Global Scientific JOURNALS

GSJ: Volume 8, Issue 10, October 2020, Online: ISSN 2320-9186
www.globalscientificjournal.com

A REVIEW OF SUSTAINABLE MODULAR REFINERIES DEVELOPMENT IN NIGERIA: PROSPECTS AND CHALLENGES

S.K. Bello[1], S.B. Lamidi[1] and K.A. Bello[2]

[1]Mechanical Engineering Department, Lagos State Polytechnic, Ikorodu

[2]Total Nigeria Plc, Victoria Island, Lagos

Corresponding e-mail: skolabello@yahoo.com

ABSTRACT

Modular refineries are designed and fabricated in a manufacturing environment based on the detailed requirements of the owner. As the name implies, the equipment is constructed in modules that are designed to be transported quickly and easily anywhere in the world. and comes in a variety of sizes and capacities. Depending on the refining capacity, Modular refineries can be designed and constructed with the major part of the work accomplished in a factory controlled atmosphere. This paper explores the development of small-scale modular private refineries and large-scale conventional private refineries. For the largest Modular Refineries, some of their components (such as distillation columns) are too heavy that they are normally shipped separately. Before shipping and while still in the factory where it is manufactured, the components are pre-assembled directly to the modularized process systems, so as to make the field assembly short and efficient. Modular refining solutions provide single-source project management, quick construction in challenging environments and superior quality control for reliable and cost-effective operations. This paper provides analyses of the current state of the refining sector in Nigeria and the refining revolution that will take place within the next 3-5 years. Modular refining solutions are best suited for projects with: strict product specifications, short project timelines requiring fast track delivery, limited, critical onsite resources and remote locations

Keywords: Capacity, Fabrication, Petroleum Product, Modular, Refinery.

1.0 INTRODUCTION

Most of the world's supply of petroleum comes from the Middle East, Nigeria, Angola, Libya, etc. (Heinberg 2005.). Petroleum is sold in the world market per oil barrels where a

unit oil barrel is equivalent to 42 US gallons or about 159 litres. Petroleum cannot be used in industry in its crude state; hence it is transformed into useful products such as liquefied petroleum gas (LPG), gasoline or petrol, kerosene, jet fuel, diesel oil and fuel oils. This process of transformation is known as refining and it occurs in special facilities known as petroleum refineries (or oil refineries). An oil refinery is considered an essential part of the downstream side of the petroleum (Gary and Handwerk 1984).. There is usually an oil depot (tank farm) at or near an oil refinery for the storage of incoming crude oil feedstock as well as bulk liquid products. Nigeria's refining capacity is currently insufficient to meet domestic demand, forcing the country to import petroleum products. In fact, Nigeria is the only major oil producing country in the world without adequate domestic refining capacity. Nigeria's state-held refineries (Port Harcourt I and II, Warri, and Kaduna) have a combined nameplate capacity of 445,000 barels per day

