MODULAR REFINERY CRITICAL INFRASTRUCTURE INVESTMENT IN NIGERIA: A STRATEGIC PROJECT PLANNING ASSESSMENT

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Abstract
This study examined strategic project parameters for a modular refinery critical infrastructure investment in Nigeria. Technological and project economic data for the modular refinery alternative were obtained and the Technology Foresight Analysis (TFA) methodology was used. The results indicated total oil energy consumption from 2019–30 to be 13.55 Quadrillion BTU. The selected 30,000 barrel/day modular refinery plant (MRP) had estimated costs of ₦159.59 billion, throughput of 7.2 million barrels/year and requiring 30 acres of land for construction. Initial investment was ₦ 193.87 billion, with estimated annual net profits of ₦ 70.62 billion. Profitability indices showed Net Present Values of ₦ 3,022 billion, payback period of 2 years 9 months, and Annual Return on Investment of 36.4%. The study concluded that the modular refinery infrastructure investment in Nigeria was technically and economically viable, and recommended its implementation.

Keywords: Modular refinery; Critical infrastructure; Technology foresight analysis (TFA); Project planning and management; Strategic project assessment; Infrastructure investment; Nigeria

1.0 Background to the Study

It is imperative for a modern State to provide the critical infrastructure essential for the effective functioning of their societies and economies, and one such critical infrastructure is the petroleum refining system (Goldberg, 2013; Ogundari *et al.*, 2016; Olujobi, 2021). Modern industrial civilization is greatly dependent on petroleum and its products. The strategic sectors of the economy like the Health, Agriculture and Food Security, Security and Defence, Manufacturing, Energy, Environment, ICT, Housing, Transport and Construction among others, are dependent on the production of medicines, fertilizers, plastics, foodstuffs, building materials, paints, clothing and apparels, electricity, ceramics, cosmetics and so on, which are direct or indirect derivatives of petroleum or petroleum products (Oredeko, 2020: Olujobi, 2021). It is thus not implausible to say that the discovery of petroleum and the development of its refining process have completely revolutionized the human way of life.

Developed countries tend to exhibit advanced petroleum refining systems with reliable petroleum products delivery (Nivard and Kreikjes, 2017; Billing and Fitzgibbon, 2019; Park, 2020); developing countries however exhibit limited petroleum refining capabilities and severe deficiencies in their national distribution of petroleum products leading to incessant supply abnormalities, fuel scarcity, black market peddling of fuel, and disruption in socio-economic activities in their countries (PwC, 2017a; Ogbuigwe, 2018). The identified challenges to petroleum refining and petroleum products delivery systems in developing countries include technical inefficiencies, limited funding, population growth, resource scarcity and non-existence of basic modern petroleum/petroleum products supply infrastructure (PwC, 2017a; Ogbuigwe, 2018).

In Nigeria, the Federal Government is the dominant player in the petroleum upstream and downstream sectors and consequently the failures in the system are predominantly the inadequacies of the Federal Government to build and sustain the necessary infrastructure for the smooth operations of these sectors (Federal Republic of Nigeria, 2004; FMST, 2011; Federal Ministry of Petroleum Resources, 2016). Nigeria is an energy-rich country (crude oil production: 1.9 million barrels/day; proven crude oil reserves: 36.9 million barrels; proven natural gas reserves: 5.8 billion cubic metres) (OPEC, 2020) with aspirations of significant technology-based, inclusive socio-economic development and strategic relevance in the global area (proshare, 2022; PwC, 2022). The National Development Plan (2021 – 2025) is premised on manufacturing, services and agriculture dominating the structure of national output, with investment requirements of ₦348.1 trillion (US$839.6 million) and Gross Domestic Product (GDP) projections of ₦ 434.40 trillion (US$1,048 billion) by 2030 (FMFBNP, 2021; IMF, 2022; macrotrends, 2022). The attainment of this Plan would require a significant amount of energy. Nigeria, inopportunely, has only 4 petroleum refineries with combined nameplate capacities of 445,000 barrels/day (Ogbuigwe, 2018; NNPC, 2022), and the country's refining performance has been suboptimal, with consolidated capacity utilization of 7.87% between 2015 and 2020, and the importation of 91% of petrol consumption (and a sizable volume of other petroleum products) to meet domestic demands (BudgIT, 2021; NNPC, 2022). Inexplicably, Nigeria is the only oil and gas producer in the world that relies completely on the importation of refined petroleum products to meet domestic need (Ogbuigwe, 2018; Omorogbei, 2018; BudgIT, 2021; FMFBNP, 2021: NNPC, 2022). This development has led to economic challenges, infrastructural gaps and unemployment especially as the government pays humongous subsidies on the estimated domestic consumption of over 55 million litres of Premium Motor Spirit (petrol) daily (Omorogbei, 2018; BudgIT, 2021; FMFBNP, 2021: NNPC, 2022).

