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Propescts for Autonomy of Angola´s Transformation Industry ith Growth in Oil Refining, Meeting the Challenges of the World Energy Transition

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A R T I C L E I N F O

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Oil Refining,
Industry,
Transformation,
Autonomy,
Energy Transition.

In order to take full advantage of oil's energy potential, it must be submitted to a series of refining processes in order to be broken down into its various derivatives. Angola has more than 60 years of oil exploration and still has today, the refinery in Luanda that is of the "hydroskimming" type, whose activity is essentially geared towards producing fuel for the Angolan domestic market and without the capacity to meet the demand of the rapid national economic growth that has evolved over the last 14 years. For this reason, in the first quarter of 2019, the Angolan state, via Sonangol, spent around USD 549 million on importing 704.7 million metric tonnes of fuel for to satisfy the domestic consumer market. Normally, the path most followed by producing countries to leverage the transformation industry is to invest in petrochemical companies to produce most of the products that serve as raw materials that leverage the other industries. However, once again we have refineries to produce the main materials for petrochemicals. On the other hand, the XXI Century poses to human societies this challenge of decarbonisation of the world energy matrix, which, according to the studies we carry out in different research centres around the world, points to the need to modify (revamp) oil refineries, when possible, to increase the production of oil derivatives with non-energy use (petrochemicals, lubricants, fertilizers. ...), process cargoes not based on fossil consumables (e.g. vegetable oils or pyrolysis oil in severe hydrotreatment) and reduce atmospheric emissions from refining processes[3]. In this sense it is necessary that the alternatives that lead to an autonomy for the growth of the transformation industry, such as the growth of the oil refining activity in Angola (being a producing country for over 60 years), and its extension to petrochemicals, should be adapted to the challenges of the world energy transition. Therefore, this study aims to present the perspectives and impacts of refining in Angola, as well as the suggestion of a refining industry model applicable to the Angolan reality, especially in order to enhance the position of the Angolan refining industry in the challenges of the global energy transition.

1. Introduction

The evolving landscape of the oil industry, influenced by the fluctuating price of a barrel of oil, the imperative to maximize the energy potential of raw materials, advancements in alternative energy technologies, and the recent integration of the oil sector, transitioning from upstream to state-of-the-art petrochemicals, prompts a critical examination of the Angolan oil scenario. In this context, several pertinent questions arise:

a) Why does Angola, a nation with over 50 years of involvement in the oil industry, find itself with a refining capacity that falls short of accommodating its Exploration and Production capacity?
b) What accounts for the inadequacies in fuel distribution within Angola, despite its status as an oil-producing nation?
c) How should the downstream management of the Angolan Oil Industry respond to the challenges posed by the global energy transition?
d) When can Angola expect to achieve self-sufficiency in the production of second and third-generation petrochemical derivatives, encompassing plastics, fabrics, rubbers, fertilizers, adhesives, paints, and other crucial raw materials vital to various manufacturing sectors?

These inquiries hold substantial significance due to Angola's standing as an oil-producing country, boasting an extensive history of oil production and exploration. Even as the nation pivots towards diversifying its revenue sources by exploring other resources, oil trade remains the principal revenue stream for the Angolan state.

It is widely recognized within the technical echelons of the oil industry that the full energy potential of oil is harnessed through a sequence of processes that necessitate refining. Petroleum refining comprises a series of procedures that raw mineral resources undergo to yield valuable derivatives, which are of considerable commercial interest. Presently, there are more than 700 refineries dispersed across the globe. The economic significance of these refineries lies in their capacity to transform crude oil, an inherently low-value commodity, into a wide array of products that underpin the fabric of modern societies, thereby ensuring a continual source of economic profit for nations.

1.1 The New World Energy Matrix

Since the latter half of the 19th century, the global energy landscape has been overwhelmingly shaped by fossil fuels, specifically coal, crude oil, and natural gas. To comprehend this topic more fully, it's essential to define the energy matrix as a quantitative representation of all available energy resources within a given territory, region, country, or continent, earmarked for deployment in diverse production processes.

The energy transition, in turn, can be delineated as a comprehensive international movement that has prompted a reevaluation of methods for generating and utilizing energy and electricity, leading to profound transformations in the electricity sector, and bearing significant political, economic, and social implications for humanity.

The substantial reliance on and prevalence of hydrocarbons in the global energy matrix are similarly conspicuous in Africa, notably in Angola. This has had notable environmental repercussions, necessitating a shift in the composition of the energy matrix towards a new paradigm, where low-carbon energy sources will take center stage. However, fossil fuels are expected to retain a pivotal role during this transitional phase. The Figure 1 illustrates the prevailing structure of the global energy matrix as outlined in the 2023 Statistical Review of World Energy.

