SSRG International Journal of Economics and Management Studies
ISSN: 2393–9125 / https://doi.org/10.14445/23939125/IJEMS-V10I9P101

Volume 10 Issue 9, 1-8, September 2023

Original Article

Driving Industrialization using Gas as a Transition Fuel in Nigeria

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Received: 05 July 2023 Revised: 07 August 2023 Accepted: 26 August 2023 Published: 09 September 2023

Abstract *- There is a rising need for the transition into a more sustainable energy resource base in Nigeria, which oftentimes becomes a thing of concern to the government and the citizens to reflect on a sustainable energy system. It is important to note that policymakers have a great role to play in regulating the affairs of energy supply, as most of the infrastructure is determined by the dynamics and structure of the energy systems. With this, the quest to understand the energy system is at its zenith. This study focuses on exploiting natural gas as a transition fuel, capable of driving industrialization and improving the Nigerian economy.*

This study used exploratory research tools to investigate the dynamics of adopting gas as a transition fuel for driving industrialization in the Nigerian energy ecosystem. Secondary data from archives and published documentation linked to the Nigerian energy systems were used for the analysis and to derive useful insights for the validation of the objectives of this study.

From the result of the analysis, three parameters were applied in the measurement of the energy systems to determine which system is best positioned to act as a transition fuel. They are: (1) The extraction rate of the energy system from its original source, (2) CO2 emission rate and content, (3) Carbon and other impurities contents. The proposed transition fuel (natural gas) showed the best response to the three parameters. Gas returned a 100% extraction rate; it was also observed that gas has the lowest CO2 emission of about 59.4% with a lower deposit of carbon content.

This study concludes that there is a need for the Nigerian power system to tackle its energy challenges by adopting gas as a transition fuel in support of sustainable energy. It also suggests the combination of gas as a fuel with other advanced technologies for optimal industrialization of the nation. This study also affirms that to sustain energy supply, there is a need to monitor consumption rates and patterns adequately, and this dynamic should be considered as a primary deciding factor during policymaking.

Keywords *- Industrialization, Natural gas, Transition fuel, Carbon emission, Electricity, Alternative energy.*

1. Introduction

In Nigeria, several constraints in the electricity sector have been influenced by factors including poor power generation, weak transmission and distribution infrastructure, deficiency in utility management and lack of adequate investment and maintenance of the infrastructure. The 2005 Nigeria Electricity Sector Reform Act had a primary objective of ensuring that Nigeria developed a sustainable electrical system that is capable of meeting the national demands of the 21st century (Yeh, 2007). To ensure that the demand is met, several schemes have been implemented to achieve this objective, such as the restructuring, unbundling and privatization of the electricity systems. This also led to calls for the diversification of the power generation sources. Some alternatives have been adopted to improve power supply, amongst which are hydropower, solar, wind, biomass, wave and tidal, and some geothermal energy. However, the prominent sources of energy generation are crude oil, tar sands, natural gas and coal (Ibitoye, 2007).

In Nigeria, renewable and nonrenewable energy resources are abundant, allowing for a better energy mix. The prominent energy sources have challenged the environment because of the associated global warming and the climatic changes frequently occurring globally. So there is a need for transition into alternative, cleaner energy systems. Nigeria has suffered as a result of the transition to a better energy system; according to World Bank sources, only about 10% of the

population in Nigeria has had access to consistent electricity from 2017, which has posted several uncertainties in the electricity sector (Nwozor, Oshewolo, Owoeye, & Okidu, 2021).

It has been observed that Natural Gas (NG) should be considered as one of the major streams in the Nigerian energy system that will provide more innovative scope and breadth of industrialization across all the sectors in the Nigerian economic landscape, including technology development (Hefner, 2007). The adoption of Natural Gas will definitely reduce the high dependency of the nation on other fossil fuels, such as Coal and Oil, which produce higher Carbon Dioxide (CO2) emissions that are highly detrimental to the environment. It is also expected to support a smooth, social and more sustainable economic environment for the citizens of Nigeria.

