

NIGERIA HYDROGEN MARKET UPDATE REPORT

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Foreword

This report is a publication of Clean Technology Hub. It was written and produced by Abigail Adaramola, Abel B.S. Gaiya, Ifeoma Malo and Samantha Kaiser. It was compiled using both primary and secondary sources such as meetings with key stakeholders, published reports, new reports, and online sources, and is intended to give stakeholders a snapshot of recent major developments in the green hydrogen sector in Nigeria.

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Abbreviations

AGHA	African Green Hydrogen Alliance
AHP	African Green Hydrogen Partnership
CAGR	Compound annual growth rate
CCS	Carbon Capture and Storage
ECOWAS	Economic Community of West African States
ECREEE	ECOWAS Centre for Renewable Energy and Energy Efficiency
ECN	Energy Commission of Nigeria
FCEVs	Fuel Cell Electric Vehicles
GDP	Gross Domestic Product
GIZ	Germany's main international development agency, Deutsche Gesellschaft für Internationale Zusammenarbeit
GW	Gigawatt
IEA	International Energy Agency
LCOH	Levelized Cost of Hydrogen
MW	Megawatt
NGTC	Nigerian Gas Processing and Transportation Company
NNPC	Nigerian National Petroleum Corporation

PV	Photovoltaic
PtX	Power-to-X product
REEEA-A	Renewable Energy and Energy Efficiency Association Alliance
R&D	Research and Development
TWh	Terrawatt hour
WAGP	West African Gas Pipeline
WASCAL	West African Science Service Centre on Climate Change and Adapted Land Use

Executive Summary

The energy industry accounted for 78.4% of global CO2 emissions in 2016. The need for its decarbonization has moved a lot of attention to hydrogen as a fuel option, particularly for hard-to-abate sectors such as aviation, steel, and other heavy industry. In 2021, the global hydrogen-generating market was worth USD 129.85 billion, and it is predicted to increase at a compound annual growth rate (CAGR) of 6.4% from 2022 to 2030.

Hydrogen is being widely promoted because it has the potential to compensate for the intermittency of energy from renewables like solar photovoltaics (PV) and wind, the supply of which does not always meet demand. Hydrogen is mostly employed in oil refining and fertilizer production, as well as transportation, construction, and power generation. Hydrogen is adaptable; it can produce, store, move, and utilize energy in a variety of ways utilizing existing technologies. Hydrogen can be created using a variety of technologies, including renewables (green hydrogen), nuclear, natural gas (blue hydrogen), coal, and oil.

Nigeria has significant green hydrogen production potential, due to the availability of land, water and renewable energy resources. The areas with the highest technical maximum technical green hydrogen potential per area (Kaduna, Kwara, Oyo and Borno states) are likely to have Levelized Cost of Hydrogen between 2 USD/kg to 2.4 USD/kg by 2050.

As the cost of green hydrogen declines globally, several African countries are beginning to build capabilities and partnerships in the sector. There is comparatively muted activity in Nigeria. The Nigeria Energy Transition Plan's place for hydrogen for decarbonizing ammonia production sees its viability after 2030. There is no hydrogen policy in the country, despite the efforts by German actors to open the way for German-Nigerian hydrogen partnership to stimulate Nigerian green hydrogen exports to Germany.

Nonetheless, there is some ongoing activity by the Energy Commission of Nigeria (ECN) and the Federal Ministry of Power to promote policies and regulations to ensure the delivery of renewable energy for green hydrogen production at least possible costs. Several companies have also begun conducting feasibility studies and are having discussions on a pilot hydrogen plant in Nigeria. Yet no major concrete announcement has been made unlike member countries of the Africa Green Hydrogen Alliance (AGHA) and Angola.

To achieve decarbonization in various sectors and find alternatives to fossil fuels in the electricity industries, there is a need to provide an enabling policy and framework for investors and potential partners to ensure that binding constraints are resolved. Hydrogen policies

should target industrial applications. Within Nigeria, there are no policies that encourage hydrogen. A hydrogen policy must include:

- Clear land and water use regulations to protect communities and populations against disruptive resource use by green hydrogen developers, and to encourage an integrated approach to water resource use.
- The support of Research and Development (R&D) and provision of more accessible data for research. Public R&D funding can pivot research activities to encourage technology development that will benefit the national industry.
- The need for building capacity and well-known technical know-how and upskilling of local talent. By building capacity, infrastructure, and skills, these mutually supportive opportunities can help to scale up infrastructure development, enhance investor confidence, and lower costs.
- Provide financial and fiscal support to address investment risks of first-movers. New applications for hydrogen, as well as clean hydrogen supply and infrastructure projects, stand at the riskiest point of the deployment curve. Targeted and time-limited loans, guarantees, and other tools can help the private sector to invest, learn and share risks and rewards. This should reduce the cost gap between green hydrogen and mature fossil fuel technologies.
- Health and safety regulations in the production, transportation, storage and use of hydrogen, and the quality that relevant infrastructure and technologies need to possess.
- Deployment of a regulatory agency to oversee the development of hydrogen. The development of hydrogen requires policies in place to support its deployment.



1. Introduction

The global climate crisis has brought more emphasis on finding viable solutions to decarbonize a wide variety of sectors including finding alternatives to fossil fuels. While renewable energy sources such as solar, wind, and hydropower have grown in use and prioritization, they are difficult to embed in several industries, including aviation, shipping, transportation, buildings, steel, petrochemicals, and manufacturing industries. Since energy and industry account for 78.4% of global CO2 emissions in 2016, their decarbonization is critical.[1] Moreover, they still require improvement in efficiency and durability as renewable resources are not available in constant quantities. There is a need for lasting solutions that enable renewable energy transfer across sectors and address the challenge of storage and transport of energy generated from renewable sources.

Hydrogen-based fuels can play an essential role in solving these challenges. Hydrogen can be categorized into four major categories: grey, brown, blue, and green. What distinguishes them from one another are their production processes. Grey hydrogen is produced from burning natural gas or petroleum and brown hydrogen is made from the burning of coal. These hydrogen options are not ideal when targeting decreased greenhouse gas emissions. On the other hand, blue hydrogen is produced by splitting natural gas into hydrogen and carbon dioxide; the carbon is prevented from escaping into the atmosphere by using carbon capture and sequestration technology. Green hydrogen is produced from clean energy sources and involves splitting water into hydrogen and oxygen. Its low carbon-intensive generation process has made it a preferred solution over other types of hydrogen in terms of achieving net zero emissions targets.

Hydrogen can be seen as an energy carrier as the production process is built off of other energy sources. Green hydrogen in particular can be used in combination with renewable energy to transfer and store energy to solve the intermittency concerns associated with renewables. It is economically produced in locations that have an optimal combination of abundant renewable resources, access to water, abundant renewable resources, and the ability to transport and export hydrogen and hydrogen products to large demand centers.

[1] Hannah Ritchie and Max Roser (2020). "CO_2 and Greenhouse Gas Emissions", Our World in Data. https://ourworldindata.org/emissions-by-sector.

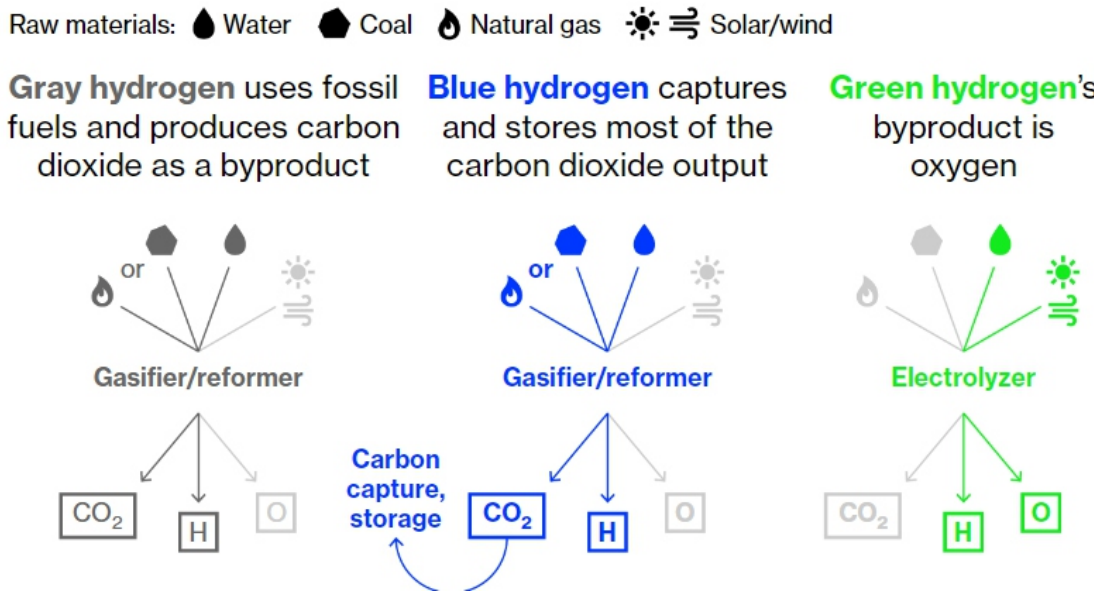

Figure 1: Hydrogen production processes.

There is a global attraction to green hydrogen within the context of the Paris Agreement and widespread decarbonization efforts. As a result, green hydrogen production could reach around two-thirds of the global hydrogen supply by 2050, while gray hydrogen could be totally supplanted.[3] Blue hydrogen, accounting for up to 30% of total hydrogen production over the same time period, would likely be limited to regions such as North America and the Middle East, where costs of natural gas are lower and carbon capture and storage are more likely to be economical.[4]

Hydrogen is versatile.[5] It is able to be produced by a wide variety of fuels (including renewables, nuclear, natural gas, coal, and oil). It is one of the leading options for storing energy from renewables and the lowest-cost option for storing electricity over days or weeks. It could be transported as a gas by pipelines or in liquid form by ships. And it could be transformed into electricity to power homes, methane to feed industry, and fuels for vehicles. Hydrogen will also make various technologies and derivatives available, including fuel cells, fuel cell electric vehicles, hydrogen heaters, green ammonia, methanol, and synthetic kerosene:

[2] Paul Vechiatto (10 February 2022). South Africa in Talks With Investors on Green Hydrogen Projects. *Bloomberg*. https://www.bloomberg.com/news/articles/2022-02-10/south-africa-in-talks-with-investors-on-green-hydrogen-projects?leadSource=uverify%20wall

[3] Africa Green Hydrogen Alliance (2022). *Africa's Green Hydrogen Potential*. Konrad Adenauer: European Investment Bank (EIB), p. 13.

[4] Ibid.

