Application of Fischer Tropsch Technology for Reducing Gas Flaring and Producing Cleaner Burning Fuels for Sustainable Development in the Nigeria Niger Delta

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Abstract

Associated natural gas is often considered a by-product during crude oil extraction in Nigeria, and flaring of this gas is a regular practice in the rich oil-producing communities of the Niger Delta region of Nigeria. Some of these flares have been burning nonstop for several years, emitting CO_2, Methane, Black soot, and other greenhouse gases that have contributed to Climate change. Energy technologies that can make alternative use of this supposed flared gas are applicable, preferably a Gas-to-liquid technology that can convert this gas into synthetic fuels. One possible solution to reducing gas flaring is converting the gas into liquids using the Fischer Tropsch synthesis in a gas-to-liquid plant. In this paper, we review Nigeria's natural gas reserve, gas flaring, its health and environmental impacts as well as the synthesis process of the Fischer Tropsch Technology for its application in reducing gas flaring and producing cleaner-burning fuels for sustainable development the Nigeria Niger Delta. With energy being a very important part of human existence and its present shortage in the country, as well as the increasing concern of greenhouse gas emission (GHG), and the need for sustainable sources of energy, the move towards technology to produce cleaner and more sustainable energy cannot be overemphasized and Fischer-Tropsch technology is one way of achieving this goal. The Fischer-Tropsch technology converts synthesis gas, a mixture of carbon monoxide and hydrogen, into hydrocarbons which are further upgraded to fuels and chemicals of high quality. These synthesis gases can be derived from carbon source feedstock such as the associated natural gas that is been flared in the Niger Delta and converted to cleaner-burning liquid hydrocarbons by using a catalyst. The Pearl Gas-to-liquid plant, located in Ras Laffan industrial city in Qatar and the Bintulu Gas-to-liquid plant located in Sarawak Island in Bintulu Malaysia are two successful examples of plants making use of this technology for converting stranded gas into several high-performance and environmentally friendly fuels. Improved research is needed on this technology with specific reference to the high operational and maintenance costs. Further, it requires combining the proposed technology with other energy conversion technologies, such as ranking cycles and gas turbines. Other technologies use light hydrocarbon gases and CO_2 produced in the process to provide power, thereby reducing GHG and increasing the technology's efficiency. This paper strongly recommends the adoption of Fischer Tropsch Technology in the Nigeria Niger Delta, thereby helping in a more efficient energy conversion process as well as reducing the carbon footprint of the country.

1. Introduction

With an estimation of 206.5 trillion cubic feet of natural gas, Nigeria is said to have the highest proven gas reserve in Africa and ranked at number 9 in the list of top 10 gas-flaring nations of the world. (EIA2023). Most of the natural gas produced in the Niger Delta region of Nigeria is considered as associated natural gas and they has mostly been reinjected into oil wells to enhance oil recovery or they are being flared. In 2022, according to data from the (Global Gas Flaring Reduction Partnership, 2022), Nigeria flared a total of about 5.318 billion cubic meters of natural gas associated with the exploration of crude oil. Flaring of these gases is an extremely harmful practice which results in the wastage of valuable resources, as well as the release of several pollutant gases such as Carbon monoxide, Carbon dioxide, volatile organic compounds, and particulate matter. It is a well-established fact that this practice has several detrimental effects on the environment and the economy. Still, with the right technology, these gases can be collected and converted into useful and valuable environmentally friendly hydrocarbons. Energy technology is a broad science that joins several disciplines to accomplish objectives concerning energy efficiency in storage, transportation, conversion, safety, positive environmental impact, economic benefits, and usage [1]. There are different types of energy technology ranging from hydrogen and nuclear fusion, combined cycle gas turbines, Enhanced oil recovery, and Thorium reactors, among others including the Fischer-Tropsch technology which will be discussed in this report. The Fischer-Tropsch technology was developed by Franz Fischer and Hans Tropsch, two German inventors in 1916. It was a source of liquid hydrocarbon for the Germans during the World War and the South Africans during the apartheid era. The

