

Review

Law and Policy Review on Green Hydrogen Potential in ECOWAS Countries

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Abstract: This paper aims to review existing energy-sector and hydrogen-energy-related legal, policy, and strategy documents in the ECOWAS region. To achieve this aim, current renewable-energy-related laws, acts of parliament, executive orders, presidential decrees, administrative orders, and memoranda were analyzed. The study shows that ECOWAS countries have strived to design consistent legal instruments regarding renewable energy in developing comprehensive legislation and bylaws to consolidate it and to encourage investments in renewable energy. Despite all these countries having a legislative basis for regulating renewable energy, there are still weaknesses that revolve around the law and policy regarding its possible application in green hydrogen production and use. The central conclusion of this review paper is that ECOWAS member states presently have no official hydrogen policies nor bylaws in place. The hydrogen rise presents a challenge and opportunity for members to play an important role in the fast-growing global hydrogen market. Therefore, these countries need to reform their regulatory frameworks and align their policies by introducing green hydrogen production in order to accomplish their green economy transition for the future and to boost the continent's sustainable development.

Keywords: renewable energy; green hydrogen; green economy; laws and policies; ECOWAS



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1. Introduction

Energy is key to economic growth, and it is crucial for development. Access to affordable and clean energy is a key component to meet sustainable Development Goals for the Economic Community of West African States (ECOWAS) countries, whose vision is to increase the share of renewable energy in the overall electricity capacity to 48 percent by 2030 [1,2]. Over the last decade, ECOWAS members, which comprise 15 countries, experienced an increased population of over 334.6 million people, which represents one-third of Sub-Saharan Africa's total population [3,4]. ECOWAS countries are facing several challenges in terms of access to electricity by their population. Only 42% of the total population and 8% of rural residents have access to electricity [5,6]. The electricity access varies widely, from Niger with an electrification rate of just 13% in 2019 to 96% in Cabo Verde which has achieved nearly universal access. In some countries, such as Sierra Leone and Burkina Faso, the estimated share of rural populations with access to electricity may be as low as 1 to 4% [7]. This low access emanates from a combination of several factors, which may include socio-economic, technical, political, financial, and institutional

policy framework barriers. ECOWAS members can meet their electricity demand through the promotion of green hydrogen because of their huge renewable energy potential. For instance, hydropower potential is sufficient to cover all the energy demands in the ECOWAS countries [8]. The region, throughout the year, also has huge solar energy potential with a very high radiation mean of 5 to 6 kWh/m² [9]. According to IRENA (2018), West Africa's solar potential could reach 20 GW by 2030 [10]. Despite the available renewable resource potential (solar, hydro, and wind), the ECOWAS countries' objective of transiting to a green economy using renewable energy resources still faces constraints that hinder its further economic development.

The transition to a green economy using renewable energy implies strong political engagement, important investment, the modernization of infrastructure systems, and a concerted effort from different scientific disciplines, which is a significant challenge. Therefore, in 2019, as a recommendation of COP21, many countries such as China, France, Japan, and South Korea set investment targets to deploy hydrogen energy technologies globally. In early 2021, more than 10 countries including Australia, Chile, Finland, Germany, Norway, Portugal, and Spain, plus the European Union (EU) developed and adopted hydrogen strategies and roadmaps. This was largely catalyzed by the United Nations Climate Change Conference in Glasgow (COP26) in November 2021 [11]. Nine further countries are expected to unveil their strategies in the near future [12]. The EU hydrogen strategy places particular emphasis on cooperation and complementarities with sub-Saharan African countries as part of its green hydrogen strategy and economic transition. According to Elkhan (2021), the deployment of green hydrogen will bridge the gap between the energy transition between Europe and Africa on the one hand, and climate and development goals on the other [13]. At the same time, ECOWAS countries have entered into global agreements and processes where the green economy is defined explicitly as a Sustainable Development Goal. These are, for example, the decision of the Paris Climate Agreement; the African Union's Comprehensive Strategy on Climate Change; the African Development Bank's Green Growth Framework; UN Sustainable Development Goals (SDG 7); Nations Framework Convention on Climate Change (UNFCCC) in order to move to a low-carbon economy, etc. Further, to facilitate this sustainable green economy transition in ECOWAS countries, appropriate research and development efforts that are transdisciplinary are necessary. Such efforts will be required to update the existing infrastructure and technologies-based fossil fuel and regulations framework concerning green energy policies.

