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An Assessment of the Potential Benefits of Refining Crude Oil in Ghana

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Abstract: Refining is vital in the oil and gas industry, converting crude oil into products like gasoline, diesel, and LPG. Since discovering oil in 2007, Ghana's petroleum sector has experienced significant growth; however, the country still relies on imports to meet its domestic demand, importing nearly four million metric tonnes of petroleum products in 2022, with gas oil (diesel) being the most significant component. This study, therefore, explored the potential benefits of refining Ghana's crude oil, with a focus on its economic feasibility and the implications thereof. Considering the construction of a new refinery, a cost-benefit analysis was conducted using the Jubilee field crude oil, evaluating Net Present Value (NPV), Return on Investment (ROI), and Payback Period with the aid of Aspen HYSYS and an Excel Spreadsheet. The cost-benefit analysis indicated a positive NPV, a payback period of 3.5 years and an ROI of 29%. The predicted cost savings for local refining, with 2022 as a case, were estimated to be $1.4 billion (GH₵16.3 billion). By refining petroleum locally, an estimated net gain of $8.66 (GHS 96.99) per barrel was computed. A 2013 – 2033 forecast analysis projected increasing consumption volumes, rising import costs, and escalating ex-pump prices, further supporting the need for enhanced local refining capacity. The Government of Ghana should therefore prioritize refining crude oil locally as part of its industrialization strategy. This will help create jobs, generate foreign exchange savings, and enhance energy security.

Keywords: Crude oil, Economic Analysis, Forecast, Refining.

1 Introduction

The oil and gas sector provides a range of services encompassing transportation, electricity, heating, lubricants, and a diverse array of chemical and petrochemical products [1]. Ghana contributes to the global oil industry through its crude oil production. Ghana's crude oil export substantially increased from 24.5 million barrels (MMbbls) in 2011 to 55.4 MMbbls in 2021. Ghana's total petroleum products consumption in 2021 was 4630 kt, representing an over 300% increase from 2000. However, the production of petroleum products (kerosene, gasoline, gas oil, and LPG) has significantly declined from 659 kt in 2000 to 199 kt in 2022, leading to a 500% increase in imports from 2000 to 2021 [2]. Amongst the imported products, gas oil has seen the highest rise in import volumes, followed by gasoline. As imports grew, the cost of these products also surged, with a notable increase in the value of petroleum imports, especially for gas oil. Consequently, the average pump prices for gas oil, gasoline, and LPG have risen, reflecting the higher import costs [2], [3]. This trend highlights the country's struggle to meet growing demand while managing rising import costs.

Most finished products in Ghana are imported by Bulk Distribution Companies (BDCs) using Rotterdam spot prices with added transportation, demurrage, insurance, and other charges [3]. Ghana's continuous importation of finished petroleum products is attributed to several factors, including the unavailability of midstream sector facilities to engage in petroleum processing, refining, and storage, which hinders the achievement of energy sufficiency and security. In light of the escalating demand for petroleum products, the nation faces an energy security imbalance. In contrast, Ghana exports 97% of its crude oil production, resulting in a significant economic reliance on external resources and associated challenges. However, this exported crude could be refined and processed to support the high demand for petroleum products in the country.

Crude oil refining helps to maximize value addition [4]. The refining of Ghana's crude oil has the potential to increase its economic value compared to importing it in its unprocessed or refined state. In this paper, the potential benefits of refining Ghana's crude oil rather than importing refined products are examined. A simple topping refinery is employed for the analysis, utilizing the Aspen HYSYS simulation software. This study also analyzes the economic factors that underscore the advantages of refining crude locally, considering its potential contribution to increased revenue, job creation, and overall economic resilience.

2 Methodology

Fig. 1 illustrates the workflow diagram. It consists of data collection and processing, process simulation for possible petroleum product yields, forecasting of petroleum consumption and imports in Ghana, and then economic analysis of both product refining and importation.