[5] IEA (2019). *The Future of Hydrogen: Seizing Today's Opportunities*. Paris: International Energy Agency (IEA), p. 13.



Hydrogen Fuel Cells

Hydrogen fuel cells operate like batteries but differ by not requiring recharging or wearing down. The cells produce electricity and heat when fuel is supplied and consist of two electrodes—a negative electrode (or anode) and a positive electrode (or cathode), enclosing an electrolyte[6]. Since a fuel cell acts similarly to a battery, they are an alternative to lithium batteries, which is beneficial given that the supply of lithium might not keep pace with growing demand.[7]



Fuel Cell Electric Vehicles (FCEVs):

In contrast to FCEVs, battery electric vehicles use lithium-ion batteries. However, the price for lithium has surged in recent years as there is stress placed upon the concentrated supply and increased demand for lithium-ion batteries. FCEVs are not impacted by this shortage as FCEvs are powered by hydrogen, increasing the potential to drive demand for hydrogen.



Hydrogen Heaters

As a replacement for natural gas for heating, hydrogen heaters use fuel cells, similar to FCEVs. Hydrogen heaters use a fuel cell as an energy converter where hydrogen is used as the fuel. Rather than the fuel being burnt, the hydrogen reacts with oxygen to generate electricity to power heat. However, recent studies have shown that the cost-benefit of hydrogen heaters is unsuitable for heating individual homes entirely compared with alternatives such as heat pumps, district heating, and solar thermal.[8] Nonetheless, as costs for green hydrogen decrease, there is potential for hybrid heating techniques to decrease emissions for industrial heating.



Green Ammonia

The use of green hydrogen can be used to create green ammonia to target both the concern over food security and climate goals. As seen in the Market Update - Africa section, one of the trending initiatives across countries has been the application of green hydrogen to create green ammonia.

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[6] Office of Energy Efficiency & Renewable Energy (2023). "Fuel Cells". *Office of Energy Efficiency & Renewable Energy, U.S. Department of Energy*. https://www.energy.gov/eere/fuelcells/fuel-cells.

[7] Loz Blain (22 September 2022). "Awesome-looking SUV cleverly sidesteps hydrogen's biggest problem", *New Atlas*. https://newatlas.com/automotive/namx-pininfarina-hydrogen-suv/.

[8] Fiona Harvey (27 September 2022). "Hydrogen is unsuitable for home heating, review concludes", *The Guardian*. https://www.theguardian.com/environment/2022/sep/27/hydrogen-is-unsuitable-for-home-heating-review-concludes.

These wide applications for green hydrogen, its value for reducing carbon emissions in hard-to-abate industries, its geopolitical instrumentality for diversifying sources of energy, and its potential for export diversification for fossil fuel-dependent countries, are placing the technology at center stage in the global sustainability transition.

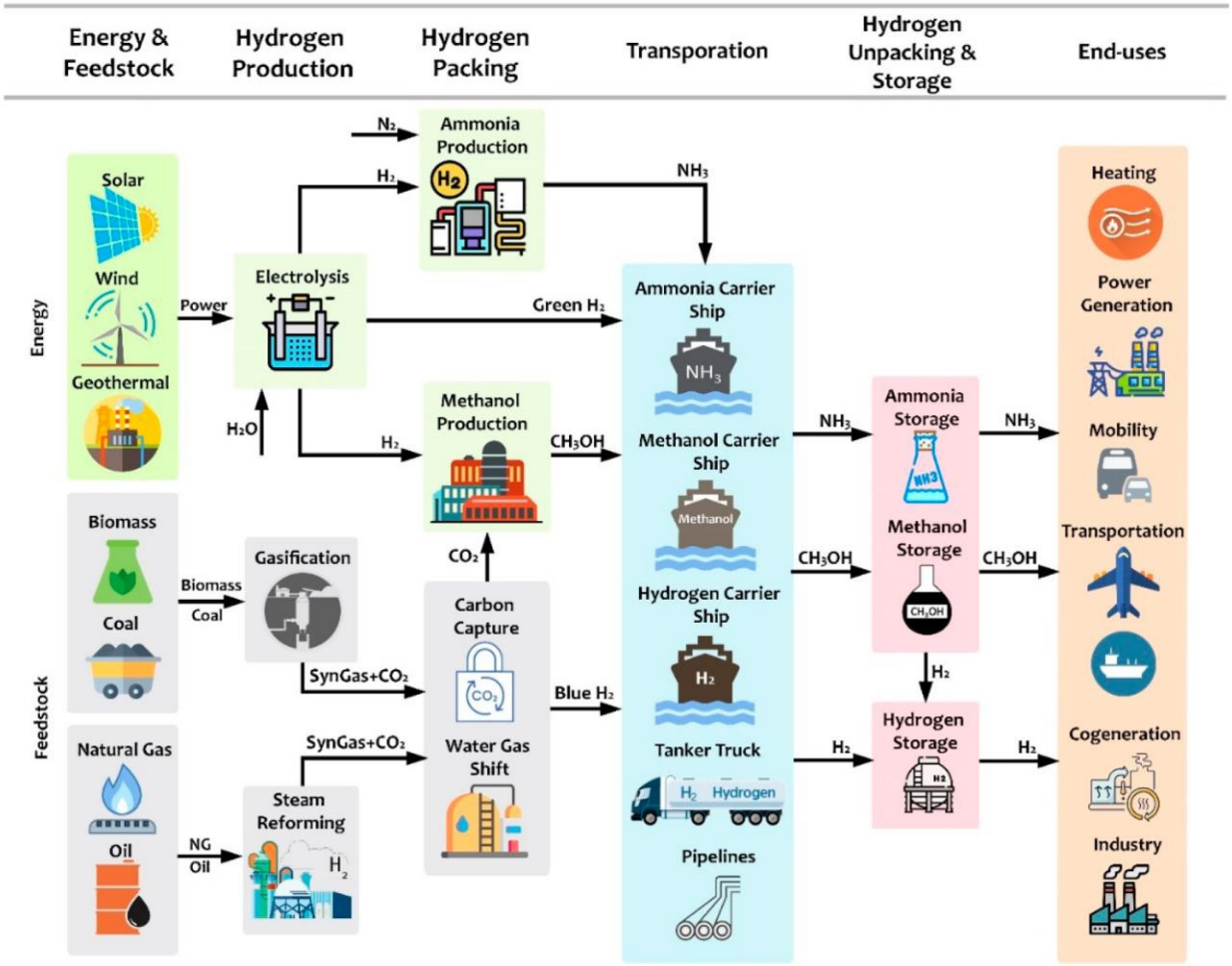


Figure 2: The hydrogen energy value chain[9]

This report presents developments in the green hydrogen sector, with a particular focus on Nigeria within the context of African and global developments. Although hydrogen investments have historically been concentrated in Europe, It draws on data collected through semi-structured and unstructured interviews with industry experts, outcomes from hydrogen industry workshops, seminars and conferences, geospatial data from H2 Atlas-Africa, news reports and a review of the extant academic and industry literature.

[9] Mohsen, Salimi, Morteza, Hosseinpour, Tohid N.Borhani T. (2022). The Role of Clean Hydrogen Value Chain in a Successful Energy Transition of Japan. *Energies*, 15(16): 6064. https://doi.org/10.3390/en15166064.

2. Overview of the Hydrogen Landscape

In 2021, global hydrogen demand increased by 5% from 2020 to 94 Mt (metric tonnes), concentrated in the chemical sector and refining[10], especially in the production of fertilizers and oil refining.[11] Demand in new applications such as [12]transport, high-temperature heat in industry, and power in buildings grew by 60% in 2021 to 40,000 tonnes (0.04% of global hydrogen demand).

Announcements of green hydrogen projects have accelerated since 2019, and as of June 2022, are at 175 GW of electrolyzer capacity by 2030.[13] In addition to progress in project development, many countries are acting on hydrogen's increased potential in arriving at net zero goals, driving 26 governments (such as China, countries in the EU, the United States, India, etc.) to commit to adopting hydrogen as a clean energy tool in their systems. Targets set by these countries include transport demand to deploy Fuel Cell Electric Vehicles (FCEV) or cumulative targets for low-emission hydrogen in industrial settings. In addition, there has also been progress made in terms of international cooperation, with key developments in the global hydrogen space including:

- **November 2021:** Breakthrough Agenda launched at COP26 with commitment from 44 countries in which hydrogen is a breakthrough that was adopted.[14]
- **May 2022:** The G7 launched Hydrogen Action Pact to accelerate the development of low-emission hydrogen, tech development, and shaping the regulatory framework/standard/financial commitments.[15]

The IEA (International Energy Agency) Hydrogen Project Database (2019) covers all projects worldwide that have been commissioned since 2000 for the production of hydrogen for energy or climate change mitigation purposes, i.e. their objective is either to reduce the emissions associated with the production of hydrogen for existing applications, or the introduction of hydrogen as an energy carrier or industrial feedstock in new applications where it is not currently widely used and has the potential to be a low-carbon technology option. It indicates that the majority of hydrogen projects since 2000 occurred in European countries, with more hydrogen projects than the rest of the global regions combined.

[10] International Energy Agency (2022). "Hydrogen", *IEA*. https://www.iea.org/reports/hydrogen.

[11] IEA, *The Future of Hydrogen*, p. 14.

[12] Clean Hydrogen joint undertaking, p. 284

[13] Africa Green Hydrogen Alliance, *Africa's Green Hydrogen Potential*, p. 9.