ECOWAS countries have many existing law and policy framework conditions that may boost renewable energy development and other green energy options such as green hydrogen energy. The development of green hydrogen fits perfectly into the global approach towards reducing greenhouse gas emissions and protecting the environment and climate. Indeed, green hydrogen technologies release no greenhouse gases and make it possible to decarbonize several sectors of human activity (transport, combustion, industrial processes, production and storage of electricity) while offering an opportunity for economic growth for West African countries. Investing in green hydrogen energy in the ECOWAS region will be very helpful to achieve the ambitious goal of the European Union (EU), the ECOWAS, and the Union Economique et Monétaire Ouest Africaine (UEMOA) which includes [14]: (i) universal access to sustainable energy services by 2030, (ii) 31% of the share of renewable energy in the electricity mix by 2030 [15]. Hydrogen has the highest specific energy content among all conventional fuels and can be extracted from water. It has been projected that green hydrogen will play a great role in the future scenario of energy sectors [16]. Hydrogen utilization is free of toxic gas formation as well as CO₂ emission compared with other fossil fuels and the energy yield of hydrogen is about 122 kJ/g, which is 2.75 times greater than that of hydrocarbon fuels [17]. This will help decarbonize and help achieve greater green energy and economic transition that lay emphasis on clean energy technologies such as green hydrogen technology.

Additionally, in many ECOWAS countries, the status of renewable energy resources is not clearly defined, but rather incorporated within the competitive and regulatory

frameworks of the electricity or energy sector. This approach poses several challenges for investors wishing to invest in renewable energy projects [18,19]. Based on the over-emphasized gaps in the insecure legislation in the renewable energy sector, there is an urgent need for ECOWAS member countries to clearly define a legal statutory policy for renewable energy resources with robust regulatory laws which will significantly contribute to attracting large-scale investment in the sector.

The research problem is, therefore, to investigate the gaps that exist in hydrogen energy policy and strategies that can meet sustainable development goals on green hydrogen deployment at the national and regional levels. The paper also attempts to examine the policy barriers to the development and the implementation of renewable energy and hydrogen technologies across ECOWAS member countries. The significance of this review is to make recommendations that will guide ECOWAS governments on green hydrogen policy and strategies for the transition to a green economy.

2. Methods

To review the current renewable energy focusing on hydrogen laws and regulation in the ECOWAS region, a review of relevant documentation was carried out based on scientific literature, articles in journals, acts, executive orders, presidential decrees, administrative orders on hydrogen-based energy, web pages, and research platforms. In addition, this paper reviews a large number of reports and information regarding hydrogen and renewable energy law and policy published by the ECREEE, the International Energy Agency (IEA), International Renewable Energy Agency (IRENA), and other reports from research and development institutions that are relevant to the renewable energy and hydrogen economy [20,21]. Comparisons of energy policies and legislation of countries were also carried out. The selected countries included Benin, Burkina Faso, Cabo Verde, Cote d'Ivoire, The Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Niger, Nigeria, Senegal, Sierra Leone, and Togo.

As a rule, this review paper recommends improving the performance of current renewable energy strategies by using new opportunities like green hydrogen. The paper will be useful in helping decision-makers and stakeholders to have a better overview of the concept of hydrogen energy to facilitate access to clean and affordable electricity by the population. In order for more detail, the different stages undertaken for this review are explained below:

Stage 1: Reviews the different policies and laws concerning renewable energy and hydrogen energy in the fifteen (15) ECOWAS countries for the promotion of hydrogen deployment.

Stage 2: Review of policies that support green hydrogen promotion and avoid barriers to hydrogen development.

Stage 3: Evaluates the general energy policies in all the ECOWAS countries, which will allow policymakers and investors to know more about each country's energy gaps and uncertainties, which needed to be addressed.

Stage 4: Establishes the significant role of government and policies in the development of renewable energy and the hydrogen economy. This will help respective governments to know their responsibilities and the importance of achieving their energy target.

Stage 5: Explains the significance of renewable energy and hydrogen energy concerning UN SDGs, and how the use of hydrogen-based energy can achieve their energy target by 2030.

Stage 6: Gives strategies that can be used to accomplish green hydrogen policy formulation in ECOWAS countries.