With rapid population growth, increasing domestic demand for energy in general, and petroleum products in particular are projected (Omorogbei, 2018; BudgIT, 2021; FMFBNP, 2021: NNPC, 2022). Inopportunely, Nigeria's petroleum refining sector cannot meet this demand, with sector limitations attributable to poor governance and regulatory framework, fragile planning and operations, insufficient funding, inadequate number of refineries and the poor performance of the existing ones, weak political will, meager infrastructure investment and maintenance, deficiencies in the distribution networks, and inadequate power supply (Omorogbei, 2018; BudgIT, 2021; FMFBNP, 2021: NNPC, 2022). This situation is further exacerbated by specific dynamics such as exploitation in the polity, climate change mitigation policies and regulations, inadequate enforcement of policies and regulations, subsidies for imported fuel, petroleum pipeline leakages and theft from the public petroleum downstream system (Omorogbei, 2018; BudgIT, 2021; FMFBNP, 2021: NNPC, 2022).

Government measures to mitigate the disconcerting limitations in the refinery sector include refurbishing the decrepit state-owned refineries, infrastructure investment of 20% share value in the private Dangote refinery, reducing or eliminating subsidies for imported fuel, enabling private and decentralized public investment in modular refineries, and the signing of the Petroleum Industry Act (2021) (Ogundari *et al.*, 2016; PwC, 2017; Mondaq, 2021, Proshare, 2021). These government measures were to institute a petroleum products supply programme robust enough to provide for current and future demand, diminish waste and petroleum products loss, ensure improved service delivery and enhanced petroleum products access and guarantee appropriate investment recovery within a dependable secure governance and regulatory framework (Omorogbei, 2018; BudgIT, 2021; FMFBNP, 2021: NNPC, 2022).

Private and decentralized public investment in modular refineries as a strategic government measure to mitigate limitations in petroleum products supply in Nigeria has generated much excitement in Nigeria, with several modular refineries given licenses to operate (Ogundari *et al.*, 2016; Olujobi, 2021). The ineffectualness of the modular refinery alternative as a mitigating option in spite of the considerable financial and material investments in the sector may be attributable to limitations in the capabilities of state agencies and private sector developers to adequately analyse the national petroleum products demand and comprehensively plan and deliver the modular refinery alternative for successful project implementation.

This study detailed a strategic project assessment of modular refinery infrastructure investment in Nigeria as critical intelligence for petroleum refining infrastructure development in a developing economy. The specific objectives were to analyse the petroleum and petroleum products consumption from 2019 to 2030, determine the technological specifications for the robust singular petroleum products supply initiative and ascertain the techno-economic viability of the modular refinery system development.

1.1 Overview of petroleum refinery and the modular refinery alternative

A petroleum refinery is a complex industrial processing plant where petroleum is processed or purified (refined) into several industrially valuable products such as light distillates (premium motor spirit - PMS or petrol, liquefied petroleum gas - LPG, and naphtha), middle distillates (Automotive Gas

Oil - AGO or diesel and Dual Purpose Kerosene - DPK), and heavy distillates/residuum (paraffin wax, lubricating oils, asphalt/tar/bitumen, heavy fuel oils) (Cenam Energy Partners, 2014; VFuels, 2021). Petroleum refineries are typically large (occupying huge expanses of land), complex (comprising many different processing units and auxiliary facilities such as utility units and storage tanks, with capability for processing as much as 800,000 to 900,000 barrels of crude oil per day) and very expensive (costing millions or billions of dollars to build and operate) (Brickstone, 2019; Singh, 2021). Refineries perform three basic activities – Separation (fractional distillation), Conversion (cracking and rearranging the molecules), and Treatment. Several of the refinery processing units operate at steady state – or near steady state – over long periods of time (months or years) in a continuous nature, rather than in batches (Brickstone, 2019; Singh, 2021).

A modular refinery (or mini-refinery) is a simplified refinery built of several self-contained interchangeable units which can be rearranged, replaced, combined or interchanged easily (Brickstone, 2019). Modular refineries are built to be easily transported and assembled; and they entail considerably less capital investment than regular refineries (VFuels, 2021). The modular path way is to reduce costs, accelerate delivery schedule, and efficiently achieve technical scope (VFuels, 2021). Modular refineries are built across several sizes and capacities from 500 to 30,000 barrels per day, with construction time of between 15 to 18 months and costing an estimated US$ 200 million (Cenam Energy Partners, 2014; VFuels, 2021).

Figures 1 and 2 depict the schematics of a conventional petroleum refinery and a typical modular refinery respectively. The Figures show the difference in complexity between the conventional and modular types of refineries. While the conventional refinery is made up of many units with its many products (light, middle and heavy distillates), the modular refinery is basically limited to the crude distillation unit, and the products consisting of light and middle distillates. The products made from a barrel of crude oil refined in a conventional refinery are presented in Table 1 while Table 2 showcases the differences between the conventional and modular refineries.