[14] UN Climate Change Conference UK 2021 (2021). "COP26 World Leaders Summit - Statement on the Breakthrough Agenda". https://ukcop26.org/cop26-world-leaders-summit-statement-on-the-breakthrough-agenda/

[15] G7 Germany (2022). *G7 Leaders' Communiqué*. Bavarian Alps: Germany, p. 6. https://www.g7germany.de/resource/blob/974430/2062292/9c213e6b4b36ed1bd687e82480040399/2022-07-14-leaders-communique-data.pdf?download=1

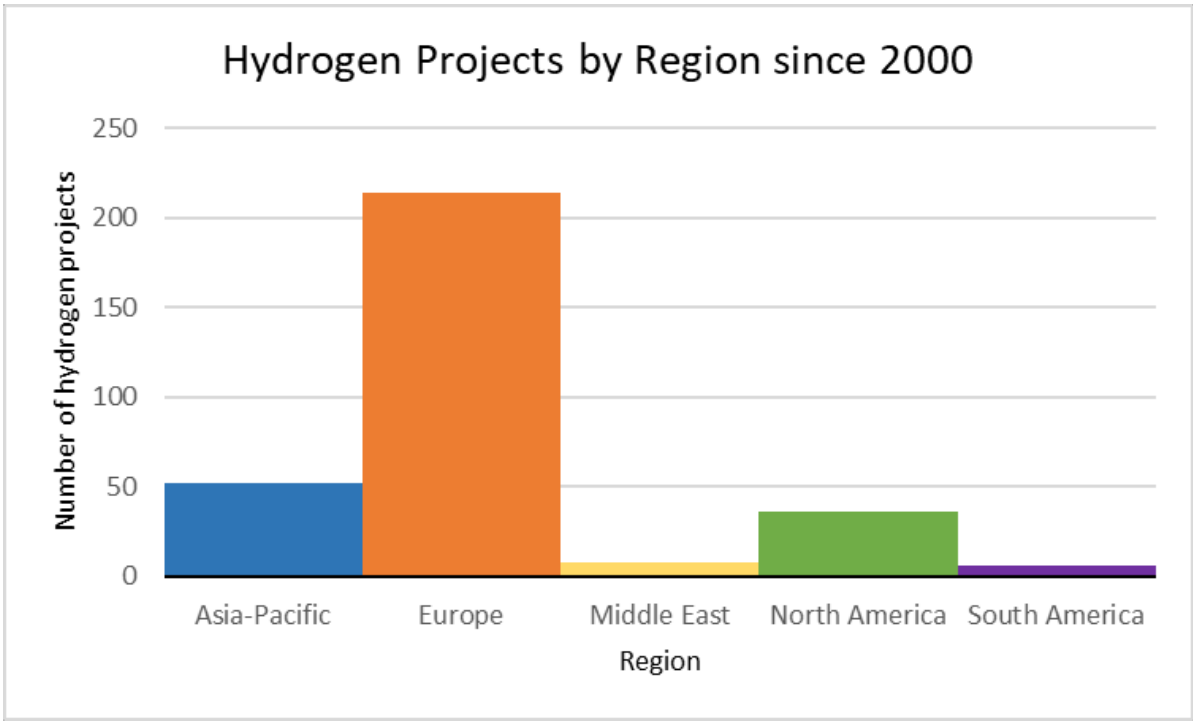


Figure 3: Hydrogen projects by region since 2000[16]

Although countries have been increasing their attention towards hydrogen, over 17% of the global hydrogen supply is a byproduct of facilities and processes in the petrochemical industry. Low-emission production grew by 9% in 2021 to account for ~1% of total hydrogen production over the last 3 years.[2] This demonstrates a significant gap in the global supply of green hydrogen. A major reason for this is the cost differential between green hydrogen and blue hydrogen. Green hydrogen and green products share the barrier of cost with transition-related technologies. Green hydrogen production processes for materials cost more than the fossil fuel-based mature processes. It requires very large capital intensive but produces a very low-profit margin.

The production cost for green hydrogen is determined by the cost of renewable energy, the investment cost of the electrolyzer, and its operating hours. Renewable-based electrolysis plants are being re-designed and optimized, thereby reducing investment costs by up to 80% by 2050. According to IRENA, the current cost of producing (grey) hydrogen ranges from 1.5 to 2.5 USD/kg, whereas the cost of producing green hydrogen ranges from 2.5 to 7 USD/kg.[17]

[16] IEA (2020). "Hydrogen Projects Database". https://iea.blob.core.windows.net/assets/a02a0c80-77b2-462e-a9d5-1099e0e572ce/IEA-Hydrogen-Project-Database.xlsx.

[17] Swetha RaviKumar and Bhagwat M. Olczak (2020). *Green Hydrogen: Bridging the Energy Transition in Africa and Europe.* San Domenico di Fiesole, Italy: European University Institute, p. 6.

However, as the cost of renewables and electrolyzers decline, and as the scale of green hydrogen production increases, costs are expected to decrease.[18] Green hydrogen production could therefore reach ~70% of global hydrogen supply by 2050 if leading countries adopt netzero commitments and implement them through purposeful policies.[19]

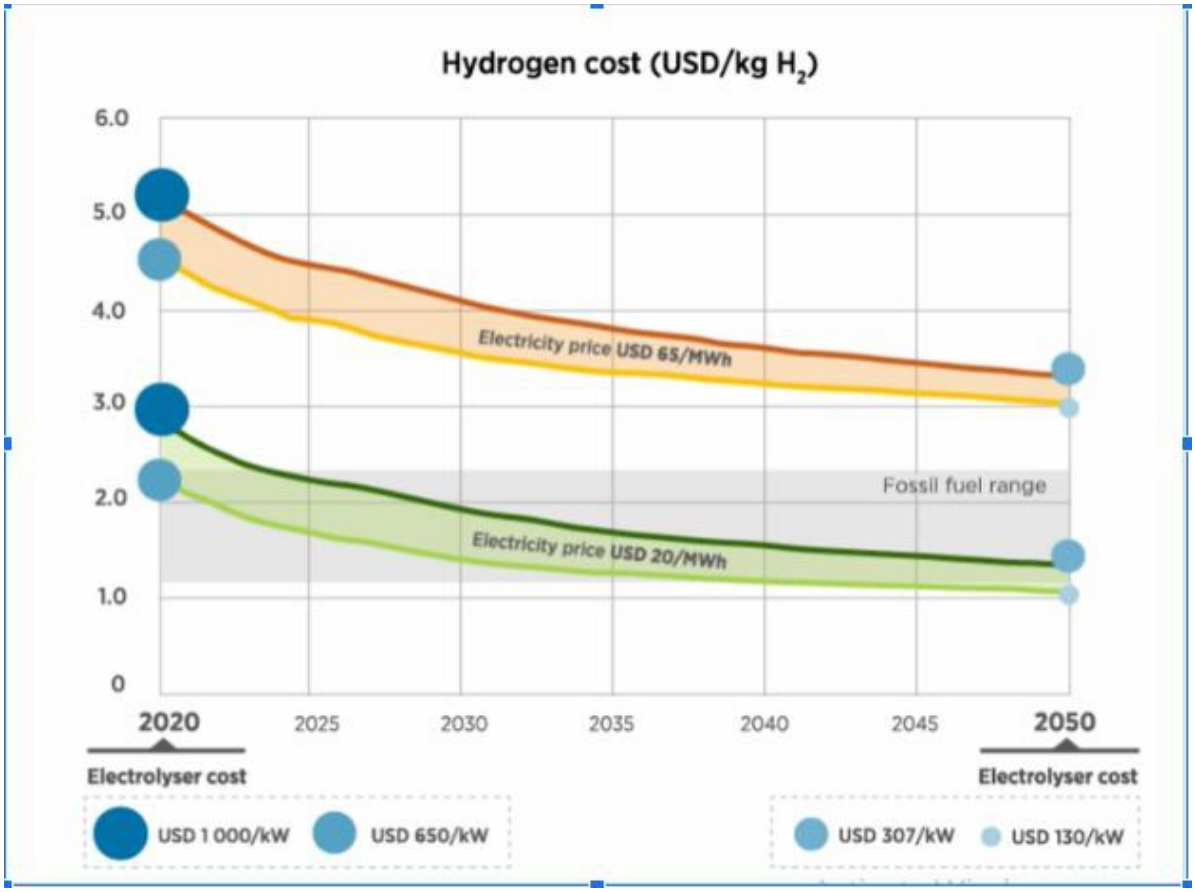


Figure 4: Green hydrogen cost reduction potential.[20]

To attain profitability economies of scale, low costs of raw materials and energy prices are required, given that energy costs account for >60%2 of hydrogen production costs.[21] For green hydrogen to be competitive in the transport sector, this would require reaching a cost of around 5 €/kg at the pump to achieve cost parity with diesel fuel. For Industry, green hydrogen costs must reach levels between 2-3 €/kg as a feedstock in order to achieve parity with fossil-based inputs, once the cost of carbon is included in the feedstock cost.[37] Strategies to achieve the required cost reduction include innovation to improve the performance of the electrolyzer, scaling up manufacturing capacity, standardization, and learnings from deployment. These could reduce the costs below the $2/kg mark and make it competitive. Green hydrogen costs are projected to fall 60% by 2030.[22]

[18] Ibid., p. 6.

[19] Africa Green Hydrogen Alliance, *Africa's Green Hydrogen Potential*, p. 13.

[20] Africa Green Hydrogen Alliance, *Africa's Green Hydrogen Potential*, p.

[21] Ibid., p. 15.

[22] Ibid., p. 6.