3. Status of Hydrogen Energy in ECOWAS

Currently, the West African Science Service Centre on Climate Change and Adapted Land Use (WASCAL) produces the Atlas of Green Hydrogen Generation Potential (H2Atlas) in fifteen (15) West African countries. The H2Atlas–Africa project is funded by the Ger-

man Ministry of Education and Research BMBF's Energy and Hydrogen Technologies Department [22]. It is estimated that many ECOWAS countries have very good prerequisites to produce green hydrogen. The region's potential was estimated at up to 165,000 terawatt-hours of green hydrogen per year, which is about 1500 times Germany's estimated hydrogen demand for 2030. It was also estimated that in ECOWAS countries three-quarters of the land area is suitable for wind turbines. By using wind and solar energy, ECOWAS countries could produce up to 165,000 terawatt-hours of green hydrogen annually, 120,000 terawatt-hours of which could already be produced for less than 2.50 euros per kilogram compared with 7–10 euros/kg in Germany [23]. Green hydrogen offers a real opportunity to initiate development in the ECOWAS region that will make the region a global green hydrogen powerhouse, and will also help member states meet their energy needs and benefit economically from the export of green hydrogen. To support local capacity in this regard, WASCAL, in partnership with RWTH Aachen University and Forschungszentrum Jülich GmbH, took up the topic of hydrogen in its newly created Master's Programme in Energy and Green Hydrogen, which admits students from all ECOWAS member states [24].

3.1. Review of Hydrogen-Related Laws and Policies in ECOWAS

In the coming years, hydrogen, produced with renewable electricity, is projected to grow rapidly. Many ongoing and planned projects across the world point in this direction. Hydrogen from renewable power is already technically important and is rapidly becoming economically relevant for the global energy transition. For Africa to be part of this global movement towards green hydrogen, it is important to create legislative frameworks that facilitate hydrogen-based sector coupling. However, in common with many jurisdictions, the fifteen ECOWAS members do not yet have official hydrogen policies fully in place. The lack of a legislative framework creates many gaps and uncertainties, which need to be addressed before the hydrogen economy can start to flourish in the region. ECOWAS members need a dedicated new legislative framework for renewable hydrogen production which may facilitate its deployment and the related economic benefits. Although in many ECOWAS countries there exist specific laws that deal with renewable energy, the level of intervention and implementation remains a challenge and varies from country to country.

Benin. Law No. 2020-05 of 1 April 2020 guides the energy policy in Benin. It describes new-generation capacity regulations with the aims of promoting renewable energy sectors and increasing their share in the energy mix in order to improve the rate of national energy independence. The idea behind this law is for the government to promote all sources of renewable energies and, in particular, the promotion of technologies for the enhancement of local energy resources. This is based on in-depth knowledge of the real potential of renewable energies and on the existence of adequate human resources in setting up an environmental regulation policy conducive to its implementation. This law grants subsidies, tax advantages, or guarantees to companies, enterprises, and establishments that undertake to produce or promote the production of electricity from renewable energies. Therefore, the import, purchase, or acquisition of materials and equipment intended for the production and exploitation of electricity based on renewable energies and those intended for research and development in the field of renewable energies benefit from a total exemption of taxes except for road taxes, statistical tax, and community taxes (LOI No 2020-05, 2020). On these, an indicative program is adopted every five (05) years by the Council of Ministers in charge of energy. In addition, this law gives greater allocation to the development of energy efficiency and renewable energy but gives no explicit allocation for green hydrogen technology.

Burkina Faso: In Burkina Faso, Law No. 014-2017/AN of 20 April 2017 and Law no. 058-2017/AN of 20 December 2017 were established for renewable energy promotion and regulations. These laws fixed the conditions of eligibility to the exemption from tax on imports and sales of solar equipment and materials. The innovation under these laws is to achieve 50% renewable energy in the electricity mix by 2030 and increase the share in urban

and rural electrification rates by 95% and 50% for 2030, respectively. For this, the share of renewable energies, excluding biomass for cooking needs, will reach 50% of the electricity mix in 2030 in terms of capacity. Therefore, the installed PV capacities would increase from 65 MW in 2015/16 to 205 MW in 2030 [25]. However, concerning hydrogen-based energy, Burkina Faso lacks a clear act or policy framework on hydrogen energy strategy.

Cape Verde: In Cape Verde the government established Decree-Law No. 14/2006 of 20 February and Law no. 39/2019 of 8 April, to guide the renewable energy policy framework. This law aimed to boost and target electricity production from renewable energy sources by 2025 and 2030, and set commitments for wind and solar energy use, promotion of energy efficiency, and combating energy losses. Furthermore, the government has decided on the inclusion of 50% renewable energy in the energy mix as a target for 2030 [26].

