysis is more cost-effective than the Wind/Electrolysis based hydrogen production in Cameroon.

Keywords: Hydrogen production; PV/electrolysis; Wind/Electrolysis; PV/Wind/Electrolysis; LCOH; LCOE.

1. Introduction

The hydrogen consumption is keep growing all over the world for various applications such as in industry (production of ammonia and methanol, refining), in transportation (hydrogen vehicle, fuel cell for airplanes), in power systems (hydrogen storage for backup power supply). However, this prosperous technology is not developed and even unknown in many localities around the world, such as in Sub-Saharan Africa. Renewable energy sources are effective solutions for electricity supply [1-11]. The water electrolysis based on renewable

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energy systems (RES) as sources of the electrical energy supply is one of the methods used to produce hydrogen. Several studies based on RES for hydrogen production have been performed in the literature [12-21]. A hybrid PV/Wind system for hydrogen production in Egypt has been designed by Nassser *et al.* [12]. The proposed system was suitable for hydrogen production and storage. It has been found that the hydrogen production cost ranged from 4.54 $/kg to 7.48 $/kg. The economic feasibility of hydrogen production in Djibouti, via water electrolysis has been studied by Mohamed *et al.* [13]. A Wind and Geothermal energy sources have been considered for the electricity supply. A comparative analysis shown that the wind energy cost is more profitable than the geothermal energy cost. The cost of hydrogen using wind energy ranged from 0.672 $/kg to $1.063 $/kg, while the producing cost of hydrogen using the geothermal energy ranged from 3.31 $/kg to 4.78 $/kg. Masad and Gamze [14] realized a techno-economic study of hydrogen production via a PV/Wind energy system for three different cities of Iraq. The maximum hydrogen produced was 49,150 m^3 per year corresponding to 0.752 $/m3 hydrogen production cost. Abdulrahman and Abdullah [15] analyzed the hydrogen production based on a hybrid PV/Wind energy system in Dhahran city, a province of Saudi Arabia. The minimum hydrogen production cost was 36.32 $/kg. Rezaei *et al.* [16] performed a techno-economic analysis of the production of electricity and hydrogen using the wind turbine energy supply. Different scenario have been considered and analyzed for this purpose. The results shown that the electricity cost was in the range of 0.0325 to 0.0755 $/kWh, and the hydrogen cost ranged from 1.375 to 1.59 $/kg. Tebibel [17] proposed a Wind/Battery system to produce hydrogen via water electrolysis. A multi-objective optimization of the system has been realized based on a dynamic power and hydrogen management strategy. The designed system comprising 857.5 kW Wind turbine, 2022 kg H2 tank, 250 kW electrolyzer, and 719 kWh storage battery, resulted on a LCOH of 33.70 $/kg. Clarke *et al.* [18] studied the generation of hydrogen by a direct coupling of an electrolyzer to a solar PV system. The objective of this study was to maximize the transfer of the energy from the PV generator to the electrolyzer, by avoiding the use of any electronic device or converter. The authors have demonstrated the practical feasibility of a direct coupling, by matching the current-voltage characteristics of the PV array and the electrolyzer. A 2.4 kW of PV system has been considered for this study. It has been shown that, about 0.126 kg/day (7.55 kg in 60 days) of hydrogen could be generated by this system. Barbir *et al.* [19] demonstrated that, the PEM electrolysis is a possible solution to generate hydrogen via renewable energy sources, and particularly via photovoltaic. According to them, the generation of hydrogen via the PV/electrolysis is very expensive and should be recommended for remote areas or for special applications. Ahshan [20] analyzed the potential and the economics of a Solar-to-Hydrogen production. The Sultanate of Oman has been considered as the study site. The hydrogen potential production of 15 locations of this Sultanate have been evaluated based on the PV/electrolysis. They have shown that the green hydrogen production using solar PV in the Sultanate of Oman was promising. Boudries *et al.* [21] designed a PV system for the energy supply to an industrial unit of hydrogen production. Thanks to a techno-economic analysis, they have proven the viability of a PV system coupled with the hydrogen production unit in the southern of Algiers suburb.

