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Exploiting the Electrolysis Industry for Sustainable Climate and National Economic Growth: Exploring the Science Classroom Privileges

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Abstract

This research explores the potential of the electrolysis industry as a catalyst for sustainable climate practices and national economic growth, with a focus on leveraging science classroom privileges. This research adopted the descriptive research design. It recognizes electrolysis as a pivotal process for mining and refining many of Nigeria's endowed under-utilized mineral resources such as bauxite, copper, and lead and for producing hydrogen, a clean and versatile energy carrier with applications in various sectors. The investigation aims to bridge the gap between theoretical knowledge in science classrooms and real-world applications within the electrolysis industry. It delves into the science behind electrolysis, emphasizing its role both in the refining of these mineral resources which in turn drive economic growth and in green hydrogen production and its potential to mitigate climate change. The research also analyzed the economic advantages of harnessing electrolysis for a nation's energy portfolio via an interdisciplinary approach, between the science education sector and the electrolysis industry. It also examined the need for educational reforms that align the science curricula with the evolving needs of sustainable technologies.

Keywords: *Electrolysis, Sustainable climate, Curricula, Clean energy, Economic growth, Greenhouse emissions*

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Background to the Study

Nigeria, a richly endowed nation on the African continent characterized by its abundant solid mineral deposits but plagued by numerous developmental challenges which have forced it to remain in financial deterioration. At the fore of these predicaments are climatic and environmental degradation, erratic energy and power systems and economic and revenue crises (Yusuf, 2023 & Kemi, 2019). Despite its abundant deposits of naturally occurring solid mineral resources, it has continued to suffer the impacts of the paucity of the techniques and skilled manpower required to transform these resources into economic commodities, produce sufficient renewable energy and power, symbiotically leading to a sustainable environment and climate through reduced fossil fuel induced-carbon emissions. According to U.S Energy Information and Administration (EIA) (2021), the global energy-related carbon emissions has increased from 32.3 billion metric tons in 2012 to 35.6 billion metric tons in 2020 and is projected to reach 43.2 billion metric tons by 2040 (Anwar et al., 2023). In Nigeria, the increased reliance on fossil fuel energy and poor investment in renewable energy resources has significantly increased the carbon emission level in Nigeria, proliferating diseases, destroying farmlands and livestock, thereby hindering income generation from agriculture (Haruna et al.,, 2023). However, the application of electrolysis has remained a major technique through which many developed nations have cautiously and judiciously industrialized the value chain of these mineral resources for the enormous benefit of their environment and economies. Electrolysis refers to the chemical change or decomposition reaction which occurs when electric current is passed through an electrolyte. (Turner et al.,., 2023 & Chai et al.,., 2019). It is a science concept stipulated to be taught at the senior secondary school level , then subsequently at the tertiary levels of education according to the Nigerian science curriculum. It represents a dynamic body of knowledge with potential for driving positive economic growth through its application in the extraction and refining of some natural resources such as bauxite, lead, copper etc. It is also utilzed extensively in the production of green hydrogen from water. Green hydrogen is produced through the electrolysis of renewable water and in this process water is split into hydrogen (H2) and oxygen (O2) under the influence of electricity with zero carbon emissions (Carmo et al.,., 2013). This process of energy production serves as a viable alternative in mitigating the effects of fossil fuel burning on climate change and instrumental to achieving a decarbonized planet (Kumar & Lim 2022).

However, research shown that the quality of Science education is always a sine qua non for the economic advancement and prosperity of any nation. A nation which recognizes the essence of education as being a tool for national development sets up itself for exponential socioeconomic growth (Ogbonnaya 2020). A scientifically literate workforce is essential for innovation and technological advancements, which will engender economic prosperity (National Research Council 2012). The technological development of nations has always been positively correlated with the quality of their science classrooms. Thus, the optimum exploitation of electrolysis industry in Nigeria depends to a large extent, on the efficacious teaching and learning of electrolysis in science classrooms across the country. This article also seeks to justify the need to reinvent pragmatic instructional methodologies and approaches in the teaching of electrolysis in schools while explicating the roles of the different stakeholders

in producing the next generation of technically skilled human resources required for optimum exploitation of this industry.

Literature Review

Exploiting the Electrolysis Industry

The industrial application of electrolysis is one with many potential benenfits for driving economic growth through renewable energy creation, natural resources extraction and refining. Gobally, the industrialization of electrolysis has gained moementum and many countries have continued to adopt this science in especially in the decarbonization of the planet (Cavaliere, 2023), production of green hydrogen, wet-cell batteries, refined copper and zinc, extraction of aluminium from bauxite and electrolplating.