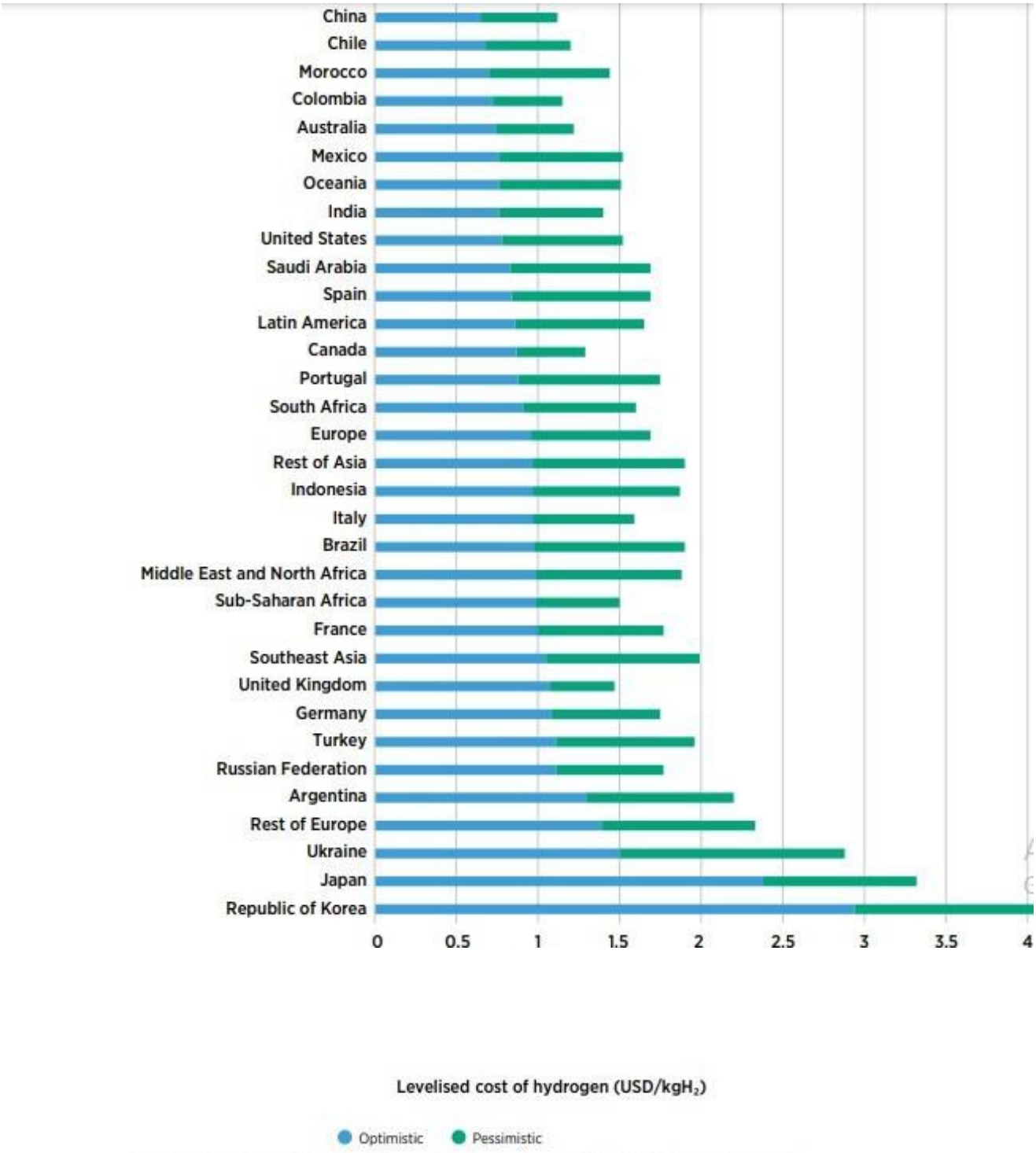


Figure 5: Levelized Cost of Hydrogen (LCOH) range in 2050 derived from supply-demand analysis[23]

[23] IRENA (2022), Global hydrogen trade to meet the 1.5°C climate goal: Part III – Green hydrogen cost and potential, International Renewable Energy Agency, Abu Dhabi.

Levelized cost of hydrogen derived from supply cost curves of individual countries and regions based on their estimated hydrogen demand for 2050. Water availability for electrolysis is considered in the hydrogen supply-cost curves. Based on the estimated Levelized Cost of Hydrogen (LCOH) estimated for single countries and regions, the best-suited countries for the production of hydrogen and consumption appear to be China, India, and the United States. They all present a large production potential at low LCOH (USD 0.65/kgH2 to USD 0.78/kgH2) mainly because of their high-quality solar resources.

European countries such as France, Germany, Italy, and Spain are characterized by a higher LCOH, around USD 0.8/kg to USD 1.1/kg. The production potential is usually quite large even for these countries; only Italy has a lower economically viable potential (1000 petajoules at LCOH lower than USD 1.15/kg) due to its orography and dense urbanization. On the other hand, the United Kingdom presents a higher LCOH (USD 1/kgH2 to USD 2/kgH2) mainly because of its poor solar resource quality. Indeed, the European Union, despite high existing and new green hydrogen demand applications, is constrained in terms of renewables due to varying load curves and limited space availability.[24] Therefore, Hydrogen and ammonia import demand could largely be driven by Europe, Japan, and South Korea, and Europe, Japan, South Korea, and Southeast Asia could account for ~65% of the import market by 2050.[25]

These parts of the world will likely drive hydrogen imports to meet the expected demand in a cost-efficient manner. There is also an international and geopolitical dimension to this imperative. As European nations are seeking to reduce their dependence on gas imports from Russia within the context of the Russia-Ukraine War. It is as a result of these constraints and pressures that European countries have looked towards Africa as a potential source of green hydrogen supply. It is therefore Germany that has taken the lead in supporting hydrogen development in Africa,[26] and Angola is now set to become Germany's first supplier of green hydrogen from renewable energy.[27]

[24] Ibid., p. 13.

[25] Ibid., p. 14.

[26] Miguel Artacho (19 October 2022). "Angola Invests in Hydrogen Production Facility", Energy Capital & Power. https://energycapitalpower.com/angola-invests-in-hydrogen-production-facility/#:~:text=A%20number%20of%20hydrogen%20projects,green%20hydrogen%20facility%20in%20Angola.

[27] Andreas Rinke, Miranda Murray and Madeline Chambers (15 June 2022). "Angola set to become first supplier of green hydrogen for Germany", Reuters. https://www.reuters.com/article/germany-angola-green-hydrogen-idINL6N2Y20AE.



Figure 6: Technical potential for producing green hydrogen under USD 1.5/kg by 2050, in TWh.[28]

3. Green Hydrogen in Africa

Green hydrogen provides an opportunity for Africa to satisfy the growing energy needs of the continent while at the same time providing prospects for economic growth and industrial development through the export of hydrogen and its derivatives.

African countries are promising partners for producing cost-competitive green hydrogen due to Africa's abundant resources in renewable energies, its low population density and large-scale availability of non-arable land for large-scale deployment of renewable energy.[29] Several African countries, especially around the Northern and Southern Tropics have excellent solar (average daily potential of 4.49kWh/kWp) and wind resources (180,000 TWh per year) for potential green hydrogen production.[30] Africa has an installed hydropower capacity of over

[28] Leonie Beaucamp and Eugene Nforngwa (2022). *Green Hydrogen in Africa: Risks and Benefits*. Bonn: Germanwatch, p. 2; IRENA. (2022). *Geopolitics of the Energy Transformation – The Hydrogen Factor*. Abu Dhabi: International Renewable Energy Agency (IRENA). https://www.irena.org/publications/2022/Jan/Geopolitics-of-the-Energy-Transformation-Hydrogen, p. 45.

[29] IRENA (2022). *Renewable Energy Market Analysis: Africa and its Regions*. Abu Dhabi: International Renewable Energy Agency (IRENA).

[30] Chigozie Nweke-Eze (23 August 2022). "Africa has what it takes to supply green hydrogen to the world – but what must be considered?" *illuminem*. https://illuminem.com/illuminemvoices/06011e7a-bf80-4c5f-b7a8-e35313649e79.

38 gigawatts (GW) and the highest untapped potential across the world, utilizing only about 11% of its capacity.[31]

Countries in North Africa as well as Namibia, South Africa, Angola, and Botswana, have extensive non-arable land and proximity to ports.[32] Countries like South Africa and the Democratic Republic of Congo, have an abundance of mineral resources essential for producing solar panels, wind turbines, electric motors, batteries, electrolyzers, and biological carbon. All of these potentials position Africa as a viable supplier of green hydrogen and Power-to-X (PtX) products at competitive costs. The sub-Sahara subregion has the technical potential for producing 754TWh of green hydrogen under USD 1.5/kg by 2050.[33]

Green hydrogen could be exported by Africa and could be utilized domestically. Domestic demand for hydrogen is likely to be driven largely by transportation and industries such as cement, nonferrous metals, materials, mining, manufacturing, construction, food and tobacco, and agriculture and forestry.[34] The major end products are likely to be hydrogen and ammonia (making up roughly 85% of domestic ambition), while smaller but significant roles will likely be played by methanol, synthetic kerosene, and direct reduced iron.[35] In order to unlock these opportunities, many countries will need technology transfers, infrastructure, and investment at scale.

African countries like Morroco, Namibia, South Africa, Mauritania, and Egypt have been identified as notable hubs for green hydrogen production. Most of the potential green hydrogen projects are in the feasibility study and planning phases (in the case of South Africa, Morocco, and Egypt) or in the early stages of project development (in the case of Namibia and Angola).

Kenya plans to build a 300MW capacity of green ammonia and green fertilizer facility that will unlock socio-economic benefits, stimulate new green industries, and create local green jobs while promoting energy security. At full capacity, the $10 billion Hyphen Hydrogen Energy project in Namibia is expected to generate 300,000 tons of green hydrogen per annum for

[31] Chigozie Nweke-Eze and Lauren Johnston (5 August 2022). "Green hydrogen offers a window to redefine the Africa-Australia and Africa-Australia-Europe partnerships," South African Institute of International Affairs (SAIIA). https://saiia.org.za/research/green-hydrogen-offers-a-window-to-redefine-the-africa-australia-and-africa-australia-europe-partnerships/; International Hydropower Association (2022). "Region Profile: Africa". https://www.hydropower.org/region-profiles/africa.

[32] Chigozie Nweke-Eze, "Africa has what it takes to supply green hydrogen to the world".

[33] Leonie Beaucamp and Eugene Nforngwa (2022). *Green Hydrogen in Africa: Risks and Benefits*. Bonn: Germanwatch, p. 2

[34] Africa Green Hydrogen Alliance, *Africa's Green Hydrogen Potential*, p. 20.

[35] Ibid.

domestic use and for export. The large-scale project will require 5 GW to 6 GW of renewable generation capacity and 3 GW of electrolyzer capacity, estimated to cut 5 to 6 million tons of CO_2 every year.

A similar project in Angola from the state-owned oil company Sonangol in conjunction with German companies Conjucta and Gauff Engineering is looking to develop 280,000 tons of green ammonia for export to Germany by 2024. Germany is also expecting the production of green hydrogen and its derivative products from projects in the works in Morocco.

Beyond their own national plans, six African countries (Egypt, Kenya, Mauritania, Morocco, Namibia and South Africa) launched the African Green Hydrogen Alliance (AGHA) in 2022, a platform led by governmental bodies of the member states. The Alliance aims to strengthen intergovernmental collaboration on capacity building, financing, policy design, and certification. It also strives to bring the private sector, development finance institutions, and civil society together. It is estimated that by 2050, green hydrogen could increase the Gross Domestic Product (GDP) of the six AGHA member countries by $126 billion, the equivalent of 12% of these countries' current GDP, and create up to 4 million jobs.[36]

The maximum technical hydrogen area is notably seen in North Africa and the interior part of the Greenwich meridian. Morocco, for example, is forecasted to have the third lowest cost of green hydrogen production in 2050 and has the potential to meet Europe's energy demand. AGHA's addressable market for green hydrogen could reach 30 to 60 Mt of hydrogen equivalent by 2050. Approximately one-third of this potential could be local (i.e., within the member countries) and two-thirds is export, roughly equivalent to 22% of the expected international cross-border hydrogen and derivatives trade by 2050.[37] The AGHA countries will greatly benefit from the projected decline in hydrogen costs over the next 28 years,

[36] Africa Green Hydrogen Alliance, *Africa's Green Hydrogen Potential*, p. 5.

[37] Ibid.