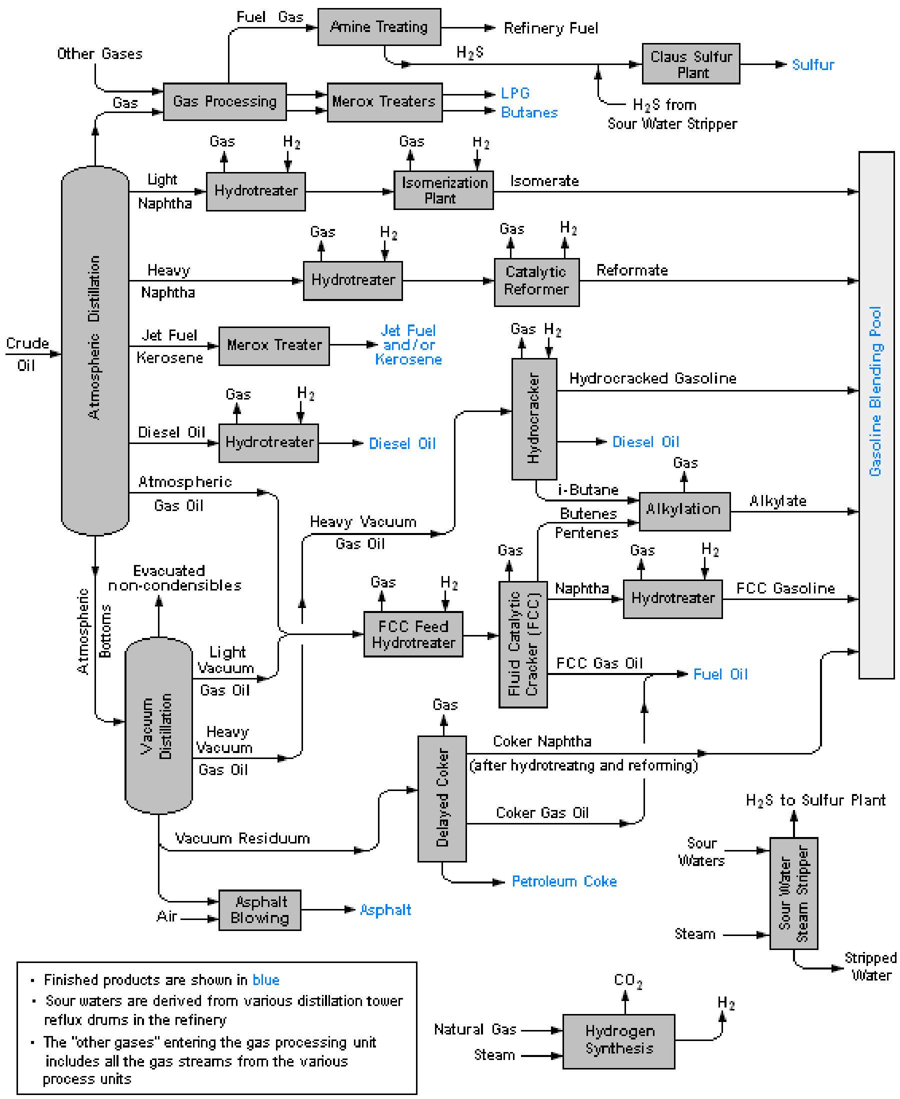

Fig. 1: Schematic diagram of a Petroleum Refinery
Source: Ogundari *et al*. (2016)

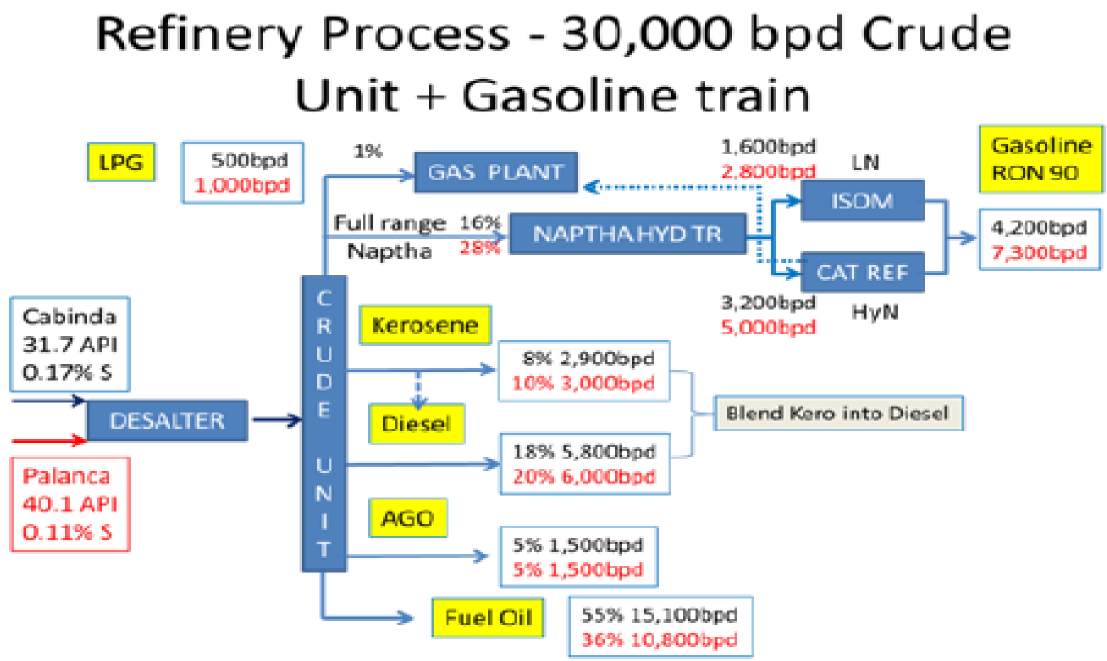

Figure 2: Configuration of a Typical Modular Mini Refinery
Source: Singh (2021)

