Assessing the Economic Advantage of Hydrogen to Fossil Fuel in Nigeria

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Abstract

Hydrogen is an abundant element and a flexible energy carrier, offering substantial potential as an environmentally friendly energy source to tackle global energy issues. When used as a fuel, hydrogen generates only water vapor upon combustion or in fuel cells, presenting a means to reduce carbon emissions in various sectors, including transportation, industry, and power generation. Nevertheless, conventional hydrogen production methods often depend on fossil fuels, leading to carbon emissions unless integrated with carbon capture and storage solutions Hydrogen which is a clean energy carrier, offers a promising alternative. However, the transition from a conventional petroleum-based energy economy to a hydrogen economy involves many uncertainties regarding concerns such as the development of efficient fuel cell technologies, problems in hydrogen production and distribution infrastructure, hydrogen safety issues and the response of carbon-based fuel markets. This paper presents an assessment of the economic impact of hydrogen energy on the transportation and energy use sectors of Nigeria, along with implications for Greenhouse Gas (GHG) emissions. It also assesses the economic advantage of hydrogen to fossil fuel in Nigeria, considering production costs, infrastructure, and market demand. Our analysis reveals that hydrogen production can create new industries, jobs, and revenue streams, while reducing greenhouse gas emissions and environmental impact. Although hydrogen production costs are currently higher than fossil fuel extraction, Nigeria's abundant resources and growing energy demand make hydrogen an attractive option for future energy security and economic growth.

Keywords: Greenhouse Gas; Hydrogen; Petroleum-based energy; Fossil fuel

Introduction

Energy is vital for daily life, powering numerous aspects of our existence. Historically, Africa has primarily depended on fossil fuels for its energy needs. However, the prolonged use of fossil fuels has highlighted significant drawbacks, such as the substantial emission of greenhouse gases. These disadvantages have led to a growing imperative to seek alternative energy sources (Ajayi et al., 2016). The urgent need to combat climate change and cut greenhouse gas emissions has driven the global energy sector towards cleaner and more sustainable options. Within this framework, hydrogen, especially green hydrogen produced from renewable energy, has emerged as a viable solution for reducing carbon emissions in various sectors, including industry, transportation, and power generation (Ewing et al., 2020). With its abundant renewable energy resources, Africa is well-positioned to play a crucial role in the global hydrogen economy.

Literature Review

Hydrogen is gaining traction as a potential replacement for fossil fuels due to increasing concerns about their environmental and financial drawbacks (Mustafa et al., 2020; Pastore et al., 2022). Bhagwat and Olczak (2020) highlight hydrogen's significant potential in various sectors, such as transportation, power generation, and industrial processes, with global production reaching around 120 million tonnes annually. In contrast, the continuous consumption of fossil fuels releases large amounts of CO2, exacerbating global warming, and depletes energy resources (Mustafa et al., 2020). Currently, China leads the world in hydrogen production and consumption, using approximately 23.9 million metric tons in 2020. The United States follows, with 11.3 million metric tons of global hydrogen consumption (Kumar et al., 2024). Hydrogen's appeal lies in its storage capabilities, efficiency, cleanliness, and compatibility with renewable energy sources (Qian et al., 2023). Consequently, hydrogen is crucial in decarbonizing various sectors and mitigating climate change, particularly in transportation and steel manufacturing (Banava, 2023). However, it is important to recognize that while burning hydrogen only emits water vapor, producing it from fossil fuels can still result in CO 2 emissions. To achieve truly emission-free hydrogen production, dependence on renewable energy sources is essential (Stavroulakis et al., 2023). According to Liu et al. (2023), green hydrogen is expected to replace fossil fuels in the near future. However, the methods used to produce hydrogen vary widely, influencing greenhouse gas emissions such as carbon dioxide (CO_2) and methane (CH_4) (Sánchez-Bastardo et al., 2021). Green hydrogen, produced from renewable sources like wind, solar, and hydropower, is viewed as a clean alternative to fossil-derived hydrogen (Kakoulaki et al., 2021).

Hydrogen production, storage and distribution

The development of clean and cost-competitive hydrogen production processes is essential to the market success of any future hydrogen economy. Excellent reviews of hydrogen production methodologies have been published (Dincer *et al*., 2011), but for brevity's sake are not restated here. The diversity of ways to produce hydrogen certainly contributes to the security of energy supply. In addition, versatility in the production of hydrogen along with its interchangeability with electricity makes it exceptionally valuable as an energy carrier. Continued efforts to develop cost-effective hydrogen production methods could lead to a new form of energy transformation that would revolutionize the energy economy of nations of all sizes. Various methods to store hydrogen energy exist. These include on-board storage in vehicles , gaseous storage, liquid storage, and solid storage . Interested readers may consult these references for detailed information on hydrogen energy storage technology. Hydrogen can be distributed in a variety of forms by using various technologies. The first node of the supply chain and production determines some of these forms of distribution and technologies. Unlike conventional fuel, hydrogen can be produced via large centralized production facilities or in small-scale decentralized plants, although this may increase the complexity in finding the optimal configuration. For instance, on one hand, centralized production is beneficial in that it enables large scales, but currently hydrogen demand does not yet justify large scale production. The centralized large-scale production approach also incurs additional costs for distribution from production to demand nodes. On the other hand, small-scale production can exploit decentralized onsite hydrogen plants, leading to significant reduction in transportation costs. Many authors agree that centralized systems should not be prioritized in the foreseeable future (IEA, 2007). Hydrogen can be utilized in both liquid and gaseous forms. Liquefied hydrogen can be transported in tankers via rail, road, or ship, while gaseous hydrogen can be transported via pressurized pipelines or tube trailers. This diversity in transportation must be leveraged to find the most cost-effective transportation modes to connect production to demand centers. Its portability notwithstanding, hydrogen is difficult to transport. It can embrittle steel and other metals, weakening them to the point of fracture. Trucking and rail distribution, pipeline distribution, and local production at point of use or need constitute other ways to distribute hydrogen

(Dagdougui et al., 2012).