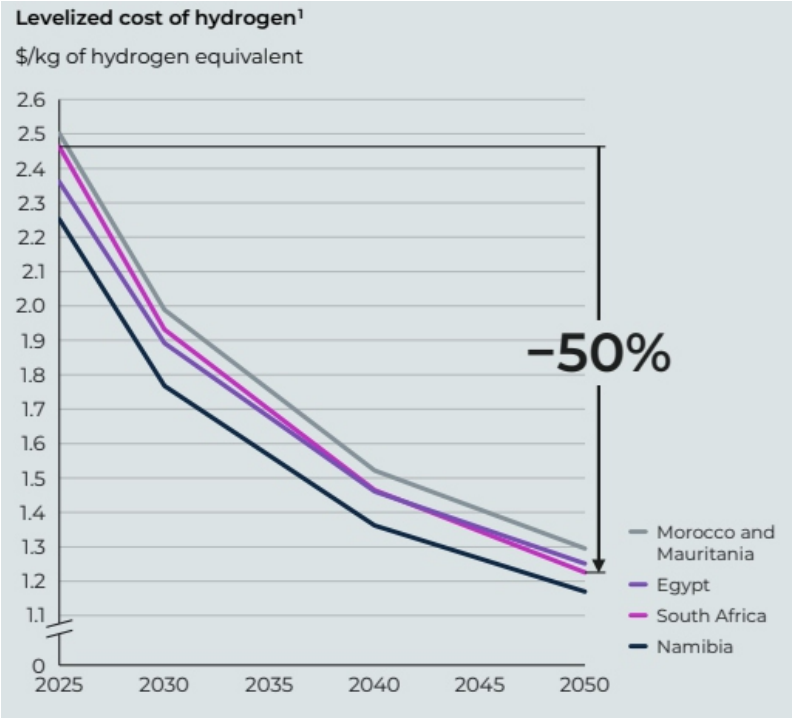


Figure 7: Levelized Cost of Hydrogen for selected AGHA members.[38]

AGHA countries are taking several initiatives to promote hydrogen production and cost-reduction with the aim of achieving local production of hydrogen and international competitiveness for hydrogen exportation. Table 1 depicts some of these initiatives.

Table 1: Green hydrogen initiatives among AGHA members

Country	Initiative	Target
Namibia	2021: Announced $9.4 billion green hydrogen project to enter in 2026.[39] Expected to enter production in 2026 to create 2GW of renewable electricity capacity to produce green hydrogen for conversion to green ammonia.	Produce 300,000 tons of green hydrogen per year for regional and global markets (in the form of green hydrogen or in the derivative form of green ammonia).
Morocco	Moroccan National Strategy (2021) includes a three-stage action plan for green hydrogen	Installation of the first green hydrogen production system in the country to produce

[38] Africa Green Hydrogen Alliance, *Africa's Green Hydrogen Potential*, p. 16.

[39] Bitsat Yohannes and Arona Diedou (13 July 2022). "Green hydrogen: A viable option for transforming Africa's energy sector", Africa Renewal. https://www.un.org/africarenewal/magazine/july-2022/green-hydrogen-viable-option-transforming-africas-energy-sector.

	2022: Construction expected to start in 2022 to replace conventional ammonia with domestic green ammonia Joint partnership between Germany and Morocco to construct hydrogen production plant	carbon-free hydrogen from an electrolyser and solar photovoltaic panels, as well as the production of other products such as ammonia, methane and green fuels.
Egypt	2022: MOU signed between Government and ReNEW Power company (India) to build a green hydrogen production facility worth $8B USD in the Suez Canal Economic Zone	To produce 20,000 tons of green hydrogen and 100,000 tons of green ammonia by the year 2025
South Africa	2022: Announcement to support a pipeline of green hydrogen projects worth ~$17.8B USD over the next 10 years Collaboration with Namibia to develop an export hub (Boegoebaai export hub) for hydrogen and ammonia	

Beyond North Africa, green hydrogen is most prominently encouraged in southern Africa and East Africa. In addition to their representation within the inter-governmental AGHA, the Africa Hydrogen Partnership (AHP), registered in Mauritius in 2020, is composed of over 14 members from the private sector, with pioneer member organizations are based across Ivory Coast, Ghana, Mali, South Africa, Zimbabwe, and outside the continent with the large-scale commercialisation of hydrogen technology in Africa as a key focus. The AHP envisions five feasible hydrogen routes along existing trans-African highways and business centers:

- Beira - Harare - Lusaka - Lubumbashi - Lobito -Luanda
- Cape Town - Gaborone - Bulawayo - Lusaka - Mbeya - Nairobi - Addis Ababa - Djibouti
- Gaborone - Windhoek - Walvis Bay - Lüderitz
- Durban - Johannesburg - Harare - Lilongwe - Blantyre - Mbeya - Dar es Salaam
- Mombasa - Kampala - Kigali - Bujumbura - Mwanza - Bagamoyo - Dar es Salaam

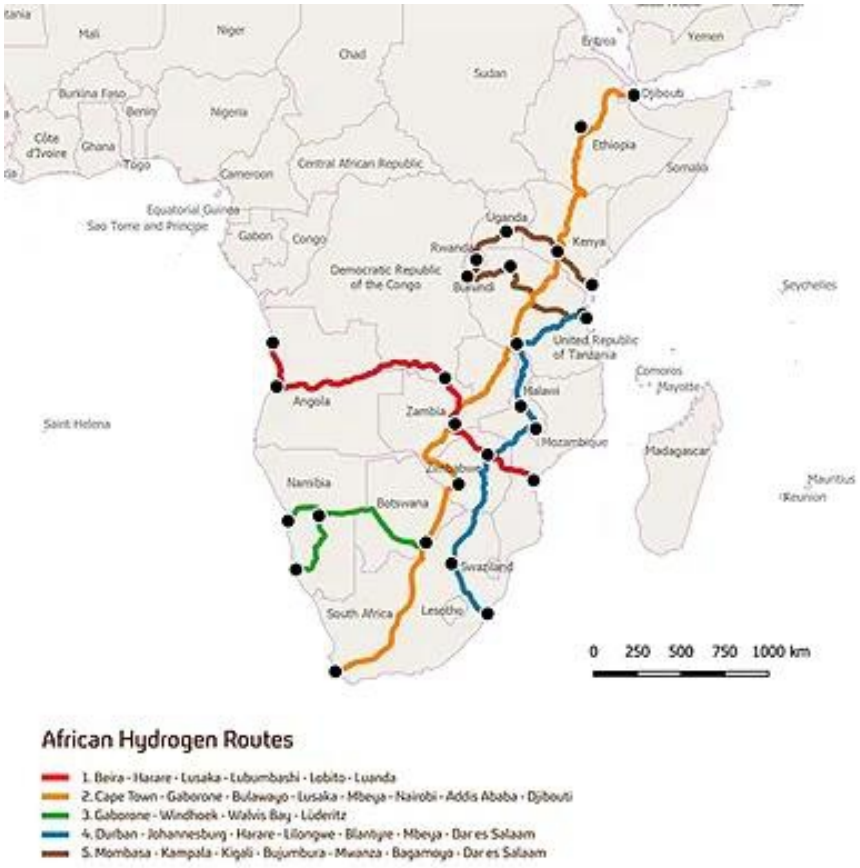


Figure 8: African hydrogen routes connecting 15 capitals (metropolitan regions), several significant mining regions, and 11 major harbors, proposed by the African Hydrogen Partnership (AHP).[40]

Announced, ongoing, and completed hydrogen projects in Africa are also concentrated in North and Southern Africa, as demonstrated in Figure 8. Likewise, the AGHA report *Africa's Green Hydrogen Potential* explicitly argues that North and Southern Africa will likely emerge as the key exporting hubs partly because they comprise countries with complementary load profiles of wind and solar with the highest potential to capture the full advantage of green hydrogen production to meet domestic demand as well as export it. In contrast, in both East and West Africa, solar and wind profiles are less optimized for exports, making it likely that they would be more focused on domestic demand.[41]

[40] African Hydrogen Partnership (2021). "About". https://www.afr-h2-p.com/about.

[41] Africa Green Hydrogen Alliance, *Africa's Green Hydrogen Potential*, p. 23.



Figure 9: Map of hydrogen projects in Africa by 2022 based on publicly available information and news reports.[42] Red icons indicate projects in the study phase, gray icons are competency centers, green icons are completed projects, and yellow icons are ongoing projects.

While the maximum technical hydrogen area is notably seen in North Africa and the interior part of the Greenwich meridian, and Sub-Saharan Africa is characterized by a moderate LCOH of USD 1/kgH2 for most countries, there is a case to be made that Africa's biggest oil producers, among which are Nigeria and Angola, could invest heavily in green hydrogen as a means of decarbonizing their economies, strengthening regional hydrogen hubs and diversifying their exports.

In recognition of this, Germany, which is the largest economy in Europe and which is planning to receive large quantities of green hydrogen in order to become climate neutral by 2045, has opened hydrogen offices in strategically important countries including Nigeria and Angola. To date, Germany has taken the lead in supporting hydrogen development in Africa.[43] Angola is now set to become Germany's first supplier of green hydrogen from renewable energy after its state-owned energy company Sonangol signed a letter of intent in 2022 to build a factory with two German engineering firms.[44] The green ammonia factory should be ready to export from 2024, initially 280,000 tons of green ammonia.

[42] Ivoire Hydrogène (2022). "Mapping of hydrogen projects in Africa". https://ivoireh2.com/cartographie-h2-afrique.

[43] Miguel Artacho (19 October 2022), "Angola Invests in Hydrogen Production Facility", *Energy Capital & Power*. https://energycapitalpower.com/angola-invests-in-hydrogen-production-facility/#:~:text=A%20number%20of%20hydrogen%20projects,green%20hydrogen%20facility%20in%20Angola.

[44] Andreas Rinke et al, "Angola set to become first supplier of green hydrogen for Germany".