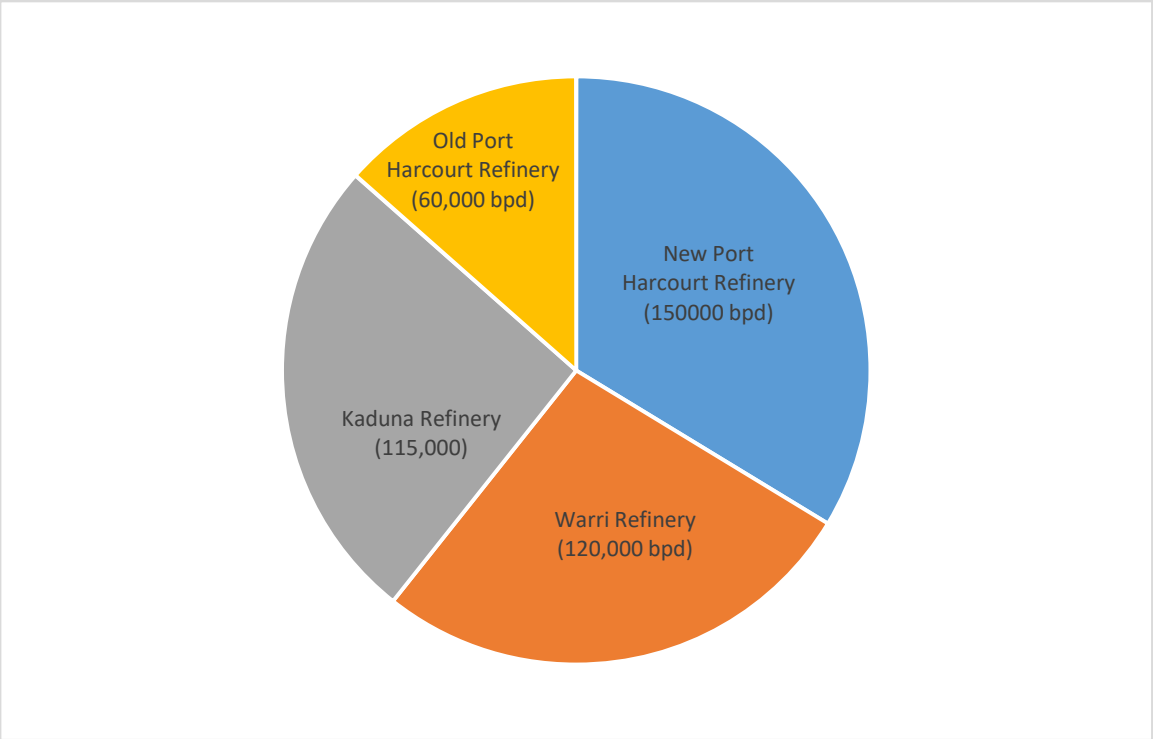

Fig. 1 Operational refineries in Nigeria with total installed capacity of 445,000 barrels per day

A modular refinery is a processing plant constructed entirely on skid mounted structures. Each structure contains a portion of the entire process plant, with interstitial pipping components to create an easily manageable process

According to Cenam Energy Partners (2014) 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. Such a refinery comes in a variety of sizes with capacities that range from 500 to 30,000 barrels per day. They are thus considered to be mini refineries.

Nigeria has been one of the world's leading importers of refined petroleum products for over two decades now. This unenviable position has earned the nation a very bad image among the Organization of Petroleum Exporting Countries (OPEC). It is very clear that the absence of functional refineries has multiple negative effects on the nation's economy it is a big strain on foreign reserves in particular and the economy in general (Aliko, 2015). How Nigeria can get out of the problem of importing refined products and become 2 an exporting country of refined petroleum products expected of a big crude oil producer through the establishment of private refineries.:

Modular topping plants or Crude Distillation Units (CDUs) are the simplest and economical way to extract valuable fuels from crude oil. A topping plant can be up and running within fourteen months of contract execution, giving host communities access to valuable fuels for vehicles, power generation, water treatment, and opportunities for jobs.

Module size is influenced by two major factors: the refinery output and the path to its location. A facility built to produce 5,000 units of refined product per day will be smaller than one cranking out tens of thousands of units. A refinery located near a port can be assembled from larger modules because the move involves fewer trips — assuming that a large enough vessel is available for transport. Getting modules from their fabrication point to an inland refinery site is a challenge.

Modular refineries are usually available in capacities ranging from 1,000 to 30,000 barrels per day (bpd). Modular refineries provide flexibility and can be constructed in a phased manner. The relatively low capital cost and flexibility for upgrades can make it a cost effective supply option for investors; especially if diesel is planned to be the lightest yield compare to conventional refineries that are usually larger refineries with capacities higher than 100,000 bpd. Conventional refineries are not as flexible as modular refineries and they require relatively high investment in resources and specialized labour to run, maintain and upgrade.

Petroleum is sold in the world market per barrels where a unit oil barrel (abbreviation bbl.) is equivalent to 42 US gallons or about 159 litres (EIA, 2014). Petroleum cannot be used in industry in its crude state; hence it is transformed into useful products such as liquefied petroleum gas (LPG), gasoline or petrol, kerosene, jet fuel, diesel oil and fuel oils (Colwell, 2009). This process of transformation is known as refining and it occurs in special facilities known as petroleum refineries (or oil refineries) (Colwell, 2009). The petroleum refining

processes are primarily chemical engineering processes. An oil refinery is considered an essential part of the downstream side of the petroleum industry (Gary and Handwerk, 2014)

Petroleum refineries are very large industrial complexes that involve many different processing units and auxiliary facilities such as utility units and storage tanks. Each refinery has its own unique arrangement and combination of refining processes largely determined by the refinery location, desired products and economic considerations (Gary and Handwerk, 1984).As a result of the high capacity, many of the units operate continuously, as opposed to processing in batches, at steady state or nearly steady state for months to years. The high capacity also makes process optimization and advanced process control very desirable (Colwell, 2009). The schematic diagram of petroleum refinery is shown in Fig 1. The petroleum refineries separate crude oil into constituent parts by the process of distillation. Petroleum products are usually grouped into three categories: light distillates (LPG, gasoline and naphtha), middle distillates (kerosene and diesel), heavy distillates and residuum (heavy fuel oil, lubricating oils, wax and tar). This classification is based on the way crude oil is distilled and separated into fractions (called distillates and residuum) (Drobny, 2006).

