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Toward the Adoption of Green Hydrogen in Africa: Prospects and Challenges

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Abstract **- The United Nations Sustainable Development Goals (UNSDGs) required the world into an accelerated approach to achieving sustainability goals and decarbonisation. To achieve these goals, the key Green hydrogen (GH) presents such opportunity for Africa with high renewable energy potential to make financial gains and create job opportunities for its rapid population growth through GH production. A significant opportunity for economic and social advantages for Africa may lie in the production and trade of GH. Investigation into the use of GH is gaining attention among researchers because it's a clean energy source and a possible substitute for fossil fuels. The quest for clean, eco-friendly, and sustainable energy sources has increased researchers' interest in the production of GH. This paper examines the GH production in Africa, its prospects and challenges. A brief overview of the GH description, applications, types by methods of production, prospects, challenges, future projections and recommendations was stated. Applications for the present and future of hydrogen are adequately discussed to buttress African nations' potential for GH production hub centres and the prospect of exporting GH because of abundant renewable energy resources. Currently, the high cost of GH is the limitation for its utilisation despite the varieties of its application. To achieve the decarbonisation goal, there is a need to reduce the cost of GH production which can be achieved by collaboration between Africans and Europeans. More concerted research is required to ensure cost reduction, process improvement, and commercialization perspective.**

Keywords: green hydrogen, decarbonisation, renewable energy, hydrogen application, types of hydrogen

I. INTRODUCTION

GH is a clean hydrogen form produced using renewable energy such as wind, solar, and biomass [1]. The by-product of hydrogen is water vapour and water [2]. By application of electrolysis, water is converted into hydrogen and oxygen in fuel cells. GH is hydrogen produced from renewables-based electricity through water electrolysis [3]. By 2050, Africa has the potential to produce 31 to 61 million tonnes per annum of GH, creating 3.8 million new jobs and increasing the African GDP to $58 billion. Globally, around 126 million tonnes of hydrogen are produced each year, with 96% produced using natural gas and coal by steam methane reforming and coal gasification [4, 5]. GH has the potential to supplement other energy carriers like electricity to aid in the thorough decarbonisation of the energy sector and the usage of energy in end-use sectors like transportation, buildings, and industry [6]. Africa has yet to fully realise its renewable energy potential [7]. It is projected that Africa's entire renewable potential is significantly larger than what is required to meet current and future needs. The International Renewable Energy Agency (IRENA), reported that Africa's solar PV and concentrated solar power (CSP), are significantly high, making African nations favourable for GH production. Similarly, wind energy has the potential to generate electricity every year, with Egypt, South Africa, Algeria, Somalia, and Sudan among the countries with the best prospects. Electrolysis is a clean method of producing GH [8, 9]. An electrolyser is a device used in this process that splits water molecules into oxygen and hydrogen using electricity. When producing GH, clean electrical energy is an essential factor. Additionally, it is produced using a variety of renewable resources, including wind and solar energy, making Africa a favourable place for the production of GH. The viability of GH from the abundant renewable energy sources in the African nations was investigated by the German Federal Ministry of Education and Research (BMBF) [10, 11]. The results show socioeconomic benefits such as job generation, tax income, and pollution reductions, among other things. By improving electrification rates for GH production zones which would function as a substitute fuel to replace fossil fuel. GH will help to meet the SDG7 goal [10, 12]. The world will substantially decarbonise the energy system with green hydrogen-enabling policy, investment, and innovation. With these initiatives, we can accelerate the development of technology and infrastructure that will allow us to rapidly increase renewable energy productivity and expand it into new areas. High costs of production, storage, transportation, and safety are challenges to overcome in the actualisation of a hydrogen-based economy, [13]. Figure 1 depicts the global energy consumption sources from 1950 to 2050. Most of the energy sources have adverse impacts on the environment, animals, food production and human health. To achieve the carbonisation goal GH is the energy source focus by the year 2050 as shown in Figure 1.