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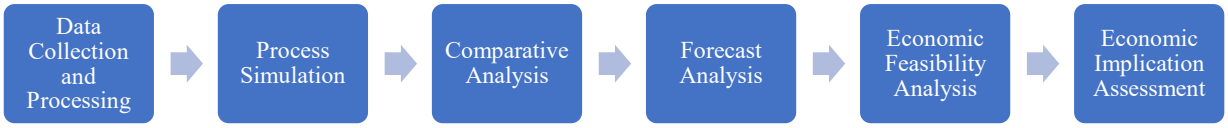

Fig. 1. Workflow of Methodology used in the Study

2.1 Data

Feedstock data for crude oil from Ghana's Jubilee Field, including its composition, was collected from a published petroleum assay. Estimates for construction and operational costs, as well as market prices of refined products and import costs, were also gathered from the literature. The data on petroleum import and export volumes, crude oil and refined product production, historical price trends, and cost estimates for refinery establishment and operations were sourced from Government Agencies and Oil companies' reports, including the Public Interest and Accountability Committee reports on Ghana's domestic energy sector [5]–[11].

2.2 Products Refining Simulation

The simulation of the product refining yield of Ghanaian crude oil from the Jubilee field was conducted in Aspen HYSYS 11 using the Peng-Robinson Equation of State [12]. The refining process follows a simple topping refining configuration. This system was selected to minimize product yields in favour of the economic benefits. The crude oil distillation Column was designed with 48 trays, as shown in Fig. 2, operating at 70,000 BPD to produce products such as off-gas, naphtha, kerosene, diesel, atmospheric gas oil, and residue.