Some research gaps have to be highlighted concerning the development and the expansion of the hydrogen applications around the world:

- Hydrogen is not widely use in developing countries and the perspectives of implementing it should be explore;
- The hydrogen energy potential via water electrolysis of many localities of Sub-Saharan Africa, having an important renewable energy resources (such as wind and solar energy potential) are unknown and could be a limitation to attract the investors;
- The economic feasibility of renewable energies to hydrogen production of Cameroon has not been performed for decision-making.

The contributions of this research work are: (1) The evaluation of the hydrogen energy potential of some localities of Cameroon, via water electrolysis based on PV and wind energies supply (2) Analyzing the economic feasibility of hydrogen production in different representative locations of Cameroun; (3) Comparing different configurations of renewable energy systems-based hydrogen production.

2. System components and site of study

The objective of this research work is to evaluate the hydrogen potential production in Cameroon based on renewable energies including PV and Wind electrolysis. An economic analysis approach is used for this purpose. Table 1 presents the average solar radiation, the average ambient temperature, and the daily average peak sun hours, for the different main locations of Cameroon. The 1-sun insolation approach [22] has been used to evaluate the peak sun hour of the different sites. Table 2 presents the average monthly wind speed data of the study sites at 50 m height. The PV/Wind/Electrolysis system for hydrogen production is presented in Fig. 1. The system is composed mainly by the PV generator and the Wind turbine used to produces the electrical energy, the electrolyzer that converts this electrical energy into hydrogen, the inverter used to convert AC to DC power, and the hydrogen storage component. The DC bus in Fig. 1 is used to describe the power distribution shared by the components of the system. This type of circuit uses the direct current voltage level as a reference. The geographical map location of the study sites is marked in red color in Fig. 2.

Table 1

Meteorological data of the study sites [23]

Location	Average Solar radiation (kWh/m².day)	Average ambient temperature (°C)	Daily average peak sun hours (h)=Average solar radiation/(1kW/m²)	Average wind speed (m/s)
Maroua	6.18	27.77	6.18	4.77
Garoua	6.17	29.65	6.17	4.48
Ngaoundéré	5.76	23.20	5.76	4.12
Bertoua	5.45	25.2	5.45	2.44
Yaoundé	5.11	23.56	5.11	1.87
Ebolowa	4.94	23.6	4.94	1.82
Douala	4.99	26.05	4.99	2.26
Bafoussam	5.68	20.53	5.68	2.41
Buea	4.11	21.97	4.11	2.26
Bamenda	5.51	21.17	5.51	2.41

Table 2

Monthly wind speed data of the study sites at 50 m height [24]

	Maroua	Garoua	Ngaoun-déré	Bertoua	Yaoundé	Ebolo-wa	Douala	Bafous-sam	Buea	Bamenda
Jan	5.2	4.84	4.32	2.79	2.18	2.03	2.47	2.68	2.47	2.68
Feb	5.11	4.78	4.35	3	2.35	2.24	2.58	2.74	2.58	2.74
Mar	5.6	5.24	4.72	2.85	1.98	1.85	2.22	2.61	2.22	2.61
Apr	5.8	5.42	4.9	2.69	1.69	1.58	1.86	2.36	1.86	2.36
May	5.29	4.98	4.59	2.38	1.53	1.48	1.85	2.33	1.85	2.33
Jun	4.42	4.18	3.97	2.23	1.71	1.67	2.33	2.49	2.33	2.49
Jul	4.09	3.86	3.67	2.23	1.94	1.94	2.68	2.40	2.68	2.40
Aug	3.89	3.7	3.56	2.3	2.11	2.17	2.82	2.49	2.82	2.49
Sept	3.6	3.45	3.32	2.23	2.02	2.06	2.56	2.33	2.56	2.33
Oct	4.06	3.84	3.58	2.11	1.66	1.67	1.96	2.03	1.96	2.03
Nov	4.77	4.45	4.01	2.14	1.55	1.52	1.84	2.16	1.84	2.16
Dec	5.41	5.02	4.45	2.37	1.69	1.64	1.97	2.29	1.97	2.29