The most abundant chemical substance in the universe is hydrogen. It is an energy carrier that may be produced and stored rather than an energy source. Depending on the energy source, hydrogen can be produced in a variety of ways. Different types of Hydrogen are explained in section II. It is necessary to have sufficient information at a glance on GH

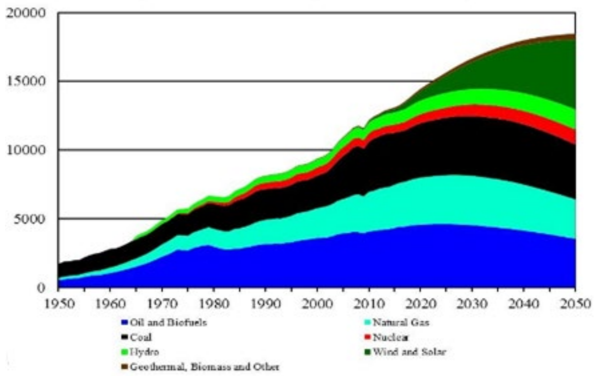


Fig. 1. Global energy consumption (million tons, 1950-2050) [36]

adoption in Africa, its prospects and challenges to serve as an information base for government, businessmen, industrialists, researchers, etc. which is the main purpose of this review.

II. APPLICATIONS OF HYDROGEN

Currently, around 90% of hydrogen is primarily used in three key industrial processes: methanol production, ammonia generation for fertilisers, and the reduction of sulphur content in diesel during refining [14, 15]. When the cost of producing GH becomes affordable, it is anticipated that the responsiveness of the widespread application of hydrogen will rise. The projected hydrogen utilisation by DNW Energy's transition outlook for the years 2035, 2050, and 2055 is shown in Figures 2a, 2b and 2c. The DNW project clearly shows the anticipated increase in the use of hydrogen around the world. These uses include transportation, power and heat generation, and the manufacture of e-fuel. The key question is whether African countries would seize this opportunity to become the world's biggest suppliers of green hydrogen in order to achieve economic stability and a sustainable environment.

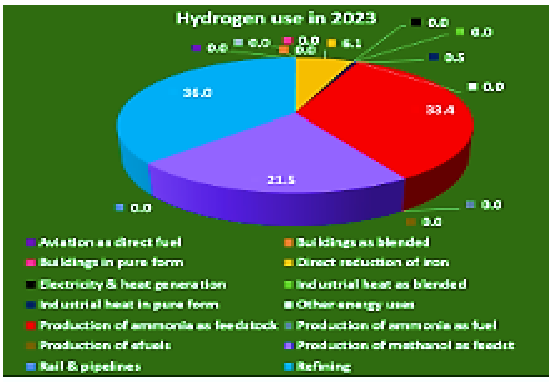
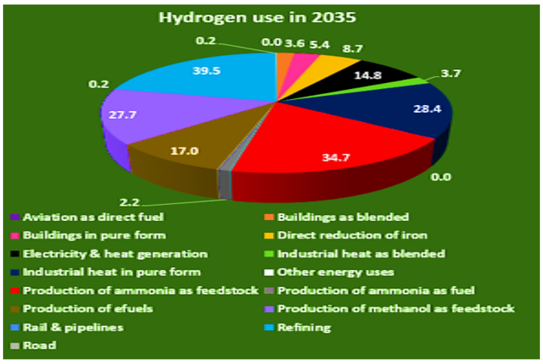
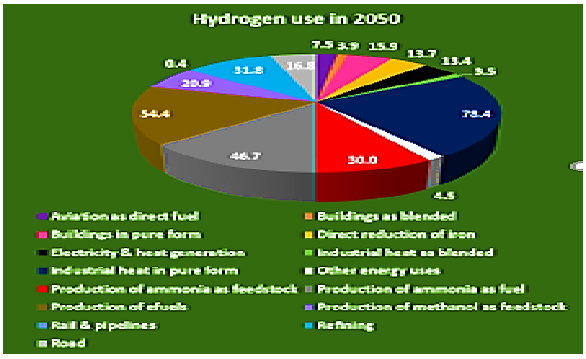


Fig. 2a. Projected Hydrogen Utilisation by the year 2023. [Source DNW Energy transition, 2022]



Fig, 2b. Projected Hydrogen Utilisation by the year 2035. [Source DNW Energy transition, 2022]



Fig, 2c. Projected Hydrogen Utilisation by the year 2050. [Source DNW Energy transition, 2022]

III. TYPES OF HYDROGEN BY PRODUCTION

Hydrogen colour by classification as usually called has nothing to do with actual colour but simply refers to the method by which the hydrogen is produced as clearly explained in Table 1.