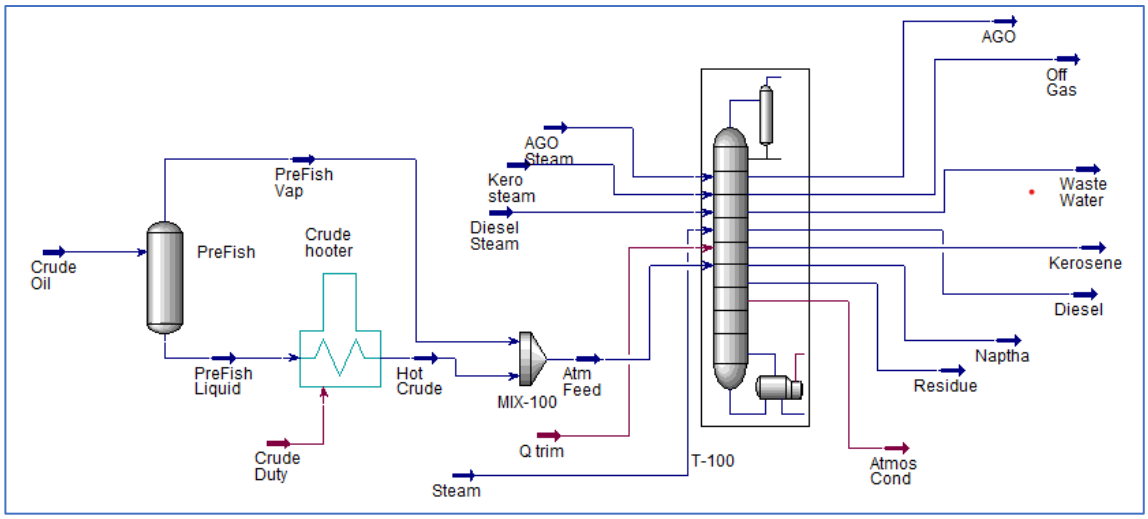

Fig. 2. Model of Refinery Simulated using Aspen HYSYS

2.3 Economic Analysis and Forecasting

The products, including gasoline, diesel, and kerosene, were obtained from the Aspen Hysys simulation. The Aspen Process Economic Analyzer (APEA) module calculated annual operating costs, encompassing utilities, maintenance, labour, and other operational expenses. The crude oil feed price was set at $78.63 per barrel, reflecting the 2023 average cost [11]. The cost for utilities, maintenance, labour, and other operational expenses were included in the total estimated annual operating cost. Data on Ghana's energy supply and utilization trends from 2000 to 2023 were compiled. Ex-refinery and Ex-pump prices for locally refined products were predicted using the NPA's computation template. Ex-refinery prices in Ghana Cedis were calculated and adjusted for dealers' and marketers' margins, set at 5% of the ex-pump price. The ex-refinery prices for each product were calculated by dividing the cost per barrel by the volume of each product from a barrel, using an exchange rate of GHC 11.2 to $ 1 for 2023 [13]. Cost data for imported petroleum products from 2013 to 2023, based on CIF values in USD, are provided in Table 1.

Table 1. Ex-Refinery Price Floor for Petroleum Products

Product	Ex-Refinery Price Floor	Ex-Pump Price Floor
Petrol, GHC/Lt	10.28	13.55
Diesel, GHC/Lt	10.97	14.22
LPG, GHC/kg	9.33	11.49
Kerosene, GHC/Lt	11.14	12.94

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Data was obtained from Compass International Inc. to estimate capital expenditure (CAPEX), while operational expenditure (OPEX) estimates were derived from Aspen HYSYS simulations. The six-tenths rule was applied to scale CAPEX from a 25,000 BPD refinery to a 70,000 BPD refinery, resulting in an estimated capital investment of USD 577,673,181. It was assumed that the refinery would work for 350 days a year. The simulations detailed the yields and qualities of refined products. At the same time, economic analysis tools in Microsoft Excel were utilized to estimate financial metrics, including Net Present Value (NPV), Payback Period (PP), and Return on Investment (ROI). The financial estimated indicators were calculated using Equations 1-9. The collected data and simulation results were used to compare the economic implications of local refining versus importing refined products. The unit costs, ex-pump prices, and refinery gains from processing crude oil were analyzed to assess financial benefits.

$$C_B = C_A \left(\frac{S_B}{S_A}\right)^{0.6} \quad (1)$$

where C_B, is the approximate cost of equipment of size, S_B and C_A, is the known cost of the equipment of size S_A.

$$\text{NPV} = \sum(\text{Present Values}) \quad (2)$$

$$\text{PV} = \frac{\text{Cash flow at time,t}}{(1+\text{Discount rate})^{\text{time period}}} \quad (3)$$

$$\text{ROI} = \frac{\text{Net Profit}}{\text{Cost of Investment}} \times 100\% \quad (4)$$

$$\text{PP} = \frac{\text{Initial Investment}}{\text{Annualised Expected Cash Inflow}} \quad (5)$$

$$\text{Cost of refining a barrel} = \frac{\text{Annual Operating cost}}{\text{Annual Volume of Crude oil refined}} \quad (6)$$

$$\text{Revenue from refining a barrel} = \frac{\text{Total Annual Revenue}}{\text{Total Annual Volume Refined}} \quad (7)$$

$$\text{Net Gain per Barrel} = (\text{Revenue} - \text{Cost}) \text{ per barrel refined} \quad (8)$$

$$\text{Cost Savings} = \text{Cost of Importing} - \text{Cost of Refining} \quad (9)$$

3 Results and Discussion

3.1. Forecast Analysis

Fig. 3 and 4 illustrate the forecasted total final consumption volumes of refinery products and the projected costs of importing various petroleum products over 10 years, respectively. The forecasted consumption volumes show an increasing trend, reflecting growing demand for petroleum products. The projected results indicate a steady increase in total petroleum product consumption over the 10-year forecast period. From a value of 4,326 kt in 2023 to a projected value of 5,709 kt in 2033 (see Figure 3). This trend underscores the importance of local refining capacity in efficiently meeting future demand.