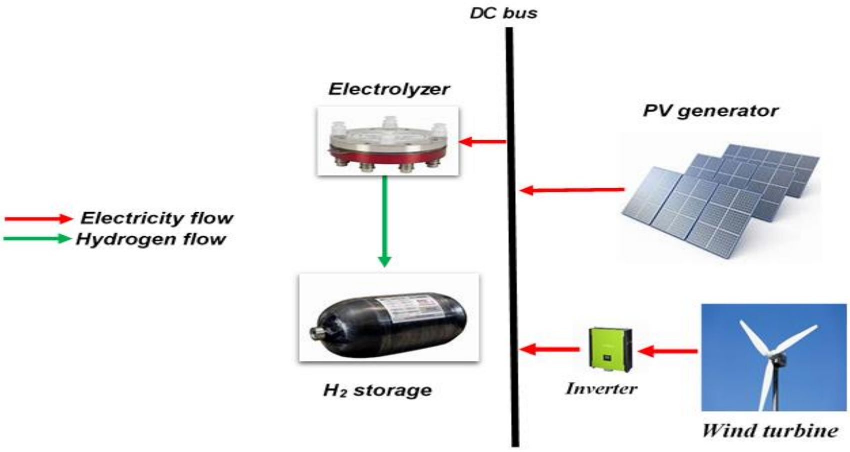

Fig 1. Hydrogen production via PV/Wind/Electrolysis

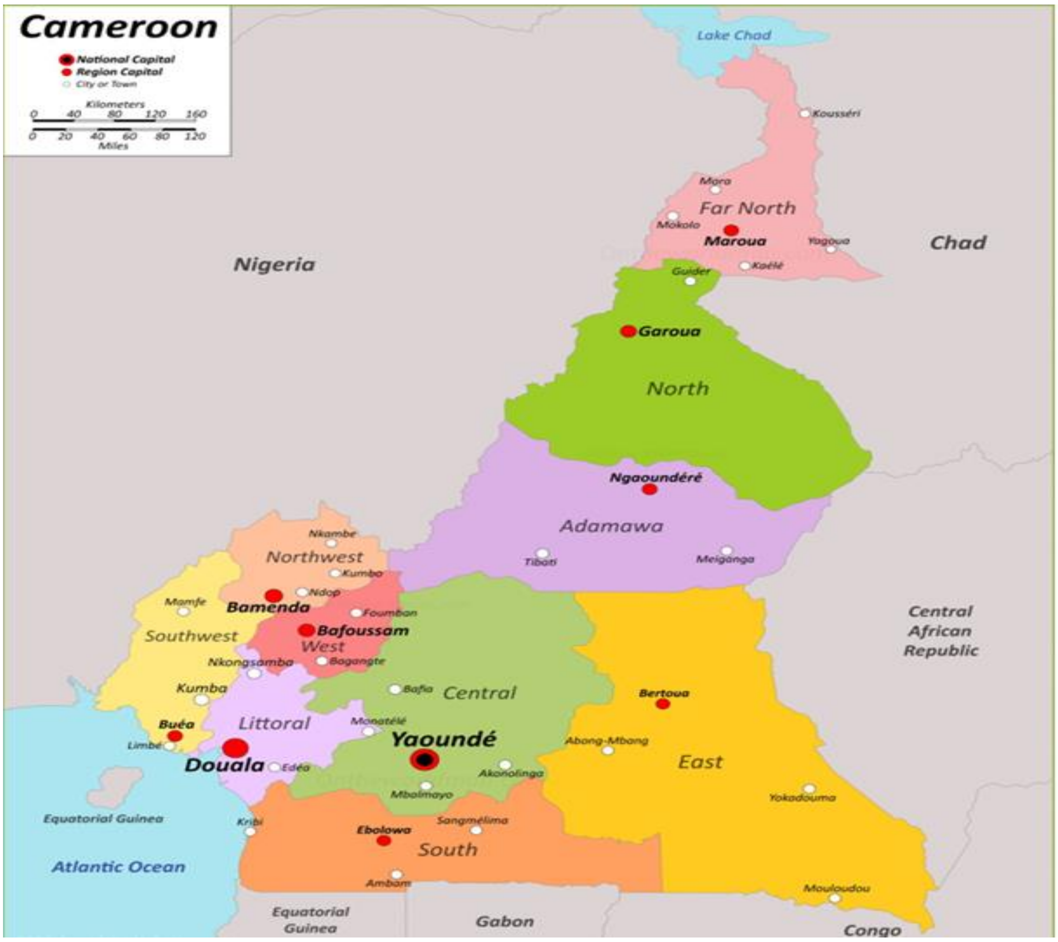

Fig 2. Location of the study sites marked in red color on the geographical map [25]