Production of green hydrogen: Green hydrogen is now becoming the world's most sought after energy resource. It is now the focus of many countries across the globe in transistioning into a carbon-free energy era, with many countries seting a decarbonaization target by 2050 in response to prevailing global climate change (Hassan et al.,, 2024). Many countries such as Japan, China, Germany, USA, France, Canada, India, Australia and others are already commiting large financial resources in developing green energy infrastructures (Braga et al., 2024). Research has shown that on the African continent, South Africa, Nigeria, Morroco and Kenya are also developing a number green hydrogen projects to be included in their national energy portfolios (Yohannes & Diedou, 2022).

Studies have revealed that green hydrogen, in the next three decades will approximately supply up to 20% of the global energy needs, while up to generating USD2.5 trillion in revenues. By 2050, it is estimated that green hydrogen will substitute up to 10.4 billion barrels of oil equivalent, with a projected producing capacity of close to 530 million tons of green hydrogen. It is forecasted that the globally, green hydrogen industry will worth USD300 billion in value annually and will 42 million jobs worldwide by 2050 (Braga et al., 2024). Green hydrogen serves as both an energy carrier and a versatile industrial feedstock, fostering the development of intricate and resilient economic value chains. In Addition, green hydrogen can be processed into consumable commodities such as renewable fertilizers and chemicals, while effectively decarbonizing highly polluting and challenging-to-abate sectors, including cement, steel and glass production (Barigozzi et al., 2024, & Kamil et al.,. 2024). Green hydrogen as fuel in fuel cell vehicles also plays an important role in decarbonizing the transportation sector (Wang & Li 2023).

Countries on the African continent have rapidly began to develop green hydrogen projects in the recent years, marking a significant step towards sustainable energy innovations. Countries like Egypt, Namibia, South Africa, Mauritania, Algeria and Morroco are already on the bandwagon of global producers of green hydrogen production (Kamil et al.,, 2024).

However, Nigeria stands to earn a competitive economic advantage over a wide range of countries in the production and exploitation of green hydrogen in two major ways which are identified below:

1. Abundance of Seawater bodies: Water electrolysis for the production of green hydrogen in commercial quantities is usually produced through Proton Exchange Membrane Electrolyzers. (Stiber et al., 2022 & Kim et al., 2022). This procedure heavily requires a very large volume of freshwater to produce green hydrogen in commercial quantities, costing enormous financial resources in achieving and inhibiting the sustainability of green hydrogen technology, making Seawater, which accounts for 96.5 % of the total water on Earth, is the most suitable resource for electrolysis (Zhao et al., 2024). Given that Nigeria is a coastal nation stretching an approximately 853 km with 9 out of its 36 states sharing the Atlantic Ocean coastline (Olaoye & Ojebiyi 2018), it stands a better chance in utilizing the vastly abundant seawater surrounding it in producing green hydrogen for complementing its current hydroelectric energy portfolio.
2. High Solar Energy Profile. Nigeria is endowed with a high solar energy radiation potential, receiving an abundance of sunshine and irradiance, with average daily sunshine hours of 6.3hours/day and average daily irradiance ranging between 3.7kWh/m2 day in the coastal regions to 7.0kWh/m2 day in the northern arid regions (Ojosu & Salawu 1990). In a study conducted to estimate the quantity of green hydrogen produced through Solar energy in Pakistan, a country whose solar potential mirrors closely with Nigeria's getting an average daily irradiance of 5.3kWh/m2 (Sheikh, 2009), it revealed an annual production capacity of 2.8 million tons of green hydrogen (Irfan et al. 2018). This shows the close competitive advantage Nigeria stands to gain in green hydrogen production capacity. Sister African nations like Mauritania (Sow et al. 2024) and Niger (Bhandari, 2022) have developed clean energy projects harnessing their solar potentials for green hydrogen production. Nigeria stands at a competitive advantage in harnessing its abundant solar potential in powering the electrolyzers for green hydrogen production. This will in combination with its existing hydroelectric power generating capacity, further boost the energy portfolio of the country

Extraction of Aluminum from Bauxite: Nigeria is endowed with a vast amount of bauxite, the raw mineral from which aluminum is extracted Aluminum is versatile for its low density and its resistance to corrosion, while its alloys are majorly used in the production of aircrafts, automobiles, beverage containers, and used in both transportation and building industries (Olade, 2021). According to Schwarz (1997), Nigeria has an abundance of over one million tons of bauxite deposits in its Mambila Plateau region only. Despite this enormous quantity of bauxite deposits, Nigeria still remains a big import market for aluminum. As at 2022, available statistics reveal a net value of USD 367,000. (Observatory of Economic Complexity, 2024). By leveraging on the industrial application of electrolysis in refining aluminum, Nigeria can pitch a strong hold in the global aluminum export market, creating a more job opportunities for its growing population, Increasing the country's GDP leading to rapid economic growth and development.