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technology can be referred to as coal-to-liquid, Gas-to-liquid or biomass-to-liquid synthesis depending on the feedstock (source of the syngas). [2] The process involves a catalytic chemical reaction where the hydrogen and the carbon monoxides in the synthetic gas are converted into hydrocarbons of different molecular weights as in Figure 1 and represented by the equation:

$(2n+1)\ H_2 + n\ CO \rightarrow Cn\ H(2n+2) + nH_2O$……. (i)

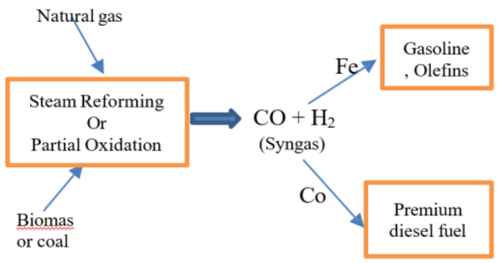

Figure 1. Syntheses Process of the Fischer-Tropsch technology

In equation (i), where n is an integer, when n is 1, the reaction produces methane as a byproduct. The reaction is highly exothermic, and the types of hydrocarbons derived from the synthesis is dependent on several factors such as temperature, the process employed, and the catalyst used [3].

2. Natural gas reserve and gas flaring in Nigeria's Niger Delta.

With approximately 5,848 billion cubic metres of natural gas reserve as of 2022, Nigeria is ranked as the 8th largest natural gas reserve in the world and number one in the continent of Africa[4]. Nigeria has had a low volume of Natural gas usage over the years because of low level of her industrialization and the dependence on imported refined liquid fuel to meet local demand. According to[5].

Gas flaring is a practice that has been in existence since the beginning of oil production. It is a regulated burning of natural gas that is associated with oil extraction, and it has been practised due to several factors such as technology, economics, and market constraints as well as the absence of befitting regulations. Flaring of gas is considered a waste of a nation's valuable resources that should be collected and conserved for use World Bank, 2023), it has several disadvantages such as ecosystem disturbance, economic wastage, energy loss, adverse health consequences and global warming, caused by greenhouse gas emissions. With the abundant natural gas reserve in Nigeria and its production of crude oil which is a major contributor to her GDP, Nigeria is also ranked 7th in the 2021 list of gas global highest flaring nations, flaring about 6.6 billion cubic meters and emitting about 17.67 metric tonnes of CO_2[6]. Nigeria has flared approximately 1.2 trillion cubic feet of gas worth $ 3.9 billion in the last four years . When gas is flared, it burns methane and converts it to carbon dioxide which is released into the atmosphere, with a conversion of about 90-98% depending on the efficiency of the flare[7]. Flaring of Gas has led to several environmental effects such as increased concentration of heavy metals on ground and surface water, increased occurrence of acid rains and adverse modification of ecological and bacteria spectrum.

3. The Fischer-Tropsch Technology

The Fischer-Tropsch technology deals with the conversion of a mixture of carbon monoxide and hydrogen from the gasification of carbonaceous materials known as syngas resulting in a mixture of oxygenates, water, carbon dioxide, heavy waxy hydrocarbon as well as liquid hydrocarbon known as Syncrude. The light hydrocarbons can be refined to produce more environmentally friendly gasoline and diesel while the waxy heavier ones can be hydrotreated to produce better diesel, lube oil and naphtha. This synthetic crude (SYNCRUDE) from the Fischer Tropsch process can be differentiated into high-temperature and low-temperature Syncrude based on the operation temperature during the synthesis.

The high-temperature process is operated between 300 to 350 0C, making use of iron as a catalyst and producing short chains of hydrocarbons liquid product and synthetic gasoline, while the lower-temperature process is operated between 200 to 400 0C, with either cobalt or iron as catalyst and this process fancy the formation of longer hydrocarbon chains such as kerosene and diesel [8]. The feedstock for the Fischer- Tropsch process is hydrogen (H) and carbon monoxide (CO) from either natural gas, coal or biomass. For coal (solid feedstock) to liquid process, the feedstock is solid coal which is first converted into gas by gasification, a process where the coal is reacted at a very high temperature between 5930C - 1260 0C in very limited oxygen present and/or steam, to produce hydrogen and carbon monoxide as main product and by-product of water and carbon dioxide, which is cooled, cleaned and conditioned as it leaves the gasifier while for the gaseous feedstock like natural gas, an Autothermal Reformer and Pre- reformer are used.