Table 1. Types of Hydrogen Production Methods and Colours

Types of Hydrogen	Method of Production	Intensity of CO_2	References
Green Hydrogen	When made with renewable resources, e.g. wind energy, solar energy, etc.	Zero	[16]
Blue Hydrogen	When made with fossil fuels but the carbon is captured	Low	[17, 18]
Pink/red/violet Hydrogen	When made with electrolysis powered by nuclear energy	Low	[19, 20]
Brown Hydrogen	When produced using a coal gasification process	high	[21]
Turquoise Hydrogen	When made using methane pyrolysis	low	[22, 23]
Yellow Hydrogen	Hydrogen that is made through electrolysis using solar power	low	[24]
Grey Hydrogen	When produced using fossil fuels	High	[25, 26]
White Hydrogen	A form of natural geological hydrogen deposit found underground and produced through fracking processes	low	[27, 28]

Figure 3 shows different types of Hydrogen and their energy sources. About 120 million tonnes of hydrogen are produced annually, with natural gas and coal accounting for 96% of that total.

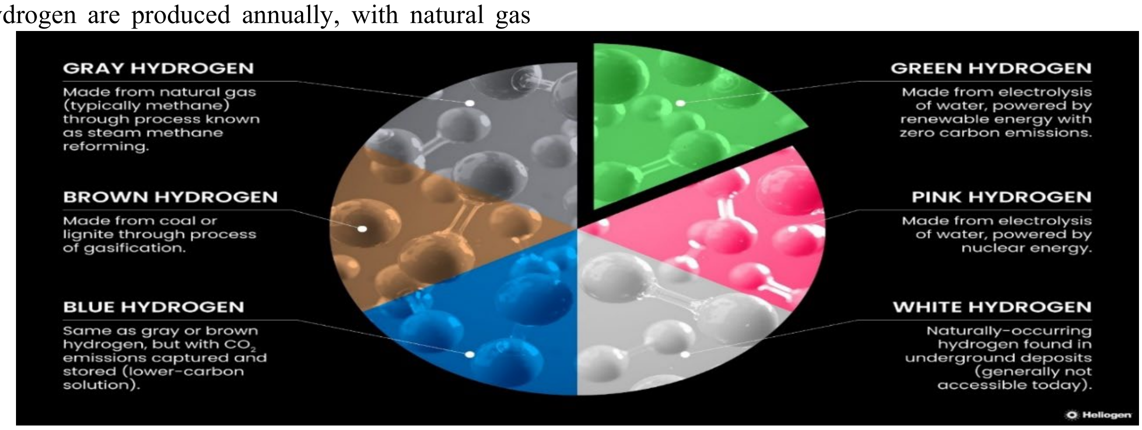


Fig. 3. Different types of Hydrogen and Energy Production Sources [29][37

The major quantity of hydrogen is used in the production of ammonia in the fertilizer industries, followed by hydrocracking and desulphurisation in the refining of crude oil, and smaller quantities of hydrogen quantities are used in other areas such as metal, glass, electronics, food processing and methanol production [30]. To achieve the decarbonisation goal, GH production is expected to increase as shown in Figures 2b and 2c.