3. System modeling

3.1 PV output modeling

$$E_{pv} = P_{Pv,ref} \times D_f \times \left[1 - \alpha\left(T_c - T_{c,ref}\right)\right] \times D_{sh} \times N_D \tag{1}$$

In the above equation, the cell temperature T_c for a module under conditions of 1-sun isolation [26] is given by:

$$T_c = T_a + \frac{NOCT-20}{G_{NOCT}}.G \tag{2}$$

$P_{pv,ref}$ *is* the rated power of the PV generator, D_f is the derating factor due to system components, α is temperature coefficient (%/°C), T_a is the ambient temperature (°C), G is the solar irradiance (G = 1 kW/m^2 when applying the 1-sun insolation approach [22]), T_c is the cell temperature (°C), $T_{c,ref}$ is the cell temperature at reference conditions (25 °C), *NOCT* is the Nominal Operating Cells Temperature (47 °C), D_{sh} is the daily average peak sun hour, N_D is the number of days in one year period, G_{NOCT} is the solar irradiance at the NOCT (0.8 kW/m^2).

3.2 Wind turbine output energy model

The adjustment of the wind speed for height is used in the present study following the equation:

$$v_2(y_2) = v_1(y_1) \times \left(\frac{y_2}{y_1}\right)^{\delta} \tag{3}$$

The law power exponent δ is given by [23]

$$\delta = \frac{0.37-0.088\ln(v_1)}{1-0.088\ln\left(\frac{y_2}{10}\right)} \tag{4}$$

The wind output energy calculation model is given by the following relationship [27]

$$P_{WT} = P_{R,WT} \times \left[\frac{e^{-(V_{in}/c)^k} - e^{-(V_r/c)^k}}{\left(V_r/_c\right)^k - \left(V_{in}/_c\right)^k} - e^{-\left(V_{off}/c\right)^k}\right] \tag{5}$$

The shape parameter k is calculated by eq. (6) [16], and the scale parameter c is determined by eq. (8) [28].

$$k = 0.83 \times \overline{V}^{0.5} \tag{6}$$

where

$$\overline{V} = \frac{1}{n}\sum_{i=1}^{n} V_i \tag{7}$$

$$c = \left(\frac{1}{n}\sum_{i=1}^{n}(V_i)^k\right)^k \tag{8}$$

The total annual wind energy produced is given by

$$E_{WT} = P_{WT} \times N_D \tag{9}$$

In the above equations, $P_{R,WT}$ is the total rate power of the wind generator, *n* is the number of data of wind speed, v_1 is the wind speed at hub height y_1, v_2 is the wind speed at the height y_2 (measured data), $\overline{V}$ is the mean of n data of wind speed, V_{in} is the cut-in wind speed (m/s), V_{off} is the cut-off wind speed (m/s), V_r is the rated wind speed (m/s).

3.3 The electrolyzer size modeling

The capacity of the electrolyzer is determined by the following relationship:

$$P_{elz}(kW) = \frac{E_{supply}}{N_D \times \varepsilon_{elz}} \tag{10}$$

where:

$$E_{supply} = E_{pv} + E_{WT} \times \eta_{inverter} \tag{11}$$

ε_{elz} is the utilization factor of the electrolyzer, E_{supply} is the total annual energy supplied to the electrolyzer, $\eta_{inverter}$ is the inverter efficiency.

3.4 The inverter modeling.

The inverter power equation model is defined by:

$$P_{inverter}(kW) = \frac{E_{WT}}{N_D \times \varepsilon_{inv}} \tag{12}$$

ε_{inv} is the utilization factor of the inverter.

3.5 Hydrogen production capacity

The hydrogen capacity production via PV/Wind/Electrolysis is calculated as [29]

$$C_{H2}(kg) = \frac{E_{supply}}{E_{avg,cons}} \tag{13}$$

$E_{avg,cons}$ is the average electrical energy consumption by the electrolyzer.

3.6 The economic modeling

3.6.1 The electricity cost model

The electricity cost is derived from the PV/Wind system energy annualized cost. The net present cost of this system include the initial investment cost (*Inv*), the replacement cost (*Repl*), and the operation and maintenance cost (*O&M*). The different components of the present studied system, for electricity production, are the PV generator, the Wind turbine (*WT*) generator, and the inverter (*invert*).

