

Chemical Engineering in Nigeria: Development, Challenges, and Prospects

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Nigeria is a nation endowed with abundant natural resources and engineering talent. Current policy and reforms in the downstream and natural gas sectors are expected to boost Nigeria's economy and restore growth and vibrancy to its chemical process industries.

Chemical engineering emerged as a distinct technological discipline and profession in the western world at the dawn of the twentieth century. The discipline subsequently gathered momentum and spread to other parts of the world, including Africa.

In Nigeria, chemical engineering is a relatively young profession, dating back only to about the 1960s, when the first wave of Nigerian students graduated from chemical engineering schools in the United States and the United Kingdom. Even so, the profession was virtually unknown in Nigeria until the late 1960s, when several overseas-trained graduates returned to their home country. Many of these young engineers were beneficiaries of an American government-sponsored assistance program — the African Scholarship Program for American Universities. The scholarship recipients were among the brightest Nigerian students of their era, with many going on to advanced chemical engineering studies at premier technical universities in the U.S. and the U.K.

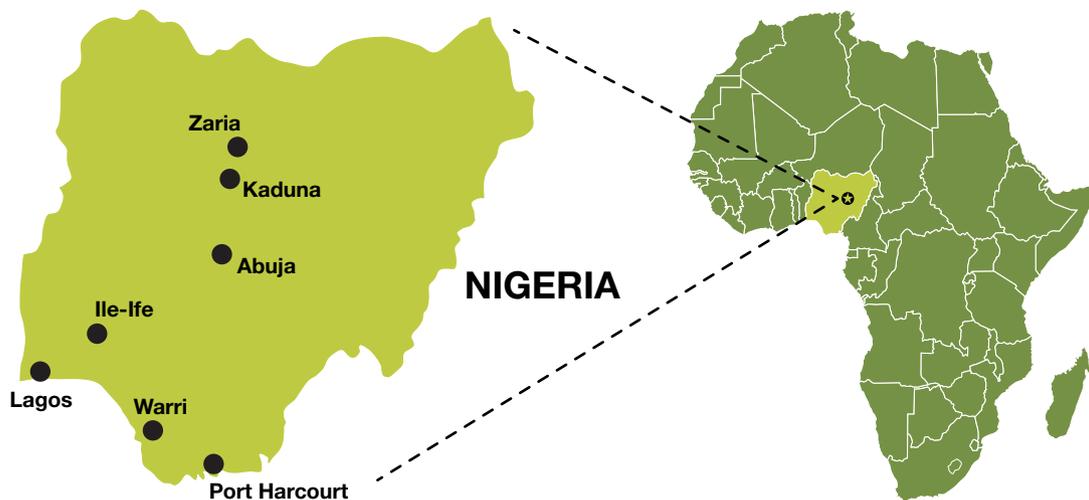
Chemical engineering education in Nigeria

Nigeria launched its first domestic training ground for chemical engineers when the Univ. of Ife (now Obafemi Awolowo Univ.), in the southwest Nigeria city of Ile-Ife,

introduced a course in chemical technology in 1969. By 1972, the school had upgraded to a full chemical engineering program, leading to the graduation of the first Nigeria-trained chemical engineers in 1973. Around that time, the Univ. of Lagos and Ahmadu Bello Univ., in Zaria, also developed chemical engineering programs, producing their first graduates in 1976 and 1977, respectively.

Since then, chemical engineering education has grown steadily. Today, 26 Nigerian universities offer chemical engineering degrees, and produce an estimated 1,500 to 2,000 chemical engineering graduates annually. (Meanwhile, five polytechnic institutes train other chemical technologists and technicians.) Admission into the chemical engineering schools is one of the nation's most coveted academic distinctions. Consequently, admission standards are relatively high, although not as high as in the 1970s, when the capacity to train chemical engineers was extremely limited and only the most exceptional students were eligible to be admitted.

In the 1970s and 1980s, class sizes were in the range of 15 to 20 students. The classes were compact and carefully aligned with the available facilities, as well as the needs of the economy. Today, however, while chemical engineering



▲ **Figure 1.** Nigeria is situated in the west of Africa along the Gulf of Guinea, where its major seaports are Lagos and Port Harcourt. The nation shares land borders with Benin to the west, Niger to the north, and Chad and Cameroon to the east.

enrollment continues to grow, university facilities, infrastructure, and resources are not keeping pace due to low levels of investment in higher education by the federal government.