IV. GH PROSPECTS IN AFRICA

Grey hydrogen is produced mainly from fossil fuels, making it a carbon-intensive process [31]. When other types of hydrogen, producing green hydrogen is quite expensive. However, Africa's tremendous renewable energy potential makes it a perfect GH production hub to offset the significant decarbonisation targets of the European Union (EU) in 2050. Figures 4 and 5 depict the quantity of GH production in million tonnes per continent and African countries respectively. European countries are likely to produce the highest GH by 2035 as shown in Figure 4, though the cost of producing GH is high. The Renewable Energy Sources in Africa as shown in Figure 5 could compensate for energy cost reduction.

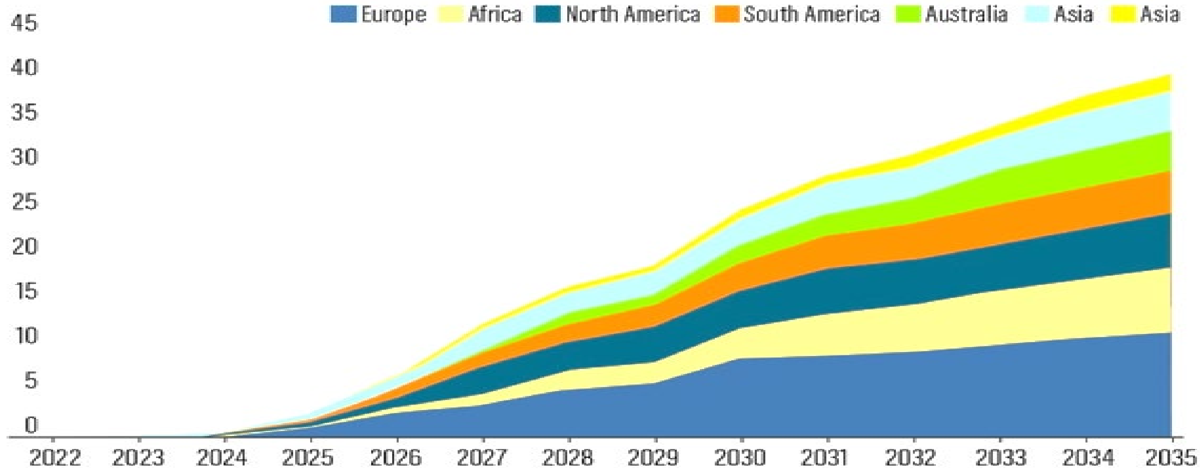


Fig. 4. Green Hydrogen production by Continents in million tonnes [38]

However, since the Europeans cannot meet their hydrogen need, renewable energy partnerships with Africa to produce GH would be required to achieve their decarbonisation goals.

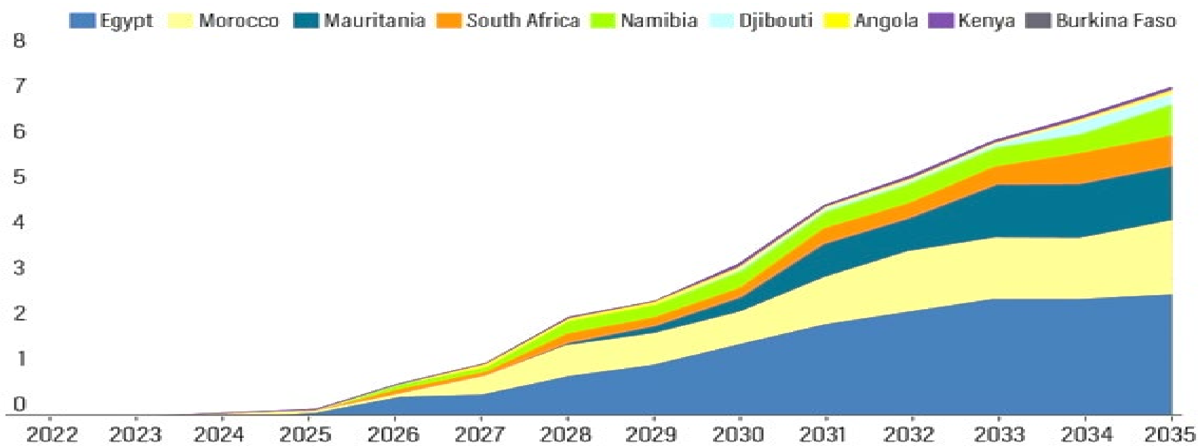


Fig. 5. Green Hydrogen production by African Counties in million tonnes [38]

African nations have the potential to export GH shortly [32, 33]. The following are the prospects of GH as an energy source:

A. Environment friendly

Hydrogen is a clean fuel that releases only vapour water as a byproduct when used in a fuel cell [33]. Hydrogen has the propensity to minimise greenhouse gas emissions because of its great efficiency and zero emissions.

