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Sustainability of modular refinery operation in Nigeria: Product quality and value chain

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Abstract

The modular refineries in Nigeria have the potential to create a bigger quantity of commodities while keeping the quality of those goods, and to deliver those products to their end customers in a manner that is both more expedient and more cost-effective. As a method of contributing to the nation's energy security and economic expansion, the purpose of this evaluation is to evaluate and improve the long-term sustainability of the product quality and value chain of modular refineries. To compile articles pertinent to the subject, "Google scholar" was used. To perform the analysis on the data that was obtained, methodologies for the foresight and analysis of material and energy projects, descriptive statistics, and life cycle cost analysis were used. Using the right techniques of financial management for infrastructure projects, indicators of profitability were estimated. These indicators included levelized costs of petroleum products, Net Present Value (NPV), Break-even and Payback Period, and return on investment. According to the findings, to assure the ongoing growth of modular refinery operations in Nigeria, it is vital to have a strategy that is both comprehensive and well-coordinated. Modular refineries can realize their full potential, which would contribute to energy security, economic prosperity, and environmental responsibility. For Nigeria to be able to establish a modular refinery sector that is both sustainable and profitable in its product quality and value chain, it is required for government agencies, industry players, and local communities to be committed and engaged in the process.

Keywords: Sustainability; Evaluation; Value Chain; Modular Refineries; Profitability

1. Introduction

By almost any measure, the petroleum industry is one of the most important contributors to Nigeria's overall economic growth and development. As of the year 2000, oil and gas exports were responsible for more than 98% of total revenues from exports, around 83% of total income to the federal government, and the generation of more than 14% of total GDP. Additionally, it accounts for about 95% of the country's foreign currency profits and 65% of the country's overall budgetary income [1].

The term "modular refinery" does not have a single, agreed-upon meaning. It has been defined in accordance with the requirements and the conditions. According to the definition provided by Refinery Equipment of Texas [2], it is A standard definition of a mini-refinery is a tiny refinery that fractionates less than 5000 barrels of crude oil per day using atmospheric distillation. A modular refinery is a refinery that is constructed in pieces or modules so that it may be readily moved or relocated; the architecture of most mini refineries is modular. According to the article "The Case for Modular Mini-Refineries" [3], "a modular refinery is a refinery whose parts or equipment are constructed in modules designed to be easily transported quickly and easily anywhere in the world and comes in a variety of sizes with capacities that range from 500 to 30,000 barrels per day." This definition describes a refinery whose parts or equipment

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are constructed in modules designed to be easily transported quickly and easily anywhere in the world. They are hence regarded as being miniature refineries. According to Rocky Costello [4], small refineries are skid-mounted modular crude oil distillation units that have the capacity to process between 200 and 10,000 barrels of crude oil per day. These machines are also able to produce finished products such as naphtha (straight run gasoline), kerosene, diesel, and fuel oil. The production of high-octane gasoline could benefit from the addition of a reformer. It is possible to establish two or more processing plants or units on a same piece of land, which will allow for the simultaneous processing of several types of crude oil. With this kind of configuration, it is possible for one plant to continue functioning even if the other one has technical difficulties. Installing more units that are functionally identical to those already present in parallel is one way to boost the overall processing capability of this kind of configuration [4].

The Nigerian government adheres to the concept of a modular refinery that was popularized by Chemex of the United States, which states that a processing facility is modular if it was built completely on skid-mounted platforms. According to Gbonegun [5], each structure of the plant comprises a fraction of the overall process plant, and using interstitial pipes, the various components are linked together to produce a process that is simple to manage. A modular refinery is a refinery that is constructed in sections or modules so that it may be readily moved or relocated. In layman's words, a modular refinery is often a small refinery that fractionates less than 5000 barrels of crude oil per day by atmospheric distillation; in contrast, a modular refinery is a refinery that is built in pieces or modules. Most small refineries use a modular approach to their architecture. Even refineries with a capacity of up to 30,000 barrels per day may be classified as mini refineries, and in certain situations and in some areas, they can even be classified as tiny refineries. In a country as unstable as Nigeria, large-scale refining presents several significant challenges. This has been shown over the course of many years by the inability of plants to work properly and the country's continued strong reliance on fuel imports, despite the construction of facilities [6].