Hydrogen end use efficiency and hydrogen production processes

An important characteristic of a hydrogen economy is the gain in end-use efficiency. Once hydrogen reaches consumers, it can be used for electricity in addition to powering vehicles. However, the resulting energy loss associated with hydrogen produced by steam methane reforming or by electrolysis is such that, when used in producing electricity, the resulting efficiency of the process is roughly equal to that of today's power plants, which incur much lower costs for raw materials. Direct generation of electricity through wind and solar power is also more efficient for most stationary applications.

Economic Advantages of Hydrogen to Fossil Fuel

One major advantage of green hydrogen is its environmental cleanliness. Unlike other types of hydrogen, green hydrogen is produced using renewable energy sources, resulting in zero carbon emissions. It can be used in a wide range of applications across various industries, including transportation, power generation, and industrial processes, offering a sustainable and carbon-free alternative.

Transportation

According to Pasini et al. (2023), green hydrogen can be used for transportation and is considered as one of the most promising options for decarbonizing the different modes of transportation, including cars, buses, trucks, trains, and airplanes. Green hydrogen can be used as a fuel for hydrogen fuel cell vehicles. These vehicles use a fuel cell to convert hydrogen into electricity, which then powers an electric motor (Inci et al., 2021). The only emission from a hydrogen fuel cell vehicle is water vapor, making it a zero-emission vehicle. The use of green hydrogen as a and improve air quality (Vardhan et al., 2022). Green hydrogen may also be used as a fuel for waterborne transport, such as ships and boats (Jie et al., 2023). Hydrogen fuel cell vessels are becoming increasingly popular, especially for ferries and small inland waterway ships (Chatelier, 2023).

Power generation

Green hydrogen can also be used to generate electricity in fuel cells or through combustion in a gas turbine (Hwang et al., 2023). Green hydrogen can be used as a fuel in fuel cells, which convert the chemical energy of hydrogen and oxygen into electrical energy, water and heat (Liu et al., 2023). Fuel cells are highly efficient and emit only water vapour, making them a sustainable alternative to

traditional fossil fuel power plants (Azni et al., 2023). This can be particularly useful in remote locations or off-grid settings, where traditional power sources may not be available. The use of green hydrogen for power generation can help to reduce greenhouse gas emissions and improve energy security. Green hydrogen can be used in fuel cells (an electrochemical device that converts the chemical energy of green hydrogen and oxygen into electricity) to produce electricity (Yu et al., 2023). Fuel cells have high efficiency and emit only water and heat as byproducts. Green hydrogen can also be burned in combustion engines to generate electricity (Teoh et al., 2023), similar to burning natural

gas, except that the only emission is water vapor. It can also be used in specially designed gas turbines to generate electricity (Hassan et al., 2023a). However, it is important to note that green hydrogen, like other forms of hydrogen, cannot be used in conventional gas turbines without modifications (Bothien et al., 2019). The development of specific turbines capable of efficiently burning hydrogen is an area of active research. Additionally, natural gas-hydrogen blends can be used for electricity generation via modified gas turbines, providing a transitional solution towards cleaner energy. Similarly, green ammonia produced from hydrogen can also be used for electricity generation in gas turbines, offering another pathway to leverage hydrogen for sustainable energy production (Ağbulut et al., 2023).

Industrial processes

Green hydrogen can also be used in a variety of industrial processes, such as refining, chemical production, and steel production (Genovese et al., 2023). The global transition to climate neutrality will necessitate not only renewable power but also climate-neutral energy carriers such as hydrogen and its derivatives (Runge et al., 2023). These processes typically require large amounts of energy and produce significant greenhouse gas emissions. The use of green hydrogen as a feedstock or fuel for these processes can help to reduce greenhouse gas emissions and improve the sustainability of these industries. Considering the factors that need to be considered when producing green hydrogen from renewable energy sources.

Reduction of greenhouse gas emissions and dependence on fossil fuels

Green hydrogen offers substantial benefits for Africa, including the potential to reduce global and local greenhouse gas emissions (Li et al., 2023). In Africa, where fossil fuels dominate the energy landscape and contribute significantly to greenhouse gas emissions, green hydrogen can serve as a cleaner alternative in sectors like transportation, power generation, and industry, fostering a more sustainable future. By generating green hydrogen from renewable sources, African countries can advance sustainable development goals, improving air quality and promoting environmental sustainability. Adopting green hydrogen also holds promise for reducing Africa's reliance on imported fossil fuels, which exposes the region to volatility in global oil prices and supply disruptions (Odoom et al., 2023).

Instead, green hydrogen production offers a stable and locally sourced energy option, enhancing energy security across the continent. Furthermore, embracing green hydrogen technology presents Africa with an opportunity to lead the global transition to renewable energy, a role that has often been overlooked in past energy revolutions (Panchencko et al., 2023). The adoption of green hydrogen stands to benefit Africa through enhanced energy security, job creation, reduced dependence on imported fossil fuels, and leadership in renewable energy innovation. It is crucial for African governments and stakeholders to prioritize the development of green hydrogen infrastructure, supported by robust policies and regulations that facilitate its widespread adoption across the region.

Conclusion:

Hydrogen offers a very promising economic potentials over fossil fuels in Nigeria, despite the increase in production costs. The abundant resources in Nigeria and the rapid energy demand, and need for diversification of the economy make green hydrogen an attractive alternative for future energy security and economic growth.

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