The reserve estimate of Natural Gas in Nigeria is over 200 trillion cubic feet, capable of providing sufficient energy for power generation and effective industrialization compared to other energy sources. In addition to huge gas reserves, natural gas is a source of energy associated with least CO2 emissions.

2. Definition of Terms and Literature Review

2.1. Industrialization

Industrialization in an Oil and Gas Jurisdiction is a process by which the society transforms itself from a crude-based economy to a manufacturing-based economy. It involves the development of industries, mass production, and the use of automated machines to increase productivity and efficiency. Industrialization significantly impacts human society as it contributes to economic growth and increases living standards by providing a better socioeconomic environment (Erb, Gingrich, Krausmann, & Haberl, 2008). However, the process often brings about environmental and social challenges which cut across pollution and exploitation of workers.

2.2. Natural Gas (NG)

Natural Gas is a fossil fuel primarily composed of methane with a minimal amount of other gases such as ethane, propane and butane. NG is formed beneath the earth's surface over millions of years as a result of the remains of plants and animals. It is important to note that NG is a nonrenewable resource found in formations like shales, sandstones, coal seams, etc. The process of extraction of NG is by drilling into the formation and by fracturing to release the gas. NG is considered a transition fuel in Nigeria because of its variety of uses, such as heating homes and businesses, generating electricity, and as fuel for vehicles (Economides & Wood, 2009).

2.3. Transition Fuel

Natural gas is considered Nigeria’s transition fuel since it is considered a cleaner-burning fossil fuel compared to coal and crude oil. Its carbon content is seen to be lesser than other fossil fuels. NG is a cleaner and more sustainable source considering the global energy transition. It is considered a potential bridge or transition fuel to help reduce greenhouse gas emission effect while transiting to renewable energy sources like solar and wind. Natural gas is already in existence as it acts as backup power, which is more reliable than other renewable energy sources due to factors that affect the supply from other energy sources (Aguilera & Aguilera, 2020).

Natural gas has been proposed as a transition fuel aimed at minimizing carbon emissions. As proposed by Joan et al., the two transition strategies are adapting natural gas for refueling infrastructures for now and future use and blending hydrogen into the NG system. It was observed that this system of transition fuel will be needed if the zero-emission target is to be achieved, and it plays a vital role in a future low-carbon world in Nigeria (Ogden, Jaffe, Scheitrum, McDonald, & Miller, 2018).

In the quest to establish a sustainable energy source, Gursan examined the impact of gas as a transition fuel. In their research, it was inferred that for an energy source to be considered as a transition fuel, it should meet the goals of providing a sustainable power supply to society and, at the same time, achieve a reduced carbon emission to mitigate climate change. They concluded that Natural Gas has a higher tendency to perform this role as other renewable energy sources are not viable and may not be technologically and economically mature for use in society as the cost of installation is usually higher (Gürsan & de Gooyert, 2021). To consolidate assumptions made on adopting natural gas as a transition fuel, policymakers have reviewed the source with an unending effect on the long-term uses to avoid negative effects.

The Petroleum sector is critical to the Nigerian economy as it contributes significantly to the nation's per capita income. However, several researchers in their studies postulated that the over-dependence of the Nigerian economy on natural resources without diversification to other economic sectors has a negative effect on the development and growth of the economy and, as such, has been termed inappropriate. They stated emphatically that natural resource-based growth will not lead to sustainable economic growth unless the revenues are used to diversify the economy. These hypotheses were derived from empirical studies which can be properly addressed using the following strategic policy: There is a need for successive governments to adequately utilize resource revenues for the development of the non-oil sector, which will boost the volume of exports while generating revenue for growth and development of the entire economy. To ensure the diversification of the Nigerian economy and avoid over-dependence on one commodity, which may fail, there should be a regularization of the consumption rate of the natural resources, and the exploitation of these resources should be

done with caution (Ubani, Okutimiren, Simeon, & Remo, 2014) and to reduce negative climatic effects (Levi, 2013). In order to fully adopt NG as an alternative to crude oil as a revenue earner, there should be concrete studies and the development of a discrete transition strategy. This should cut across the study of the CO2 emissions and the energy efficiencies of this NG as a source of energy to replace crude oil (Hekkert, Hendriks, Faaij, & Neelis, 2005).