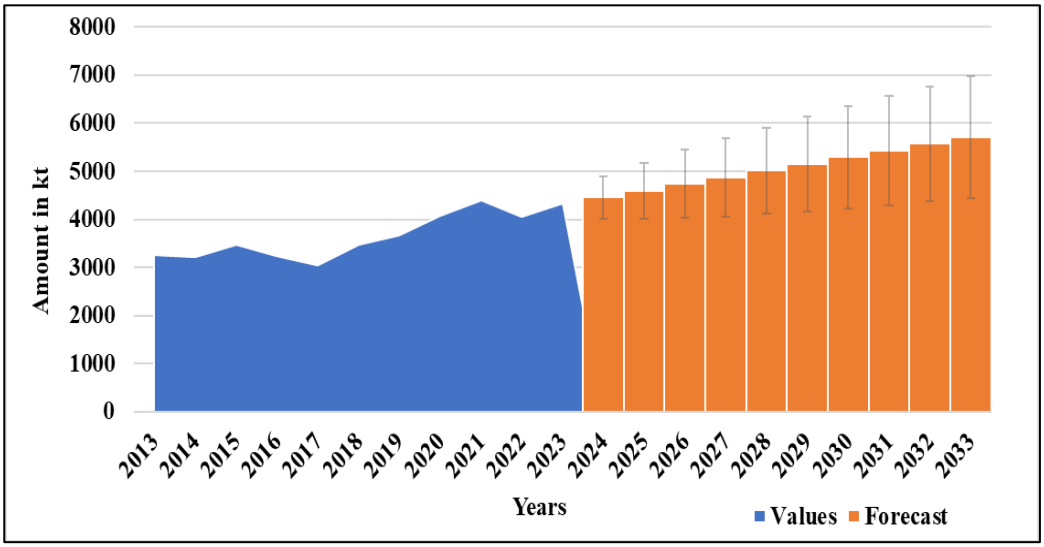

Fig. 3. Forecasted Total Final Consumption Volumes of Petroleum Products

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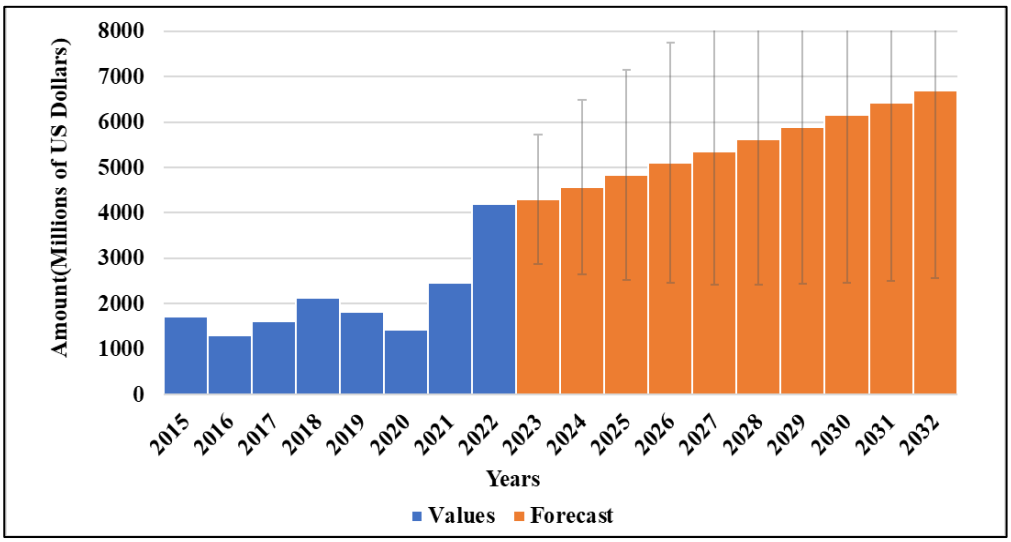

Fig. 4. Forecast of Petroleum Products Imports (C.I.F) by Value

The forecasted import costs indicated a rise in the financial costs of importing petroleum products. From projected costs, it can be observed that import costs would rise to approximately $6,683 million after 10 years, from an initial amount of $4,192 million in 2022, with continuous increments during the 10-year forecasted period. This is a result of the growing demand for petroleum products. This would, in turn, lead to an increase in ex-pump prices of the refinery products due to the dependence on imported products for consumption.