Côte d'Ivoire: In Côte d'Ivoire, Decree No. 2016-862 of 03 November 2016 was enacted to grant tax and customs benefits on renewable energy equipment, and projects that contribute to the improvement of energy efficiency. For the implementation of these laws, the Ivorian state has decided to double the rate of improvement of energy efficiency by 2030. By 2030, national objectives have been set to improve access to energy by the population, to improve the level of renewable energies, and to increase energy efficiency. To achieve this, indicators have been identified to assess the actions to be taken. This is a 42% increase in the energy mix from renewable energies to meet electricity consumption, as well as a 26% increase for large and medium hydraulics, and 16% for various other renewable energy sources by 2030

The Gambia. The renewable energy sector in the Gambia is governed by the Bill/Act of 2013, which establishes a legal, economic, and institutional basis to promote the use of renewable energy resources and for connected matters. Furthermore, the Ministry of Energy has developed an energy strategy that facilitates the use of renewable energy resources for both power and non-power applications from import duty. The Act guides all renewable energy equipment that fulfills the eligibility to be exempted from value-added and any other retail tax for fifteen years from commissioning, and all proceeds from the sale of carbon emission credits shall be exempt from sales taxes [27]. Nevertheless, Gambia lacks a clear Decree/Act/Bill on renewable energy.

Ghana. Act 832 in Ghana provides for the development, management, and utilization of renewable energy sources for energy production in an efficient and environmentally sustainable manner. The Act was legislated in light of the policy direction and with the specific objective of accelerating the development and utilization of renewable energy technologies to achieve a 10% penetration of national electricity by 2020. Electricity generation capacity from renewables is projected to reach 1353.63 MW by 2030 which will contribute to the creation of 220,000 jobs, and carbon savings of about 11 million tonnes of CO₂ by 2030 [28]. Act 832 stipulates that fossil fuel-based wholesale electricity suppliers, fossil fuel producers, and any other companies that contribute to greenhouse gas emission shall invest in non-utility scale renewable energy to offset greenhouse gas emissions and mitigate the impact of climate change [29].

Guinea. Guinea has adopted law No 2014/30/1/6/1/2/N on the appropriate fiscal policy for the implementation of energy-saving measures for the promotion of renewable energies. For this, the state grants bonuses, subsidies, or loans at subsidized rates on renewable energy equipment by reducing customs duties to minimum rates and exemption from import VAT [30]. Nevertheless, the country lacks a clear Decree/Act on renewable energy.

Guinea Bissau. In Guinea Bissau, the legislative framework is composed of two laws that regulate the energy and electricity sector, namely Decree-Laws No. 2/2007 and 3/2007. Decree-Law No. 2/2007 defines the structure of the energy sector, its organization, and the provisions that apply to the different forms of energy. Decree-Law No. 3/2007 regulates the production, transport, distribution, import, and export of electrical energy within the country. However, no specific fiscal and investment frameworks or provisions exist for the energy sector currently. As the country disposes of several renewable energy resources

such as solar, hydropower, and biomass, the exploitation of these resources will enable the country to reach its ambitious targets of installing more than 70 MW of renewable capacity by 2030. According to the government off-grid systems, with 80% penetration of renewable energy, this will contribute to meeting 100% of the demand by 2030 [31].

Liberia. On July 6, 2015, the Liberian government established a wholly autonomous Rural and Renewable Energy Agency (RREA). The RREA aims at addressing the challenges faced by the energy supply in rural areas. The RREA operates to ensure universal access to modern energy services in an affordable, sustainable, and environmentally- friendly manner in order to foster the economic, political, and social development of Liberia.

Mali. The development of renewable energies (RE) appears to be a priority in Malian public policy and strategic framework for growth and poverty reduction. Mali has several strategies, policies, acts, and regulations governing renewable energy. These include the following:

- The Malian Agency for the Development of Domestic Energy and Rural Electrification (AMADER), established by Law No. 03-006 of 21 May 2003. The vision is to implement the policy and regulatory framework of rural electrification and domestic energy.
- Mali Renewable Energy Agency (AER-Mali), established by Decree No 2015-0049/P-RM of 6 February 2015. AER is mandated for the popularization and promotion of clean energies in Mali. It works to enable an ecological transition and also to expand the use of renewable energies by facilitating its access to a large majority of the Malian population [32].
- Regulation, Electricity, and Water Commission (CREE), created by Law No 00-185/P-RM of 14 April. 2000 is responsible for regulating the electricity sector and the public drinking water service in urban centers. The Act mandates CREE to issue licenses to support the development of the public electricity and water service; defend the interests of users and the quality of public service; promote and organize a competition between operators [33].
- National Directorate of Energy (DNE), created by Law No 99- 0 1 3 IP-RM OF 01 April. 1999's mission is to develop the elements of national energy policy. Its vision is to increase the national electrification rate to 87% by 2030 (42% in 2017, source: DNE); and the share of renewable energies connected to the grid would be 977.4 MW or 52.5% by 2030 (including 538 MW of solar; 389 MW of hydroelectricity; 20 MW of wind; and 30 MW of bioelectricity [34]).
- National Energy Policy (PEN), adopted in 2006, with the aim to balance energy availability and national socio-economic development needs, foster synergy between the major energy sector stakeholders, and guide their interventions.
- National Strategy for Renewable Energy Development, adopted in 2006, aims to promote the widespread use of renewable energy technologies and equipment. It is intended to increase the share of renewable energy in national electricity generation and also to develop biofuel, and create better conditions to sustain renewable energy services. It further aims to search for sustainable and suitable financing mechanisms for renewable energy in Mali.