The net present costs of the aforementioned components are respectively defined by eqs. (14), (15), and (16).

$$Cost_{pv} = \left(Inv_{pv} + Repl_{pv} + \sum_{x=1}^{25} \frac{O\&M_{pv}}{\left(1+\frac{i'-f}{1+f}\right)^{x-1}} - Salv_{pv} \right) \tag{14}$$

$$Cost_{WT} = \left(Inv_{WT} + Repl_{WT} + \sum_{x=1}^{25} \frac{O\&M_{WT}}{\left(1+\frac{i'-f}{1+f}\right)^{x-1}} - Salv_{WT} \right) \quad (15)$$

$$Cost_{invert} = \left(Inv_{invert} + Repl_{invert} + \sum_{x=1}^{25} \frac{O\&M_{invert}}{\left(1+\frac{i'-f}{1+f}\right)^{x-1}} - Salv_{invert} \right) \quad (16)$$

Eq. (17) defines the salvage values (*Salv*) of the different component, where "*component"* could be replaced by *pv, WT,* or *invert.*

$$Salv_{component} = Repl_{component} \times \left(\frac{Life_{component} - \left(\omega - Life_{component} \times floor\left(\frac{\omega}{Life_{component}}\right)\right)}{Life_{component}} \right) \quad (17)$$

The levelized cost of energy (*LCOE*) of the PV/Wind system is defined by

$$LCOE\left(\frac{\$}{kWh}\right) = \frac{(Cost_{pv} + Cost_{wind} + Cost_{inverter}) \times CRF}{E_{supply}} \quad (18)$$

where the capital recovery factor (*CRF*) is given by

$$CRF = \frac{i(i+1)^{\omega}}{(1+i)^{\omega} - 1} \quad (19)$$

and

$$i = \frac{i'-f}{1+f} \quad (20)$$

In the equations above, i' is the nominal interest rate, f is the annual inflation rate, ω is the project lifetime (25 years in the case of this study), $Life_{component}$ *is* the component lifetime, "*floor"* is a MATLAB function to get an integer part of a number.

3.6.2 The hydrogen cost model

The electricity cost, the cost of the electrolyzer, and the hydrogen storage cost, are used to evaluate the levelized cost of hydrogen (*LCOH*) through the eq. (21). The cost of the electrolyzer is given by eq. (22), where the salvage value of the electrolyzer is calculated using eq. (13). The hydrogen storage cost ($Cost_{H2,storage}$) is 0.5 \$/kg of the hydrogen produced [20].

$$LCOH\left(\frac{\$}{kg}\right) = \frac{(Cost_{pv} + Cost_{wind} + Cost_{inverter} + Cost_{elz} + Cost_{H2,storage}) \times CRF}{C_{H2}} \quad (21)$$

$$Cost_{elz} = \left(Inv_{elz} + Repl_{elz} + \sum_{x=1}^{25} \frac{O\&M_{elz}}{\left(1+\frac{i'-f}{1+f}\right)^{x-1}} - Salv_{elz} \right) \quad (22)$$

The details concerning the costs of the system components is presented in table 3. Some used values for simulation are given in table 4.

Table 3

Costs of the key components

DESIGNATION	Initial investment	Replacement cost	O&M cost	Lifetime (year)
PV	1500 $/kW [30]	-----	1% of investment/year [31]	25
Wind	3000 $/kW [32]	3000 $/kW	3 % of the initial investment/year [32]	20
Inverter	715 $/kW [30,31]	715 $/kW	100 $/year [33]	15
Electrolyzer	2700 $/kW [33]	2700 $/kW	3 % of the initial investment/year [34]	20
H_2 storage	0.5 $/kg H2 [20]	------	------	------

Table 4

Parameters used for simulation

Designation	Value
PV rated power	2000 kW
Coefficient temperature	-0.5 %/°C
PV derating factor due to system components	0.7895
Wind turbine rated power	2000 kW
Wind turbine Hub height	67 m
Rated wind speed	16 m/s
Cut-in wind speed	4 m/s
Cut-off wind speed	25 m/s
Electrolyzer average energy consumption	50.283 kWh/kg H_2
Electrolyzer utilization factor	0.85
Inverter utilization factor	0.85
Interest rate	8 %
Annual inflation rate	4%
Project lifetime	25 years