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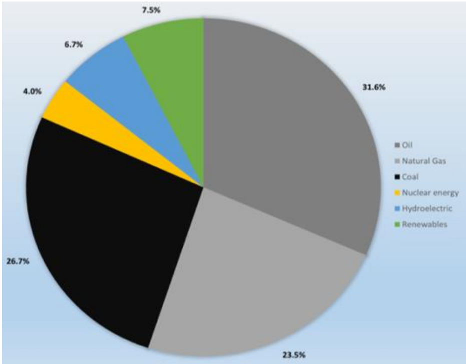

Figure 1: Primary Global Energy Consumption 2022 [4]

Hence, our study endeavors to underscore the imperative of initiating the process of integrating the Angolan oil industry within a framework that aligns with our unique circumstances. This framework hinges on the expansion of the refining sector, serving as a linchpin for the production of consumer goods, particularly fuels and lubricants, and, more crucially, as a source of raw materials for the petrochemical industry across its various generations. In doing so, it not only secures the production of immediate consumer goods but also furnishes the foundation for other industries encompassing manufacturing, agriculture, pharmaceuticals, food, textiles, civil construction, and other goods and service sectors like tire production, finished plastics, and packaging. Consequently, this approach reduces our dependency on imports, propels industrial growth, and, by extension, augments the nation's economic development.

The pronounced reliance on hydrocarbons within the global energy matrix is likewise evident in Africa, specifically in Angola, resulting in substantial environmental consequences. To address this, a paradigm shift in the composition of the energy matrix is required, transitioning towards a novel structure dominated by low-carbon energy sources. Nonetheless, fossil fuels are anticipated to play a pivotal role during this transitional phase.

The prospective energy landscape reflects an estimated escalation in worldwide primary energy demand from 285.7 million barrels of oil equivalent per day in 2021 to 351.0 million barrels of oil equivalent per day in 2045, translating to an average annual growth rate of 1% [5]. The Figure 2 illustrates this projected scenario.

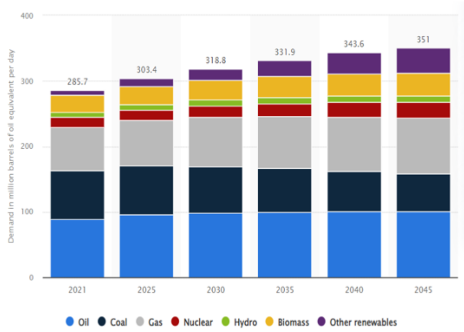

Figure 2: Primary energy demand worldwide in 2021, with a forecast until 2045, by fuel type [6]

1.1.1. Oil Refining and the Energy Transition

To harness the complete energy potential of oil, it necessitates undergoing a sequence of refining processes to segment it into its myriad derivatives. These derivatives are not only essential for fulfilling everyday consumption needs but are also fundamental as inputs in various other industries. Hence, it is imperative to augment production, all while taking into account the pressing environmental concerns, such as those related to global warming. Consequently, the processing of petroleum, the consumption of its derivatives, and the utilization of its byproducts must be premised on the indispensable requirement that these activities are environmentally sustainable to serve the interests of the current generations.

This places the petroleum industry, in its entirety, and refineries, in particular, in the dual role of engaging in discussions and implementing mechanisms that allow their continued existence on one hand, while simultaneously confronting the challenges posed by the energy transition on the other.

Let us now delve into these two facets of refinery operations: first, the imperative of increasing supply to facilitate industrialization in producer countries like Angola and second and the critical importance of adhering to the principles of the energy transition.

1.2 Impacts of Refineries for the Industrialization of Countries

Within the technical and industrial elite, industrialization is comprehended as the process of converting a specific geographical area through the establishment of industries and affiliated companies, both directly and indirectly connected to these industries. The objective is to harness available resources, convert them into economically viable products on an industrial scale, and ensure their safe production and distribution to meet the consumption demands within the geographical region where these industries and companies operate.

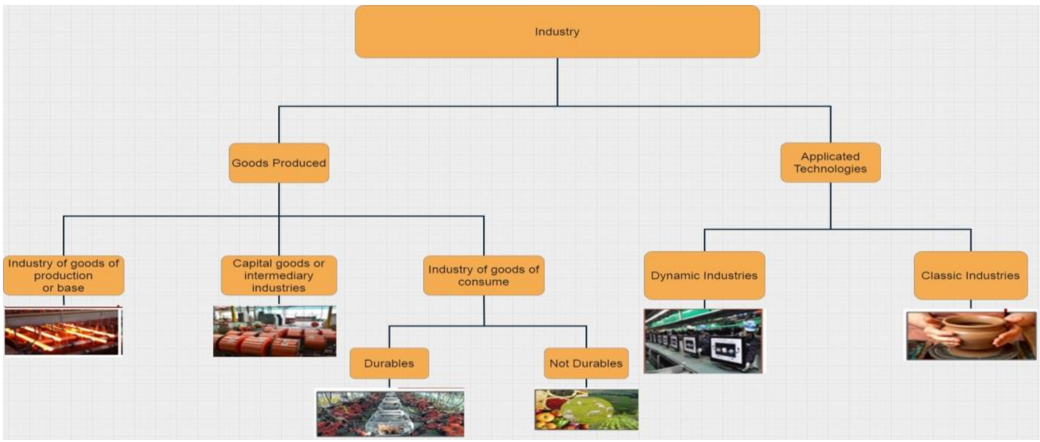

Figure 1: Classification of industries

For these industries to operate effectively, they require a consistent supply of fuels, raw materials, secondary materials, and, when applicable, additives. In many cases, the initial stages of production are rooted in refineries.