3.2. Economic Feasibility Analysis

Based on the Aspen HYSYS simulations, a total of 24,500,000 barrels of crude oil would be refined annually, with an operating cost of $2,082,820,000 per year, including feedstock costs. The results showed that naphtha was the dominant product (30%) due to the light nature of the crude oil (API of 37). Conversely, the yield of off-gas was found to be significantly low (< 0.1%). Table 2 presents the refining yield of each product from the refining of Jubilee crude using a topping refinery

Table 2. Refinery yield percentages of Jubilee crude from the simulation

Refinery Product	Yield Percentage (%)
LPG (Off Gas)	1.22×10^{-6}
Naphtha (Raw Gasoline)	30
Kerosene	16
Diesel	16
Atmospheric Residue	38

3.3. Cost-Benefit Analysis

The annual revenue was estimated to be GH₵ 25,703,327,059 ($2,294,939,916) using a rate of GH₵ 11.2 to a dollar for 2023. Table 3 shows the various revenue streams of each product.

Table 3. Estimated revenue streams from refined products

Product	Volume (BPY)	Volume (l/yr)	Selling Price (GH₵/L)	Revenue (GH₵)
Petrol	7,296,100	1,160,079,900	10.28	11,925,621,372
Kerosene	3,966,550	630,681,450	11.14	70,257,991,353
LPG	0.002980303	0.40532114	9.33	3.7816
Diesel	3,871,000	615,489,000	10.97	6,75,914,330
Total				25,703,327,059

The PV for each year was calculated using a constant annual cash flow of $166,000,000 after tax deductions to determine the NPV. The various PVs are presented in Table 4. The NPV was estimated to be $ 838,224,853, suggesting a positive NPV, which indicates that the project generates more value than its initial investment, making it economically feasible.

Table 4. Computation for Parameters for Financial Analysis

Input Parameters		
Parameter		**Value**
Project Life		20 years
Capital Costs		$577 673 181
Operational Costs		$2 082 820 000
Annual Revenue		$2 294 939 916
Taxes		25%
Interest Rate		10%
Output Parameters		
Parameter	**Computation**	**Value**
Annual Depreciation	$\frac{\$\ 577673181}{20\ \text{years}}$	$28 883 659 /year
Taxable Income	$\$\ 2\ 294\ 939\ 916 - \$\ 2\ \ 082\ 820\ 000 - \$28\ 883\ 659$	Approx. $183 000 000
Taxes	$\$183\ 000\ 000 \times 25\%$	$45 800 000
Net Income	$\$183\ 000\ 000 - \$45\ 800\ 000$	$137 000 000
Annual Cash Flow	$\$137\ 000\ 000 + \$288\ 883\ 659$	$166 000 000

The payback period, which measures the time required to recover the initial investment, was determined to be 3.5 years. The relatively short payback period of 3.5 years indicates that the refinery project will quickly begin to generate positive returns, thereby enhancing its attractiveness to potential investors.

The ROI was estimated to be 29%, indicating that for every dollar invested in the refinery project, there is a return of $0.29 in profit. This percentage reflects the efficiency and profitability of the investment, suggesting that the project is generating a significant return relative to its initial cost. In the context of the refinery project, a 29% ROI implies that the investment not only covers its costs but also provides a substantial profit margin. The cost estimate for refining a barrel of crude oil locally and the revenue from refining a barrel were estimated as $85.01/bbl and $93.67/bbl, respectively. This resulted in a net profit of $8.66 per barrel after covering all associated costs. Based on these findings, the refinery would be economically feasible. Table 5 presents the results from the economic analysis in this work.

Table 5. Results from Economic Analysis

Parameter	**Value**
Net Present Value, $	838 224 853
Payback Time, year	3.5
Return on Investment, %	29
Cost for Refining, $/bbl	85.01
Revenue from Refining, $/bbl	93.67
Net Gain, $/bbl	8.66

3.4. Economic Implications of Local Refining

To comprehensively assess the economic viability of refining crude oil locally, an analysis of various cost and revenue streams was conducted. This section focuses on comparing the economic performance of importing refined products versus local refining, as well as the potential financial gains of refining crude oil domestically.