The oil and gas business in Nigeria is subject to stringent regulation from several different agencies, including the Ministry of Petroleum Resources (MPR), the Department of Petroleum Resources (DPR), and even the Nigeria National Petroleum Corporation (NNPC). The Nigerian Extractive Industries Transparency Initiative (NEITI) estimates that Nigeria loses $15 billion annually in international investments because to the regulatory ambiguity that exists in the country [7]. The oil and gas business also faces considerable hurdles in the form of sabotage at industrial facilities, theft of crude oil, illicit refining activities, damage of pipelines, and piracy. Investors in modular refineries may be impacted on their decisions by the security situation in the nation. Investors want an atmosphere in which their investments are not only safe but also secure. Despite the many efforts made by the Nigerian government and several international corporations to reduce instability in the Niger Delta Region, security continues to be a significant obstacle [8].

The state of the Nigerian modular refineries called for this study aimed at assessing and enhancing the long-term viability of the product quality and value chain of modular refineries as a means of contributing to the country's energy security and economic growth.

2. Material and methods

A comprehensive search of Google Scholar was conducted using keywords such as "Sustainability," "Modular," "Refineries," and "Nigeria." It is of the utmost importance to track down the many scholarly works that have been published on the many different areas of the petrochemical process that have been substantially contributed to by Nigerian scientists, scholars, and institutions. Previous research has shown that Google Scholar is a helpful tool for the extraction of scholarly articles [9]. This finding supports the findings of the most recent research study [10, 11]. The years 2019 through 2023 are included in the scope of the study. The query that was used for the advanced search on Google Scholar is shown in Table 1.

A search for "Sustainability of Modular Refineries in Nigeria" returned 7,960 results before any further refining was performed on the search terms. After that, to reduce the results, irrelevant search phrases were eliminated, and study papers that included forecasts for the furthest possible future was selected. The drop was also the consequence of an in-depth analysis that deleted duplicate entries (that is, references to the same document), material that was either missing or incorrect in the bibliography, and sources that could not be relied upon. The sophisticated search function on Google Scholar returned 3,220 results; however, there is a significant technological barrier that prevents the extraction of information for further bibliometric research. It was not beneficial for dealing with a large data collection since the data from Google Scholar was missing numerous important pieces of information, and thus made it impossible to utilize.

We looked at how the literature on the subject was dispersed geographically, what languages were used, what kinds of documents were published, who wrote them, and what keywords were used to find them in the index to examine the

opportunities for sustainability with projections far into the future over the course of the past four years. Our goal was to determine whether there were any such opportunities.

Table 1 Google Scholar advanced search

Advanced search	**Filter**
Find articles	
with all of the words	Modular Refineries in Nigeria
with the exact phrase	
with at least one of the words	Sustainability of Product Quality and Value Chain of Modular Refineries
without the words	Human Scanning Electron Microscopy Controlled Male Female Nonhuman Priority Humans Economics Animal Animals Adult Infant Child, Preschool Child Diet Protein Body Weight Unclassified Drug Animal Food Malnutrition Preschool Child Rat Kwashiorkor Zea Mays Plants botany Maize Animalia Adolescent Nutritional Status Rats
where my words occur	Anywhere in the article in the title of the article
Return articles authored by	
Return articles published in	
Return articles dated between	2019-2023

3. Results and discussion

3.1. Sustainability Specifications for Improved Product Quality and Value Chain of Modular Refineries in Nigeria

This is the study for the development of the modular refinery infrastructure by Ogundari [12] to meet the indicated yearly petroleum demand predictions and projections for petroleum products. Within the scope of this investigation, the output of the purposefully chosen modular refinery facility was 30,000 barrels per day (bpd). Although the annual nameplate total petroleum refining production by modular refining plants is anticipated to be 30,000 365 = 10,950,000 barrels per year, it was assumed for the purposes of this research that the modular refinery would work at an efficiency of 80% for a period of 300 days each year.