2.0 METHODOLOGY

This study was majorly conducted based on the analysis of secondary data collated from the following sources:

1. NNPC Monthly Financial and Operations Report.
2. National Bureau of Statistics Petroleum Products Consumption Statistics in Nigeria OPEC Annual Statistical Bulletin
3. Data on Nigeria's Gross Domestic Product (GDP) in Purchasing Power Parity (PPP) and Energy Intensity (EI)
4. Technological and economic data on the modular refinery plant alternative (US Department of Energy, Energy Information Agency.
5. Energy planning and foresight analysis methodology was used to determine national petroleum energy demand and petroleum products forecasts (in billion litres) from 2014 – 2020 (US Department of Energy, Energy Information Agency.

A typical large (conventional) refinery costs billions of dollars to build and millions more to run and upgrade. It runs around the clock 365 days a year, employs hundreds of people and occupies as much land as several hundred football pitches (Drobny, 2006).

2.1 NIGERIA CONVENTIONAL REFINERIES

Although Nigeria presently has four conventional refineries (Kaduna, Warri, Old Port-Harcourt and the New Port-Harcourt) controlled by the Federal Government under the

auspices of Nigerian National Petroleum Corporation (NNPC), none operates above 60 percent of its design capacity.

Fig 2. A Refinery complex

It is unfortunate that with a total of 445,000 bpd (NNPC 2018) expected from these refineries, the country is presently still battling with scarcity of refined products as a result of its low refining state.

2.2 PRIVATE INVESTORS INITIATIVE

It is believed that the 500,000 BPD plant by Dangote will alleviate the national and regional shortages in petroleum products supply, it should be understood that the problems that crippled the older plants are still in place, and by the sheer size of the refinery, it may suffer the fate of the older ones if extensive reforms are not implemented. Modular refineries, however, offer some unique options that may be more suitable for emerging economies like Nigeria. A modular refinery by definition is a prefabricated processing plant that has been constructed on skid mounted surfaces, with each structure containing a portion of the entire refining process plant connected together by interstitial piping to form an easily manageable process. Due to its manageability it is in my opinion better suited for the Nigerian Environment in an effort to encourage private investors into the petroleum downstream sector, preliminary licenses were issued to 26 private companies between year 2002 and

2004, to help build both refineries and petrochemical companies, (Colwell R.2009) but up to date, little success story has been recorded.:

Table 1. MODULAR REFINING PROCESS TECHNOLOGIES:

Crude Distillation Units (CDU)	Fractional distillation of crude for further processing
Saturated Gas Plants	Separation of refinery gas components
Naphtha Hydro-treaters (NHT)	Removal of sulphur upstream of naphtha processing units
Isomerization Units	Catalytic conversion of normal-paraffin's to iso-parafins for improved octane
CCR and Fixed-bed Platforming Processing Units	Catalytic reforming of naphtha to high-octane gasoline blending components and continuous catalyst regeneration
Merox Process Units	Catalytic chemical process for mercaptan removal (LPG, kerosene/Jet, LSR Gasoline, FCC Gasoline)
Distillate Hydro-treaters (DHT)	Catalytic process to improve quality of distillate boiling range feed stocks to meet stringent fuel regulations
Outside Battery Limits (OSBL)	Ancillary systems, off-sites and utilities necessary to support operation of the main process units

Source: US Department of Energy, Energy Information Agency EIA (2014)

2.3 THE MODULAR REFINERY ALTERNATIVE

The concept of modular refinery is not a practice that is relatively new. Although they were earlier used in the early forties, this concept later re-surfaced in the seventies when there were needs to solve problems associated with the conventional refinery.

A modular refinery is a conventional refinery constructed in a fragmented way or simply a big refinery in miniature form. Globally this concept is applied successfully when crude oil and a ready market are available but low refining capacity is recorded. (Okoko, and Nna 1998

2.4 ADVANTAGES OF MODULAR REFINERIES

Generally, modular refinery has a great effect toward development and maintenance of any community. This importance includes;

- Fuel shortages will be greatly reduced
- Setting up modular refineries at strategic demand locations would be a stop-gap pressure reducing measure to the product demand challenges.
- Setting up a modular refinery will enable employment opportunities for the citizens.

