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# A Techno-Economic Analysis of Using Natural Gas as Alternative Transport Fuel in Nigeria

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**Abstract**

*The increasing rate of population and the consequent increasing demand for transportation and higher number of vehicles has resulted in an increase in the $CO_2$ emitted by the transport sector in Nigeria, this has increased the need for alternative fuel for the transport sector in Nigeria. this study comparatively analyses and compares the technical and economic aspects of using two natural gas fuel forms (CNG and LPG) as alternative transport fuel in Nigeria. The study evaluated the total annual $CO_2$ emissions, the total monthly fuel consumption, the effect of fuel price and the annual fuel cost savings from using these natural gas fuels as alternative fuel to the widely used liquid petroleum fuels. The profitability of using these natural gas fuels were also evaluated using economic parameters of net present value (NPV) and payback period (PP). The study was conducted using a privately owned vehicle converted from diesel or petrol driven to gas-driven travelling 100km daily for 28 days a month within Abeokuta city of Ogun State Nigeria. Results of this study revealed that running a vehicle on natural gas fuels significantly reduced the total annual $CO_2$ emission and also saved cost on fuel enough to recover the initial cost of converting the vehicle within the first few years of running the vehicle. Results of the economic analysis showed how profitable an investment in natural gas fuels is, with positive net present values at 10% discount rate for natural gas fuels provided the gas price was maintained below the gasoline price. This study recommends that the government develop policies that would encourage and increase private participation in this sector*

## 1. Introduction

The finite The rapid industrialization and urbanization of cities have led to a remarkable increase in the demand for transportation worldwide, driven by an increase in the number of automobiles in urban cities. This has conversely resulted in a spike in the demand for petroleum-based fuels to satisfy the increasing energy demand from the increasing number of vehicles available today. The demand for energy is quite significant in a growing economy because energy is a major driver of economic growth. The increasing awareness of global warming, climate change and carbon emission has made it necessary for countries to rethink their current fuel options and to find alternative cleaner and more safer fuel types. Petroleum-based liquid fuels such as automated gas oil (AGO) and premium motor spirit (PMS) are considered unsafe because of their negative impact on the ecosystem. On the other hand,

gaseous fuels such as compressed natural gas (CNG), liquefied petroleum gas (LPG) and liquefied natural gas (LNG) are regarded as cleaner fuel types as their impact on the environment is less severe. These gas-based fuels are currently being considered alternatives to AGO and PMS as automotive fuel sources [3], [25]

The consequences of climate change have necessitated the quest for clean fuels with a less severe negative impact on the environment. liquid petroleum fuels (AGO and PMS) are the most common automotive fuels and are more expensive when compared to gas-based petroleum fuels (CNG, LPG and LNG). LPG which is otherwise called autogas is a fossil-based fuel composed of lighter hydrocarbons ranging from propane, propene, and butane [ 30]. Currently, autogas is the second most adopted alternative automotive fuel globally in use after ethanol [23]. The choice of selecting between CNG or LNG is dependent on (1) vehicle size and (2) desired range. CNG is natural gas pressurised to 200-300 bar and is more suitable for cars and small trucks with relatively low annual mileage. On the contrary, LNG is cooled to -161°C and it is mainly considered for heavy-duty vehicles with an annual mileage above 100,000 km [ 14].

The 2022 United Nations world population prospect report revealed that Nigeria's population increased by 2.41% between 2021 and 2022. Nigeria's population grew from 213,401,323 in 2021 to 218,541,212 in 2022 [36]. Although future projections from the United Nations as shown in Figure 1.0 indicates a steady decline in the annual population growth rate, the present figures are worrisome as it directly affects this study. An accompanying report on urbanization in Nigeria showed that in 2021, 52.75% of the total Nigerian population lived in urban cities[1]. Figure 2.0 gives a clear indication of the steady rise in urbanization in Nigeria. With these figures, it is no longer news that the demand for automobiles has increased and so has the demand for automotive fuels for transportation. Regardless of these looming challenges, Nigeria gas utilization is inadequate as it continues to flare gas from various oil and gas production fields.