Countries endowed with oil resources actively encourage the establishment of industries that produce consumer goods. They invest in refining capabilities and petrochemical processing facilities within their borders to facilitate the industrialization and growth of their manufacturing sectors. The process begins with refining, generating finished and basic products that subsequently find their way to petrochemical facilities.

These products, upon arrival at petrochemical plants, are transformed into intermediate products, known as the 1st generation of petrochemicals. These industrial facilities where such products are created are referred to as petrochemical plants. To optimize supply logistics, petrochemical plants are often strategically located near their primary sources of raw materials, typically in close proximity to oil refineries and natural gas production fields, including natural gas production units (UPGN) [7].

Once the intermediate products, such as butadiene and acetylene, in the 1st generation petrochemical category, are obtained, they are further processed in units to produce final petrochemical products, including rubber and other derivatives. The facilities responsible for manufacturing these final petrochemical products are designated as 2nd generation petrochemical facilities [7].

In response to technological advancements and the imperative to maximize raw material utilization, there has emerged a 3rd generation of petrochemical facilities. These facilities comprise industrial processing units dedicated to transforming polymers and plastics. Unlike the previous generations, the source of raw materials for 3rd generation petrochemicals is not exclusively organic or mineral; it does not always originate from 2nd generation petrochemicals and, consequently, not always from refineries.

The petrochemical chain comprises three distinct generations:

a) **1st generation**: These petrochemical plants produce essential petrochemical products using ethane, propane, butane (derived from natural gas), naphtha, and diesel (derived from petroleum) as raw materials. The primary products obtained include ethylene, propene, butadiene, benzene, toluene, and xylene.

b) **2nd generation**: Companies engaged in the production of thermoplastic resins utilize ethylene, propene, benzene, xylene, and other materials through polymerization processes to manufacture polyethylene, polypropylene, polystyrene, PVC, PET, and related products.

c) **3rd generation**: Industries involved in transforming plastic resins into finished goods, producing various items such as packaging, plastic components, household utensils, and more, catering to diverse market segments [7].

The Figure 4 illustrates the interconnectedness of these petrochemical generations, highlighting the sources of raw materials and their origins, along with the principal products.

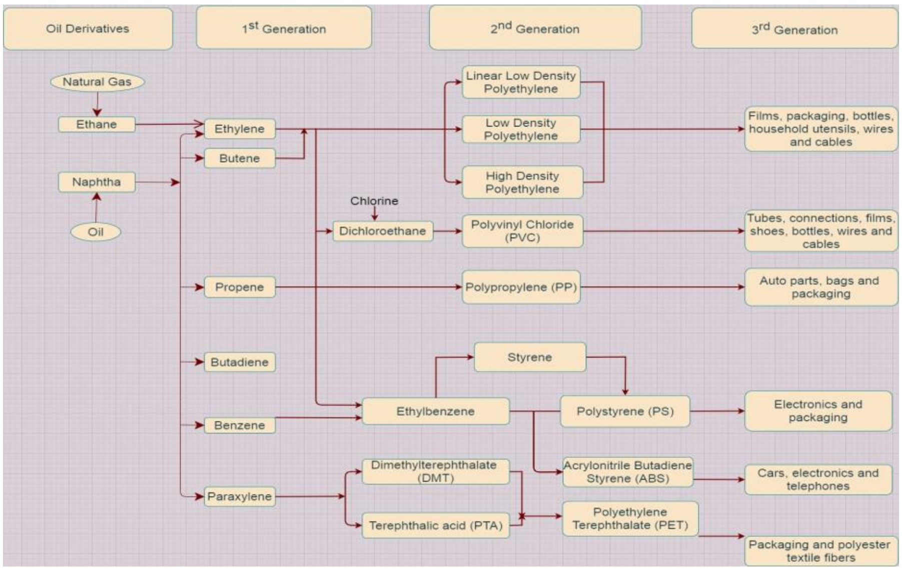

Figure 2: Petrochemical chain with its main products [7]

The majority of these petrochemical products serve as raw materials, secondary materials, or consumer goods for a wide array of other industries. In nations endowed with oil resources, it is not only more logical but also more advantageous if these essential goods originate from domestic industries.

To ensure the local production of these goods, countries must undergo a process of industrialization. This industrialization is imperative to make the integrated chain of raw materials, intermediate products, and final consumer goods feasible within the nation's borders. It not only fosters self-sufficiency but also bolsters economic growth and stability.

1.2. The Pressuposed of the Energy Transition

For these goods to be locally sourced, countries must undergo an industrialization process to establish a viable integrated chain of raw materials, intermediate products, and consumer goods. In light of strong political and governmental motivations, established during the Rio Conference in 1992, leading to the creation of the United Nations Framework Convention on Climate Change, and further reinforced by the Kyoto Protocol in 1997, and the Paris Agreement in 2015, governments have outlined agendas, objectives, and procedures for international cooperation regarding the energy transition. The central objective of these agreements is to combat climate change by substantially reducing greenhouse gas emissions.