4. Results and discussion

The implementation of an energy system is preceded by the evaluation of the availability of the energy resources in the considered site. Renewable energy sources (including PV and Wind) are used in this study to produce hydrogen via electrolysis. The knowledge of the hydrogen production capacity of Cameroon is an asset to measure the capability of this country to respond efficiently to the hydrogen demand for different applications. The range values of the characteristics of the main components of the designed PV/Wind/Electrolysis system for hydrogen production is presented in table 5, for the ten different localities chosen. When considering the different study sites, it has been demonstrated that, the Weibull parameters k and c, increase when the average wind speed increases too. The output power of the wind turbine is highly influenced by the values of the Weibull parameters. It is shown in table 5 that the yearly total energy produced for the case study, ranges from 2729570 kWh/year to 5044000 kWh/year. The higher total (PV+Wind) energy produced (5044000 kWh/year) has been identified in the locality of Maroua, whereas the lower has been identified in Buea. For the same rated power of PV and wind turbine considered (2000 kW), it comes out from table 5 that, the PV energy produced is more important than the wind energy produced in all the study sites. This result demonstrates that, the solar energy potential of Cameroon is more important than the wind energy potential, for the electricity production. The present study has shown that, 38.327 % of the renewable energy potential of Cameroon (PV and wind) is from the northern part of the country comprising Maroua, Garoua and Ngaoundéré. The capacity of the inverter (converting AC to DC) is related to the wind turbine output power (generating AC output), while the capacity of the electrolyzer is related to the total energy output (both PV and wind energies). It is shown that the size of the inverter increases when the wind output energy increases, and the electrolyzer's size increases when the total energy generated increases.

Table 5

System size and energy generated for a PV/Wind/Electrolysis system

k	c (m/s)	$\overline{V}$ (m/s)	P_{pv} (kW)	P_{WT} (kW)	P_{elz} (kW)	$P_{inverter}$ (kW)	E_{pv} (kWh/y)	E_{WT} (kWh/y)	E_T (kWh/y)
1.25 - 1.97	2.29 - 5.68	2.28 - 5.63	2000	2000	364.18 - 667.5	33.17 - 198.19	2372400 - 3568300	246950 - 1475700	2729570 - 5044000

Table 6 presents the balance concerning the total energy consumed by the electrolyzer to produce hydrogen for the different main localities of Cameroon. The main part of the energy supply is provided by the PV generator ranging from 71.79 % to 92.4 % of the total energy supply. The hydrogen production increases gradually with the increases of the PV/Wind energy supply. The yearly hydrogen production in Cameroon ranges from 53928 kg/year to 98844 kg/year. The most important amount of hydrogen production is in Maroua (98844 kg/year). The hydrogen production from the wind energy represents 7.6 % to 28.21 % of the total hydrogen produced.

Table 6

Energy consumption balance for hydrogen production via PV/Wind/Electrolysis

E_{pv_s} (kWh/y)	E_{WT_S} (kWh/y)	E_s (kWh/y)	E_{pv_s}/E_s (%)	E_{WT_S}/E_s (%)	C_{H2} (kg/year)
2851700 - 3568300	234610 - 1401900	2711700 - 4970200	71.79 - 92.4	7.6 - 28.21	53928 - 98844

The rest of the hydrogen produced (the biggest part) is from the PV energy. It comes out that, the hydrogen production via PV electrolysis is more important in Cameroon than the Wind electrolysis-based hydrogen production.

Table 7 presents the economic balance of the proposed hydrogen production system. It is shown in this table that the levelized cost of hydrogen (LCOH) is proportional to the levelized cost of electricity (LCOE). This means that, the higher cost is the electricity, the higher cost is the hydrogen production too. The hydrogen production cost in Cameroon, via PV/Wind/Electrolysis, ranges from 8.409 $/kg to14.070 $/kg. The lower cost of hydrogen production is in Maroua (8.409 $/kg of hydrogen, corresponding to 0.138 $/kWh of electricity cost), and the higher hydrogen production cost is in Buea (14.070 $/kg of hydrogen, corresponding to 0.251 $/kWh of electricity cost).