- With modular refineries, our marginal field operators will be better placed
- To improve the economy of the country.
- Lower capital requirements/ Short payback period.
- Minimal Space/Land requirements.
- Quick and easy installation.

Table2: DIFFERENCES BETWEEN CONVENTIONAL AND MODULAR REFINERIES

Comparing factors	Modular Refinery	Conventional Refinery
Production capacity	4,000 to 50,000 bpd	Above 120,000 bpd
Construction period	12 to 18 months	2-5 years
Operational flexibility	Flexible to meet demand changes	Complex
Production expectation	Unleaded Gasoline, Diesel, Kerosene and Fuel Oil	Unleaded Gasoline, Diesel, Kerosene, and Fuel Oil, Lubricating oil, waxes and asphalt (Caters for all range of products)
Construction process	Parts or equipment are constructed in modules designed to be transported quickly and easily anywhere in the world	Constructed on site
Operational efficiency	Good	Better
Land size	Limited refinery project land space	Maximum land take
Cost of installation	Low installation cost	High cost of installation
Return on Investment	Quicker investment recovery	Longer period

Source: Delivery Products (2014)

2.5 MODULAR REFINERY CONFIGURATIONS

The configuration of a modular refinery comes in different packages with increasing degree of sophistication, performing the three basic purposes of crude oil refining; separation, conversion and treatment. The different configurations include the following:

- **2.5.1 Topping (Atmospheric Distillation) Unit**

A crude distillation unit separates crude oil into different fractions or distillates based on their boiling points. It is mainly used for the production of diesel, kerosene, naphtha, liquefied petroleum gas while the residue serves as its by-products.

2.5.2 Hydro-Skimming Unit

This is simply a gasoline train in addition to an atmospheric unit. The addition of a reformer and hydro-treating unit helps to produce high octane unleaded gasoline and LPG.

- **2.5.3 Vacuum Distillation Added Unit.**

A modular vacuum distillation unit, includes the addition of a second distillation tower to distil the residual from the atmospheric tower into vacuum gas oil and heavy vacuum residual oil under vacuum condition.

- **2.5.4 Full Conversion Unit**

This is also known as a full conventional refinery and includes the addition of a hydro-cracker and fluid catalytic cracking unit.

3.0 PROSPECTS

Its key advantage lies in its size, cost differential and flexibility. It is constructed in a controlled environment and properly tested before being shipped out. It is relatively easier to fabricate and erect. Also, when an area becomes unsuitable for business, it can be disassembled and reassembled in a more suitable environment. For areas with non-cohesive geopolitics like Nigeria, modular plants can be scattered throughout the country to each serve the needs of the various regions of the country. The maintenance cost is low; considering that it processes 2,000 to 15000 BPD of mainly light sweet crude, routine turn around maintenance and on-stream inspections would require less personnel and down time.

In Nigeria, setting up modular refineries at strategic locations within the country will help in the following areas:

- Supporting the low performance of the existing refinery.
- Eradicate the incessant shortage of petroleum products across the country
- Drastically help to minimize our reliance on imported petroleum products.
- Totally remove the need for subsidy and pipeline vandalization
- Encourage private investors since start-up capital is low compared to a conventional refinery.

3.1 CHALLENGES OF MODULAR REFINERY OPERATION IN NIGERIA

In a volatile nation like Nigeria, large scale refining has some profound disadvantages that has over the years been proven by the non-functionality of plants and the heavy dependence on fuel import even after the plants were built.

3.2 Uncertainties: The Nigerian oil and gas industry is heavily regulated by multiple regulators including the Ministry of Petroleum Resources (MPR), Department of Petroleum Resources (DPR) and even the Nigeria National Petroleum Corporation (NNPC). According to the Nigerian Extractive Industries Transparency Initiative (NEITI), Nigeria loses an estimated $15 billion yearly in foreign investments due to regulatory uncertainty.

3.3 Security: Industrial sabotage, crude oil theft, illegal refining operations, pipeline vandalism and piracy present significant challenges in the oil and gas industry. Modular refinery investors can be swayed by the security condition of the country as investors would, more often than not, desire an environment, where their investment is not only safe but also secure. The several initiatives to curb instability within the Niger Delta Region of the Nigerian government as well as multinationals notwithstanding, security still mains a major challenge.

3.4 Infrastructure: Damaged pipelines, shallow channels and the absence of an effective logistics backbone are some major infrastructural impediments that have constrained growth of refineries in Nigeria.

3.5. **Feedstock Access**: One of the biggest challenges which local and new modular refineries are most likely going to be faced with is how to access feedstock supply on a regular basis. Guaranteed feedstock access has not been aided by inadequate infrastructure, insecurity and unstable production.