Given the current energy sources and their extraction and transformation processes, this objective necessitates a transformation of the global energy landscape, a topic of significant discussion in various energy and environmental sectors. As per the International Renewable Energy Agency, the energy transition represents a journey toward the transformation of the global energy sector, transitioning from being "fossil fuel-based" to "zero carbon" by the latter half of this century [8].

However, it's important to acknowledge that activities in refineries, responsible for converting crude oil into its derivatives, and the consumption of fossil fuels, contribute to the emission of greenhouse gases. This places the oil industry and its products at odds with the goals of the energy transition. The Paris Agreement, as established during the COP 21 conference in 2015, recommended reducing greenhouse gas emissions by 37% below 2005 levels by 2025 and by 43% below 2005 levels by 2030 [9], accord Figure 5.

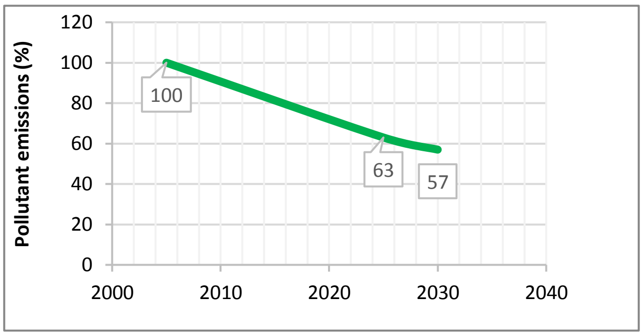

Figure 5: Polutant emission prevition

The inability to achieve the targets set in the Paris Agreement has prompted countries to endorse the latest report by the Intergovernmental Panel on Climate Change (IPCC). The report emphasizes that, in order to limit global warming to 1.5ºC, emissions must cease their growth by 2025 and decrease by 43% by 2030, compared to 2019 levels. This stringent target underscores the urgent need for swift transformations across all sectors to avert the most severe climate consequences [10]. These transformations encompass:

- **Expanding the use of clean energy**: Promoting and adopting renewable energy sources to replace fossil fuels in electricity generation and other applications;

- **Decarbonizing industry**: Implementing measures to reduce greenhouse gas emissions in industrial processes and operations;
- **Encouraging green buildings**: Developing and adopting energy-efficient and sustainable building practices to reduce energy consumption and emissions;
- **Redesigning cities and transitioning to zero and low carbon transportation**: Reimagining urban planning and transportation systems to reduce emissions and promote sustainable mobility;
- **Conserving natural ecosystems**: Protecting and preserving natural habitats to maintain carbon sinks and biodiversity;
- **Improving food systems**: Enhancing the sustainability and efficiency of agricultural and food production practices.

The report further underscores the critical role of changes in behavior and lifestyle in mitigating climate change, the necessity of carbon removal from the atmosphere, and the imperative to increase climate finance three to sixfold by 2030 [9]. In this context, refinery projects may not align with the principles of the energy transition. The Table 1 outlines the sectors directly influenced by the energy transition and offers recommended actions

Fields	Presupposed
Industry	**Presupposed of base:** ESTABLISH PATTERNS OF ENERGETIC EFFICIENCY Actions: • To promote the buy clean energy in free market; • To accelerate technologies of carbon low to heating.
Transport	**Presupposed of base:** TO ACCELERATE THE CHANGE FOR ELECTRICAL VEHICLES Actions: • To promote service of mobility (autonomous ccars andsharing of vehicles); • Prioritize the biofuel.
Electrical energy	**Presupposed of base:** INCREASE THE FLEXIBILITY OF SYSTEM (INTERMITTENCY) Actions: • To accelerate the insertion of renewables; • Appropriate tariff structure (real attributes of sources); • Stimulate the Generation Distributed.
Edification	**Presupposed of base:** COMBINE ENERGY EFFICIENCY AND RENEWABLES Actions: • Establish paterns of energetic efficiency Accelerate the roll-out of smart meter; • To accelerate technologies of low carbon to heating.

Table 1: Presupposed of energy transition [8]

The operations of oil refineries involve the utilization and generation of a wide range of chemical compounds, and as a consequence, various chemical compounds are released in different forms as pollutants in the oil industry. These forms of emissions include atmospheric emissions, liquid effluents, and solid waste.

Atmospheric emissions from refineries encompass fugitive emissions of volatile compounds found in crude oil and its fractions. These emissions are generated by the combustion of fuels in furnaces and boilers. They typically contain substances such as carbon monoxide (CO), sulfur oxides (SOx), nitrogen oxides (NOx), particulate matter, and hydrocarbons, which are collectively referred to as greenhouse gases. While individual emissions from each source might be relatively small, the cumulative impact of fugitive emissions from an entire refinery can make it one of the significant sources of emissions in the refinery industry [11], [25], [26].

A similar situation arises in the context of fossil fuel consumption, especially through burning in internal combustion engines. This process leads to the emission of gases. If combustion is incomplete or if engines and equipment are contaminated with other residues, these emissions can become noteworthy.