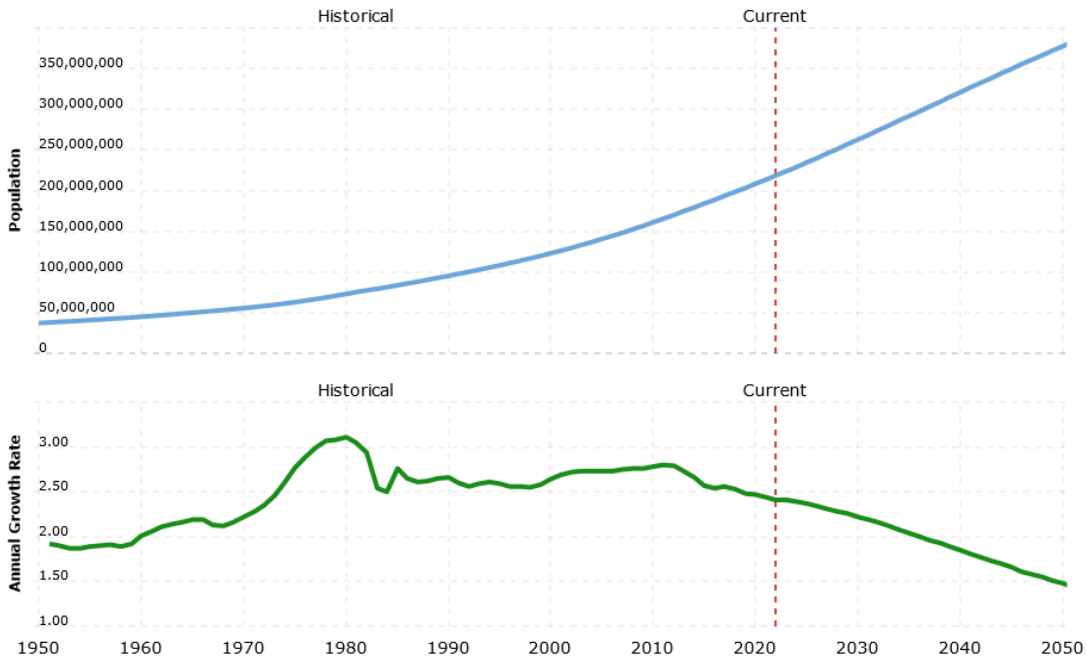


**Figure 1.0: Nigeria Population and Annual Growth Rate 1950-2022 Source: [36]**

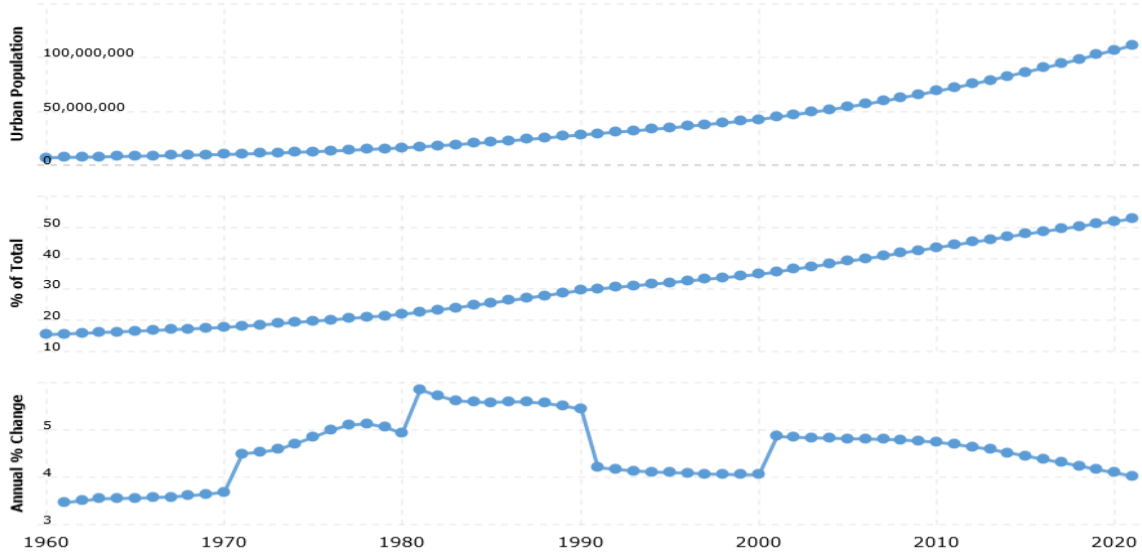


**Figure 2.0: Nigeria Urban Population 1960-2022 Source: [40]**

The Nigerian Government had declared 2021 to 2030 as the decade of gas development in Nigeria and has been able to reduce gas flaring during oil production by 32% between 2012 to 2021 as depicted in Figure 3.0. However, her gas-flaring intensity has increased by 10% between 