The purified syngas obtained from gasification is then sent to a reactor where it is reacted in the presence of a catalyst at increased pressure and temperature to produce hydrocarbon and a byproduct of reaction water and oxygenated hydrocarbon which are collected and undergoes purification. The

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hydrocarbon produced from the reactors is cooled and its components begin to liquefy, then this liquified product is fractionated into various products such as Jet fuel, Diesel, and Butane as shown in Figure 2.

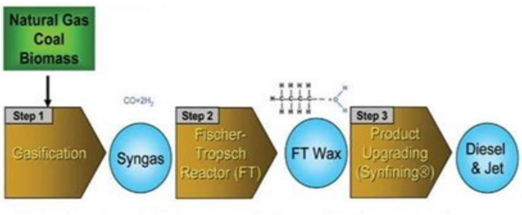

Figure 2. Fischer- Tropsch Process [9]

4. Methodology

The data used for this report was sourced from various literature regarding the Fisher-Tropsch technology, its development and improvement as well as its efficiency towards the development of cleaner hydrocarbon.

5. Technical Development and Improvement

The Fischer-Tropsch technology combines three processes which are a reformer for syngas generation, a Fischer-Tropsch reactor and product hydrocracking which cracks the produced waxes into synthetic crude. The technological development over the years has notably been on the reactors as well as the catalyst used in them, with several adjustments on Catalytic development and Reactor design made over the years as in Figure 3. The developed reactors include fixed-bed reactors, fluidized-bed reactors and slurry-bed reactors.

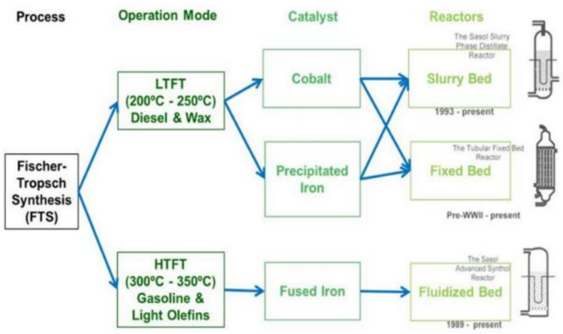

Figure 3. Different Commercial Rectors and Catalysts [11]

The fixed-bed reactors also referred to as the Arge reactors were developed and commissioned in 1955 by Lurgi and Ruhrchemie. It was developed to make gains out of stranded natural gas in secluded locations. This reactor only made large-scale progress of greater than 30,000 barrels per day in areas with low natural gas prices, and they were used to produce mainly heavy liquid hydrocarbon and waxes. These reactors have the most heat transfer challenges.

The fluidized bed reactor was first designed in a circulating mode for high-temperature synthesis to produce molecular gaseous hydrocarbons before the fixed bed was designed. It operates in the gas phase, making it very difficult to control.

The Slurry bed reactor is regarded as the modern technology for low-temperature Fischer-Tropsch synthesis, with better temperature control and a higher conversion rate when compared to the other types of reactors. This reactor is a vessel containing a slurry mixture of catalysts suspended in their own Fischer-Tropsch liquid product. As syngas are fed into this reactor from the bottom of the mixture, the heat of the reaction is removed through the cooling tubes that pass through the slurry by constant movement of the slurry. The slurry bed reactors are about 25% cheaper than the fixed bed reactor and more isothermal in nature[10]

6. Efficiency of the Fischer-Tropsch Technology

The carbon, in the carbon monoxide used in the Fischer-Tropsch process is derived from different sources and the output appears to be a combination of liquid and gaseous petroleum products as well as ethane. The technology provides an alternative means to more efficient use of Coal, Biomass and natural gas in a more attractive way in terms of environmentally friendly and economic value. Using the coal-fired power plant in South Africa as an example which produces low-cost electrical power, with an environmental penalty for large-scale coal combustion can be replaced with Fischer-Tropsch technology produced low heating value synthesis gas which is cleaned before being combusted in a combined cycle power plant using both steam and gas turbine.