A crucial distinction for the industry, particularly with regard to mitigating the adverse environmental impact of refineries, is the imperative to produce and use clean fuels. The utilization of these clean fuels, such as refinery gas, fuel oil, or natural gas, results in relatively low emissions. This transition to cleaner fuels can play a pivotal role in reducing the environmental footprint of refineries, particularly in alignment with the expectations of the energy transition assumptions for our century.

2. Methodology

Through a comprehensive documentary review, valuable information was compiled regarding industrialization, oil refining, and the global energy transition. Subsequently, a field study was conducted, coupled with interviews involving key stakeholders in the Angolan Downstream sector. These stakeholders included the government regulatory body, MIRMPET, the national operator Sonangol, and, more specifically, the entity overseeing the downstream sector, SONAREF. Participatory observations of the Angolan industrial landscape provided additional insights. Collectively, these efforts facilitated the formulation of a model for integrating the oil industry, with a focus on the prospects for enhancing the self-reliance of the Angolan manufacturing sector, while concurrently accommodating the dynamics of the global energy transition.

The study also aims to substantiate the growing need for an expanded supply of refined products in response to population growth. To accomplish this, an arithmetic methodology [12]-[13] is employed to project population growth over the next decade. This projection is based on the growth rate observed from 2019 to the first half of 2023. The methodology adheres to the Equation (1)

$$P_t = P_2 + K_a\,(t_2 - t_0) \text{ e } K_a = \frac{P_2 - P_0}{t_{2-t_0}} \tag{1}$$

Where:
P_t: Total projected population;
P_0: Population in the first year of data;
P_2: Population in the last year of data;
K_a: Coefficient (regression analysis is preferable, since the entire existing data series can be used, and not just P_0 and P_2);
t: First year of data;
t_2: Last year of data.

To facilitate a comparative analysis, a projection of refined product consumption for the upcoming decade was established using Microsoft Office Excel. This projection is predicated on a 5-year baseline, guided by the performance of global sales of trading companies from 2019 to the 1st Quarter of 2023. The analysis is based on data extracted from the 4th Quarter Balance Sheet Reports for the years 2019, 2020, 2022, and the 1st Quarter Balance Sheet Report for 2023, which was sourced from Sonangol and IRDP. This comprehensive approach provides valuable insights into the consumption trends and growth expectations within the refined products sector.

4. Results and Discussion

The history of oil refining in Angola is characterized by five significant milestones:

- Commencement of oil processing on May 3, 1958, with the establishment of the PETROFINA refinery in Petrangol, Cacuaco, Luanda, Angola, boasting a capacity of 100,000 metric tons per year.
- Transfer of the PETROFINA refinery to Sonangol on July 26, 2007.
- Announcement by Sonangol of the Lobito Refinery project in March 2001, with the ambitious goal of processing approximately 200,000 barrels of crude oil daily. The commitment was to begin operations in the first quarter of 2006. Furthermore, the executive's program for the oil sector in the legislative period of 2013/2017 anticipated the completion of the Lobito refinery construction by 2018, spanning an area of 3,805 hectares and generating 10,000 direct and indirect jobs [14].
- In 2008/2009, the first cohort of Senior Technicians, trained in Angola, entered the workforce, having graduated in Petroleum Refining from the Jean Piaget University of Angola. This course was regulated by Decree No. 48/04 of April 23 and was later complemented by a similar program at the University of Belas, also regulated by Decree No. 77/08 of June 13 at the higher education level. The National Petroleum Institute also contributed by providing training in this specialty at the technical and professional education level.
- In 2015, Sonangol announced the initiation of the Soyo Refinery project, and construction commenced on June 4th. The project aimed to start processing 110,000 barrels of oil per day, with operations expected to commence in 2017 [15].

The growing population in Angola necessitates an increase in the supply of refined products. This population growth is currently estimated at an annual rate of around 3.1% [16]. According to the yearbooks of the National Institute of Statistics, Angola had a population of 32,353,587 inhabitants in 2019, and by the first quarter of 2023, the estimated population of Angola is approximately 36,684,202 inhabitants [17].

Based on an arithmetic methodology [12]-[13], population growth projection until 2033 can be calculated using Equation 1 and the data presented in Table 2.

Year	Population (Habitants)
2019	**32 353 587**
2020	**33 428 485**
2021	**34 503 773**
2022	**35 588 987**
2023	**36 684 202**
2024	41 014 817
2025	42 097 470
2026	43 180 124
2027	44 262 778
2028	45 345 432
2029	46 428 085
2030	47 510 739
2031	48 593 393
2032	49 676 047
2033	50 758 700

Table 2: Projection of Angolan population growth 2019-2033 (Determined with the data [17] used arimetric methodology [12]-[13])

In the 1st quarter of 2023, imported volumes constituted 64% of the total refined products purchased, with contributions from the Luanda Refinery at 35% and the Cabinda Topping Plant at 1% [1].

In line with the population growth projection, this study also offers a projection of refined product consumption for the upcoming decade. This projection is derived from an analysis of the behavior of global sales by retailers from 2019 to the 1st Quarter of 2023. By considering these trends, it's possible to anticipate the future consumption patterns for refined products.