3.4.1 Unit Cost Prices

Taking 2022 as the case year, with a total imported volume of petroleum products of 5,112,980,706 L and an associated cost of $4,192,110,000, the unit price of importing these products was calculated. Also, the unit prices of locally refined products, assuming the same volume was refined locally, were calculated to determine the potential cost savings and financial benefits of local refining. Table 6 presents the computations and results for the unit prices of locally refined products and imported products.

Table 6. Unit Cost Prices for Locally Refined and Imported Products.

Parameter	**Total Volume (L)**	**Total Cost ($)**	**Unit Cost ($/L)**
Imported Products (2022)	5,112,980,706	4,192,110,000	0.82
Locally Refined Products	5,112,980,706	2,733,774,477	0.53

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From Table 6, the calculated unit cost of importing petroleum products was $ 0.82 per litre, while the unit cost of local refining is substantially lower at $ 0.53 per litre. In practical terms, for every litre of imported petroleum product, the country effectively spends an additional $ 0.29 compared to what it would have paid if the products were refined locally. Refining petroleum products locally at $0.53 per litre offers a savings of $0.29 per litre compared to the importation cost of $0.82 per litre. Over large volumes, these savings can accumulate significantly, improving the financial performance of the country's energy sector.

3.4.2 Cost Savings

In addition to evaluating the unit costs and net gains of local refining, the potential cost savings from refining petroleum products locally instead of importing them were analyzed. The analysis conducted reveals that refining petroleum products locally, rather than relying on imports, results in substantial cost savings for Ghana, specifically amounting to $1,458,335,523 per year (GH₵16,333,357,858). Local refining proves to be economically more efficient, allowing Ghana to save over $ 1.4 billion annually. This saving is derived from the lower unit cost of refining petroleum products locally, which stands at $0.53 per litre, compared to the higher unit cost of importing these products at $0.82 per litre.

3.4.3 Ex-Pump Price Analysis

The ex-pump prices for locally refined products were predicted and presented in Table 7. The table presents the estimated ex-pump prices for each product, assuming local refining, along with their corresponding ex-refinery prices, marketers' margins, and dealers' margins.

Table 7. Estimated Ex-Pump Prices of Locally Refined Products

Parameter	Petrol (GHC/L)	Diesel (GHC/L)	Kerosene (GHC/L)	LPG (GHC/kg)
Ex-Refinery Price	5.99	5.99	5.99	7.00
Marketers Margin	0.41	0.43	0.39	0.34
Dealers Margin	0.27	0.28	0.26	0.23
Ex-Pump Price	9.93	9.94	8.43	9.73

Comparing this to the average ex-pump prices of 2023 for the same products, it was observed that there was a significant reduction in the ex-pump price of petroleum products when refined locally. Fig. 5 shows the comparison of the average ex-pump prices of locally refined products and imported products.

