



**CATALYZING SUSTAINABLE ECONOMIC DEVELOPMENT IN
AFRICA: THE POTENTIAL OF CHEMICAL SCIENCES AND CHEMICAL
INDUSTRIES**

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Abstract

Science in general is one of the key drivers of economic development. Advances in science and technology are instrumental to the rapid industrialization of many developed nations. Chemistry which is the only fundamental science that has a specific industry attached to it in sharp contrast to other major science disciplines, such as physics, mathematics and biology, has great potential for enhanced

economic development. Records have shown that the chemical industry plays a pivotal role in the strength of many developed economies such as that of the United States, Germany, United Kingdom, Belgium, etc. and the advancement of humankind. The many sectors reliant on the United States (U.S.) chemical economy which account for about 25% of the U.S. GDP and support 4.1 million U.S. jobs are worthy of note. In this work, we present the potentials inherent in chemical sciences which are capable of catalyzing sustainable economic development in Africa. We also highlight ways chemical sciences will help to achieve sustainable development goals (SDGs) in Africa. Challenges and rich opportunities associated with an investment in chemical industries are also presented. The Chemical industry has a great positive potential for the advancement of the African economy.

Keywords: Chemical sciences, Chemical Industries, Economic development, Challenges, Prospects, Investment opportunities

Introduction

Chemistry is the science of molecules: the basic building blocks of all known matter. In a way, this makes chemistry the science of everything. The chemical sciences provide an understanding of the physical and chemical properties of atoms and molecules and practical methods for creating new molecular structures with useful applications. Chemistry is a central science contributing to fundamental aspects of a range of other sciences and underpinning the dramatic advances seen in recent decades in such fields as biochemistry, nanoscience, biotechnology, molecular and synthetic biology, physics and soft condensed-matter physics, energy, environmental science, genetics, materials science and medicine [1].

Historically, Chemistry as a discipline has been, and remains, a significant contributor to the wealth, prosperity and health of humanity [2]. Over the last five (5) centuries, it is chemistry, more than any other discipline that has made global industrialization possible. Early extraction and processing of simple metals enabled military advancement and

eventually economic superiority. The discovery of gunpowder gained ascendancy in many areas of the globe. Innovations, such as the development of specific cements, mortars and, later on, concrete, glass and plastic, allowed urbanization on a massive scale. The industrial revolution was enabled by the rapid improvements in understanding the combustion and thermodynamics of fossil fuels. This led to global power shifts to those countries, which were able to implement these innovations on an industrial scale [2].

At the fourth United Nations Environment Assembly (UNEA-4) in 2019, the International Council of Chemical Associations (ICCA) released an analysis of the chemical industry's contributions to the global economy and stated that the chemical industry touches nearly every good-producing sector, making an estimated \$5.7 trillion contribution to world Gross Domestic Product (GDP) through direct, indirect and induced impacts, equivalent to seven percent of the world's GDP, and supporting 120 million jobs worldwide [3].

The global chemicals market forecast for 2022-2026 showed that the market is expected to grow from \$4,241.18 billion in 2021 to \$4,620.17 billion in 2022 at a compound annual growth rate (CAGR) of 8.9% and to \$6,371.09 billion in 2026 at a CAGR of 8.4% [4]. These indices point out to the positive potential of Chemical Sciences in catalyzing global sustainable economic development. This record leaves a question for Africa and Nigeria in particular to ponder upon the position in the stated forecast or the strategy to tap into these economic gains both now and in the future.