This study is focused on highlighting the potential of NG as a transition fuel capable of driving industrialization in Nigeria. It also determines the impact of industrialization on the economic growth in Nigeria. It answers the following research questions;

Does Natural Gas have a reduced carbon content compared to another natural sources of energy?
How large is the reserve to sustain and to cater for the national economy?

Does adopting natural gas as an energy source reduce carbon emissions and eliminate the greenhouse effects?
How much of the natural gas is exploitable?

3. Methodology

In this study, the exploratory analysis method was adopted alongside comparative analysis to show the areas where gas has dominated in driving industrialization. There is a brief description of the process of extraction and purification of NG to consumable products and distribution to end-users. There are three major processes involved in the production and delivery of NG, as briefly described below;

3.1. Natural Gas Production Process

This is the first process stage, which involves the extraction of natural gas from reservoirs (either under-saturated or saturated). When the extraction of the product has been done and brought to the surface, it is subjected to several pre-processing techniques, which involve separating products (oil, gas and water) into separate facilities for further purification.

The purification or processing of natural gas involves several steps, among which are dehydration, removal of non-hydrocarbon products, venting and flaring, etc. All these are done to meet the specifications required for compression, transmission and storage technology (CST) handling.

3.2. Natural Gas Transmission and Storage

The Gas, when processed on the surface, is transmitted to the storage, which could be on the main transmission lines or underground reservoirs. This process is achieved with the help of the Compressor to boost the movement of the gas in pipelines and storage to reduce the loss and ensure proper distribution when needed at various user endpoints.

3.3. Natural Gas Distribution and Storage

Gas distribution from storage facilities could be done in various ways. The major factors here are the downstream natural gas companies, which are responsible for gas distribution. Gases are distributed to various user outlets, which include factories, homes, motor vehicles, companies, schools and institutions, offices, etc., where the products can be used effectively.