Studies from [12] and [13] have observed that the Gas to liquid synthesis has an efficiency of 80% while Coal-to-liquid has an efficiency of 50% though it is believed that since the coal to liquid can produce both hydrocarbon liquid and electricity from the byproduct it may be able to compete with the gas to liquid synthesis in the nearest feature.

The efficiency of gas to liquid was calculated by [12] from the possibility of using synthetic methane created from the Fischer-Tropsch process:

Using 45 x 106 m3 /day natural gas x 10.6 KWh/m3 would produce 477GWh/day

∴ input = 477GWh/day

This gas can be liquefied to produce 22 x 103m3 /day of petroleum liquids which is equal to 22M litres/day x 9.7 kWh/litter = 213.4 GWh/day, and 120 kilo barrels of oil equivalent (730 TJ) of natural gas liquids and ethane = 203 GWh/day

∴ output = 213.4 +203 = 416.4 GWh/day Efficiency

= output/input = 416.4/477 =0.873

=87.3%

7. Future Development and Benefits of the Technology

Fischer-Tropsch technology can be regarded as a very encouraging technology in the energy industry based on its economic utilization of natural gas biomass and coal to environmentally friendly fuels, chemicals, and waxes. Future development of this technology should focus on reducing the capital cost of producing syngas and enhancing the thermal efficiency of the technology plant, by combining it with a power-generating plant that can use the low-pressure steam produced during the process [9].

Instead of flaring off natural gas, which is considered to be a byproduct of oil, its conversion to liquid hydrocarbon is one of the most promising technologies in the energy industry. Production of Synfuels from the Fischer-Tropsch process has several advantages over conventional hydrocarbon because they contain little or no sulfur and other contaminates making them cleaner and better in terms of environmental regulations As the world continues to look for cleaner and safer means of energy for transportation, its success with the current state of the art renewable sources have not made significant success in long-distance trucks, shipping and the aviation industries, hence the use of fuels derived from syngas would be a better substitution [11]

8. Discussion and Findings

This paper focuses on an energy technology capable of producing cleaner burning hydrocarbon from Natural gas which is been flared in Nigeria and is available in abundance to meet the energy demand of the populace using the Fischer-Tropsch technology putting into consideration the push for the reduction of the effect of climate change in the world. While the world looks to avoid a future marked by floods, tropical storms, drought and other disasters collectively called climate change, and with a country like Nigeria which depends on oil for 40 percent of her GDP, 70 per cent of budget revenues and 95 percent of foreign exchange earnings, its therefore important to study the Fischer-Tropsch technology which can be regarded as a very encouraging technology in the energy industry base on its economic utilization of natural gas to environmentally friendly fuels, chemicals, and waxes for sustainable development. With its natural gas reserve, Nigeria has the potential to be a formidable force in the global gas industry, but very little has been achieved in terms of the effective exploitation and utilization of these reserves with most of the natural gas being produced in the country being reinjected into wells or flared as an associated product, but with the right technology, it is believed that the gas flaring can be reduced and supposed flared gas converted into useful and environmentally friendly fuel using the Fischer Tropsch technology. Future development of this technology should focus on reducing the capital cost of the production of syngas and enhancing the thermal efficiency of the technology plant, by combining it with a power-generating plant that can use the low-pressure steam produced during the process [9].

9. Conclusion

Energy is undeniably vital to our existence, yet the increasing concern over greenhouse gas emissions cannot be ignored. These emissions trap heat from the sun, leading to climate change and global warming. That's why it's crucial to propose a cleaner hydrocarbon paradigm that supports sustainable development. To achieve this goal, a study was conducted using data from various literature to propose the development of a cleaner hydrocarbon paradigm for sustainable development in the Global South, using Fischer-Tropsch Technology in the Nigeria Niger Delta. The study examined the technological development and improvement of reactors and catalysts used by the technology, the efficiency of gas-to-liquid and coal-to-liquid synthesis, and ways to reduce CO_2 emissions in the conversion process.

Future development of this technology should focus on reducing capital costs for syngas production and enhancing the thermal efficiency of the plant by combining it with a power-generating system. The benefits of this technology include reducing gas flaring and producing liquid hydrocarbons containing little or no sulfur and other contaminants from syngas of coal and natural gas which are readily available in Nigeria and can meet our energy needs without harming the environment.

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