Niger. In Niger, the energy sector is governed by the Electricity Law No. 2016-05 of 17 May 2016, implemented by the Minister in charge of Energy. This law ensures the implementation of the entire energy policy framework and regulations, as well as increased financing for the country's energy and economic growth. The law established a fund that domiciles in an account at the Banque Centrale des États de l'Afrique de l'Ouest (BCEAO) for the financing of renewable energies and the control of electrical energy. These funds, for instance, consist in particular of state subsidies; the contribution of the carbon tax; and part of the cost of controlling renewable energy equipment. Therefore, due to the importance of renewable energy, the government of Niger is projecting an increase in the national electrification rate to 65% by 2030 (currently at 10%). This includes targets for 30% renewables in the national energy mix by 2030 (150 MW from grid solar; 100 MW from off-grid solar; 20 MW from wind) [35].

Nigeria. The Nigerian Electricity Regulatory Commission, through Act No. 6 of 2005, made the Regulations on Feed-In-Tariff for Renewable-Energy-Sourced Electricity to develop, promote, and harness the Renewable Energy (RE) resources of the country and incorporate all viable ones into the national energy mix. The commission is also intended to enhance the attainment of the national targets on renewable-energy-sourced electricity. Due to the restricted access to electricity supply in the largely off-grid rural areas of Nigeria, the Federal Government developed the Nigerian Renewable Energy and Energy Efficiency Policy (NREEEP) to facilitate its plan to utilize renewable energy as an alternative source of electricity for off-grid rural areas. The NREEEP therefore generally aims to set out a framework for action to address Nigeria's challenge of inclusive access to modern and clean energy resources, improved energy security, and climate objectives. Nigeria has several national policies and action plans on renewable energy and energy efficiency. These include:

- National Energy Policy (NEP) created in 2003 (revised 2006 and 2013). It covers all aspects of the energy sector, including renewable energy, energy efficiency, and rural electrification. It defines, among other aims, a national target for 75% electrification rate by 2020 and a reduction in electricity generation, transmission, and distribution losses from 15–40% in 2013 to less than 10% by 2020 [36].
- National Renewable Energy Master Plan (REMP) created in 2005 (revised 2012). The REMP was developed by the Energy Commission of Nigeria (ECN) in collaboration with the United Nations Development Programme (UNDP) and was later revised in 2012. The REMP sets out Nigeria's roadmap for increasing the national deployment of renewable energy and promoting sustainable development [37].
- Rural Electrification Strategy & Implementation Plan (RESIP) created in 2006 (revised 2014). It aims to expand electricity access in a cost-effective way, for both off-grid and on-grid electricity supply. One tool for achieving this is to focus subsidies on expanding access rather than on electricity consumption. The RESIP includes targets for 75% and 90% electricity access by 2020 and 2030, respectively, with at least a 10% renewable power share by 2025 [38].
- National Energy Master Plan (NEMP) created in 2007 (revised 2014). It covers all energy sources, energy consumption, capacity development, energy financing, energy databases, and the project cycle (planning, implementation, and monitoring and evaluation). The NEMP sets targets for a share of renewable energy (excluding large hydro) in the national energy sector of 10.6% in the long term (2016–2030) [39].
- National Biofuel Policy and Incentives created in 2007. This policy is aimed at creating a viable biofuels industry, reducing the nation's dependency on gasoline, and reducing pollution of the environment [40].
- Sustainable Energy for All (SEforAll) Action Agenda developed by the Federal Ministry of Power. The document provides useful information on energy access and energy efficiency as well as the renewable energy potential and market in Nigeria and relevant policies and barriers to be overcome [41].
- National Energy Efficiency Action Plan (NEEAP) created in 2016. It sets targets for energy savings and proposes actions for meeting the set targets. The NEEAP targeted 40% and 100% efficient lightening in households by 2020 and 2030, respectively; and efficient energy increase by 20% and 50% in the transport, power, and industrial sectors by 2020 and 2030, respectively [42].
- Intended Nationally Determined Contribution (INDC) approved in 2015. The INDC set conditional and unconditional objectives as 20% and 45%, respectively, and targeted 13 GW solar PV off-grid in the Nigeria electricity mix by 2030, with an annual increase in energy efficiency from 2% to reach 30% by 2030. [43].