Table 1: Products made from a Barrel of Crude Oil (By Conventional Refinery)

S/N	Product	Percentage of Total (%)
1	Gasoline	47
2	Diesel Fuel & Heating Oil	23
3	Other Products	18
4	Jet Fuel	10
5	Liquefied Petroleum	4
6	Asphalt	3

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

Table 2: Comparison of a Modular Refinery with a Conventional Refinery

Modular Mini-Refinery (Hydro-skimming)		Conventional Refinery (Hydro-cracking)	
1. Skid Mounted: a. Improves engineering quality b. Faster construction	+ve	1. Fabrication on site 2. One location for different markets 3. High initial capital outlay/long payout	-ve -ve -ve
2. Close to Markets	+ve	4. Restricted de-bottlenecking	-ve
3. Low capital	+ve	5. Greater volume high value products	+ve
4. Flexible to meet demand (add modules)	+ve	6. Scale and operating efficiency	+ve
5. More personnel per Effective Distillation Capacity	-ve	7. Less personnel per Effective Distillation Capacity	+ve

Source: Brickstone (2019)

2.0 Methodology

This study is premised on a Technology Foresight Analysis (TFA) framework for critical petroleum refinery infrastructure development in a developing economy. Technology foresight entails the generation of intelligent assertions about the future, the elucidation of such assertions in terms of informed action, and the over-all learning processes that entail appropriate responses to challenges of the future (Salo and Cuhls, 2003; Gibson *et al.*, 2018). Technology foresight has a wider viewpoint than just futures forecasting. It entails providing strategic intelligence for crafting the future aspired for (Yim, 2010), especially in critical sectors like petroleum downstream activities (Na, 2015; Gobson *et al.*, 2018). Technology Foresight Analysis (TFA) utilizes Qualitative (Backcasting, literature reviews, expert panels, genius forecasting, strategic assessment, etc), Semi-quantitative (roadmapping, game-simulation, Delphi Technique, System/Structural analysis etc), and Quantitative (benchmarking, extrapolation, modeling simulation, bibliometrical analysis etc) techniques individually or in a multifaceted combination of methods (Yim, 2010; Ogundari and Otuyemi, 2020; Ogundari *et al*., 2021).

The study entailed the following steps

i. Estimating petroleum energy demand and petroleum products forecasts for Nigeria from 2019 to 2030 taking into cognisance national development aspirations;
ii. Collecting and analysing data on the technological specifications for the modular refinery infrastructure option; and
iii. Collecting and analysing data on the economic viability of the modular refinery infrastructure.

The determination of the energy and petroleum products demand entailed several steps: (i) obtaining, for Year 2019 from literature, the Gross Domestic Product in

Purchasing Power Parity (GDP in PPP) in US dollars and primary energy consumption (in British Thermal Units, BTU) to produce this GDP (PPP) (ii) obtaining from literature for Year 2019, the percentage oil component of primary energy consumption in Nigeria, (iii) determining estimated oil component of primary energy consumption in Nigeria by 2019 by multiplying the primary energy consumption obtained for Nigeria in 2019 by (ii), (iv) obtaining estimated GDP (PPP) for Year 2030 from literature, (iv) by extrapolation, determining the estimated oil consumption (in British Thermal Units, BTU) to produce this GDP (PPP) for Year 2030, (iv) determining annual growth rate of oil consumption and total oil consumption in Nigeria from 2020 to 2030 by extrapolation, and (v) estimating the petroleum products demand by petroleum refining percentages.

The technical specifications for the modular refinery alternative entailed (i) determining the number of modular refineries required in the country based on the total oil consumption analysis executed, (ii) determining land mass requirement for the construction of individual and total number of modular refineries, and (iii) determining the material and energy balances for the petroleum product refining.

The engineering economic analysis for the installation of individual modular refineries entailed obtaining project definition information such as time (time of infrastructure installation and lifecycle in years), costs (capital costs, land costs, operations and maintenance costs, energy costs etc, measured in Naira), and technical scope (equipment size and landmass requirements, measured in appropriate dimensions like liters and square meters) were obtained from manufacturers/equipment vendor and estate agents' price lists, project financial analysis reports, and other relevant literature.

The data obtained were analysed using material and energy project foresight/analysis techniques, descriptive statistics and Life Cycle Cost Analysis. Profitability indices (levelised costs of petroleum products, Net Present Value - NPV, Break-even and Payback Period, and return on investment) were determined using appropriate infrastructure project financial management methods.

3.0. Results

The calculations are presented in this section.