Sustainable Development Goals and the Potentials of Chemical Sciences

The sustainable development goals (SDGs) created by the United Nations (UN) in 2015 universally call to action to end poverty, protect the planet,

and ensure that all people enjoy peace and prosperity by 2030. The UN identified 17 aspirational goals in which many organizations and nations worldwide have adopted [5]. The goals include 1. To end poverty in all its forms everywhere, 2. end hunger, achieve food security and improved nutrition and promote sustainable agriculture, 3. ensure healthy lives and promote well-being for all at all ages, 4. ensure inclusive and quality education for all and promote lifelong learning, 5. achieve gender equality and empower all women and girls, 6. ensure access to water and sanitation for all, 7. ensure access to affordable, reliable, sustainable and modern energy for all, 8. promote inclusive and sustainable economic growth, employment and decent work for all, 9. build resilient infrastructure, promote sustainable industrialization and foster innovation, 10. reduce inequality within and among countries, 11. make cities inclusive, safe, resilient and sustainable, 12. ensure sustainable consumption and production patterns, 13. take urgent action to combat climate change and its impacts, 14. conserve and sustainably use the oceans, seas and marine resources, 15. sustainably manage forests, combat desertification, halt and reverse land degradation, halt biodiversity loss, 16. promote just, peaceful and inclusive societies, 17. revitalize the global partnership for sustainable development [5-7]. Currently, any form of global development and growth is adequately captured in these SDGs.

The place of Chemical Sciences in the SDGs is eminent. We have identified seven (7) priority SDGs that are foundational to the work of the chemistry community. The chemistry enterprise has a broad reach into technology, the economy, and human health, and there are already many ways chemists are working to support global sustainable development. Here we present the seven priority SDGs for the Chemical Science community.
SDG 2- Zero Hunger

Chemical Science, technologies and industries can help societies achieve SDG 2 through pests and drought protection for crops, phosphate recovery and reuse, targeted crop protection agents and active packaging

to prevent food spoilage, etc. Advances in chemistry will help to produce agrochemicals that will better protect plants from pest infestations and enhance high crop yields. High-yield seeds in combination with new approaches to fertilization will help to increase food production. Technologies for sustainable ammonia production, phosphate recovery and reuse and targeted crop protection agents will help to strengthen food production and combat malnutrition in areas with limited access to healthy foods. Also, advances in packaging will improve food distribution channels, extend the shelf life of food and maintain food quality and safety [8].

SDG 3- Good Health and Well-being

Chemistry plays a critical role in medical diagnosis and drug development, enabling people to live longer and healthier lives. Several medical breakthroughs and technologies are made possible through advances in chemistry which provide a deeper understanding of how human health is impacted by disease and hazardous chemicals in our food, water and the environment. Chemistry also offers new solutions for reducing pollution and its impacts on human health. The application of green and sustainable chemistry can help eliminate or reduce hazardous chemical pollution. Greater efforts should therefore be made to develop tools for greener chemical manufacture and utilization. Committees on environmental improvement should be constituted and organize green chemistry pharmaceutical roundtables should be in top gear [8, 9].

SDG 6- Clean Water and Sanitation

Chemists have an immense need to help society meets the clean water and sanitation goal through the development of new methods of water purification and lower-cost desalination processes. Water quality will improve through the deployment of greener technologies and pollution prevention strategies. The chemical industry can work toward manufacturing practices that minimize water usage and waste management practices that avoid pollution. International partnerships

will be crucial to ensure that new technologies and water management strategies will benefit the entire planet. Research is also needed to find new low-energy, high-efficiency separation methods for the removal of metals and micropollutants [10].

SDG 7- Affordable and Clean Energy

Through the development of new materials for renewable energy, being more energy efficient in the chemical processing industries, and advancing cleaner fuel technologies, Chemistry will help meet the Affordable and Clean Energy goal. A major issue with renewable energy production is the use of scarce and/or hazardous materials for solar and wind conversion and energy storage. Chemical researchers are working on the development of Earth-abundant advanced materials for renewable energy production, including photovoltaics, wind turbines, thermal energy collection, batteries, supercapacitors and energy storage solutions. The chemical processing industries can improve manufacturing efficiency through new catalysts, optimized process design, and new separation processes [8-10].