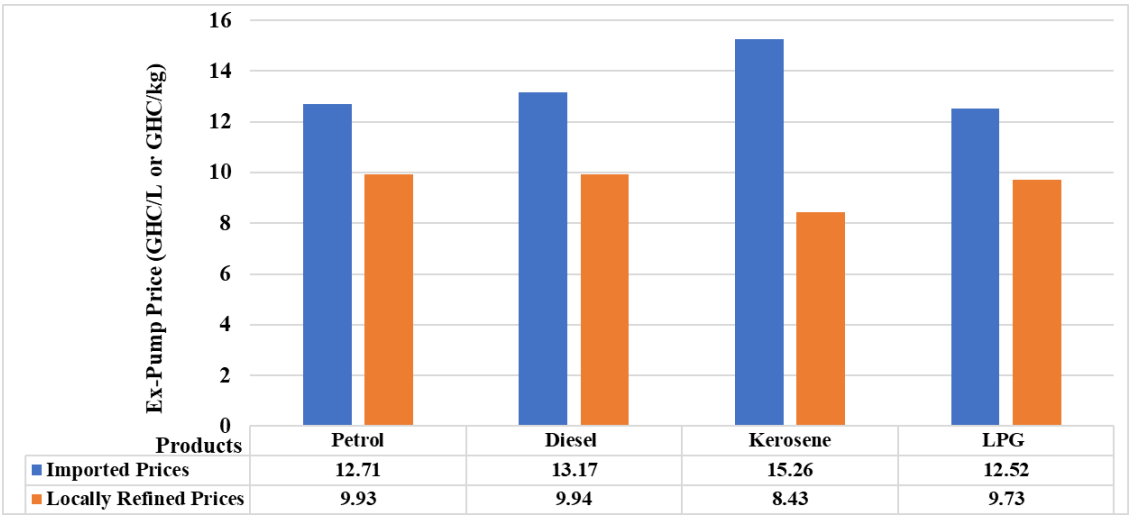

Fig. 5. Ex-Pump Prices of Locally Refined Products versus Imported Products

Based on the data and analysis, the benefits of refining Ghana's crude oil will positively impact the country's socio-economic development, making local refining a strategic priority for Ghana's growth. These include the addition of value to the crude oil when refined locally, thereby increasing its market value, generating more revenue, and boosting the country's GDP. In addition, this will boost the creation of job opportunities, both directly for engineers, technicians, and other skilled workers, as well as indirectly for related sectors such as transportation, logistics, and services. This would provide a stable supply of energy due to reduced reliance on imported refined products, ensuring a more secure energy supply. Cost savings are realized through lower costs for fuel and other petroleum products, which in turn reduce overall energy expenses for consumers. The growth of petrochemical industries and other sectors that rely on refined petroleum products would be supported, along with improved infrastructure around refining facilities, including roads, ports, and utilities.

This will further reduce the over-dependence on imported refined products, thereby conserving foreign exchange reserves and potentially allowing for the export of surplus refined products to earn additional foreign exchange. Ultimately, it would enhance local expertise and skills in oil refining and associated technologies, while also providing opportunities for research and development in refining processes and technologies.

4 CONCLUSIONS

This study compared the economic implications of importing petroleum products and locally refining crude oil on the Ghanaian economy. The study concludes that:

i. The economic feasibility analysis of a refinery revealed promising results. The cost-benefit analysis indicated a positive net present value (NPV), a payback period of 3.5 years, and a return on investment (ROI) of 29%. These findings demonstrate that a refinery using specifically Jubilee crude oil as the reference crude oil can operate efficiently and profitably.
ii. Also, the predicted cost savings for local refining was estimated to be $ 1.4 billion (GH₵ 16.3 billion) for a case of 2022 with estimated ex-pump prices of refined products being GH₵ 9.93 per litre for Petrol, GH₵ 9.94 per litre for Gas Oil, GH₵ 9.73 per kg for LPG and Kerosene being GH₵ 8.43 per litre. By refining petroleum locally, an estimated net gain of $ 8.66 (GH₵ 96.99) per barrel was computed.
iii. The comparative analysis underscored the economic benefits of refining crude oil locally compared to importing refined products. Local refining can reduce import dependency, lower transportation and tariff costs, and stabilize ex-pump prices. The forecast analysis projected increasing consumption volumes, rising import costs, and escalating ex-pump prices, further supporting the need for enhanced local refining capacity.
iv. It is recommended that the Government of Ghana should prioritise the refining of crude oil locally as part of its industrialisation strategy. This will help create jobs, generate foreign exchange savings, and enhance energy security.
v. Additionally, policy considerations should focus on maximizing the utilization of existing refining capacity while exploring long-term strategies for domestic crude oil processing.

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ETHICS STATEMENT

This study did not involve human or animal subjects and, therefore, did not require ethical approval.

STATEMENT OF CONFLICT OF INTERESTS

The authors declare no conflicts of interest related to this study.

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