Year	National Consumption
2019	**903 276**
2020	**659 391**
2021	**903 276**
2022	**939 228**
2023	**877 783**
2024	877 783
2025	898 123
2026	918 463
2027	938 803
2028	959 143
2029	979 483
2030	999 823
2031	1 020 163
2032	1 040 503
2033	1 060 843

Table 3: Projection of growth in fuel consumption 2019-2033 (Established with the data extracted from [1])

The Figure 6 illustrates the relationship between population growth and consumption needs over the next 10 years.

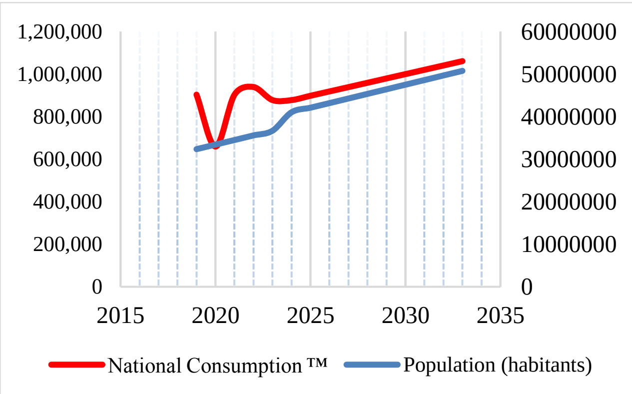

Figure 6: Population growth vs. the need to consume refined products

In this context, the growth of oil refining in Angola takes on particular significance. With a substantial portion, approximately 85.5% [1], of total sales directed towards large customers (B2B), including high industrial consumption, it becomes evident that an increase in oil refining capacity is a crucial component of meeting the growing demand for refined products, especially in the industrial sector. This alignment with the needs of large industrial consumers is instrumental in ensuring a stable and self-sufficient supply of refined products for the nation's growing population.

4.1. Refinery projects in Angola

a) Lobito Project

The Lobito Refinery project was originally planned as a high conversion refinery, incorporating separation, conversion, and auxiliary processes to transform crude oil into fuel derivatives and lubricants for consumption. The refinery was expected to occupy a vast area of 3,805 hectares and had an estimated cost of US$5.6 billion. It was designed to process 200,000 barrels of oil per day and produce a range of refined products, including gasoline, diesel, aviation oil (Jet A1), and other derivatives [14].

However, the Lobito Refinery project, which was inaugurated in 2012 with a planned completion date in 2018, faced several challenges. One notable issue was the logistical complexity due to its geographical location. At the time of its announcement, prospecting activities in Angola were concentrated in the lower Congo basin in the northern zone. Consequently, transporting crude oil from the fields in the northern region to the refinery in Lobito in the central zone, and then distributing the refined products throughout the country, posed logistical and cost challenges. This geographical separation would have influenced the operating costs and overall efficiency of the refinery, making it a less viable project given the transportation and operational complexities [14].

b) Soyo Project

The Soyo refinery, located in the Angolan province of Zaire, was designed to have the capacity to process 110,000 barrels of oil per day, with the initial goal of commencing operations in 2017. Construction of the refinery was awarded to China Tianchen Engineering Corp, and it began on July 5, 2015, in Kifuquena, a location situated five kilometers southwest of the city of Soyo. The facility occupies an area spanning more than 220 hectares [15].

However, in October 2019, the Angolan government initiated an international public tender for the construction of the refinery. While the winning bidder was announced on December 18, 2019, the deadline for the project was extended to March 31, 2020, in an effort to enhance the quality of the bids. At the time, the sector regulator envisioned the second half of 2023 as the commissioning deadline for the refinery. The contract's leadership is entrusted to the shareholder group of the refinery, known as the Quanten Consortium Angola. This consortium comprises three American companies, TGT, Quanten, Aurum & Sharp, along with the Angolan company Atis-Nebest. The consortium holds 90% of the refinery's capital, while Sonangol retains the remaining 10% [18].

c) Namibe Project

The NAMREF project, which aims to process 400,000 barrels per day (BPD), has received support from the Angolan government. The government allocated a 10 square kilometer area for the construction of this significant project. Additionally, the government has committed to purchasing 28,000 BPD of refined products, with this figure expected to increase to 364,000 BPD as production capacity grows [19].

The first phase of the project, estimated to last approximately three and a half years, is set to include the construction of a substantial 10 million ton electric desalination plant. This facility will be responsible for producing gasoline, diesel, and bitumen, contributing to the country's energy needs and industrial development.

The project's ownership structure involves an investment vehicle known as Namref. Namref is jointly owned, with 75% of the stake held by Rail Standard Service and the remaining 25% owned by Fortland Consulting Company [19]. This collaborative effort reflects a commitment to enhancing Angola's refining capacity and ensuring a stable supply of refined products to meet the nation's growing needs.

d) Cabinda Project

The Cabinda Refinery project was initially designed for a production capacity of 60,000 barrels per day. It will be situated on a total area covering 313 hectares, although in its initial phase, it is expected to occupy only 30 hectares [20].

The site of the refinery is located approximately 3.8 kilometers from the nearest village, Malembo. The project is planned to be executed in three phases, with the first phase scheduled to commence in the first quarter of 2022.