Senegal. For the promotion and development of renewable energies, Senegal has put in place an appropriate legal framework, and sufficient incentive to allow the production in sufficient quantity, storage, and transport, as well as the marketing of these products throughout the national territory. Thus, Law No. 2010-21 on the Orientation of Renewable

Energies emphasizes the promotion of renewable energies by granting a total exemption on the acquisition of materials and equipment intended for production of renewable energy for domestic self-consumption, and also tax incentives for the acquisition of materials and equipment intended for production, operation, and research and development in the field of renewable energies (Loi No 2010-21, 2010).

Sierra Leone. In Sierra Leone, the electricity sector and water regulatory commission are governed by the National Electricity Act (2011). This was established on the basis of furthering renewable energy development to attract private investments, extending electricity to rural and remote areas, increasing the percentage contribution of solar energy to the total energy mix, improving healthcare, and enhancing other human services. In addition, the law commits the government to take numerous enabling measures to ensure that renewable energy becomes a significant part of its energy portfolio over the next fifteen years.

Togo. In Togo, Law No 2018-010 establishes the legal framework governing the equipment/materials, installations, and other necessary infrastructure for the production, storage, transport, distribution, marketing, and consumption of electricity based on renewable energy sources. For instance, Law No. 2018-010 in its Title II, articles 16 and 17 highlights this in the three (3) legal regimes for electricity production projects based on renewable energy sources. However, the system of declaration and freedom is applied to the activities of production of electrical energy based on renewable energy sources intended for the needs of clean consumption without injection into the national electricity grid. The Togolese government also grants tax and customs exemptions of up to 10 years for projects to build power plants and infrastructure based on renewable energy sources used for their own needs or the sale of electricity [44].

3.2. Policy Support for Hydrogen Energy

The deployment of hydrogen worldwide is facing several barriers through production, infrastructure, market, industry (see Table 1). The development of hydrogen requires policies in place to support its deployment. The lack of an existing hydrogen value chain represents one of the major obstacles to overcome for the development of the green hydrogen economy. Table 1 groups the types of barriers that hydrogen has to overcome in order to be the next energy paradigm into five blocks. The different elements (i.e., technological, infrastructure, industry, shipping, aviation) interact with each other, creating new and harder barriers for hydrogen deployment. As a preliminary example, one of the hydrogen problems is its electrolyzer [45], which is a technological barrier, but to avoid this barrier, investment is needed, and this investment has to be funded by an African investment bank. The lack of infrastructure for hydrogen production, storage, and transportation has been identified as the greatest challenge to market expansion. The electrolyzer and infrastructure barriers can easily be overturned if there are sufficient economic incentives for producers to research further in order to find a solution; these incentives will be only generated if a market for hydrogen exists, and if it is profitable for investors [22,45].

Table 1. Barriers and policies for hydrogen value chain [19].

Barriers	- Capital cost	- Limited existing infrastructure	- High cost	- High cost	
	- Electricity cost	- Technical limitations of users	- Lack of demand for green products	- Procurement of sustainable CO ₂	- High cost
	- Lack of hydrogen market	- Lack of investment	- Global competition and carbon leakage	- Policy focus on biofuels	- Technical barriers
	- Barriers to power market				

Table 1. *Cont.*

	ELECTROLYSIS	INFRASTRUCTURE	INDUSTRY	AVIATION	SHIPPING
Policy Options	<ul style="list-style-type: none"> - Set capacity targets - Offer loans - Introduce feed-in premium - Allow participation in ancillary markets 	<ul style="list-style-type: none"> - Collaborate on global trading of hydrogen - Identify priorities for conversion - Align blending targets - Provide financing 	<ul style="list-style-type: none"> - Offer dedicated loans - Develop public procurement of green products - Phase out high emission technologies 	<ul style="list-style-type: none"> - Set targets - Review policy focus - Expand emissions trading system 	<ul style="list-style-type: none"> - Introduce fiscal incentives - Set targets for zero-emission vessels - Support infrastructure development

4. Results and Discussion

Table 2 shows general review of the energy policies in all the ECOWAS countries. It shows that in all ECOWAS countries there exist specific laws that deal with renewable energy. The level of intervention of each institution concerning renewable energy is well articulated in the legal text. Nevertheless, ECOWAS members currently have no official hydrogen policies in place. Such policy regulation is necessary for encouraging the generation of green energy.

Table 2. ECOWAS Energy Policy Evaluation.