Copper and Lead Refining: Copper and Lead are versatile metallic minerals, majorly used in the production of electric cables, plumbing pipes and sheet metals. Nigeria has a vast amount

of both mineral deposits. Copper deposits, spread across six states of the nation namely; Plateau, Zamfara, Nassarawa, Kano, Bauchi, Yobe, while lead deposits are located in eight states namely; Cross River, Ebonyi, Imo, Benue, Nassarawa, Plateau, Taraba, Zamfara (Olade, 2019). Electrolysis is largely deployed in the refining of copper (Nguyen et al. 2023) and lead (Arkhipov et al. 2017). This serves as a promising opportunity for the Nigeria's economic growth, by utilizing the potentials of the electrolysis industry in refining copper and lead.

Science Education as a catalyst for Growth and Development

Growth and development are both outcomes of combined critical thinking, logical problem identification, assessment of available resources for potential solutions, meticulous observation of experimented solutions, and taking deliberate but careful rational and evidence-based action in solving the identified challenges. These are the gains of scientific literacy in an individual, organization or nation. Science education offers a holistic approach in developing a skilled workforce which have the required resources to proffer solutions to challenges impeding the country's economic growth and development (Isiksal &Sahbaz, 2014). Science education also plays a vital role in addressing global challenges, it helps individuals become responsible and informed citizens who can actively participate in scientific discussions and activities necessary to drive growth and development of the society (Jolaoluwa et al. 2024). It could be viewed as a process of teaching or training especially in school to improve one's knowledge about the environment and to develop one's skill of systematic inquiry. Science education affords the individual the knowledge as well as skills that help them to solve economic, political, and social and the numerous emerging issues in the environment (Obi and Obiadazie 2015). In essence, science education can be said to be a catalyst in achieving the economic growth and political aspiration of any nation (Ekpa et al., 2022).

Teaching and Learning electrolysis in Nigerian Science Classrooms: Issues and Challenges

Electrolysis is an interdisciplinary science concept which feature in both the Physics and Chemistry curriculums in Nigeria. According to the Nigerian Educational Research and Development Council (NERDC), (2018), Nigerian science students are expected to learn electrolysis in Chemistry during their second year under the chemistry and the industry theme. On the other hand, it has also been stipulated to be taught in Physics in the third year of secondary education under the physics in technology theme. This shows the relevance of building a reliable and self-sufficient workforce through effective teaching and learning, capable of applying electrolysis for industrial processes and nation building.

However, the current state of the electrolysis industry in Nigeria characterized by insignificant exploitation and application can be said to be a function of ineffective teaching and learning of the concept in the science classrooms Many studies have reveled the relationship between industrial transformation and quality of science education in that society. For instance, the rapid economic development of Singapore, a country of about 250 square miles with no single natural resources has been attributed to the quality of its science

education (Goh, 1997) Tan et al., (as cited in Vinodhen, 2020) identified that the economy of Malaysia has over the past 50 years transformed from being a heavy dependent on primary commodities to one driven by high technology manufacturing and foreign direct investments through its development of science education. Mogbo (2002) justified the level of technological transformation of any human society to be directly dependent on the level of science education learned, derived and applied in that society.

For instance, China, a nation at the top index of the electrolysis industry, earns billions of dollars annually from trading in electrolysis derived commodities. China International Marine Containers Group Co. (CIMCG) in 2023, generated about USD132 million in sales for trading green hydrogen, a single commodity derivative of electrolysis (Economic Times 2024). The science curriculum in china is on which is prioritizes teaching science by practice emphasizing on the need to develop learners' hands-on skills and problem-solving skills (Ma, 2016).

In order to build a scientifically literate workforce that will engender the optimum industrial exploration of the electrolysis industry for the economic benefit of Nigeria, leveraging on the nation's peculiar advantages in terms of abundant varying solid mineral deposits, and geo-climatic resources, there is a need to pay attention to certain issues which underscores the teaching and learning of electrolysis in Nigerian classrooms, some of which are highlighted below:

Curriculum: The Nigerian science curriculum is rather outdated and doesn't provide relevance with the emerging needs of the science and technology industry. Adeyemi and Soyemi (2016) pointed that the science curricula in Nigeria are often obsolete, teacher-focused and majorly theory-based, which results in poor learner participation and limited application of scientific concepts.