3.1. Technological and cost specifications for the modular refinery alternative in Nigeria

This section analyses the project definitions for the Modular Refinery Alternative project. The TFA methods included were Qualitative (Backcasting, literature reviews, genius forecasting, strategic assessment), Semi-quantitative (roadmapping, system analysis), and Quantitative (benchmarking).

Determination of the energy and petroleum products demand for Nigeria from 2019 to 2030

(i) Gross Domestic Product in Purchasing Power Parity (GDP in PPP) in US dollars for Year 2019 was estimated to be US$ 990.7 Billion
(ii) Primary energy consumption (in British Thermal Units, BTU) to produce this GDP (PPP) was estimated to be 1.49 Quadrillion BTU

(iii) Gross Domestic Product in Purchasing Power Parity (GDP in PPP) in US dollars for Year 2030 is projected to be US$ 1.707 Trillion

(iv) Oil percentage of primary energy consumption (PEC) in Nigeria is estimated to be 55.79%, and it is assumed this will remain constant over the study time period.

(v) It is assumed that Nigeria's oil energy intensity will be constant over the time period of this study.

Thus,
Oil share of PEC in Year 2019 = 55.79% of 1.49 Quadrillion BTU = 0.831 Quad BTU

Oil Energy Intensity for Year 2019 = oil energy consumption per dollar of GDP (PPP)

produced.

Oil Energy Intensity for Year 2019 = $\frac{0.831\ Quadrillion\ BTU}{US\$\ 990.7\ Billion}$ = 838.8 BTU/US$

Consequent to (v),
Estimated oil energy consumption for Year 2030 = GDP (PPP) produced X Oil Energy

Intensity

= US$ 1.707 Trillion X 838.8 BTU/US$ = 1.43 Quadrillion BTU

This is the energy equivalence of the projected oil share of the primary energy consumption for Year 2022.

Annual oil energy growth rate = $\frac{difference\ in\ oil\ energy\ consumptions\ between\ Years\ 2019\ and\ 2030}{difference\ in\ tine\ between\ Years\ 2019\ to\ 2030}$

Annual oil energy growth rate = $\frac{1.43-0.831\ (Quadrillion\ BTU)}{2030-2019\ (Years)} = \frac{0.599\ Quadrillion\ BTU}{11\ Years}$

= 0.054 Quadrillion BTU/Year

Estimated total oil energy consumption from 2019 to 2030

The oil energy consumption for each year from 2019 to 2030 was determined and presented in Table 3. The table shows that total oil energy consumption over the study time frame was 13.55 Quadrillion BTU or 2,330 million barrels of oil equivalent. Using Table 1 as reference, Nigeria's petroleum energy consumption estimates and petroleum products forecast (in billion litres) are presented in Table 4. Petroleum demand is projected to rise at 2.8 billion litres per year over the time frame, petrol production is projected to rise at 1.3 billion litres per year, diesel production rise is 0.645 billion litres per year, other products production rise is 0.445 billion litres per year, jet fuel production rise is 0.28 billion litres per year, liquefied petroleum production rise is 0.11 billion litres per year, and asphalt production rise is 0.085 billion litres per year.

Table 3: Total Estimated Oil energy Consumption from 2019 to 2030

Year	Oil Energy Consumption (Quadrillion BTU)	Oil Energy Consumption (Million Barrels of Oil Equivalent)
2019	0.831	142.93
2020	0.885	152.22
2021	0.940	161.68
2022	0.994	170.97
2023	1.048	180.26
2024	1.102	189.54
2025	1.156	198.83
2026	1.210	208.12
2027	1.264	217.41
2028	1.318	226.70
2029	1.372	235.98
2030	1.430	245.96
TOTAL	**13.550**	**2,330.60**

Note: 1 Quadrillion BTU = 172 million barrels of crude oil equivalent

Table 4: Nigeria's Petroleum Energy Demand and Petroleum Products Projections via Conventional Refinery Option

Year	Petroleum (Million Barrels)	Petroleum (Billion Litres)	Petrol (Billion Litres)	Diesel (Billion Litres)	Other Products (Billion Litres)	Jet Fuel (Billion Litres)	Liquefied Petroleum (Billion Litres)	Asphalt (Billion Litres)
2019	142.93	22.72	10.68	5.23	4.09	2.27	0.91	0.68
2020	152.22	24.2	11.37	5.57	4.36	2.42	0.97	0.73
2021	161.68	25.71	12.08	5.91	4.63	2.57	1.03	0.77
2022	170.97	27.18	12.77	6.25	4.89	2.72	1.09	0.82
2023	180.26	28.66	13.47	6.59	5.16	2.87	1.15	0.86
2024	189.54	30.13	14.16	6.93	5.42	3.01	1.21	0.90
2025	198.83	31.61	14.86	7.27	5.69	3.16	1.26	0.95
2026	208.12	33.09	15.55	7.61	5.96	3.31	1.32	0.99
2027	217.41	34.57	16.25	7.95	6.22	3.46	1.38	1.04
2028	226.7	36.04	16.94	8.29	6.49	3.60	1.44	1.08
2029	235.98	37.52	17.63	8.63	6.75	3.75	1.50	1.13
2030	245.96	39.1	18.38	8.99	7.04	3.91	1.56	1.17
TOTAL	**2,330.60**	**370.05**	**173.92**	**85.11**	**66.61**	**37.01**	**14.80**	**11.10**