Hydrogen initiatives and research in Africa have so far been concentrated in North Africa (Morocco, Egypt and Mauritania) and Southern Africa (South Africa, Namibia and Angola), as membership of AGHA, the presence of the German Hydrogen Office in Angola, and the map of hydrogen projects in Africa indicate. Yet West Africa alone could produce approximately 115,940 TWh of green hydrogen per year at a price of less than $2.63/kg, assuming no water constraints.[45] The Economic Community of West African States (ECOWAS) has even produced a draft regional Green Hydrogen policy led by the ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE).[46]

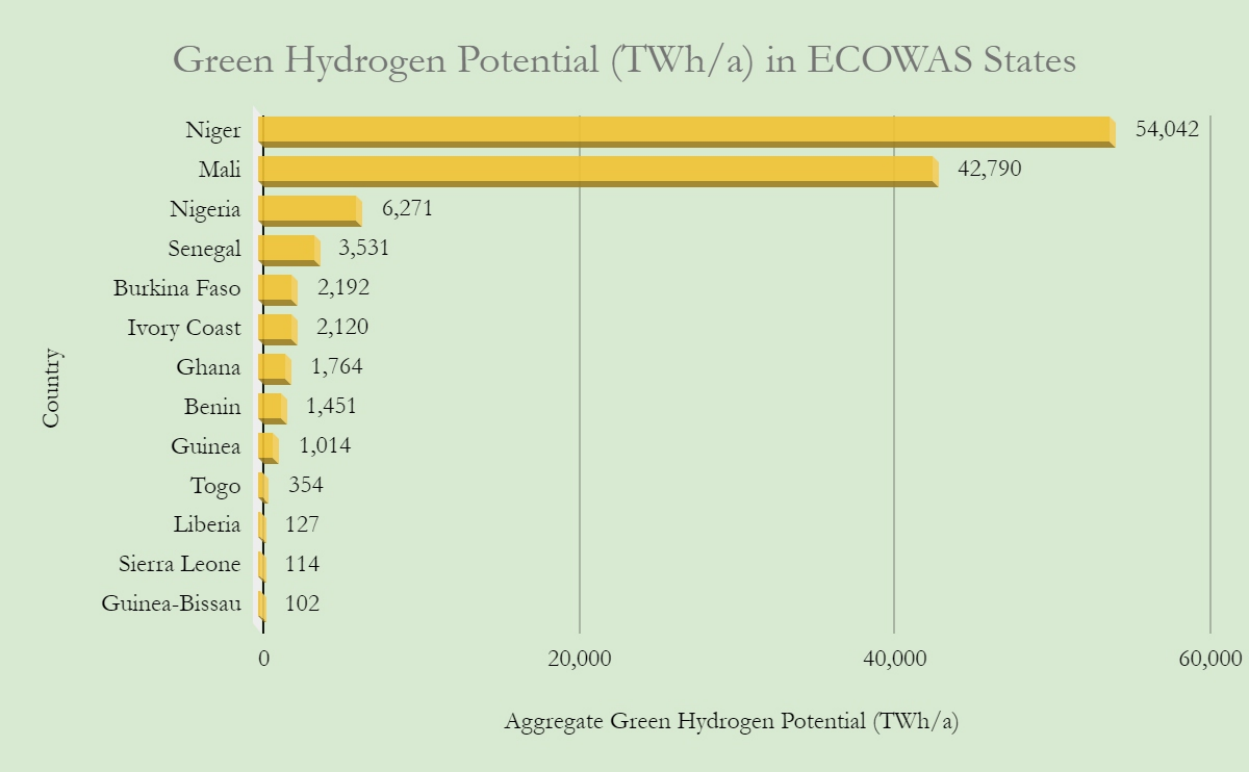


Figure 10: Green hydrogen potential (TWh/a) by ECOWAS member country.

[45] H2 Atlas-Africa (2023). "H2 Atlas-Africa ECOWAS". Jülich, Germany: Institute of Energy and Climate Research. https://africa.h2atlas.de/ecowas.

[46] ECREEE (2022). "The draft regional green hydrogen policy validated by experts from the region". http://www.ecreee.org/news/draft-regional-green-hydrogen-policy-validated-experts-region.

[47] H2 Atlas-Africa, "H2 Atlas-Africa ECOWAS".

4. Green Hydrogen in Nigeria

Although Nigeria has the third largest aggregate green hydrogen potential among ECOWAS member countries, it is a major oil producer, the largest economy in West Africa, a key player in West African transition geopolitics, and, unlike Mali and Niger (which account for 84% of the subregional potential), it is a Gulf of Guinea country with access to shipping and ocean transportation which would be valuable for participating in global hydrogen markets and for driving down hydrogen costs. This cost reduction could occur by encouraging demand from refining and chemical production already using hydrogen based on fossil fuels and are concentrated in coastal industrial zones.[48]

The country also has several locations with a high maximum technical green hydrogen potential per area, unevenly distributed across its expanse (Figure 9) – from as high as 38.4kWh/a*m² to as low as 0.6kWh/a*m², with a national total of 6,271TWh/a (about 5.4% of West Africa's total).

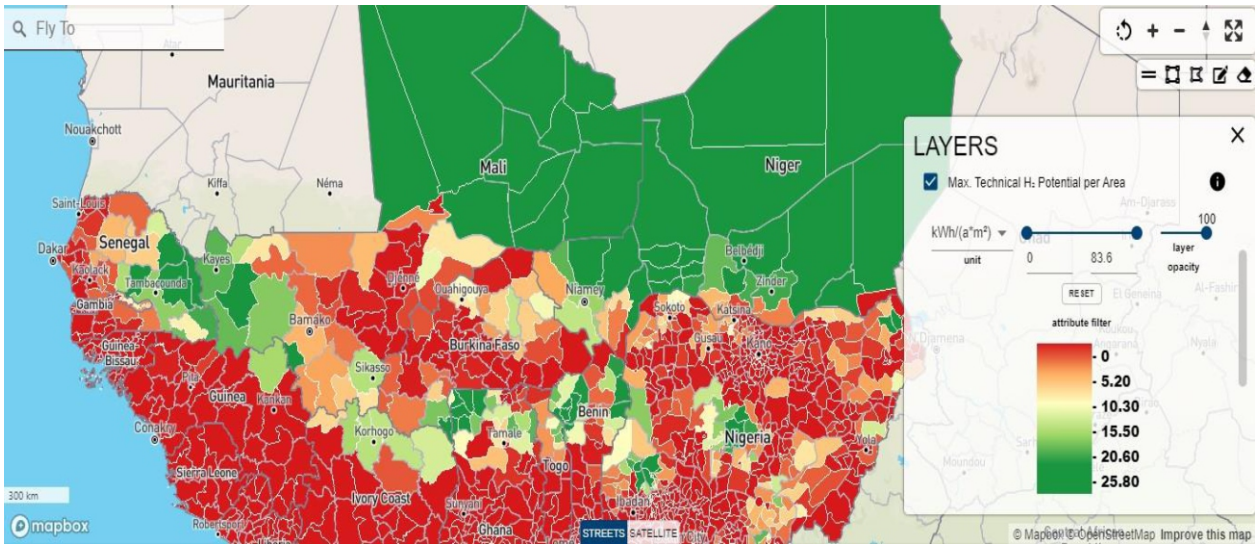


Figure 11: Maximum technical hydrogen potential per area in West Africa. Note: The max technical hydrogen potential per area represents the theoretically producible amount of hydrogen of each region divided by the region area to provide a value independent of the region size. This amount is limited only by the land eligibility constraints and the available power is limited by energy intake (wind, solar radiation).[49]

[48] IEA, *The Future of Hydrogen*, p. 15.

[49] H2 Atlas-Africa, "H2 Atlas-Africa ECOWAS".

The cost of producing green hydrogen, however, remains high. The levelized cost of hydrogen (LCOH), which includes the cost of renewable energy, cost of electrolyzer (but does not include water constraints), ranges from 4 USD/kg to 17.4 USD/kg, which is too high to be economical. This LCOE, however, is expected to decrease by 2050 to 2 USD/kg to 14 USD/kg.

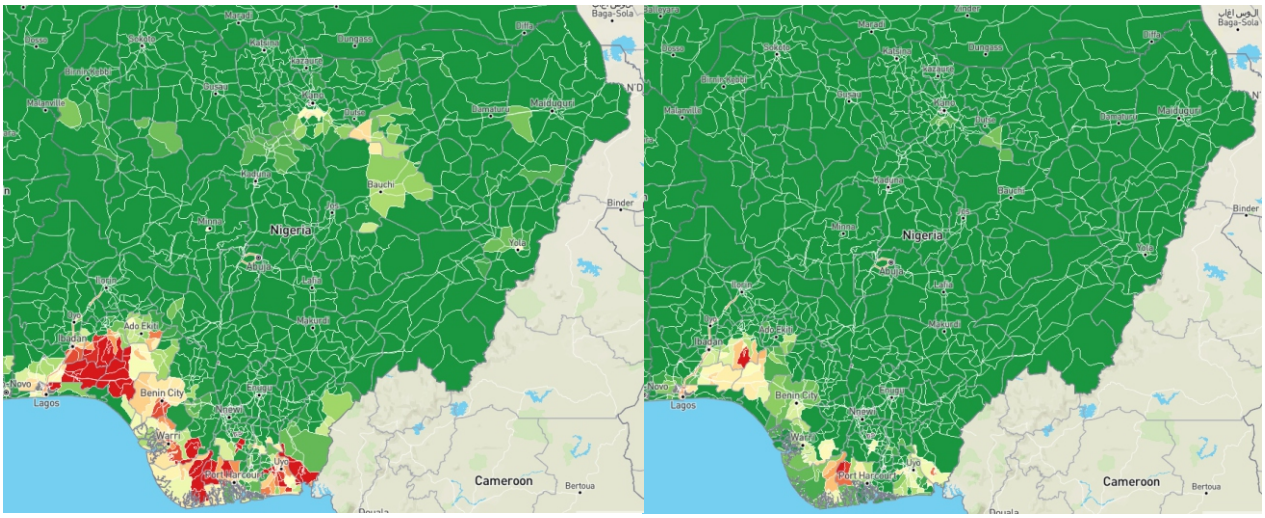


Figure 12: Levelized Cost of Hydrogen in 2020 (left) and 2050 (right).[50]

The implication is that the areas with the highest technical maximum technical green hydrogen potential per area (Kaduna, Kwara, Oyo and Borno states) are likely to have LCOH between 2 USD/kg to 2.4 USD/kg by 2050.

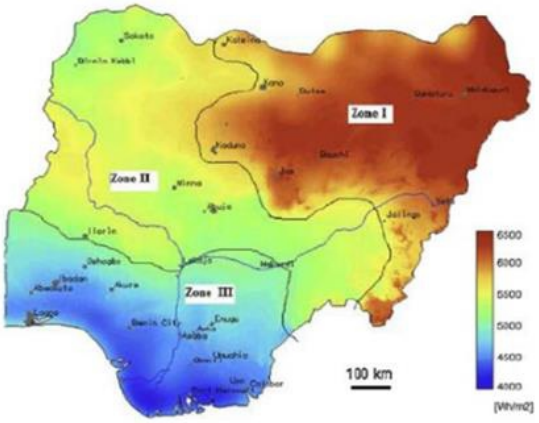
4.1 Potential for green hydrogen production in Nigeria

Nigeria has the potential to produce hydrogen and therefore we need to utilize the opportunities to achieve a net-zero carbon emission by 2050. Various factors contribute to this potential, including the country's availability of renewable energy resources, availability of land, access to water, presence of gas pipelines and presence of potential offtakers.

[50] Ibid.