	Energy Policy	Renewable Energy Policy	Hydrogen Energy Policy	Hydrogen Energy Initiative
Burkina Faso	Yes	Yes	No	No
Benin	Yes	Yes	No	No
Cape Verde	Yes	Yes	No	No
Cote d'Ivoire	Yes	Yes	No	Yes
Gambia	Yes	Yes	No	No
Ghana	Yes	Yes	No	No
Guinea	Yes	Yes	No	Yes
Guinea Bissau	Yes	Yes	No	No
Liberia	Yes	Yes	No	No
Mali	Yes	Yes	No	Yes
Niger	Yes	Yes	No	No
Nigeria	Yes	Yes	No	No
Senegal	Yes	Yes	No	No
Sierra Leone	Yes	Yes	No	No
Togo	Yes	Yes	No	No
ECOWAS	Yes	Yes	No	No

4.1. The Role of Effective Government Structures and Policies in the Development of Renewable Energy and Hydrogen Economy

The development of green hydrogen in ECOWAS countries requires a sincere partnership between governments and businesses, and national and international cooperation. This partnership will allow a good energy transition in the region towards a green hydrogen economy and will allow a fundamental modification of the economic relations of countries around the world. Significant and effective implementation of relevant supporting policies of governments in the development of the hydrogen economy will be necessary, at least until ECOWAS economies are ready to support the expectation of the population and the market forces. Government action can accelerate the development and deployment of

green hydrogen. Governments must participate in research and development as well as investment in infrastructure. Investment here must be clearly in the realm of government, which will bring dividends. Policymakers at all levels, both regional and national, must legislate and adopt development strategies and encourage investment in energy-efficiency and renewable energy technologies. Renewable energy and green hydrogen targets must be paired with specific policy mechanisms designed to help meet national goals. In addition, practical and strategic investment in infrastructure must be addressed.

However, governments should know that one country's action alone will not bring enough about a hydrogen economy; therefore, there must be a collaboration between the country's governments and private organizations at all jurisdictions for establishing a long-term plan and the creation of a viable green hydrogen energy market. Therefore, the conceptions of governance will need to shift and adapt for developing public awareness and educating communities about the relevant safety and standards surrounding green hydrogen production and use. The role of effective government must be to restructure its regulation and law to provide much stronger economic incentives for the adoption of renewable electricity targets to outline sectorial development priorities. While developments in green hydrogen energy in the region are almost non-existent, green hydrogen implementation in the region will enter into commercial use as a storage medium to buffer intermittent renewable electricity supplies in the energy sector.

4.2. The Significance of Renewable Energy and Hydrogen Energy Concerning UN SDGs

The most significant effort to balance the increasing needs of energy in ECOWAS countries aligns with the UN Sustainable Development. ECOWAS regions are disproportionately underdeveloped due to extreme energy poverty and poor governance. The increased demography and resource requirements for energy responses coupled with the economic downturn and poor governance are likely to further constrain the available finance for energy investments and further heighten the risk of energy insecurity in ECOWAS member countries. Against this background, further solutions need to be found on the one hand by minimizing the use of non-renewable energy, and on the other hand by developing new global solutions using environmentally friendly sources and technologies. This would significantly contribute to the resilience and achievement of the UN Sustainable Development Goals (SDG 7) in the ECOWAS region. Building resilience requires a broader focus that addresses multiple dimensions of energy efficiency and securities. Therefore, renewable energy and green hydrogen production in the region have the potential to become key components. Scaling renewable energy for hydrogen production in the ECOWAS region can lead to significant opportunities for additional employment, especially for youth and women, which will allow countries to achieve the Sustainable Development Goal. Most of this employment will require skills, education, and training which need to be enhanced rapidly for the rapid deployment of the generated hydrogen [46]. Nevertheless, the region still lacks decision support on the decarbonization of the energy system through green hydrogen production, which was one of the key political goals of the Paris Agreement for the mid-21st century.

5. Policy Recommendation

ECOWAS countries have a vast potential for renewable energy generation at relatively low costs. Hydrogen production could leverage socio-economic opportunities in the region and provide local industries with green e-fuels and chemicals. It also opens new perspectives for exports and revenue-raising. However, a strong legal, regulatory, and institutional framework with a Framework Act is needed as a basis for attracting and encouraging private investment as well as providing financial incentives. To accomplish green hydrogen policy formulation in ECOWAS countries, governments would need to take up the following measures:

- At the regional level a clear vision of hydrogen energy policies needs to be put in place by members to achieve their energy targets. This can be done by combining

efforts by identifying countries with a comparative advantage in renewable energy resources potential for green hydrogen production to support future energy needs for other countries. This collaboration and cooperation action will be to accelerate the development and deployment of green hydrogen and increase the amount of hydrogen gas that can be produced through electrolysis.