SDG 9- Industry, Innovation and Infrastructure

Industries, innovation and infrastructural developments are key to any economic growth. There are at least three aspects of the Industries, Innovation and Infrastructure goal to which the chemistry community can make significant contributions. First, the chemical processing industries can upgrade infrastructure and retrofit production facilities to become more sustainable. Second, the chemistry community can design, synthesize and manufacture innovative advanced materials and coatings that make infrastructure more sustainable and resilient. Third, encouraging chemistry research that enhances innovation for commercial applications [8-10].

SDG 12- Responsible Consumption and Production

From food packaging and additives to the prevention of food loss and waste, to innovations in waste management systems, the chemical processing industry helps to reduce the life cycle impacts of consumption. The chemical processing industry can go further by contributing to a transition to a circular economy by enabling the circular economy in downstream industries, and by recycling and reusing molecules to close the loop in chemical manufacturing. Achieving a stable growth economy that promotes life cycle thinking will require developing new business models, products, and solutions that look beyond the concept of using a product just once. To realize this, we must address the challenges of minimizing energy and increasing the use of biobased and alternative feedstocks. Chemistry plays a key role for responsible consumption and production in this regard [9,10].

SDG 13- Climate Action

Advances in atmospheric chemistry are central to our understanding of the causes of global climate change and our ability to predict the extent and impacts of climate change. Chemical research is essential for mitigating and adapting to climate change. Advanced materials for renewable energy, improved treatments for disease, and high-yield seeds and fertilizers for increased food production will help combat climate change. The chemical industry is moving toward a low-carbon economy by working to change to low-carbon emitting chemical production and by developing products that are playing a major role in enabling other sectors to reduce their own carbon footprints. Research and innovation are essential to help the industry to move towards circular and low-carbon emitting feedstocks, offering materials and energy solutions to our downstream customers using carbon from waste, biomass, and CO₂ and CO from flue gases. Chemical companies can work together to build resilience and adaptive capacity for the sector and its supply chain in response to the impacts of climate change. They can also play a key role in

the development of solutions that will enable other sectors to strengthen their resilience to climate-related risks [9,10].

Opportunities and Challenges associated with Chemical Sciences and investment in Chemical industries in Africa

Opportunities

The maxims "Chemistry rules the world" and "What on earth is not Chemistry?" are popular beliefs globally. Chemistry remains the mother of all sciences and the basis of all scientific research and development [11]. Chemical Science research has generated impactful outcomes for sustainable innovations and development [12]. This includes the application and practice of an idea or discovery as well as the creation of new products, services, or procedures by utilizing the results of research and invention [13]. Chemical science research also sparks the birth of new industries. It could be viewed as the lifeline of any network of local, regional, or national producers, distributors, and consumers of goods and services. With good-quality and relevant education of the youths backed with productive research, they will make an investment which will, in turn, generate employment opportunities and improve the African economy.

Chemical science graduates can find work in a variety of industries, including and not limited to mining, petrochemical, agricultural, pharmaceutical, and chemical. Special chemicals, fine chemicals, organic and inorganic chemicals, polymers and rubbers, pharmaceuticals, liquid fuel, plastics, consumer chemicals, and so on are all products and subsets of the chemical industry. These are utilized in many aspects of a value-chain economy.

Africa is experiencing a trend of urbanization, which is expected to last into the future. Generally speaking, increased consumption of products made in factories is correlated with urbanization. Therefore, this scenario

will result in higher household chemical consumption across many developing and upcoming urban centers in Africa.

A crucial part of the South African economy is played by the country's chemicals industry. It is closely related to South Africa's manufacturing industry and makes important contributions to the country's manufacturing output in addition to producing important goods that are utilized throughout the entire economy. Despite demonstrating resilience in the face of increased exposure to global competition, with local production output growing at a CAGR of 3.6% between 2001 and 2016, the local chemicals manufacturing sector has been unable to take advantage of local market growth, with imports being the main beneficiary [14]. The need for industrialization and the production of chemicals and chemical products in African countries have opened up investment opportunities for investors to take advantage of. This will enormously reduce the importation of chemicals, create employment opportunities for chemical science graduates and impacts on the economy. In specific terms, a number of opportunities are available to boost investment in chemical industries in Africa:

Raw Materials Availability: Africa holds a significant part of the world's oil reserves as well as metal supplies, arable land and vast timber resources [15]. Small- and large-scale manufacturers can easily access these resources, build their capacities and reach a leadership position by having-by-having strong vendor-base partnership arrangements.