Table 7

Economic balance of the proposed PV/Wind/Electrolysis system for hydrogen production

PV cost ($)	***Wind turbine cost ($)***	***Inverter cost ($)***	***Electrolyzer cost ($)***	***H2 storage cost ($)***	***NPC (Net Present Cost) ($)***	***LCOE ($/kWh)***	***LCOH ($/kg)***
3494700	7288800	30921-176570	1194500 - 2189400	26964 - 49422	12048949 - 13198892	0.138 – 0.251	8.409 – 14.070

Table 8 presents the cost contribution of each system component for the different locations considered. The obtained results show that, the costly component of the system is the wind turbine (with a cost contribution which varies from 55 % to 60.49 %), followed by the PV generator (with a cost contribution which varies from 26 % to 29 %), the electrolyzer (with a cost contribution which varies from 9 % to 16.59 %), the inverter (with a cost contribution which varies from 0.25 % to 1.34 %), and the H2 storage (with a cost contribution which varies from 0.22 % to 0.37 %).

Table 8

Cost contribution of the different components of the system

PV cost/NPC (%)	***Wind turbine cost/NPC (%)***	***Inverter cost/NPC (%)***	***Electrolyzer Cost/NPC (%)***	***H2 storage cost/NPC (%)***
26.48 - 29	55.22 – 60.49	0.25 – 1.34	9.92 – 16.59	0.22 – 0.37

A comparative analysis of different options of hydrogen production based on renewable energy source is presented in table 9. The levelized cost of energy varies from 0.062 $/kWh to 0.092 $/kWh, 0.335 $/kWh to 1.965 $/kWh, and 0.138 $/kWh to 0.251 $/kWh, respectively for PV/Electrolysis, Wind/Electrolysis, and PV/Wind/Electrolysis. The levelized cost of hydrogen varies from 4.527 $/kg to 6.09 $/kg (corresponding respectively to a NPC of 5102000 $ and 4563300 $), 18.288 $/kg to 69.859 $/kg (corresponding respectively to a NPC of 8096900 $ and 7485600 $), and 8.409 $/kg to 14.07 $/kg (corresponding respectively to a

NPC of 13198892 $ and 12048949 $) respectively for PV/Electrolysis, Wind/Electrolysis, and PV/Wind/Electrolysis. It comes out that the PV/Electrolysis is economically more profitable than the Wind/Electrolysis and the PV/Wind Electrolysis for hydrogen production in all the study sites considered. However, the PV/Wind/Electrolysis is economically more profitable than the Wind/Electrolysis.

Table 9

Comparison of different options of hydrogen production via renewable energy electrolysis

	PV/Electrolysis	**Wind/Electrolysis**	**PV/Wind/Electrolysis**
NPC ($)	4563300 - 5102000	7425400 - 8096900	12048949 - 13198892
LCOE ($/kWh)	0.062 – 0.092	0.335 – 1.965	0.138 – 0.251
LCOH ($/kg)	4.527 – 6.091	20.429 – 100.224	8.409 – 14.070

5. Conclusions

In this research paper, the hydrogen capacity production via electrolysis using renewable energy sources, in different localities of Cameroon, has been evaluated based on an economic analysis approach. The renewable energy systems used for electricity supply comprise the PV and the Wind generators. It came out that, these localities are qualified for the hydrogen production via the renewable energy electrolysis. This study reveals that, the hydrogen production capacity of Cameroon is enormous in comparison to some other localities worldwide [20]. The locality of Maroua has been identified as the most qualified site for the hydrogen production in Cameroon with the higher capacity and the lower levelized energy and hydrogen costs, whereas the locality of Buea has been identified as the least qualified site with the lower hydrogen production capacity and the higher levelized energy and hydrogen costs. Moreover, a comparative analysis shown that the PV/Electrolysis is economically more profitable in Cameroon for hydrogen production than the Wind/Electrolysis and the PV/Wind/Electrolysis. However, the PV/Wind/Electrolysis is more cost effective than the Wind/Electrolysis. Overall, the hydrogen production cost in Cameroon based on renewable energy sources, including PV and Wind, ranges from 4.527 $/kg (obtained with PV/Electrolysis system) to 100.224 $/kg (obtained with Wind/Electrolysis system). The corresponding electricity cost ranges from 0.062 $/kWh to 1.965 $/kWh. The implementation of the hydrogen energy in different applications could be profitable for Cameroon in particular, and for Sub-Saharan Africa in general.

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