2012 to 2021 (as shown in Figure 4.0) and still ranks 7$^{th}$ among the largest gas flaring countries as shown in Figure 5.0[40].

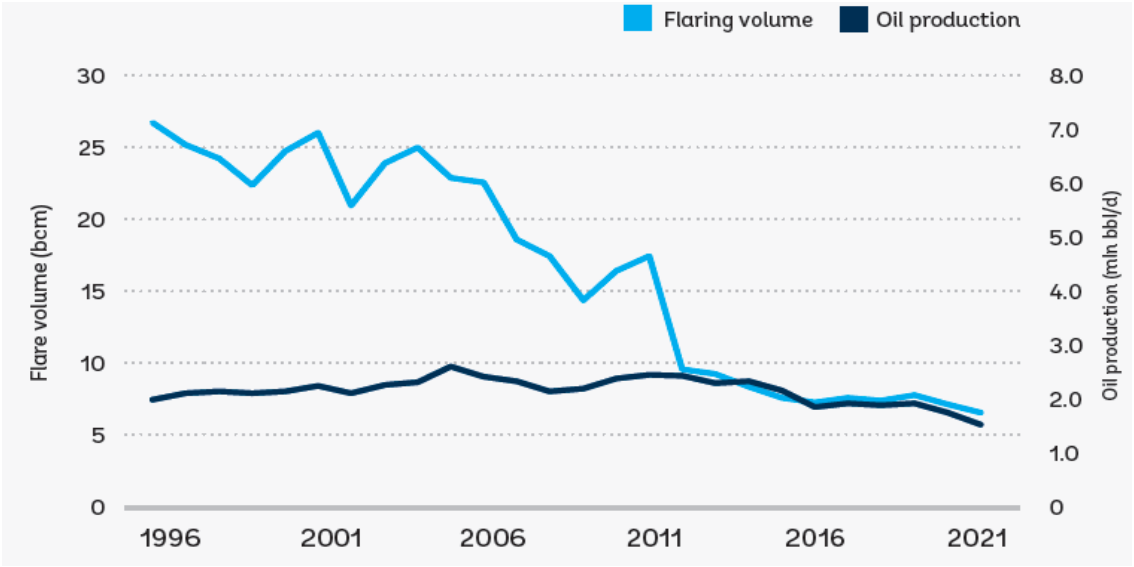


**Figure 3.0: Nigeria flare volume versus oil production 1996 to 2021 Source: [40]**

The Nigerian Oil Spill Detection and Response Agency report of August 2022 confirmed the World Bank report, revealing that Nigeria flared about 255.2bscf of gas in 2021, with an accompanying 13.6million tonnes of $CO_2$ equivalent emitted.