Youth Population: Africa possesses one invaluable asset: its youth. The world review in 2012 presented Africa as the youngest continent in the world with an average age of 18 counting 40% of its population. This percentage was predicted to go down only slightly (by 12%) by 2050 [15-17]. It is Africa's youth that will enable it to extricate itself from poverty and take its place in the global fields of science, technology and innovation

(STI). This prospective labor force if given proper education can be converted to an opportunity, creating employment and improving the economy.

Growing Population: The population of Africa is expanding much more quickly, which increases the demand for chemicals and products containing chemicals. There will be a lot of demand for chemical products, which presents investors with a great opportunity. [17-18].

Ease of doing business: African countries exhibit less taxation on goods and services compared to developing countries. This can be an opening for manufacturers to reduce their costs and attract more buyers.

Special Economic Zones (SEZ): Special economic zones ensure cheap and easy duty-free import of materials which have always been beneficial for chemical companies. This privilege in Africa represents an advantage in investing in chemical industries in Africa [19 -20].

Booming export market: with access to raw materials, African chemical industries can give their products a low-cost scorching option just like China, Singapore, and Thailand thereby generating a boom in their export market.

Challenges

Skilled Human resources: The chemical industry in Africa faces a shortage of skilled human resources. The poor performance of Chemistry students in general, and particularly in the practical aspect of the subject, has hugely impacted chemical sciences and industry development in Africa. Such failure rates have been linked to students' lack of exposure to practical activities and, as a result, poor practical skills [21]. The problem which is primarily caused by the lack of equipment, facilities, and reagents for the teeming population of science students if not averted will continue

to undermine chemical sciences development in the continent. According to Achimugu [22], many chemistry teachers don't teach practical chemistry, and some are not concerned with how they plan out such practical activities or the success of a particular laboratory program. The implication is that most schools carelessly conduct Chemistry practicals. Teachers also appeared to prefer group activity over individual work because it required less preparation and washing up and was easier to maintain discipline and control among students. This is an anomaly because experimentation necessitates individual student interaction with materials as well as manipulation of apparatus and equipment.

Government policies: These have also affected performance in chemical science and investment in chemical industries. Because of trade liberalization and the establishment of free trade industrial zones, more African countries are importing chemicals and products containing chemicals. The inability of many African countries to assess and monitor the risks associated with trade in chemicals and chemicals contained in products is of particular concern, leading to concerns such as the importation into the continent of chemicals that would no longer be permitted in industrialized countries. Due to its expanding population, Africa urgently needs to industrialize and increase agricultural production (for food and occasionally for biofuel, fiber, or pharmaceutical purposes). The use of chemicals, especially pesticides and fertilizers, will undoubtedly increase as a result of this trend. About 3 to 42% of the GDP of African nations comes from the chemical and petroleum industries [23]. However, the chemical industry still makes up a small portion of the GDP in the majority of African nations, except the major oil-exporting nations (Angola, Egypt, Libyan, Nigeria, and Sudan), as well as some emerging ones, like Ghana and Uganda.

Poor funding or lack of investment in research and Development: Government and well-to-do private individuals are not interested in funding or investing in chemical science education and research.

Chemical research is expensive and also yields high dividends if embarked upon. Domestic manufacturers cannot afford the cost of research for new products, so they stick to substandard products.

Chemical Safety measures: The vast majority of African countries still lack basic chemical legislation. While presenting the situation in Africa at the chemical watch Regulatory Summit in Brussels, it was noted that only a few African countries had implemented the Global Harmonized System (GHS) for the classification and labeling of chemicals which is considered the first step in sound chemical management [15].