NOTE: 1 barrel of oil = 158.987 Litres

Technological specifications for the modular refinery alternative

This section presents the analysis for the development of the modular refinery infrastructure to address the identified annual petroleum consumption and petroleum products projections. In this study, the purposively selected modular refinery plant output is 30,000 barrels per day (bpd). Although nameplate total petroleum refining output by modular refining plants per year is expected to be 30,000 X 365 = 10,950,000 barrels per year, for this study it is assumed that the modular refinery would operate at 80% efficiency for a period of 300 days/year.

Thus, Total daily production = 30,000*0.8 = 24,000 bpd

Total annual production = 24,000*300 = 7,200,000 barrels/yr

a. Estimation of total number of modular refinery plants required

The number of modular refinery plants required in the Nigerian market is determined by the equation:

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

Table 5 shows the total number of 30,000 bpd modular refineries that would be required to refine the total estimated oil energy consumption in the country per year. The analysis shows that while 20 modular refinery plants were estimated for Year 2019 oil energy consumption, the number of modular refinery plants required by Year 2030 was 34.

Table 5: Total Estimated Oil energy Consumption and Number of 30,000 Barrels per Day Modular Refinery Plants (MRPs) Required from 2019 to 2030

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**	

b. Total land area required for the modular refinery

The land area for a modular refinery depends on the processing capacity and process unit number. The refinery complex area requirement is typically 5 acres per 5,000 bpd refinery (Proshare, 2019; Peiyang Chemical Engr. Co, 2021)

Thus, for a 30,000 barrels per day (bpd) modular refinery,

Total land requirements = $\frac{30,000}{5,000}$ x 5 acres = 6 x 5acres = 30 acres (or 180 plots @ 1 acre = 6 plots of land).

Table 6 shows the land requirement to build the required number of 30,000 bpd modular refinery plants per years. The estimates range from 600 acres (2.43 sq. km) in 2019 to 1020 acres (4.13 sq. km) in 2030. The estimated total landmass requirement each year represents an infinitesimal fraction of Nigeria's total land mass of 923,768 sq. km.

Table 6: Total Land Requirements for the Number of 30,000 Barrels per Day Modular Refinery Plants (MRPs) Required from 2019 to 2030

Year	30,000 bpd MRP (Number Required)	Total Land Area (Acres)	Total Land Area (Sq Km)
2019	20	600	2.43
2020	21	630	2.55
2021	23	690	2.79
2022	24	720	2.91
2023	25	750	3.04
2024	27	810	3.28
2025	28	840	3.40
2026	29	870	3.52
2027	30	900	3.62
2028	32	960	3.89
2029	33	990	4.01
2030	34	1020	4.13

c. Cost of the modular refinery alternative

A modular refinery is estimated to cost from US$10,500 to US$ 15,000 per barrel. Using a midpoint of US $ 12,750 per barrel, it can be estimated that a 30,000 bpd modular refinery plant would cost around US $382.5 million or ₦159.59 billion at the current official bank rates of ₦414.53 per US$.

That is,

1 barrel costs US $ 12,750,

Thus 30,000 barrels would cost US $ 12,750 X 30,000 = US $382.5 million

US$1 = ₦414.53

US $382.5 million = ₦414.53 X 382,500,00 = ₦159.59 billion

Table 7 provides the costs for the total number of 30,000 bpd modular refineries that would be required to meet the petroleum consumption demands for Nigeria over the study time span. These data are critical to national modular refinery planning and analysis, and provide information for would-be investors in the Modular Refinery Alternative.

Table 7: Total Costs for the Number of 30,000 bpd Modular Refinery Plants (MRPs) Required from 2019 to 2030

Year	30,000 bpd MRP (Number Required)	Total Costs (US$ Billion)	Total Costs (₦ Trillion)
2019	20	7.65	3.17
2020	21	8.03	3.33
2021	23	8.80	3.65
2022	24	9.18	3.81
2023	25	9.56	3.96
2024	27	10.33	4.28
2025	28	10.71	4.44
2026	29	11.09	4.60
2027	30	11.48	4.76
2028	32	12.24	5.07
2029	33	12.62	5.23
2030	34	13.01	5.39

d. Determination of location and cost of land for the construction of the modular refinery alternative

The location of an industrial plant is a critical factor in its viability analysis (Ogundari and Otuyemi, 2020). Parameters that determine the appropriate location of an industrial plant include accessibility to raw materials, nearness to the market, availability of labour, availability of infrastructural facilities (transport, energy, water and waste disposal), availability of finance, and government policies amongst others (Ogundari *et al.*, 2021). Nigeria's Federal and State Governments, taking into consideration these plant location criteria, have long considered States in Southern Nigeria – the States of Niger Delta region (Ondo, Edo, Delta, Akwa-Ibom, Rivers, Bayelsa, and Cross River States), as well as Anambra, Imo, Ogun and Lagos States – as the most appropriate sites for modular refineries in the country (FMPR, 2017; PwC, 2017).