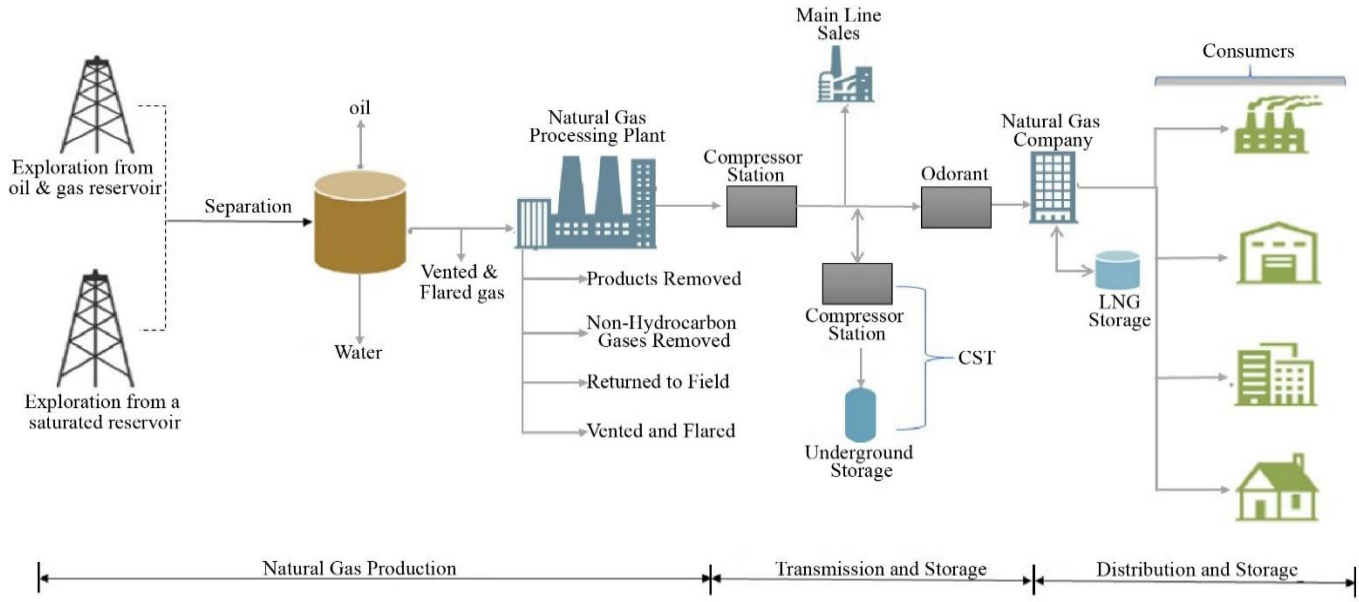

Fig. 1 Gas extraction process

The extraction of natural gas resources is not complete until it is being used by the consumers, as shown in Figure 1. The process by which the product is being produced from the reservoirs and sent to the consumers is referred to as the well-to-wheel process and involves the following stages shown in Figure 2.

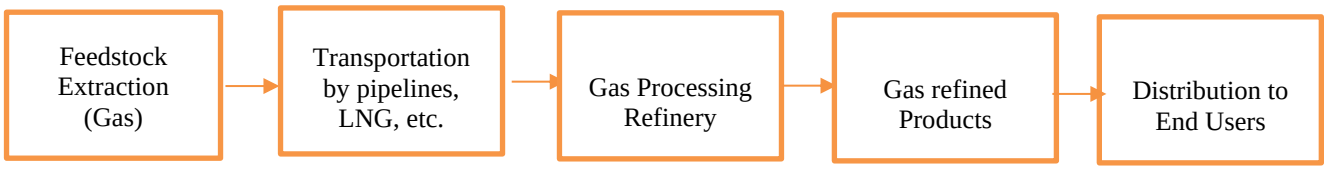

Fig. 2 Well-to-Wheel gas fuel chain

In this study, the following natural gas fuel products have been considered: Compressed Natural Gas (CNG), Liquefied Natural Gas (LNG) and Methanol. The fuel chain considered is shown below.