Like other engineering disciplines at Nigerian universities, chemical engineering has a five-year curriculum. Programs typically consist of nine semesters of classroom and laboratory work, plus one semester and three internships arranged by the universities and devoted to industrial work experience. Many schools offer training in such key fields as process safety, loss prevention, environmental management, biochemical engineering, process economics, optimization, and industrial chemistry, in addition to traditional chemical engineering subjects such as process principles, thermodynamics, transport phenomena, particulate systems, separation processes, reaction engineering, process control, and process and plant design.

Nigeria's chemical engineers in practice

Nigeria's earliest chemical engineers were engaged mostly in the few domestic process industries that existed in the 1960s and early 1970s, such as cement, soaps and detergents, paints, tires, and foods, and worked at such international companies as Michelin and Dunlop. Other notable companies in this early period included a Portland cement site in Ewekoro, in Ogun state, and Lever Brothers, located at the Apapa port in Lagos, as well as the Nigerian Bottling Co. and ICI Paints, both also in Lagos. A few others were employed by government establishments, such as research institutes, regulatory agencies, and organizations that promoted industry (e.g., the Federal Institute of Industrial Research, Federal Ministry of Science and Technology, Federal Ministry of Industries, Nigerian Industrial

Development Bank, and Northern Nigerian Development Corp.). Many other engineers of that era went to work in Nigeria's growing academic arena.

Following a boom in Nigeria's petroleum industry in the mid-1970s (discussed later), many chemical engineers drifted in that direction. Initially, most found employment in the midstream segment, *i.e.*, refining. Later, many found jobs in the upstream and downstream segments of the petroleum industry. This pattern remains evident today; an estimated 45% of the current members of the Nigerian Society of Chemical Engineers (NSChE; see sidebar, p. 55) are employed in the petroleum industry, while the chemical process industries (CPI) employ about 12% (Table 1).

In the early 1960s and into the 1970s, most chemical engineers in Nigeria's CPI were engaged in production and production management. Today, a diversity of job functions

Table 1. Engagement of chemical engineers in Nigeria by sector.	
Sector	Percentage
Oil and Gas	45%
Education	17%
Chemical Process Industries	12%
Government	8%
Engineering / Construction / Consulting	5%
Research	4%
Other	9%

Table 2. Engagement of chemical engineers in Nigeria by function.

Function	Percentage
Production	24%
Academia	16%
Technical Services	15%
Project/Construction	8%
Design Engineering / Consulting	7%
Research and Development	6%
General Management	5%
Sales	5%
Other	14%

has been achieved, with chemical engineers also working in technical services, construction, project engineering, design, teaching, sales and marketing, and a variety of other areas. Some have migrated to general management. Nevertheless, production management, teaching, and technical services remain the dominant functions, accounting for about 24%, 16% and 15% of chemical engineering jobs, respectively (Table 2).

Economic contributions and the petroleum industry

Nigeria's petroleum industry is at the heart of the nation's economy, to the extent that the industry contributes 80% of the revenue of the federal government and more than 90% of the country's foreign exchange earnings. Moreover, oil and gas accounts for an estimated 20% of Nigeria's gross domestic product (GDP) (1).

The state oil company, Nigerian National Petroleum Corp. (NNPC), dominates the activities of the industry, especially in the upstream sector. The international oil companies (IOCs) in Nigeria, including Shell, ExxonMobil, Chevron, Total, Addax, and Agip, operate mainly in joint ventures with NNPC or in production-sharing contract arrangements with NNPC.

Nigeria is the world's sixth-ranked crude oil exporter, and has the eighth-largest natural gas reserve worldwide (2). The country's reserves of crude oil and natural gas amount to about 40 billion bbl and 190 trillion scf, respectively, with corresponding depletion times of about 40 and 90 years.

The petroleum industry in Nigeria spans the entire value chain: from upstream (exploration and production), through midstream (refining, petrochemicals), to downstream (distribution and marketing), as well as the export of liquefied

natural gas (LNG) to European countries. Each of these segments — particularly refining, petrochemicals, and natural gas — is of significant interest to chemical engineers.

Nigeria's three oil refineries — at Port Harcourt, Warri, and Kaduna (which are all owned and operated by NNPC) — have a combined capacity of 445,000 bbl/d (3). There are also two integrated petrochemicals plants, one with a capacity of 1,540 ton/d of polymers, and the other 3,860 ton/d of ammonia, urea and nitrogenous fertilizer (1). Both were owned by government, but have been recently privatized. In addition, the Port Harcourt and Warri refineries have smaller petrochemicals plants associated with them, with a combined capacity of 165,000 ton/yr of products such as carbon black, polypropylene, linear alkyl benzene, heavy alkylates, and solvents.