Instructional strategies: This is another serious challenge bedeviling the effective teaching and learning of electrolysis in Nigerian science classrooms. Instructional strategies mostly adopted by teacher are majorly those which are teacher-centered, inhibiting students' active participation and motivation in their lessons. Experts in science education have always called for the use of various innovative strategies that will align with the needs of the learners. Obi and Obiadazie (2015) in their study called for use of Innovative teaching strategies such as inquiry, discovery, project and many more which would stimulate creativity in the students produce a generation of skilled scientists required for industrial take off and national transformation. For instance, Saricayir (2010) revealed that dramatization was effective in teaching water electrolysis to middle school learners.

Instructional Materials: Many teachers fail to adopt the use of instructional materials in teaching electrolysis. Instructional materials are meant to stimulate learners' interest in the knowledge content by appealing to their sensory organs (Olumorin et al., 2010).

Lack of Laboratory Equipment: Lack of laboratory equipment has been identified to be another prominent challenge confronting the teaching and learning of electrolysis in Science classrooms. Generally, electrolysis like other science concepts requires conducting practical which is meant to stimulate observation and inference skills in the learners. Oyelade and Dapiap (2019) in their study revealed that in Nigerian secondary schools, inadequate laboratory equipment was detrimental to achieving science education goals.

Exploring science Classroom Privileges as a way Forward

To achieve desirable economic growth and a sustainable climate in Nigeria through leveraging on the potentials abound in the electrolysis industry, there is a need to re-align the science education and its curriculum with the evolving sustainable technologies whilst focusing on improving the quality of teaching and learning in science classrooms to match global science education standards. The following are some of the identified strategies to be considered in achieving the above:

1. Curriculum reforms: The Nigerian science curriculum needs to be revised in order to accommodate emerging technologies and align with global trends. It should also promote hands-on learning and inquiry-based learning approaches in science education, where students actively engage in experiments, field trips and projects related to electrolysis and renewable energy. This fosters a deeper understanding of the concepts and encourages critical thinking and problem-solving skills (Ojo, 2019).
2. Research institutions and Industrial Partnership: Partnerships and collaborations between schools, and research institutions involved in electrolysis industry, such as the Nigerian Institute of Mining and Geosciences. This will facilitate knowledge exchange, research collaboration, and internship opportunities for students (Abbas et al., 2020).
3. Science teachers' training and capacity building: Government should organize specialized training and professional development opportunities for science teachers in line with current technologies in the global electrolysis industry. This will result in capacity development in the teaching of topics related to electrolysis in both theory and practical application in the classroom.
4. Career fairs and exhibition: Extra-curricular activities such as career fairs will avail students with direct exposure to companies and professionals working in the electrolysis industry and related fields. It helps them appreciate the relevance of their science education to real-world application. This exposure can inspire students to pursue careers in these sectors and thereby creating strong workforce competent to maximize the benefits of the industry for economic advantage.
5. Integration of Entrepreneurship Education: Entrepreneurship education should be integrated into the science curriculum to foster innovation and entrepreneurship in the field of electrolysis and sustainable technologies. This could involve teaching students about the economic prospects and market opportunities, abound for the electrolysis industry.

Summary of Findings:

1. Electrolysis remains a viable and sustainable technology in the adequate exploitation of the vast number of mineral endowments in Nigeria.

2. Nigeria stands a favorable chance in joining leading countries across the globe to harness the potential of the electrolysis industry for economic growth.
3. Globally, there is an increased trend in the recognition of green energy as a potential alternative to fossil fuel and to achieving economic development and sustainable climate
4. In achieving economic growth of any nation, the quality of science classroom is a major determinant. As such, the Nigerian science curriculum should be reviewed in order to meet global current standards.

Conclusion

Leveraging on the science classroom privileges for the optimum exploitation of Nigeria's electrolysis industry potentials represent a promising pathway towards achieving desirable economic growth and sustainable development. Through science curriculum alignment with evolving technologies, enhancing the quality of teaching and learning in science classrooms, and incorporating extra-curricular strategies such as exhibitions and career fairs, Nigeria can empower its workforce with relevant skills and knowledge, stimulate innovation and entrepreneurship in the electrolysis industry, and contribute to both economic growth and climatic sustainability. These efforts not only ensure that Nigeria remains competitive in the global economy and sustainable environment, paving way for a prosperous and environmentally resilient future.

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