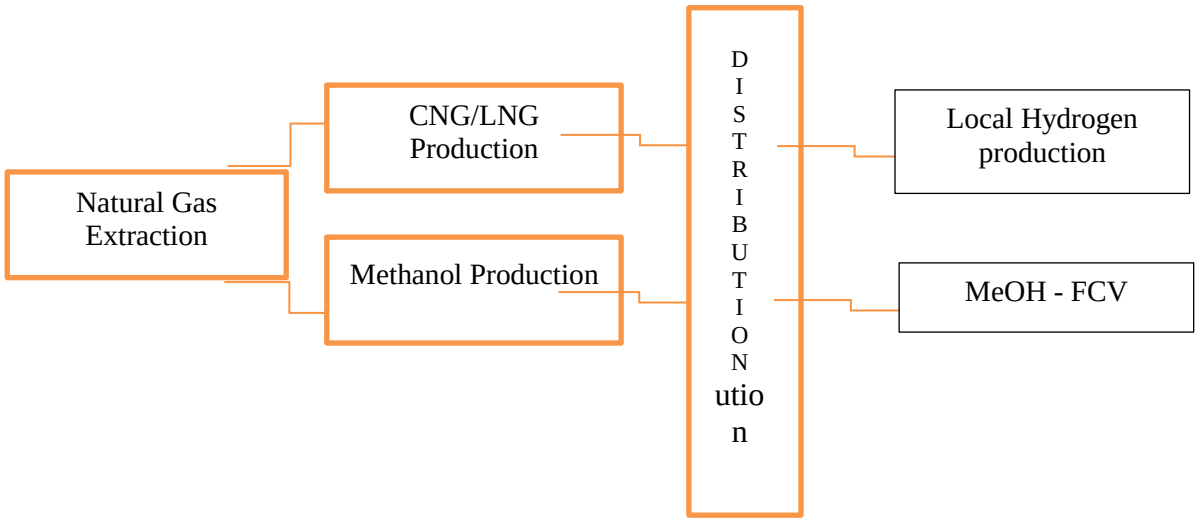

Fig. 3 Natural gas fuel chain considered in this paper

It is important to note that the energy requirement and the carbon emission per cycle of a fuel product are determined based on the energy efficiency per cycle of each step considered in the chain. Natural gas has been discovered to have a process efficiency of 97-99-100% during the extraction process.

The data that shows the effectiveness of natural gas compared to other natural resources as a source of energy will be presented in the data presentation section of this paper.

4. Results and Discussions

This section shows the hydrocarbon supply chain data, which was used to validate the assumptions stated in the previous sections. It is also used for providing valid answers to the research questions. The data involve parameters that cut across the production, distribution and supply or the distribution of data from the well to the end-users. The presentation of the data is done to show a comparative analysis of the efficiencies of Natural Gas, crude oil and other natural energy sources as fuel sources.

5. Production Extraction and Supply

From Table 1 and Table 2, it was deduced that for the extraction of these products through the distribution of the productions, NG has the best rate for extraction as it was recorded that 100% of the natural gas can be extracted and processed.

Compared to the crude oil system, the extraction was discovered to be 98.8%, which implies that adopting natural gas as a fuel system will perform better and provide a more sustainable energy source for a longer time. This study observed that the total supply rate is higher when considering Compressed Natural Gas (CNG) with a percentage rate of 97%. NG can be transported in compressed form, liquefied form or through pipelines.

Table 1. Crude oil supply chain for gasoline, diesel and LPG

Supply of gasoline, diesel and LPG						
crude oil	Efficiency (%) energy consumption process fuels			CO2 kg/GJ incl. CO2 emissions from the production of process fuels		
cases	worst	Probable	Best	Worst	Probable	Best
Extraction	92.3	95	98.8	5.9	3.6	0.8
Transport	98.2	98.9	99.4	1.3	0.9	0.4
Fuel Production						
Gasoline	81.5	88	91.5	16	9.4	6.3
Diesel	89	95	96	9.7	3.6	2.8
LPG	90	92	97	7.8	6	2.1
Distribution						
Gasoline	98.1	99	99.9	1.4	0.7	0.1
Diesel	98.1	99	99.9	1.4	0.7	0.1
LPG	96.3	97.6	99.4	2.7	1.8	0.4
Total Supply						
Gasoline	73	82	90	26	15	8
Diesel	80	88	94	18	9	4
LPG	79	85	95	19	13	4

Table 2. Natural gas supply chain for CNG, LNG and methanol

Supply of CNG, LNG, Methanol						
Natural Gas	Efficiency (%) energy consumption process fuels			CO2 kg/GJ incl. CO2 emissions from the production of process fuels		
cases	worst	Probable	Best	Worst	Probable	Best
Extraction	94.3	96.9	100	6	2.9	0
Fuel Production						
CNG	88.1	92.8	88.2	8	4.7	1.2
LNG	87.6	89.2	90.6	8.6	7.3	6.3
Methanol	47.2	68.3	70.1	56.6	17.9	15.6
Distribution						
CNG	93.3	96.6	99.2	4.3	2.2	0.5
LNG	87.6	92.6	96.4	9.8	5.6	2.6
Methanol	95	96.3	97.6	3.7	2.7	1.7
Total Supply						
CNG	79	87	97	18	10	2
LNG	74	81	88	24	16	9
Methanol	44	65	69	72	25	17