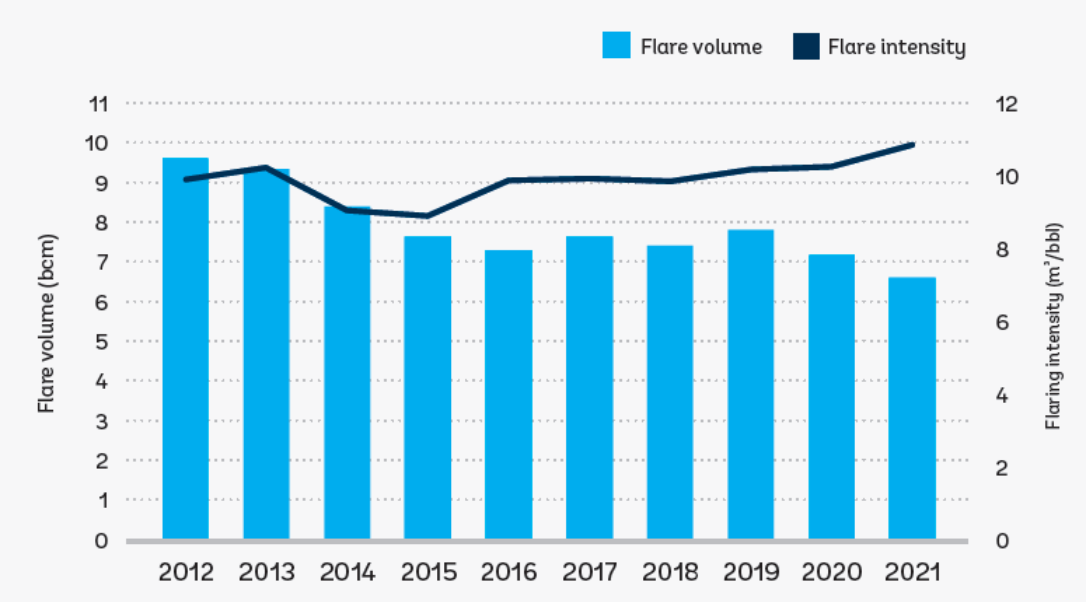


**Figure 4.0: Nigeria flare volume versus flare intensity, 2012 to 2021 Source [40]**

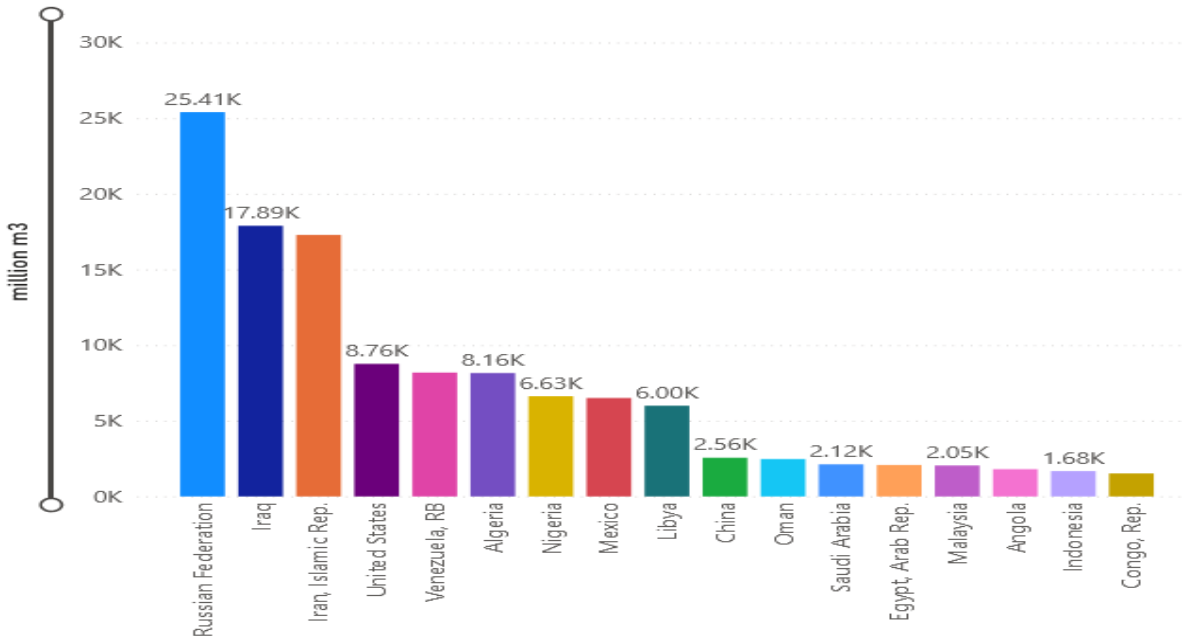


**Figure 5.0: Gas flare volume by Country Source: [40]**

International Renewable Energy Agency reported that 96% of the global energy consumed by the transportation sector in 2015 alone came from petroleum products, corresponding to 65% of the global oil consumption. Also, 7 billion tonnes of $CO_2$ representing a quarter of the global $CO_2$ emissions were reportedly released by the transportation sector. Road transport was identified as the largest energy consumer, taking up 75% of the total sector's energy demand and responsible for 80% of the transport sector's $CO_2$ emissions in 2015 [15]. Figure 6.0 shows the global sectoral $CO_2$ emission data of 2014 as reported by the International Energy Association (IEA) and Intergovernmental Panel on Climate Change (IPCC) [18]. The Nigerian

Bureau of Statistics reported that Nigeria had an estimated 11.8 million registered vehicles. Figure 7.0 shows the vehicle distribution by percentage ownership in Nigeria. A greater percentage (56%) were commercial vehicles, followed by privately owned vehicles (39%) and 1.1% were government-owned vehicles. According to NIPCO plc, a subsidiary of the Nigerian National Petroleum Company (NNPC), only about 5,600 vehicles have been converted into CNG driven. Which implies that the predominant automotive fuel types used for the over 11 million vehicles are the liquid petroleum fuel of gasoline and diesel. One can barely imagine the amount of carbon dioxide emitted by these vehicles daily [24].