Poor Infrastructure: Due to poor infrastructure, there is restricted access to facilities needed to enhance chemical industries. Other challenges facing investment in chemical industries in Africa may include logistic issues and global competition affecting imports. *Future Prospect of Chemical Science for African economic Development.*

The future of Africa is brighter considering its untapped resources. The challenge is how to use these human and natural resources to achieve people-centered and sustainable development for the continent. The role of chemistry and the chemical industries in driving sustainable economic development can never be overemphasized. It all starts with the teaching and skill sets building in young people. As a way forward, Jansen-van Vuuren et al. [24] stressed the importance of inculcating strong problem-solving ability in students, teaching them to understand and think for themselves rather than memorizing. This can be encouraged, for example, through the use of microscale chemistry kits, which are cheaper than conventional glassware and enable students to carry out a wide range of experiments themselves. Moreover, the development of teaching approaches that will encourage critical thinking is crucial to give students the right tools to be able to tackle complex issues such as environmental, energy-based, and economic questions (15). Again, the lack of relevance of

most teaching materials in schools and universities to the situations found in Africa should be tackled. The teaching materials and methods should reflect the African setting. The quality of teaching should be improved. Institutions should adopt or develop innovative approaches to teaching by embracing innovations in information and communications technologies. Moreover, existing and emerging technologies should be used creatively and innovatively to aid in chemical science research. Researchers should involve in collaborative research and publish in high-impact factor journals. Another important aspect of building capacity in chemical science is to incorporate indigenous knowledge and skill sets in the African Chemical industries plan. As demonstrated by the University of Botswana's Centre for Scientific Research, Indigenous Knowledge and Innovation (CESRIKI), CESRIKI scientists have held workshops conducting antimicrobial, antioxidant, and anthelmintic tests with members of traditional medicine associations who provided the herbs and have successfully pushed for clinical certification [15]. Furthermore, African-made chemical products should be encouraged and patronized in order to boost the economy.

In a new economic environment like Africa, where sustainability and climate protection are valued, companies that are leaders in sustainability can capitalize on their competitiveness. Market- and purchasing-based policies and tools can be key in supporting a green and circular economy. Many areas of decarbonization, sustainability, and climate improvement will benefit from advances in fundamental chemical research coupled with design and collaboration with other areas of science and engineering. A new and evolving chemistry landscape requires changes with regard to funding, training, and a focus on integrating sustainability into manufacturing, product usage, and product disposal. The chemical industry and its partners at universities, scientific research institutions, and national laboratories should align the objectives of fundamental research to directly align with new practices toward environmental

stewardship, sustainability, and clean energy. There is a need to balance the benefits of products that meet human needs with the costs of those products to public health, the environment, and the climate. This is both a challenge and an opportunity for the chemical economy. The chemical economy will need to make a transformative shift in which sustainability and decarbonization are central tenets. A sustainable chemical industry of the future will increasingly base its manufacturing on plant-based biomass, abundantly available CO₂, and end-of-use waste, which will play a crucial role in a circular economy [10, 25]. It will be powered by renewable energy sources, such as solar and wind energy, and by renewable hydrogen (derived from water splitting using renewable energy sources) to eliminate the carbon footprint of fossil fuels. The widespread availability of plant- and waste-based biomass, solar, and wind energy is an opportunity.

Conclusion

Over time, the chemical industry has become an irreplaceable part of the global economy, providing about 120 million jobs and an estimated \$5.7 trillion contribution to the global gross domestic product (GDP). In Africa, chemical science and the chemical industry have a huge potential that is capable of transforming the economy. With the level of untapped resources, chemical science and the chemical industry can offer a brighter future to the African economy. To fully utilize chemistry's potential, education in chemistry at all levels needs actions that will place its past achievements and current capacities in the context of the wider picture of global development. The chemical industry should not fear sustainable chemistry as a new cost but rather see it as a new opportunity. Chemistry is an ethical science worthy of investment. Government and private individuals should promote chemical science through research funding and investment in chemical industries. Government should provide enabling environment for investors.

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