Cabinda Oil Refinery Lda., also known as such, is 90% owned by Gemcorp and 10% owned by Sonaref. An innovative feature of this project in Angola is the use of long-term financing, which is primarily provided by private financial institutions, without requiring any State guarantees. This approach reflects a unique financing model for the project, which is set to enhance the country's refining capacity and contribute to its energy and industrial development [20].

4.3. Technological and Environmental for Growth in Refining

The refining and petrochemical sectors of the oil industry play a crucial role in stabilizing the economies of oil-producing countries. However, their activities and the way products are consumed present challenges in the context of the global energy agenda, environmental concerns, and evolving technology due to the production and emission of greenhouse gases.

Angolan refinery projects, in particular, may face potential conflicts in this regard. Refinery projects inherently involve complex processes and the production of products with emissions of greenhouse gases. This misalignment with the global energy transition goals becomes evident once these projects become operational.

To ensure that Angolan refinery projects align with the objectives of the energy transition and environmental sustainability, several macro guidelines should be considered:

a) Adaptation of refinery raw materials to incorporate non-fossil materials, such as vegetable oils or pyrolysis oil following rigorous hydrotreatment;
b) Expansion of petroleum derivatives production, encompassing not only energy but also petrochemicals, lubricants, fertilizers, and more;
c) Optimization of refinery processes and complexity to reduce atmospheric emissions generated during refining operations.

In summary, the transformation of refineries into bio-refineries or their extension to petrochemical production is expected to contribute to the energy transition, helping to reduce the greenhouse effect. This aligns with the goal of reducing emissions by 37% below 2005 levels by 2025 and by 43% below 2005 levels by 2030, as recommended in international agreements such as the Paris Agreement [9], [25],[26], [27].

By adopting these guidelines, the Angolan refining industry can play a pivotal role in mitigating the impact of greenhouse gases, promoting sustainability, and supporting the global transition towards cleaner and more environmentally friendly energy sources.

4.2. Possible Contribution of Refineries to Industrialization

The Industrial Production Index (IPI) in Angola recorded a negative variation of 3.6% in the first quarter of 2022, compared to the same period of the previous year, and since 2015[21] it has not left the 'red'. The Figure 7 shows the industrial production index for the last three years.

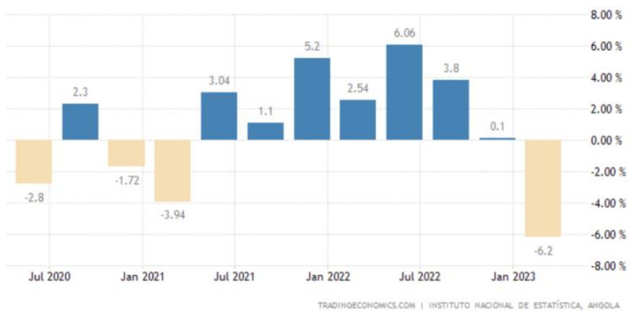

Figure 7: Angolan industrial production index 2020-2023 [21]

The first strategy that states seeking to achieve economic development use is to industrialize their countries.

Generally speaking, refineries' capacity to produce finished or intermediate products is either proportionally matched with industrial production capacity, but if we look at the United States and China, which are the biggest consumers of oil and also have the world's largest refining parks and just over 1/3 of the world's total refinery capacity, we can see a significant growth in industrial production, as shown in the Figures (8) e (9).

The industries directly affected are the plastics and rubber industry, the agro-industry, the metallurgical industry, the chemical industry, the pharmaceutical industry, the textile industry. The machinery and equipment industry and the automobile industry [22]-[23], which are considered to be part of the processing industry because they transform primary raw materials into a final product or an intermediate destined for another processing industry.

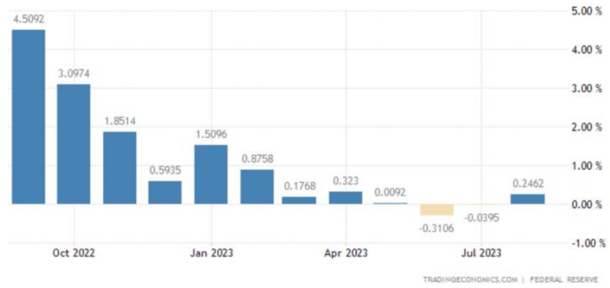

Figure 8: US industrial production 2023 [22]

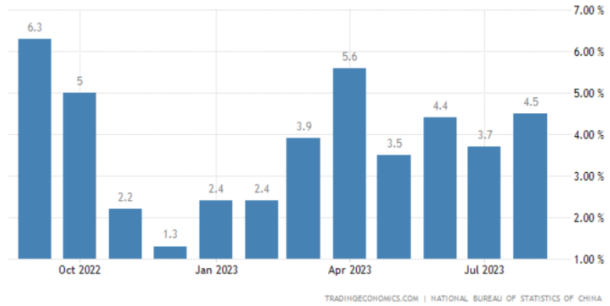

Figure 9: China industrial production 2023 [23]

Some of these raw materials come from oil refineries because, in countries with oil production in particular, the implementation of refineries entails the achievement of two basic objectives, which are:

a) Production of fuels and petrochemical raw materials;
b) Production of basic lubricants and paraffins.