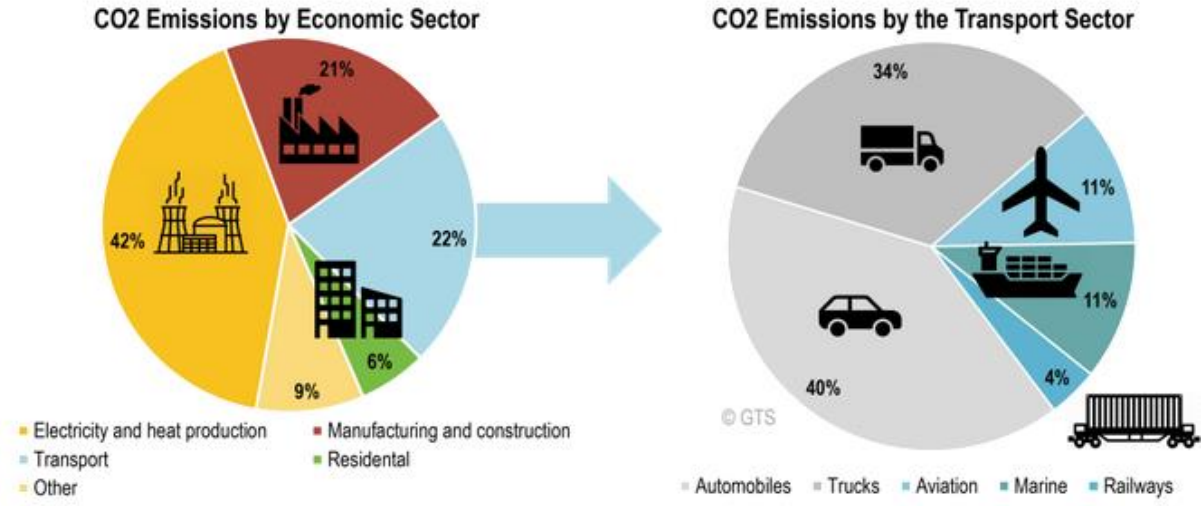


**Figure 6.0: Global Greenhouse Gas Emissions by the Transportation Sector Source: [18]**

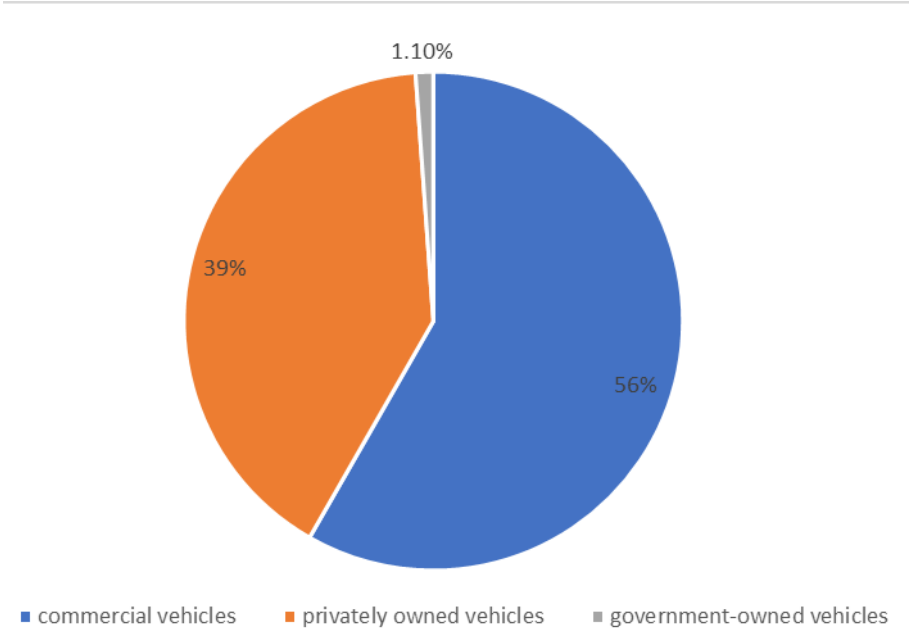


**Figure 7.0: Percentage Distribution of Vehicle Ownership in Nigeria Source: [24]**

This data does not only show the unexplored market which exists for Autogas, but it also shows the extent to which carbon dioxide is emitted into the environment from these vehicles' continuous use of AGO and PMS and further indicates the need to urgently introduce and encourage the use of gaseous based petroleum fuels as alternative fuels to PMS and AGO for vehicles in Nigeria. In a bid to address the double dilemma of gas flaring and fuel shortages in the country and to harness the country's natural gas resources, the use of compressed natural gas (CNG) as an alternative automotive fuel was proposed in the 1990s. However, the implementation process has been slow. Considering the increasingly high cost of the pump price of liquid petroleum fuels, their continuous use is not sustainable for the economy and the environment.

The need to encourage the development and use of gas-based petroleum fuels as an alternative to diesel and petrol as vehicular fuels in Nigeria is based on the following concerns: environmental pollution caused by burning petrol and diesel; recurrent scarcity of petrol and diesel; the poor state of the Nigerian refineries; the increasing cost of refined petroleum products especially diesel and petrol; and the high retail price of petrol and diesel. Nigeria being a partner of the Paris Agreement has made some conscious efforts in the upstream oil and gas industry to reduce carbon emissions through gas flare commercialisation programmes. However, her efforts are insufficient as there are no policies directed to reduce carbon emissions in the transport sector. Introducing CNG, LPG and LNG as an alternative to PMS and AGO will place Nigeria on the road to energy sustainability, autonomy and efficiency. This study analyses the technical and economic aspects of using CNG, LNG and LPG as alternative fuels to PMS and AGO in Nigeria. This initiative will result in adequate utilization of flared gases, reduction in costs of liquid fuels and carbon emissions with an overall improvement in the health of Nigerians. Using CNG, LNG and LPG as alternative automotive fuels will save fuel costs for vehicle owners and also reduce the importation of refined petroleum products.

Automobiles emit toxic pollutants into the environment which must be checkmated to reduce the likely effect of having such pollutants in the environment. Numerous harmful substances are released into the atmosphere when diesel or gasoline are used as fuels in vehicles[20]. A greater number of vehicles in the world are diesel and gasoline driven of which emissions are potentially harmful to the environment. since the number of vehicles keeps increasing, there is a need to consider alternative fuel types with less harmful emissions and are also cheaper [33].