About 30% of the total natural gas production of 6.5 billion scf/d is currently flared in the oilfields, primarily because there is insufficient manufacturing infrastructure to use it, as well as the sluggishness of the IOCs to comply with the Nigerian government's gas utilization and monetization policy. Of the 4.5 billion scf/d gainfully utilized, about 3.0 billion scf/d (67%) is liquefied for export in an integrated LNG plant. Another 0.5 billion scf/d is exported as pipeline gas to the neighboring countries of Benin, Togo, and Ghana. Only 1.0 billion scf/d (22%) is used domestically, out of which about 0.8 billion scf/d goes to power generation (4).

Aside from oil and gas, Nigeria is endowed with other natural resources, including agricultural products and solid minerals. Notable among these are cocoa, cotton, legumes, palm oil, rubber, sugarcane, limestone, talc, kaolin, clay, bentonite, barites, and coal. However, due to the lack of government attention and inadequate commitment, most of these resources were either neglected following the oil boom of the 1970s, or have never been seriously developed at all.

Likewise, the manufacturing sector, which includes the CPI, is also underdeveloped, and in fact has seen a decline in both sales and productivity. Although manufacturing contributed over 10% of the nation's GDP at the turn of the 21st century, today it accounts for less than 4% (5). These underdeveloped CPI segments include soaps and detergents, paints and coatings, cement, industrial gases, food, vegetable oil extraction and refining, glass, ceramics, textiles, and plastics.

Challenges

The decline in manufacturing, which also affects the CPI, is a major area of concern in Nigeria. This situation has arisen from a combination of factors, including:

- poor national infrastructure — most notably the lack of reliable electric power supply

THE NIGERIAN SOCIETY OF CHEMICAL ENGINEERS

The Nigerian Society of Chemical Engineers (NSChE; www.nsche.org/ng) serves the professional interests of Nigeria's chemical engineers and fosters the practice of chemical engineering nationwide. It was established in 1969 by the young chemical engineers who were returning to Nigeria after being trained overseas. The Society has grown steadily since then, and now serves a membership of about 2,500 chemical engineers and more than 1,000 students. This membership base is about 20–25% of the estimated 10,000 to 12,000 chemical engineers in Nigeria.

Prior to 1999, NSChE was completely independent of the Nigerian Society of Engineers (NSE), which traditionally catered to civil, mechanical, and electrical engineers. However, cognizant of the compelling need for engineers of all disciplines to present a unified voice, NSChE joined the NSE as one of its divisions. In this arrangement, NSChE has maintained a level of autonomy while combining forces with other engineers to pursue common interests.

NSChE organizes annual conferences and publishes the *NSChE Journal*, both of which feature papers of high technical merit on various aspects of chemical engineering research and practice. Increasingly, the Society advocates for the chemical engineering profession, with a view toward shaping public policy.

- unfavorable interest rates and tariffs
- smuggling of manufactured goods into the country
- neglect by the government.

To elaborate on the first point, electric power via the public mains is available to customers only about one-third of the time (6). Thus, manufacturers must install, operate, and maintain their own costly in-house power generators to stay in business. In the late 2000s, international companies such as Michelin and Dunlop closed their tire manufacturing businesses in Nigeria due mostly to power supply problems, as well as smuggling of tires into the country (7). Chemical engineers who worked for these companies lost their jobs.

It is instructive to note that both companies were obtaining their key feedstock — raw rubber — from domestic rubber plantations (7). Nevertheless, there is a compelling need to intensify efforts to exploit the aforementioned agricultural and mineral resources with which Nigeria is endowed as raw materials for the process industries. Closely related to this is the need for more serious attention to research and development, which the government has given a low priority.

Furthermore, although the country is blessed with abundant natural gas resources, as well as coal and water,

Institutional and public policy failures in the petrochemicals sector point to a need for chemical engineers as a group to assist in shaping future policy.

because of failures on the part of successive governments, it has not been possible to use these resources to generate adequate electricity to power industry and the country at large. This overall neglect of readily available and rich resources represents a squandering of opportunity, and is another factor that prevents Nigeria from reaching its potential as a fully competitive economic force.

Apart from the use of natural gas to generate electricity, there is also a wider question of using the vast natural gas resources as a feedstock for use by manufacturers, as well as a fuel for heating.