6. Carbon Dioxide Emission Rate

Table 3. Carbon dioxide emission rate

Process fuel	CO2 emission (g/MJ used)	Process Fuel Production Efficiency (%)	CO2 emission from process fuel production (g/MJ used)
Residual fuel oil	79.3	0	79.3
Heavy fuel oil	79.3	93	85.3
Refinery still Gas	65	0	65
Diesel	73	88	82
Gasoline	72	82	87.5
Crude Oil	78	95	81.8
Natural Gas	59.4	97	62.3
Electricity	0	45	132

For carbon emission rate, as shown in Table 3 and graphically shown in fig. 4, oil has been observed over time to be the major fuel source of carbon dioxide emission.

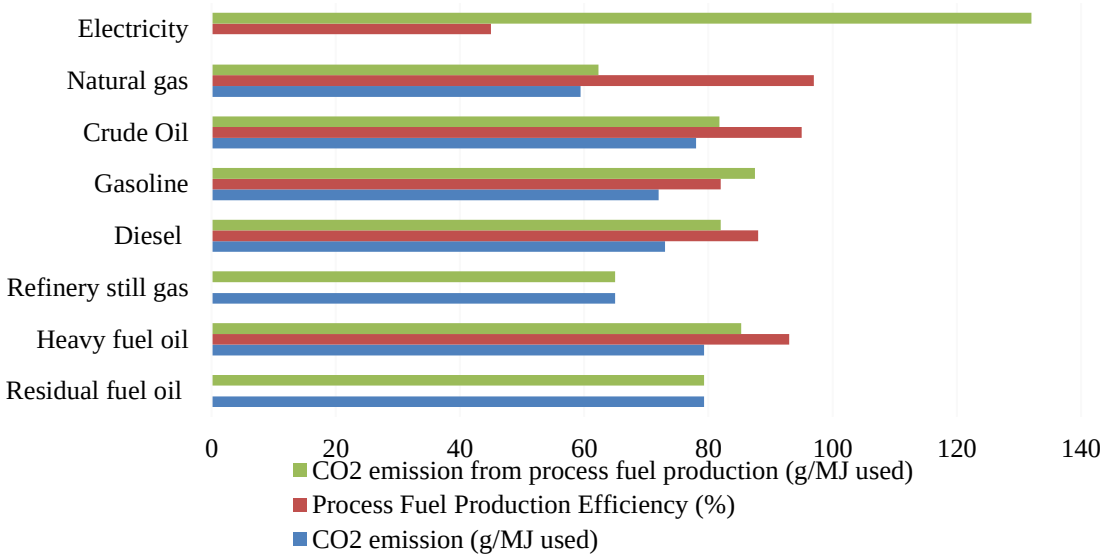

Fig. 4 Graphical representation of the carbon emission rate

In this paper, the crude oil system comprising residual fuel oil, heavy fuel oil, diesel, gasoline, and crude oil has a higher CO2 emission rate of above 70% with process efficiency or performance of less than 96%. Conversely, the natural gas systems have a CO2 emission rate of less than 60%, showing a reduced rate of emission of the product, which causes global warming and the greenhouse gas effects with a higher process production efficiency of 97% and above.

7. Carbon Content and Deposition

Table 4. Carbon content and deposition

Fossil energy carrier	CO2 emission (tCO2/TJ GCV)	C content (tC/TJ GCV)
Coal	88.2	24
Crude Oil	66	18
Natural Gas	47.3	12