B. Readily available

Water molecules are broken to create GH by electrolysis [34]. The GH feedstock is widely available. As opposed to other energy sources, which are localised and require advanced technology to be detected. The only difficult part is separating hydrogen gas from its companions. The ability to separate hydrogen gas, however, is no longer a novel concept. This makes GH the energy of the future to accomplish decarbonisation objectives.

C. Efficient fuel

Hydrogen is approximately three times as efficient as other fossil fuels [35]. Seawater electrolysis for green hydrogen is still in its early stages, but it has a high-efficiency rate (about 100%) and is suitable for areas with long coastlines and abundant sunlight. Again, GH manufacturing can use surplus electricity generated by solar and wind energy, making it a supplement to these sustainable sources. Solar and wind energy, on the other hand, are direct generators of electricity that are more suited for decentralised and domestic uses.

V. CHALLENGES OF GH IN AFRICA

A. Transportation cost

GH production may be far away from the point of utilisation. As a result, the cost of transportation from the plant to the place of use escalates. This is so because hydrogen is a particularly challenging product to safely transport. It has the lowest density of all gases and is also highly flammable when mixed with the smallest amount of air. Hydrogen delivery to the point of use comprises a significant cost because African nations do not have existing gas pipelines, unlike developed countries.

B. The high cost of production

The method used to produce GH is still in its early stages and is expensive, which raises the production cost. The current cost of manufacturing (grey) hydrogen1 ranges from 1.5 to 2.5 USD/kg, according to IRENA. As the scale of production increases from MW to GW, costs are expected to further decrease. A recent study results show that the cost of producing GH at 80% electrolyser efficiency is about 1.16 USD/kg [10].

C. Storage-related issues

Hydrogen can be preserved, allowing it to be used for reasons different from those for which it was created. However, weight and volume are significant difficulties that must be overcome before hydrogen can be properly stored. It has a modest ignition property but a broad flammability range. Because of its low density, it can be held under high pressure.

VI. FUTURE PROJECTIONS AND RECOMMENDATIONS

Africa's vast renewable energy resources present an excellent opportunity for Green Hydrogen production to meet global demand. This could pave the way for African countries to export GH. Exporting GH may provide an opportunity for Africa to create riches and compensate for technological deficiencies.

The exportation of GH to European nations will enhance the attainment of UNSDG goals. Adequate GH production shall provide a balance of trade and technology development among African nations. The global increase in GH demand shall create opportunities for Africa to participate in GH production and therefore create opportunities for infrastructural development and investment in the public sector and private. GH adoption as an alternate energy source shall create opportunities to promote novel electrolysis for strategic cost-reduction and scale-up opportunities

VII. CONCLUSION

This current study has clearly reviewed the GH adoption in Africa, its prospects and challenges. The present and future applications of GH were stated. It explained clearly the different types of hydrogen by production methods. It was noted that transportation and storage contributed to the high cost of GH production. The urgent need to achieve the decarbonisation goal has contributed to interest in the production of GH. Though the cost of GH presently is high, the cost can be reduced in the immediate future when blending the abundant renewable potential in Africa and technology availability in developed nations. Also, the adoption of GH will promote the global decarbonisation goal. Given the importance of green hydrogen to environmental sustainability, the high production cost, prohibitive initial investment, and other barriers to scaling up and commercialising green hydrogen production should be addressed. Future research should focus on developing green hydrogen production methods that are effective, efficient, and low-cost in order to reduce environmental and economic implications.

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