4.1.2. Renewable Energy Resources

Currently in Nigeria, 42 GWh is generated from solar power and 7,686 GWh of hydropower (a



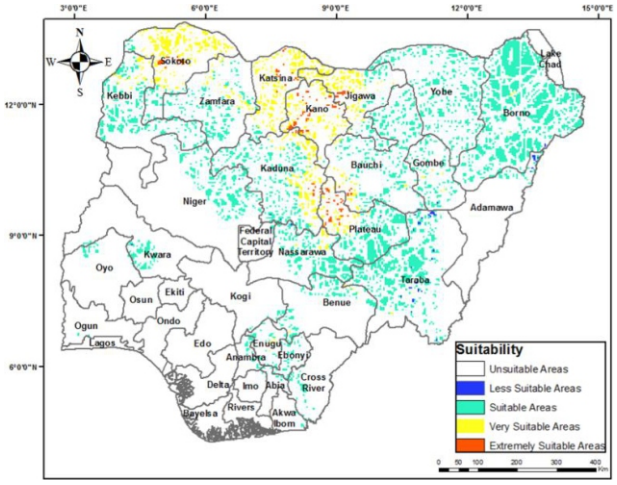


Figure 4. Nigeria's Solar Radiation Map [34]

total of 7,728 GWh, or 7.7 TWh).[45] This is approximately 8% of the electricity needed for H2 production to cover Germany's H2 needs.

Region of Nigeria[51]:

There is no grid-connected solar plant in the country currently nor an adequately functioning offshore or onshore wind power plant. The country, therefore, has some way to go in piloting utility-scale renewable energy projects that can form the foundation for the production of green hydrogen.

4.1.3. Existing Pipelines

In addition to renewable resources, infrastructure to supply and store green hydrogen is critical. Fortunately, current gas pipelines can be repurposed and offer the potential for transporting hydrogen. Nigeria's main pipelines are the following: the Alakiri–Obigbo–Ikot Abasi Pipeline (the eastern network), the Escravos–Lagos Pipeline System (the western network), and the proposed Ajaokuta–Kaduna–Kano gas pipeline connecting the north. All are owned by the Nigerian Gas Processing and Transportation Company (NGPTC).

[51] Mshelia, Richard B. (2021). Assessment of Renewable Energy Potentials of The Northeast Geopolitical Region of Nigeria. *Renewable Energy Sources Energy Policy and Energy Management*, 2(2): 24-38, p. 27.

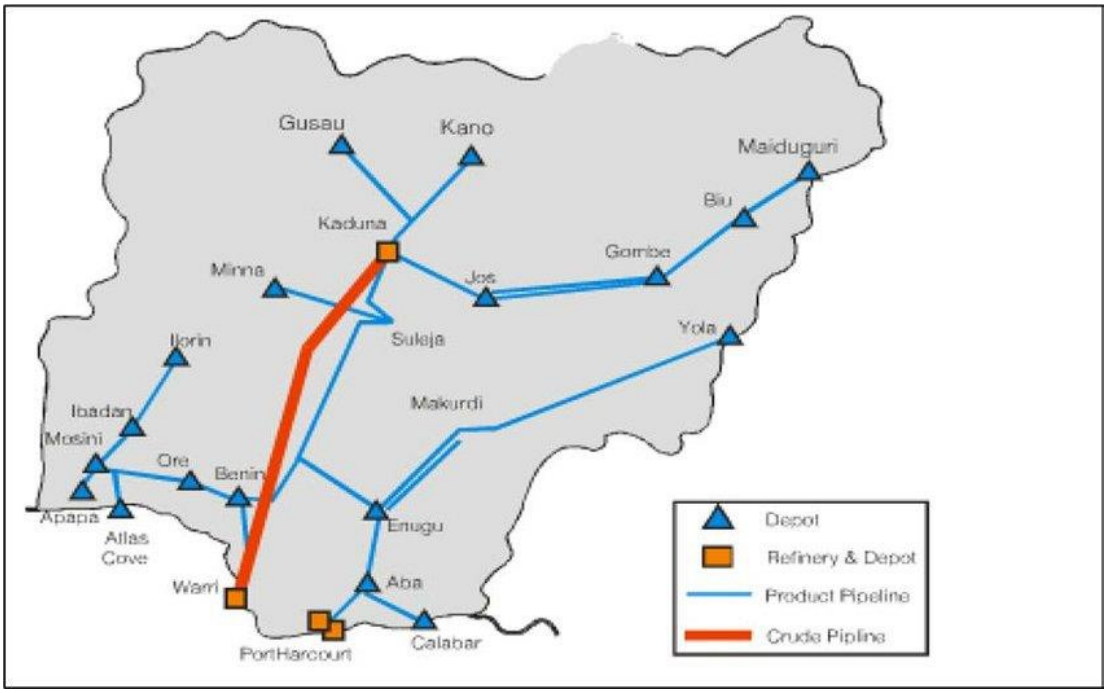


Figure 14: Nigeria's pipeline network and facilities.[52]

Further opportunities for transporting hydrogen across borders are offered by the West African Gas Pipeline (WAGP) network, which currently transports gas from Nigeria to neighboring countries Benin, Togo, and Ghana.[53] Given that this is the starting point for the Nigeria-Morocco Pipeline project, which could potentially be further extended to Europe, constructing the WAGP as hydrogen-friendly could enable it to be repurposed for the export of hydrogen from West African countries.[54]

Given the ability to repurpose the current pipeline to transfer hydrogen, this will aid in the process of generating green hydrogen across the country and increase the potential for green hydrogen exports as there is coastal access. However, many of Nigeria's gas pipelines are in need of revamping, and hydrogen production would require the development of new pipelines. Additionally, as a light gas of small molecules, hydrogen requires special equipment and procedures to handle it. Hydrogen is so small it can diffuse into some materials, including some types of iron and steel pipes, and increase their chance of failure.[55] It also escapes more easily through sealings and connectors than larger molecules, such as natural gas. Proper regulations and health and safety codes must therefore be in place to mitigate hazards and risks.

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[52] Godswill Ofualagba and O'tega Ejofodomi (2020). *Automated Oil and Gas Pipeline Vandalism Detection System*. Paper presented at the Nigeria Annual International Conference and Exhibition, online, 11 - 13 August, p. 2. https://www.researchgate.net/publication/344402868_Automated_Oil_and_Gas_Pipeline_Vandalism_Detection_System

[53] Chigozie Nweke-Eze and Rainer Quitzow (10 May 2022). "The promise of African clean hydrogen exports: Potentials and pitfalls", *The Brookings Institution*. https://www.brookings.edu/blog/africa-in-focus/2022/05/10/the-promise-of-african-clean-hydrogen-exports-potentials-and-pitfalls/.

[54] Ibid.

[55] IEA, *The Future of Hydrogen*, p. 35.

4.1.4. Available Landmass

The solar, wind, and hydroelectric power plants needed to produce green hydrogen to satisfy Nigeria's domestic and export demand would require a large expanse of land. In addition to land required for large-scale renewable energy generation, the land is required for H2 production.

4.1.4. Access to Water

Access to water is vital for green hydrogen as it involves splitting water into hydrogen and oxygen. As such, identifying potential water sources is critical for green hydrogen. According to the International Energy Agency (IEA), about 9 liters of water are used to produce one kilogram of green hydrogen (~33 kWh of energy). Most commercial electrolyzers at present even require between 10 – 11 L of water per kilogram of hydrogen (~33 kWh of energy). Approximately 8.9 billion liters of water would be required to cover Germany's hydrogen import needs. This is the equivalent of approximately 3,500 Olympic-sized swimming pools worth of water.

Water use due to electrolysis does not fully use up the water resource, because when green hydrogen is oxidized (by combustion or via a fuel cell) it yields the same amount of water as was originally electrolysed.[56] This may enter the atmosphere as water vapour, or be condensed at the point of use and recovered as liquid water. In fact, most countries would need to increase their freshwater withdrawal by less than 1% to completely transition to hydrogen-based energy.[57] By implementing green hydrogen production, a new impetus could be established for resolving water supply problems. By oversizing the water purification plant required by an electrolyser facility, a contribution can be made to supplying clean drinking water.

[56] Marcus Newborough and Graham Cooley (2021). Green Hydrogen: Water Use Implications and Opportunities. *Fuel Cells Bulletin*, 12: 12-15, p. 13-14.

[57] Bart Kolodziejczyk (28 September 2022). "Will a transition to a hydrogen economy affect water security?" *World Economic Forum*. https://www.weforum.org/agenda/2022/09/how-a-transition-to-a-hydrogen-economy-will-affect-water-security/.

Box 1. Green Hydrogen and Water Use

There may be cases where hydrogen production may conflict with local water uses, such as in situations where hydrogen production is not integrated with water treatment and supply in locations facing water scarcity but are otherwise optimal for hydrogen production. Nine litres of pure water is used up for every kilogram of hydrogen. Yet only less than 3% of the world's water is freshwater, of which two-thirds is tucked away in frozen glaciers and polar ice caps, while 30% is hidden deep underground, mostly in aquifers.[58] The world is already experiencing water scarcity, and half of the population could be living in areas facing water scarcity by as early as 2025.[59]

Desalinating seawater before splitting water through electrolysis loses most input energy in the desalination process and drives hydrogen prices higher. Direct seawater electrolysis machines die too quickly to be commercially viable, due to chlorine ion in seawater that eats away at electrodes and corrodes catalysts.

This constraint has pushed research and innovation into technologies that can electrolyze hydrogen out of the more abundant seawater that covers most of the planet. For instance, researchers at China's Nanjing Tech University have found a way around this problem and demonstrated a direct seawater electrolysis machine that ran for more than 3,200 hours (133 days) without failing, without a notable increase in operation cost, and at an efficiency level similar to a lot of current electrolyzer technologies.[60]

Another team from the University of Adelaide, Tianjin and Nankai Universities and Kent State University claims that a simple, cheap Lewis acid layer over the catalyst in an electrolyzer allows it to split seawater with "nearly 100 per cent efficiency," without any pre-treatment other than filtering.[61]

4.1.5. Availability of Off-Takers



The economic potential of green hydrogen may not correspond to market demand. The reasons for this may be the lack of off-takers in certain locations or, in some cases, it may be more economically sound to sell the generated renewable power directly to the national grid,

[58] Claudio Cassardo and Anthony A. Jones (2011). Managing Water in a Changing World. *Water*, 3(2): 618-628; Stefan Ellerbeck (12 October 2022). "Explainer: What exactly is freshwater and is there enough of it?" *World Economic Forum*. https://www.weforum.org/agenda/2022/10/water-freshwater-scarcity-uplink/.

[59] UNICEF (2023). "Water Scarcity". https://www.unicef.org/wash/water-scarcity#:~:text=Four%20billion%20people%20%E2%80%94%20almost%20two,by%20as%20early%20as%202025..