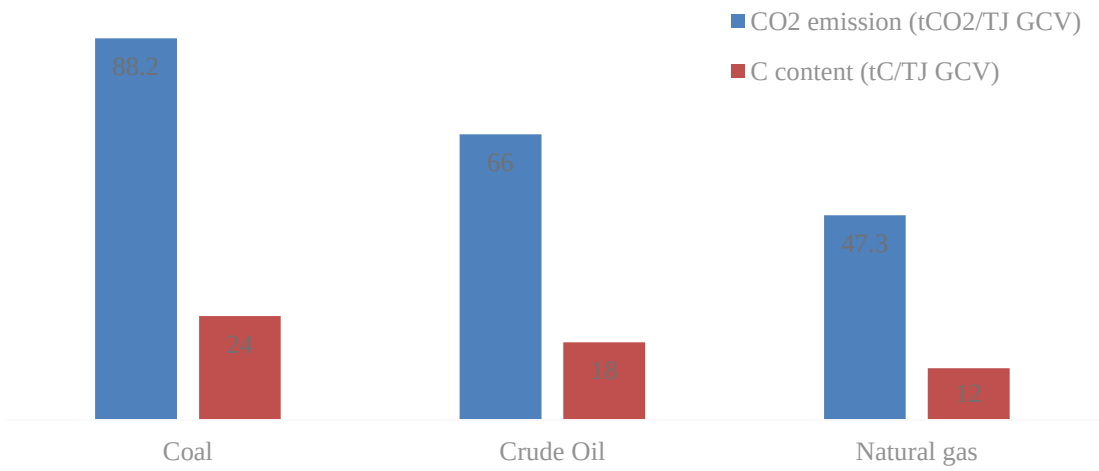

Fig. 5 Graphical representation of carbon content in fossil energy carrier

Table 4 shows the fossil energy carriers considered in this paper with their corresponding carbon emission rate and carbon abundance. From the analysis, it was observed that (NG) has the lowest carbon emission and a minimal amount of carbon content. With this, natural gas can be adopted as a reliable and environmentally friendlier energy source.

Figure 5 shows a graphical representation of the trend in the carbon abundance and carbon content deposition. The bar chart indicates that NG has a relatively better reduction in the carbon content and the CO2 emission during energy supply.

8. Conclusion

In this study, we have been able to exploit the advances associated with adopting NG as a transition fuel for driving industrialization. At the end of this research, four insights were derived from the analysis, which provides concrete answers to the research questions.

First, the research and the analysis shown in Tables 3 and 4 truly affirm that NG has a more reduced deposition of carbon content compared to the other sources of fossil fuel energy carriers. Table 4 shows that NG has a carbon content of 12% compared to coal, with a carbon content of 24%, and Crude oil, with a carbon content of 18%. This validates the fact that if NG is adopted as a transition fuel, it will reduce the rate at which CO2 is emitted into the atmosphere.

Secondly, the abundance of NG in Nigeria provides the impetus for sustainable energy supply as Nigeria is estimated to have a gas reserve estimated at about 207 trillion cubic feet, which at US$4/Mcf is worth over 800 billion dollars. With its low carbon content, natural gas, if adopted as a source of energy supply, will sustain the Nigerian Power system while generating foreign exchange revenues sufficient to drive industrialization in all sectors of the Nigerian economy.

While driving industrialization, it is important to check the effect of this particular energy source on the environment with respect to the carbon it emits therein. As stated earlier, the carbon emission rate from NG is lower than other fossil fuel energy carriers. Fortunately for Nigeria, the European Union has proposed and designated NG as green energy capable of significantly reducing the global carbon footprint when used as a transition fuel in place of Coal or Oil.

Lastly, Natural Gas is the only form of fossil energy carrier that can be seamlessly combined with other renewable energy systems like solar. It has been proven that adopting gas generators can help keep the solar inverters actively running regardless of the seasons or the weather conditions. Thus, natural gas can drive industrialization in Nigeria just as it has in China and other regions or countries of the world.

Since 100% carbon-free is not guaranteed with NG, most persons and industries are transiting to cleaner renewable energy, which is either wind, solar, etc. This project did not study the carbon-capturing technologies that can be used to remove carbon from the Natural gas energy systems.

Recommendations

Based on the results of this study, it is highly recommended that Nigeria adopt Natural Gas not only as a transition fuel for its industrial growth and development but also as a source of revenue that should be used to diversify and develop other sectors of the economy.

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