Increased public and private sector interests in modular refineries investments in the region has focused on Delta State being a strategic location, especially with the State's establishment of the Agro-Industrial Park Area in Ndokwa East, Local Government Area as suitable location for the modular refinery alternative. Consequently, this study purposively selected Delta State for the location of the modular refinery initiative.

Cost of land in the Delta State Agro-industrial park area of Ndokwa East, Local Government area of Delta State (Nigeria Property Centre, 2021)

7.2 acres of industrial land costing ₦ 90 million was found in the area

30 acres (180 plots of land) thus cost = ₦ $\frac{90,000,000}{7.2}$ X 30 = ₦ 12,500,000 X 30 = ₦ 375,000,000

e. Determination of petroleum consumption and petroleum products projections from the modular refinery alternative

Table 8 depicts the percentages of petroleum products obtained from a barrel of crude oil using the modular refinery option. The table shows that for a typical modular refinery, fuel oil is its largest production output, closely followed by gasoline (petrol), diesel and kerosene in that order. Using these percentages, Table 9 was obtained.

Table 8: Products made from a Barrel of Crude Oil (By Modular Refinery)

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

Table 9 is a depiction of the petroleum products output estimations from 2019 to 2030. The figures for gasoline (Petrol) and diesel are quite different from those estimated from the refining of petroleum using the conventional refinery as depicted in Table 4. This may be attributed to the fact that conventional refining and modular refining have different percentages of product output for these two products. The figures for Kerosene however are the same. The implication here is that for the modular refinery option, there may the need to add more processing units to the reefing plant in order to further process the Atmospheric Gas Oil AGO and fuel oil outputs for greater output of gasoline (petrol) and diesel.

Table 9: Estimations for Petroleum Consumption and Petroleum Products Output by the Modular Refinery Alternative in Nigeria

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**

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

Table 10 depicts differences in annual extant petroleum products consumption and the estimated average production from the modular refinery alternative over the study time span. For petrol, there would be a deficit of 3.6 billion litres annually. Diesel and Kerosene indicate surpluses of 1.8 and 2.1 billion litres annually, while LPG indicates a deficit in excess of 770 thousand MT. This may indicate that the modular refinery option may not meet the national petrol demand, and there might still be the need to import petrol to meet domestic demand. The LPG deficit may be met by tapping into the nation's extensive natural gas reserves estimated at 206.53 trillion cubic feet. The surplus production of Diesel and Kerosene may indicate national potential for an export market, probably in West Africa.

Table 10: Comparative Daily Petroleum Products Consumption and Average Annual Production from Modular Refining for Nigeria

	Petrol/Gasoline (Million Litres)	Diesel (Million Litres)	Kerosene (Million Litres)	LPG (MT)
Consumption: Daily[a]	50	12	2.7	2,739.73
Consumption: Annual	12,250	4,380	985.5	1,000,000
Ave Prod from Mod Ref: Annual	8,650	6,180	3,090	229,570
Production Status:	**Deficit: 3,600**	**Surplus: 1,800**	**Surplus: 2,105**	**Deficit: 770,430**

[a] These are estimates of Nigeria's daily petroleum products consumption obtained from the Federal Ministry of Petroleum Resources, Abuja, Nigeria.

Table 11: Annual Revenue Estimates from Petroleum Products Output by a Single 30,000 BPD Modular Refinery Plant in Nigeria

Petroleum (Million Barrels)	LPG (Million kg)	Gasoline (Million Litres)	Kerosene (Million Litres)	Diesel (Million Litres)	AGO (Thousand Barrels)	Fuel Oil (Million Litres)
7.2	8.51	320.52	114.47	228.94	360	411.78
REVENUE (₦ billion)	72.34	180.98	51.51	124.77	24.76	183

NOTE:
1 barrel of oil = 158.987 Litres; 1BOE LPG = 118.2033 kg
For LPG: Actual pump price as at February 2022 = ₦ 8,500.00 per kg
For Petrol/Gasoline: Actual pump price = ₦165.00 per litre, subsidy paid = ₦ 399.63 per litre making a total price of ₦564.63 per litre.
For Kerosene: Price as at February 2022 = ₦450.00 per litre.

For Diesel: Price as at February 2022 = ₦545.00 per litre
For AGO: Price as at February 2022 = ₦ 68,765.55 per barrel
For Fuel Oil: Price as at February 2022 = ₦ 444.40 per litre

f. Estimation of annual revenues from the petroleum products output

The estimated annual revenues from the sale of the petroleum product outputs from a single 30,000 bpd modular refinery plant (MRP) are depicted in Table 11. The MRP is expected to generate ₦ 72.34, 180.98, 51.51, 124.77, 24.76 and 183 billion from the sales of LPG, Gasoline, Kerosene, Diesel, AGO and Fuel Oil respectively, making estimated annual sales of ₦ 637.36 billion.