[60] Loz Blain (15 December 2022). "Clever device efficiently splits hydrogen and lithium out of seawater", *New Atlas*. https://newatlas.com/energy/hydrogen-electrolysis-seawater/.

[61] Loz Blain (2 February 2023). "Acid coating converts regular electrolyzers to split seawater", *New Atlas*. https://newatlas.com/energy/electrolysis-seawater-hydrogen/.

instead of dedicating it completely to hydrogen production. Nigeria, however, does have potential off-takers that could make green hydrogen production profitable.

With agriculture being Nigeria's largest employer of labor, 80% of fertilizer consumed is imported. On a continent level, fertilizer use is approximately 10-15% of global levels.[62] Green ammonia produced using hydrogen would benefit from fertilizer producers as offtakers. It is for this reason that Nigeria's Energy Transition Plan identifies ammonia production decarbonization as the key application for blue and green hydrogen.

4.2. Stakeholders in the Nigerian Hydrogen Space

The Nigerian hydrogen sector is very young, but quickly progressing. Several actors have already taken steps toward developing the Nigerian hydrogen sector.

4.2.1. Public Policy



There is currently no national hydrogen policy to encourage private developers and investors into the Nigerian hydrogen space. The Nigeria Energy Transition Plan launched in 2022 includes hydrogen as an option for the decarbonization of Nigeria's industry, specifically for ammonia production. Decarbonizing the ammonia industry requires 95% emission reduction by 2050 in the industry through a combination of blue and green hydrogen application.[63] With the country's Nationally-Determined Contributions, green hydrogen could make up 35% of hydrogen production and the rest could be grey hydrogen by 2050.[64] The plan does not envisage hydrogen making up a significant share of Nigeria's final energy consumption by 2030, while by 2015 it could make up a small share and enjoy a CAGR of 21% between 2030 and 2050.[65] In other words, the plan sees hydrogen production ramp-up only post-2030 due to "market uncertainty".[66] It argues that existing and new facilities built pre-2030 could use Steam Methane Reforming (SMR) to produce hydrogen with Carbon Capture and Storage (CCS) (blue hydrogen), while facilities constructed post-2030 could use green (or blue) hydrogen as the hydrogen market develops.[67]

[62] https://energycapitalpower.com/nigerian-gas-to-support-domestic-agriculture/
[63] Federal Government of Nigeria (2022). Nigeria Energy Transition Plan. Abuja: Federal Government of Nigeria.
[64] Ibid.
[65] Ibid.
[66] Ibid.
[67] Ibid.

Despite this thin attention given to green hydrogen by the Nigerian government, the push for developing the sector has been coming from German players interested in building the country's green hydrogen export capabilities. Nonetheless, there have been other efforts. Besides the ECREEE draft regional policy (which could serve as a benchmark for national policies) yet to be launched, the Energy Commission of Nigeria (ECN) and the Federal Ministry of Power seek to implement policies and regulations to ensure the delivery of renewable energy for green hydrogen production at least possible costs, including through the development of the necessary power system infrastructure. The Renewable Energy & Energy Efficiency Association Alliance (REEEA-A) is supporting the harmonization of hydrogen policies developed by the ECN, the Federal Ministry of Power, and the Nigerian National Petroleum Corporation (NNPC). The Ministry of Power has also expressed interest in working with State Governments, Distribution Companies, Regulators, and technical institutions to align the electricity ecosystem for large-scale green Hydrogen production.

4.2.2. Private Sector



Several companies have begun conducting feasibility studies, and various actors, including researchers at West African Science Service Centre on Climate Change and Adapted Land Use (WASCAL) headquartered in Accra, supported by the German government and responsible for West Africa's first open access geo-spatial resource for green hydrogen, the H2 Atlas-Africa. A German company, HPS AG, is having discussions on a pilot hydrogen plant in Nigeria, while domestic firms like Meiracopp Nigeria Ltd, New Cross Petroleum, and Dunatos Technology Consulting and Services are looking into blue or green hydrogen projects. Yet no major concrete announcement has been made –reflected in Ivoire Hydrogène's 2022 mapping of hydrogen projects in Africa –as has been the case in AGHA member countries and Angola.

4.2.3. Financing



Depending on the type of project, the cost of electrolysis could be EUR10 million, EUR7 million for a solar PV plant and additional EUR7 million for wind power. The cost of such a mid-sized hydrogen project could reach or exceed EUR25 million.[68] These costs do not take into account infrastructure costs such as the building of new distribution pipelines. These high capital costs therefore require the availability of financing and investment for the green hydrogen sector.

[68] Sebastian Timmerberg (15 February 2023). "Cost of Green Hydrogen Plant". *CODAHEA YouTube*. https://youtu.be/IFSDqs_9eGQ.

Bilateral partnerships are emerging, the key of which is with Germany. The German Government has opened Hydrogen Office in Nigeria and has launched its Global Hydrogen Diplomacy Programme and International Hydrogen Ramp-up Program (H2-Uppp) to encourage countries like oil-dependent Nigeria to use green hydrogen as a means of diversifying exports to include hydrogen exports. Germany's main international development agency, Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) appears willing to fund feasibility studies, but no major financing deal has been struck within the Nigerian green hydrogen space.

4.3. Identified Gaps

- To realize green hydrogen ambitions would require a substantial global investment of $450-$900 billion needed between now and 2050.[69] Funding would likely need to be made available at the national level to develop critical infrastructure, and access to financing for private ventures would need to be facilitated. As much as 70% of the required investments could come from foreign direct investment.
- In the race towards cost reduction, companies experiment with different technologies which can cost billions of US dollars. Without support schemes, the investment could be too great for a single firm. The recent successes of solar PV, wind, batteries, and electric vehicles have shown that policy and technology innovation has the power to build global clean energy industries. The increase in commitment towards hydrogen energy requires an increase in funding to execute initiatives. Achieving breakeven between gray hydrogen and green hydrogen in optimum locations is estimated to require the deployment of about 65GW of electrolyzer capacity (corresponding to about $50 billion in funding), to enable the learning and scale effects to drive costs down sufficiently.[70] This, together with introducing CO2 tariffs as a response to decarbonization pressure, could mean that green hydrogen is at cost parity with gray hydrogen as early as 2028.
- Additionally, the cost of transporting hydrogen hampers this competitiveness. Maritime shipping, considered the most cost-effective for distances over 3,000 km, would add an estimated $1 to $2.75/kg. For shorter distances, the cost of pipeline transport could be considerably lower, estimated at $0.18/kg per 1,000 km for new hydrogen pipelines and $0.08 for retrofitted gas pipelines.

[69] Ibid.

[70] Africa Green Hydrogen Alliance, *Africa's Green Hydrogen Potential*, p. 12.

- Public funding in research and development (R&D) experienced a 35% increase in 2021, most of which came from European Union programs, joint partnerships, funds, and projects.[71] International cooperation is vital in launching large-scale projects to implement hydrogen across industries and promote the development of international hydrogen trade. A key driver in generating more support and opportunities for hydrogen is the need to increase areas of demand; international cooperation can promote the global supply chain and stimulate global demand.
- Close collaboration between ECOWAS countries and developed countries which have advanced in hydrogen technologies, as well as the partnership between the public and private sectors along the entire value chain. Enhanced international cooperation is needed across the board but especially on standards, sharing of good practices, and cross-border infrastructure.

5. Recommendations

To achieve decarbonization in various sectors and find alternatives to fossil fuels in the electricity industries, there is a need to provide an enabling policy and framework for investors and potential partners to ensure that binding constraints are resolved. Hydrogen policies should target industrial applications. Within Nigeria, there are no policies that encourage hydrogen. A hydrogen policy must include:

- Clear land and water use regulations to protect communities and populations against disruptive resource use by green hydrogen developers, and to encourage an integrated approach to water resource use.
- The support of Research and Development (R&D) and provision of more accessible data for research. Public R&D funding can pivot research activities to encourage technology development that will benefit the national industry.
- The need for building capacity and well-known technical know-how and upskilling of local talent. By building capacity, infrastructure, and skills, these mutually supportive opportunities can help to scale up infrastructure development, enhance investor confidence, and lower costs.
- Provide financial and fiscal support to address investment risks of first-movers. New applications for hydrogen, as well as clean hydrogen supply and infrastructure projects, stand at the riskiest point of the deployment curve. Targeted and time-limited loans, guarantees, and other tools can help the

[71] Lesley Potters (2022). *The 2021 EU Survey on Industrial R&D Investment Trends*. Luxemburg: Publications Office of the European Union.

private sector to invest, learn and share risks and rewards. This should reduce the cost gap between green hydrogen and mature fossil fuel technologies.

- Health and safety regulations in the production, transportation, storage and use of hydrogen, and the quality that relevant infrastructure and technologies need to possess.
- Deployment of a regulatory agency to oversee the development of hydrogen. The development of hydrogen requires policies in place to support its deployment.

6. Conclusion

Hydrogen provides an alternative to decarbonizing sectors that are difficult to electrify such as heavy industry and long-haul transport. Hydrogen produced through renewables (green hydrogen) is the most sustainable hydrogen production technology. It is an essential component of a net zero energy system. It provides an alternative to decarbonise sectors that are difficult to electrify such as heavy industry and long-haul transport.

While green hydrogen is advancing in several African countries, there is relatively muted activity in Nigeria. The Nigeria Energy Transition Plan's place for hydrogen for decarbonizing ammonia production sees its viability after 2030. There is no hydrogen policy in the country, despite the efforts by German actors to open the way for German-Nigerian hydrogen partnership to stimulate Nigerian green hydrogen exports to Germany. However, in preparation for a future of lower green hydrogen production costs and greater government attention to the solution, it is important to begin to develop a policy and take hydrogen into consideration when planning out gas pipelines and industrial clusters.

For hydrogen to be a viable alternative to methane, it has to be produced at scale, and economically and the current infrastructure needs to be adapted. Hydrogen can be transported through gas pipelines, minimizing disruption and reducing the amount of expensive infrastructure needed to build a new hydrogen transmission network. By using natural gas for cooking and heating, hydrogen energy equivalents are emerging. There are constraints that affect production such as the high cost of production, lack of an existing value chain, safety considerations, awareness and perception, and lack of international standards and regulations.

Moving hydrogen from niche to mainstream gigawatt levels will require enabling policy and regulatory framework designed to stimulate private investment in hydrogen production. Governments are central in defining national hydrogen strategies to define the level of

ambition and serve as a reference for private sector actors to attract financing. Collaborate on global trading of hydrogen, identify priorities for conversion, align blending targets, provide financing, and set capacity targets.