It is almost impossible to think of the modern world without the existence of refineries. It is estimated that more than half of all modern man's activities are related to some or other petroleum derivative, such as:

a) Plastics, fabrics, rubbers;
b) Perfumes, detergents, insecticides;
c) Fertilisers, glues, paints;
d) Medicines;
e) Aviation, automotive and industrial fuels;
f) Asphalt, bitumen;
g) Lubrication, etc.

These products are obtained by carrying out processes that produce derivatives that are processed in separation and conversion units in order to find the final products, which are divided into three large classes, which are the Fuels Class (GA, GO, fuel oil, LPG, The non-fuel finished products class (solvents, lubricants, grease, asphalt and coke) and the chemical industry intermediates class (naphtha, ethane, propane, butane, ethylene, propylene, butylenes, butadiene and BTX) [24].

Thus, investments in refineries, with structures that satisfy the production of derivatives and raw materials that meet market demand, add value to the petroleum energy chain, which extends from crude oil exploration operations to the distribution of petrochemical products. And this context has ample logic in geographies where there is oil production.

The Angolan industry is mostly made up of consumer goods industry production industries, this fact makes the industry dependent on raw material exports, even in cases where the original raw material is extracted in Angola.

For example, the raw material for the paint and varnish industry is wax, it comes from Petroleum, more factories such as CIN in Angola depend on imports of their raw materials, all because we have in the country the capacity to extract wax from petroleum, in our more than 50 years of oil exploration.

Angola has resources, space and investment opportunities. It is necessary to review and implement the policies of the Master Plan for the Reindustrialization of Angola, in light of the world industrial reality.

Since crude oil is still the country's main resource and the main source of revenue obtained from its exploration and sale, and equally important is that oil is still at the top of the world's energy matrix as a raw material, Angola must urgently guarantee in its oil industry exploration contracts the growth of the petrochemical refining and Installation Park.

This guarantee is based on a reality practiced by other countries such as Brazil, USA, Russia, Germany and India, which is called INDUSTRIAL INTEGRATION. This integration is based on the maximum use of raw materials to produce in addition to goods for direct consumption, and raw materials are also produced for other industries. In the case of Angola, this industrial integration begins with the integration of the oil industry, and necessarily with the growth of refining and petrochemicals in Angola, in order to guarantee the autonomy of our industry.

Let's see the impact of this autonomy in the following model:

Using strategic and economic advantages such as integration into SADC and other regional and global communities where Angola can produce and export various raw materials, subsidiary raw materials or consumer products to all other industries whose chain initially starts with oil. This time generate economic growth and development.

5. Conclusions

Petroleum refining plays an important role in our lives, since most modes of transport are powered by oil products, such as gasoline, diesel, airplane kerosene and fuel oils.

Petroleum refining plays an important role in our lives, since most modes of transport are powered by oil products, such as gasoline, diesel, airplane kerosene and fuel oils.

According to the state of the world oil industry, with signs such as oil prices on international markets, the trend of global technological evolution in the field of energy (such as investments in the production of energy from renewable sources) and environmental refunds, as well as the current state of the angolan economy, there is a need to value the role of refineries in and take advantage of their possible contribution to maximize their potential for the economy in Angola.

Oil refining has the function of guaranteeing the maximum use of the Crude Oil's energy potential. As a result of the preparation of this study and the results achieved, we present the following recommendations**:**

a) Integration of the oil industry, which consists of investing in refineries coupled with petrochemicals for greater use of the value chain of raw materials, ie crude oil. It is an idealization and creation of investments that envisage the capitalization of financing and implementation of businesses that involve part of the upstream activities in the 2nd and 3rd generation petrochemicals, although greater attention goes to the integration of Refineries and Petrochemicals. This is because the cycle of using oil and its derivatives produces final derivatives that extend from refineries to petrochemicals.

b) As an alternative Implementation of Modular Refineries, which consists of investing in Mini - refineries that aim to produce specific final derivatives for a market. The modules represent a sequence of processes with the specific purpose of supplying a type of derivative, ie fuel (light or heavy) or lubricant. These refineries have a lower cost of implementation and operation, guarantee returns on investments, although they have a shorter useful life and production of residues with greater energy potential, but they safeguard the satisfaction of the specific demand need of the product to be produced.

c) To the Angolan Executive, especially MINRMPET's, we reinforce the already proven recommendations of the need to urgently increase the Angolan refining park, in order to integrate with the other national industries as a service provider, raw materials and consumables, safeguarding the fulfillment of the transition assumptions energy world. From this it is observed that refineries and/or projects must include:

- An adequacy of raw materials from refineries where the additive of crude oil with non-fossil materials is expected (eg vegetable oils or pyrolysis oil after severe hydrotreatment);
- A perspective of increasing the production of petroleum derivatives using not only energy, petrochemicals, lubricants, fertilizers, betwenn others;
- Ensuring the optimization of refineries, their complexity and processes in order to reduce atmospheric emissions from refining processes.

Conflict of interest

The authors declare that there is no conflict of interest regarding thepublication of this manuscript.

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