Thus, Total daily production = $30{,}000 \times 0.8 = 24{,}000\ bpd$

Total annual production = $24{,}000 \times 300 = 7{,}200{,}000\ barrels/yr$

3.2. Comparison of Product Quality Between Conventional and Modular Refineries

Table 2 Comparison of product quality of Conventional and Modular Refinery (Adapted from Adehanju and Manohar [13])

Quality	**Unit**	**Requirement**	**Conventional refineries**	**Modular refineries**
Sulphur	Ppm	3000	1330	2190
	References:	[13]	[13]	[14]

Sulphur is one of the main contaminants in crude oils and its determination is important for many reasons including being detrimental to refinery processing due to catalytic poisons, plant corrosion and air pollution [15].

Based on Sulphur contents, Conventional refinery crude oils are of better quality than modular refinery crude oils. Both samples of crude oil are sweet crude oils having sulfur contents of less than 3000ppm (Table 2).

3.3. Estimation of Total Number of Modular Refinery Plants Required

The following equation may be used to calculate the number of modular refinery plants that are necessary for the Nigerian market:

$$Number\ of\ MRPs = \frac{Petroleum\ Energy\ Demand\ Per\ Year}{Petroleum\ Refining\ Output\ by\ a\ MRP\ Per\ Year}$$

The total number of modular refineries with a capacity of 30,000 barrels per day (bpd) that would be needed to process the nation's annual total anticipated oil consumption is shown in Table 3. According to the findings of the study, although it was anticipated that the demand for oil energy in the year 2019 would need twenty modular refinery plants, the number of modular refinery plants that would be necessary by the year 2030 was found to be 34.

Table 3 Total Estimated Oil Energy Consumption and Number of 30,000 Barrels per Day Modular Refinery Plants (MRPs) Required from 2019 to 2030 (Source: Ogundari et al. [12])

Year	Oil (Quad BTU)	Oil (Million Barrels)	30,000 bpd MRP (Number Required)
2019	0.831	142.93	20
2020	0.885	152.22	21
2021	0.940	161.68	23
2022	0.994	170.97	24
2023	1.048	180.26	25
2024	1.102	189.54	27
2025	1.156	198.83	28
2026	1.210	208.12	29
2027	1.264	217.41	30
2028	1.318	226.70	32
2029	1.372	235.98	33
2030	1.43	245.96	34
TOTAL	**13.55**	**2,330.6**	

3.4. Determination of Petroleum Consumption and Petroleum Products Projections from the Sustainable Modular Refinery

Table 4 Products made from a Barrel of Crude Oil (By Modular Refinery) (Source: Ogundari et al. [12])

S/N	Product	Percentage of Total (%)
1	LPG	1
2	Gasoline	28
3	Kerosene	10
4	Diesel	20
5	Atmospheric Gas Oil (AGO)	5
6	Fuel oil	36

The percentages of various petroleum products that may be derived from a barrel of crude oil when processed through a conventional modular refinery are shown in Table 4. According to the data shown in the table, the typical modular refinery generates the greatest quantity of fuel oil, which is closely followed by the greatest quantity of gasoline (petrol), diesel, and kerosene, respectively.

Table 5 Estimations for Petroleum Consumption and Petroleum Products Output by the Modular Refinery Alternative in Nigeria (Source: Ogundari et al., 2021)

Year	Petroleum (Million Barrels)	LPG (Million kg)	Gasoline (Billion Litres)	Kerosene (Billion Litres)	Diesel (Billion Litres)	AGO (Million Barrels)	Fuel Oil (Million Barrels)
2019	142.93	168.95	6.36	2.27	4.54	7.15	51.45
2020	152.22	179.93	6.78	2.42	4.84	7.61	54.80
2021	161.68	191.11	7.20	2.57	5.14	8.08	58.20
2022	170.97	202.09	7.61	2.72	5.44	8.55	61.55
2023	180.26	213.07	8.02	2.87	5.73	9.01	64.89
2024	189.54	224.04	8.44	3.01	6.03	9.48	68.23
2025	198.83	235.02	8.85	3.16	6.32	9.94	71.58
2026	208.12	246.00	9.26	3.31	6.62	10.41	74.92
2027	217.41	256.99	9.68	3.46	6.91	10.87	78.27
2028	226.7	267.97	10.09	3.60	7.21	11.34	81.61
2029	235.98	278.94	10.50	3.75	7.50	11.80	84.95
2030	245.96	290.73	10.95	3.91	7.82	12.30	88.55
TOTAL	2,330.60	2,754.85	103.75	37.05	74.11	116.53	839.02
Source: Ogundari et al. [12]							