4.0 Conclusion

Modular refinery has several advantages in the society which are its cost-effectiveness in remote areas, flexibility, ease and speed of construction, low capital cost and concentrate on the production of one product at a time. Modular refinery specializes in the production of a particular product, for instance diesel, gasoline, kerosene or petrol. It is unlike conventional refinery which produces different product-mix at once.

The study (Ogbon N.O el al) revealed that: if the Nigeria four refineries working at full capacity in a year will produce over seven million liters of PMS. In addition, Dangote's upcoming refinery will likely add over ten million liters to the system bringing the total productions to over eighteen million liters. The projected demand of PMS by 2020 is at 20,233,197,507.59 + 2,800,000,000 = 23,033,197,507.59 liters. (v) By the year 2020, with PMS demand at about twenty-three million liters, Nigeria will still be saddled with PMS

importation. This will undoubtedly require the establishment of Modular refineries to complement the supply. The modular refineries remain economically viable and competitive and the revamping of the local refineries. The Modular Regime needs to thrive as it remains the sure road from importation to the export league in Nigeria

4.1 Recommendations

It is recommended that the Federal Government should augment efforts in providing investment incentives to lure investors in the modular refinery sector of the economy with an added view of not only satisfying the Nigerian PMS demand but also making Nigeria a net exporter of petroleum products.

References

1. **Aliko, Dangote (2015) 'Dangote US9bn refinery to come on stream' Dec. 2017.**
2. Campbell, C. J. "The Essence of Oil & Gas Depletion": collected papers and excerpts. Vol. 19. Multi Science Publishing Company Limited, 2003
3. Cenam Energy Partners (2014). "The Case for Modular Mini Refineries". www.cenamenergypartners.files.wordpress.com, Accessed January 19, 2018.
4. Colwell, R. "Oil refinery processes: a brief overview". Process Engineering Associates, LLC, http://www.processengr.com, Accessed January 18, 2018
5. Drobny, S. "The Real Economics of Oil". https://www.huffingtonpost.com/sheldondrobny/the-real-economics-of-oil_b_24108.html, Accessed January 19, 2018.
6. Gary, J. H. and Handwerk, G.E. "Petroleum Refining Technology and Economics (2nd Edition)", Marcel Dekker, Inc. 1984.
7. Heinberg, R. "The party's over: oil, war and the fate of industrial societies", New Society Publishers, 2005.
8. **Leprince p.** Leffler, W. L. **Petroleum Refining Conversion Process (200** "Petroleum refining for the nontechnical person (2nd Edition)", Penn Well Books. 1985**)**
9. National Bureau of Statistics. 2018"Petroleum Products Consumption Statistics in Nigeria". http://nigerianstat.gov.ng/download/467, Accessed January 19, 2018.
10. Nigerian National Petroleum Corporation Monthly Financial and Operations Report 2017. http://nnpcgroup.com/NNPCBusiness/% 20BusinessInformation/Performance Data/Monthly Performance Data/tabloid/617/Folder ID/211/Def ult.aspx, Accessed January 18, 2018.

11. Odell, P. R. "Why carbon fuels will dominate the 21st century's global energy economy", Vol. 5. Brentwood: Multi-Science Publishing Company, 2004.

12. Ogundari, I. O. "Techno-Economic Analysis of Sustainable Biofuel Development in Nigeria". Ph.D. Thesis, African Institute for Science Policy and Innovation (AISPI), Obafemi Awolowo University, Ile-Ife, Nigeria, 2014.

13. Okafor. E. E. “Corruption and implications for industrial development in Nigeria”, African Journal of Business Management. Vol.7 690 (29), pp. 2916- 2924, 2013.

14. Okoko, K. A. B., and J. N. Nna. "Emerging trends and community perception in the Nigerian oil industry", Nigerian Journal of Oil and Politics (2): 44 - 54, 1998.

15. United. States of America. Energy Information Administration (EIA, 2014). "Refiner Petroleum Product Prices by Sales Type", https://www.eia.gov/dnav/pet/ pet_pri_refoth_ dcu_nus_m.htm, Accessed January 18, 2018.

16. Toboc. "Bonny Light Crude Assay", Crude Suite. http://www.toboc.com/images/pdf/624149.pdf, Accessed January 19, 2018.

17. United States Energy Information Agency (EIA, 2017). "Independent Statistics and Analysis". https://www.eia.gov/energyexplained/index.cfm ?page=oil refining,