- Mapping the fifteen countries' existing infrastructure for future hydrogen storage and export and treating hydrogen as part of an integrated energy system.
- ECOWAS members must create a sub-regional partnership for hydrogen economy (SPHE) to foster intergovernmental cooperation on hydrogen. The objectives of the Sub-regional Partnership for Hydrogen Economy for ECOWAS (SPHE) must be to accelerate progress in hydrogen technologies and share information, resources, and infrastructure among member states. This partnership can also lead to exchanges in terms of initiatives, policies, and technology status, as well as on safety, regulations, codes, and standards. Its aims will also be to enhance public institutional finance to support research and development as well as investment in the technology.
- ECOWAS members should harmonize the regulatory framework by the implementation of a sound legal policy to attract large-scale investment and help hydrogen energy project developers develop investor confidence. Clear legal and regulatory renewable hydrogen production guidelines will contribute to stable and predictable energy production and distribution which attracts both local and international investors. It can provide a framework for the investors and can provide incentives to encourage greater investment.
- Close collaboration between ECOWAS countries and developed countries which have advanced in hydrogen technologies, as well as partnership between the public and private sector along the entire value chain. A consensus on the pivotal role of the private sector needs to be put in place for green hydrogen development and to encourage the flow of international investments. The consensus must include premium prices for green products, carbon taxes, quotas, standards, guarantees of origins, and tax incentives.
- Clear social and ecological criteria for the import of green hydrogen must be defined by the ECOWAS countries. Although the huge production possibilities for cheap green hydrogen have been emphasized by the government, the transport question and its costs need to be clearly defined.
- Priority should be given to the utilization of both the available renewable energy resources and the produced green hydrogen in ensuring that basic and affordable access to electricity is guaranteed for all the local people within ECOWAS. The option of export of green hydrogen or its derivatives should be considered if the former has been addressed.
- Strengths, weaknesses, opportunities, and threats (SWOT) of hydrogen deployment must be explored. These include:
 - ✓ develop green hydrogen economy with comprehensive legislation;
 - ✓ implement specific laws for safety and stability for utilization of hydrogen;
 - ✓ promote the use of hydrogen energy by stimulating public acceptance;
 - ✓ promote regulated hydrogen economy and green economy;
 - ✓ encourage research, innovations, and development;
 - ✓ encourage investment and development in hydrogen technology;
 - ✓ encourage funding programs by the government;
 - ✓ encourage the government to develop strategies to increase competition between renewable energy resources and non-renewable energy; and
 - ✓ encourage the government to privilege public investments to financially support hydrogen economy projects.

Furthermore, these policy strategies will help decision-makers to enhance and guide green energy transition deployment in the ECOWAS countries and the integration of green hydrogen within this mix.

6. Conclusions

In ECOWAS countries, energy demand, which mainly relies on fossil fuels such as petrol and natural gas, as well as thermal and hydro, is becoming difficult to fulfill population demands and are also causing environmental damage. Therefore, these fossil fuels need to be replaced gradually by alternative renewable energy resources such as green hydrogen energy, solar energy, and wind energy. Green hydrogen is expected to play a significant role in a future climate-neutral economy, enabling zero carbon emission. It enables investment in sustainable energy infrastructure for generating green energy. Since the hydrogen-based energy sector has not yet taken off in the region, there is a need for policymakers to elaborate a clear and strong hydrogen energy legislation roadmap for future energy strategies. This legislation must take into account the country's level of ambition and how hydrogen will meet the social, economic, and environmental objectives to achieve the UN Sustainable Development Goals (SDG) in the ECOWAS region. In addition, national governments need to formulate policies and provide support framework around the following measures in order to achieve hydrogen deployment:

- continue financing Research and Development (R&D) to explore the potential application of hydrogen energy. The scientific research and development will require significant investment for the development of hydrogen energy technologies.
- elaborate on the cooperation among all stakeholders: energy actors, Research Development centers, industry partners, investors, international partners, and politicians. This cooperation should be made attractive by providing a win-win situation for all.
- implement specific laws that address safety and stability issues for the promotion of hydrogen.
- establish green hydrogen as a key player in the energy mix by identifying its contribution to national and regional energy strategies. Incorporate technical, political, and legal concepts to make this possible.
- increasing access to clean and affordable electricity should be considered a priority. This should be addressed by harnessing the huge renewable energy resources within the region. These resources should also be explored for green hydrogen production for both local use and for export.

It can be said that hydrogen has the potential to alter the ECOWAS regions' economic and political structure in ways more profound than any previous energy options. A clear regulatory, policy and legal framework that supports and enables its deployment is needed to make this happen.

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