NOTE: 1 barrel of oil = 158.987 Litres; 1BOE LPG = 118.2033 kg

Estimates of the production of petroleum products are shown in Table 5, which covers the years 2019 through 2030. Figures for gasoline (Petrol) and diesel fuel are substantially different from those expected to result from the processing of petroleum in a traditional refinery. These results may be seen by clicking here. This may be since conventional refining and modular refining produce different percentages of product production for these two goods. Modular refining also produces more product than conventional refining does. The numbers, on the other hand, are the same for kerosene.

The implication here is that to ensure the longevity of the modular refinery, there may be a need to add more processing units to the reefing plant. These additional processing units would be used to further process the outputs of atmospheric gas oil (AGO) and fuel oil in order to produce a bigger quantity of gasoline (petrol), as well as diesel [12].

3.5. Techno-Economic Analysis of Modular Refinery Sustainability

Table 6 Provides an overview of the estimated expenses and revenues, in addition to the profitability indicators, for a 30,000 bpd MRP

Table 6 Techno-Economic Assessment of a Singular30,000 Modular Refinery Plant (MRP) (Source: Ogundari et al., 2021)

Costs	N Billion
Capital Costs	
30,000 bpd Refining plant	159.60
Land	.38
Buildings + Facilities (1% of refinery cost)	1.60
Total Fixed Capital	**161.58**
Cash in Hand (20% of total fixed capital)	32.31

Total Investment	**193.87**
Operating Costs (Annual) for 7.2 million barrels/yr.	**N Billion**
Crude Oil Feedstock (60% of TOC)	325.92
Refining costs (21% of total operating costs, TOC)	114.08
Others (19%)	103.21
Total Operating Costs (TOC)	**543.20**
Revenue:	**N Billion**
LPG	72.34
Petrol/Gasoline	180.98
Kerosene	51.51
Diesel	124.77
AGO	24.76
Fuel Oil	183.00
	637.36
Gross Profit (Revenue – Operating Costs)	94.16
Taxes (25% of Gross Profit)	23.52
Estimated Annual Net Profit	**70.62**
Profitability Indices	
Net Present Value (N Billion)	3,022
Break-even Time (Years)	1 Year
Payback Period (Years)	2.74 Years (2 years 9 months)
Return on Investment (ROI) (%)	36.4%

4. Conclusion

Since Nigeria's refining capacity is not sufficient to meet the present level of domestic demand in the country, the government must continue to rely on imports of petroleum products in order to meet its energy needs. This is something that has been a problem for Nigeria for quite some time. This is because Nigeria does not generate a sufficient amount of oil to justify the investment in such facilities due to the country's low oil output. These refineries have been beset by issues including sabotage, fire, bad management, and a lack of regular maintenance for quite some time. The modular refineries in Nigeria have the potential to manufacture a greater amount of items while maintaining the quality of those goods, and to distribute those products to their end consumers in a way that is both more expeditious and more cost-effective.

In conclusion, to ensure the continued development of modular refinery operations in Nigeria, it is essential to have a plan that is both all-encompassing and well-coordinated. If the country overcomes these challenges and takes the activities that have been recommended, it will be able to realize the full potential of modular refineries and contribute to energy security, economic success, and environmental responsibility. The commitment and engagement of government bodies, industry actors, and local communities is necessary for the development of a sustainable and viable modular refinery sector in Nigeria. The accomplishment of this objective is a necessary condition for the success of these many activities.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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