In spite of its rich crude oil reserves and the existence of three refineries, Nigeria relies on imports for more than 70% of the fuels and petroleum products it needs. This situation has arisen substantially from the operational failures in the government-owned refineries and constitutes a national embarrassment that must be reversed. Nigeria could be a net exporter of petroleum products and serve as a regional hub for supplies to surrounding African countries, given her comparative advantages and endowments.

These institutional and public policy failures are highly relevant to chemical engineering practice in Nigeria. The situation points to a need for chemical engineers as a group to strive more than ever to influence and assist in shaping future policy in these areas.

There is also concern for the standard and quality of education in Nigeria's various universities, including the chemical engineering schools, especially in light of the increase in enrollment over the past few years. Government investment in the nation's research institutions has not kept pace with modern needs. Although many chemical engineering schools have benefitted from recent government intervention programs aimed at developing local manpower for the oil and gas industry — such as the Petroleum Technology Development Fund (PTDF) to improve universities' equipment and infrastructure — this has not fully addressed the problem. Adding to the problem, the PTDF policy of supporting graduate-level training in overseas universities, rather than in local universities, has tended to undermine the research capabilities of the latter.

Meanwhile, unemployment is also a concern for young university graduates, including chemical engineers — an issue typical of many nations and professions, not only Nigeria and chemical engineering (6).

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Prospects for the future

The federal government of Nigeria is in the midst of major reforms in the power sector that should lead to privatization of key aspects of the industry, and to massive investment in refurbishment of existing installations and construction of new plants. This is expected to be a major boost for the manufacturing sector, including the CPI. In addition, Nigeria's chemical engineers are advocating for government investment in industrial research and development, as well as development of domestic resources as raw materials for the CPI, both of which will give a further boost to the industry.

Recent government initiatives in the gas sector envision total elimination of gas flaring, and give priority to domestic gas utilization — which should ensure adequate gas supplies for power generation. The initiatives also support major investments in petrochemical and fertilizer plants using natural gas as feedstock.

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The deplorable fuels supply situation has seriously engaged both government and public attention (6). A special task force was appointed in February 2012 by the government to carry out an intensive examination of the refineries and downstream petroleum sector, with a view to reversing the situation (6). This committee includes seasoned chemical engineers, who are expected to give direction to the group. It is also expected that this will be the beginning of the process of privatizing the refineries and deregulating the market for efficiency and increased investment. In addition, the government envisions that a major new refinery will be established near the commercial capital, Lagos, as a joint venture between the NNPC and private foreign partners.

In closing

Realization of these various measures is expected to lead to revival and growth in Nigeria's CPI, as well as in the refining, gas, and petrochemicals sectors. Chemical engineers will naturally be expected to drive most of the projects and processes, thereby enhancing chemical engineering practice in the country. This should lead to the creation of job opportunities for many young chemical engineers, as well as enhanced career prospects for the more experienced ones.

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LITERATURE CITED

1. **Erinne, N. J.**, "Towards an Energy Strategy for National Economic Development," Proceeding of the 36th Annual Conference of NSChE, Enugu (Nov. 2007).
2. **Okolo, H. C.**, "Domesticating LNG and Gas Process Technology in Nigeria — A National Strategic Imperative," presented at the Construction and Engineering Digest's 6th National Conference on Gas Development and Utilization in Nigeria, Lagos (Oct. 2009).
3. **Ogedegbe, A.**, "The Nigerian Petroleum Refineries: History, Problems, and Possible Solutions," a lecture delivered at the Induction Ceremony for New Fellows of the Nigerian Academy of Engineers, <http://www.businessdayonline.com/NG/index.php/oil/3203-nigerian-refineries-history-problems-and-possible-solutions-1> (June 11, 2009).
4. **Oniwon, A.**, "Towards Optimizing the Role of Gas in the Power Sector Development," Proceedings of the Nigerian Gas Association International Conference, Abuja (2010).
5. **Bolarinde, S. O.**, "The Distinguished Annual Engr. Olu Awoyinfafa Lecture," the Nigerian Society of Engineers, Ikeja Branch (May 2009).
6. **Kalu, K. I.**, "National Refineries Special Task Force Report 2012," a report to the federal government of Nigeria and the Honorable Minister of Petroleum Resources, <http://xa.yimg.com/kq/groups/17672087/728487298/> (Aug. 1, 2012).
7. **Ogedegbe, A.**, "The Nigerian Society of Chemical Engineers: Challenges and Opportunities Facing Chemical Engineers in Nigeria," presented at the AIChE Annual Meeting, Philadelphia, PA (2008).