3.2. Techno-economic analysis of the modular refinery alternative

To facilitate project investment decisions, it is imperative to appraise the techno-economics of the Modular Refinery Alternative (MRA). This is carried out in this section. Table 12 highlights the costs and revenue estimates as well as profitability indices for a 30,000 bpd MRP. Total initial investment (comprising capital costs and cash-in-hand) for the MRP was estimated at ₦ 193.87 billion. Total operating costs for the processing of 7.2 million barrels/year of crude oil and petroleum products revenues were estimated at ₦ 543.20 and 637.36 billion respectively. Estimates for gross profits, taxes, and net profits were ₦ 94.16, 23.52 and 70.62 billion respectively. The profitability indices showed Net Present Value of ₦ 3,022 billion, break-even time of 1 year, project payback period of 2 years 9 months. The Return on Investment (ROI) of the project was estimated to be 36.4% per annum.

a. Net present value analysis for the modular refinery alternative

The Net Present Value (NPV) is determined by the net cash flow over the project lifespan (25 years) discounted to the present less the initial investment (Blank and Tarquin, 2012; Shah, 2012).

The study assumed that the value of the net cash flow would be the same over the 25-year project lifespan and be equal to the first year estimated net profit ₦ 152.10 billion.

NPV = Net cash flow discounted to the Present – Initial Investment

NPV = ₦ (152,100,000,000*25 (0.9091) – 434,560,000,000)

= ₦ (3,802,500,000,000 * 0.9091) – 434,560,000,000)

= ₦ 3,456,852,750,000 – 434,560,000,000

= ₦ 3,022,292,275,000

The Break-even time is the period (in Years) in which the gains from an economic activity equal the costs incurred in pursuing it (Blank and Tarquin, 2012; Shah, 2012). This study shows that the break-even time would occur in the first year of operation.

Table 12: Techno-Economic Assessment of a Singular 30,000 Modular Refinery Plant (MRP)

Costs	**₦ 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	**₦ 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:	**₦ 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 (₦ 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%

b. Payback period analysis for the water desalination infrastructure project

The Payback Period Calculation was used for analysis (Blank and Tarquin, 2012; Shah, 2012).

$$Payback\ Period = \frac{\textit{Initial Investment}}{\textit{Annualized expected cash inflow}}$$

$$= \frac{193{,}870{,}000{,}000}{70{,}620{,}000{,}000} = 2.74$$

years or approximately 2 years 9 months

It is important to note that land appreciates over time, thus it is reasonable to deduct the cost of land and the working capital from the estimation of payback period. If this is taken into consideration, the Payback Period would be:

$$\text{Payback Period} = \frac{161.180{,}000{,}000}{70{,}620{,}000{,}000} = 2.28$$

years or Approx. 2 years 4 months.

Consequently, payback period for the water desalination infrastructure project was estimated to be in the range of 2 years 4 months – 2 years 9 months.

c. Return on investment (ROI) analysis for the water desalination infrastructure project

The Return on Investment (ROI) Calculation was used for analysis (Sullivan *et al.*, 2000; Nagarajan, 2010; Blank and Tarquin, 2012).

$$Return\ on\ Investment\ (ROI) = \frac{\textit{Net Profit}}{\textit{Cost of Investment}} \text{ X } 100$$

$$Annual\ Return\ on\ Investment\ (ROI) = \frac{70{,}620{,}000{,}000}{193{,}870{,}000{,}000} \text{ X } 100 = 36.4\%$$

4.0 Summary and Conclusion

This study analysed modular refining infrastructure investment in Nigeria as a mitigation strategy to inadequate petroleum products supply. A Technology Foresight Analysis framework entailing energy project planning and strategic assessment was used. The study determined oil energy consumption of 0.831 – 1.43 Quad BTU (142.93 – 245.96 BOE) from 2019 to 2030, with total oil consumption estimations of 13.55 Quad BTU (2,330.6 BOE) over the time period. The estimated annual oil energy growth rate from 2019 to 2030 was 0.054 Quad BTU per year. About twenty to thirty-four 30,000 bpd modular refineries, operating at 80% efficiency over 300 days a year, were estimated needed to refine all the oil energy consumption projections. These specifications provided for daily and annual oil production at 24,000 bdp and 7.2 million barrels per year respectively. Each 30,000 bdp modular refinery, with an estimated cost of ₦ 159.59 billion, was estimated to require 30 acres of land for construction. The cost of this land in the Delta State Agro-Industrial park area of Ndokwa East LGA of Delta State was estimated to cost ₦ 375 million for the total 30 acres. Techno-economic considerations determined total investments of ₦ 193.87 billion per 30,000 bpd modular refinery and annual net profits of ₦ 70.62 billion. Profitability indices showed Net Present Values of ₦ 3.022 trillion, break-even time of 1 year, payback period of 2 years 4 monts to 2 years 9 months, and annual Return on Investment (ROI) of 36.4%.

The study determined that modular refinery infrastructure investment in Nigeria, with specific focus on Delta State in Nigeria's Niger Delta region, was technically feasible and economically viable, and appropriate for deployment as a strategic petroleum products supply alternative.

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