Alternative fuel types being considered in this study are natural gas and its various forms. The use of natural gas (CNG, LPG and LNG) as alternative fuels to liquid petroleum (AGO and PMS) presents numerous advantages including low carbon and nitroxide oxide emissions, high octane number, cheaper fuel cost, and less strain on engine parts. The use of natural gas as alternative automotive fuel in Nigeria will not only reduce air pollution caused by AGO and PMS fueled vehicles, it will increase Nigeria's local natural gas demand and an opportunity to utilize its vast untapped natural gas reserves and reduce/eliminate natural gas flaring.

## 2.0 Materials and Methods

This study uses the case study of a privately owned petrol-driven vehicle converted into a natural gas-driven vehicle. The cost of converting a gasoline/diesel-driven vehicle into a gas-driven vehicle was gathered from secondary sources. This cost includes the cost of acquiring the conversion kits and the installation cost for the extra parts. The average cost of converting a gasoline/diesel-driven vehicle into a gas-driven vehicle is between N200,000 to N250,000. For this study, N250,000 was used **[35]**.

This study uses a more conservative Nigerian Naira to US Dollar exchange rate of 420 Naira per Dollar.

$$\$1 = N420 \qquad (1.0)$$

Running cost analysis, net present value and payback period are the economic tools used in this study to comparative analyse the economics of operating a vehicle on CNG and LPG as an alternative fuel to gasoline for a given distance.

$$NPV = \sum_{n=0}^{n=last\ year} \left(\frac{Cashflow\ for\ year\ n - Investment\ for\ year\ n}{(1+rr)^n}\right) \quad (2.0)$$

The initial conversion cost from gasoline-driven to natural gas-driven, estimated annual maintenance cost, fueling cost and vehicle's fuel consumption rate are some of the factors considered in this analysis. Comparison of the fuel cost was conducted. The price of gasoline with and without subsidy was compared with the price of the natural gas fuels as shown in Table 3.1. The fuel prices were used together with fuel economy data for further analysis on the various fuel types.

**Table 1: Summary of Data Gathered for Analysis: Source:** [35][7]

| Fuel Type | Distance Travelled/ day (Km) | Fuel Consumption Rate/km | Unit price of Fuel/litre (N) | Fuel Price /litre ($) | Fuel Cost/ km (N) | Fuel Cost/ km ($) |
|---|---|---|---|---|---|---|
| CNG | 100 | 0.100 (scf/km) | 110.00/scf | 0.261 | 11.00 | 0.026 |
| LPG | 100 | 0.123 | 315.80 | 0.751 | 38.84 | 0.092 |
| Gasoline (with Subsidy) | 100 | 0.144 | 165.00 | 0.392 | 23.76 | 0.056 |
| Gasoline (without Subsidy) | 100 | 0.144 | 462.00 | 1.100 | 66.53 | 0.158 |

Table 3.1 shows the summary of results collated depicting the fuel consumed for each gas fuels per kilometre travelled. The privately owned vehicle is assumed to be used for intra city movement in Abeokuta, Ogun State, Nigeria and covers an estimated distance of 100km daily for 28 days in a month. Using this assumption and the $CO_2$ emission factor presented in Table 3.2, the $CO_2$ emission for each fuel type was calculated. Considering the estimated daily distance of 100km, the total distance covered in a month will be 2,800km. The monthly fuel consumption and monthly fuel cost are further calculated using this information and presented in Table 3.3. The monthly cost spent on fuel was calculated using the total distance travelled in a day, 28 days of operation, the fuel consumption per kilometre and the fuel price. The total amount spent on fuel per day was calculated using Equation 2.0.

$$Monthly\ fuel\ cost = 100km \times 28days \times fuel\ consump.rate \times fuel\ price \quad (3.0)$$

**Table 2: $CO_2$ Emission Factor for Various Fuel**

| Fuel type | Kg of $CO_2$ per unit of consumption |
|---|---|
| LNG | 4.46 per US gallon |
| CNG | 0.053 per standard cubic feet |
| Diesel fuel | 10.131 per US gallon |
| Petrol | 8.59873 per US gallon |
| LPG | 6.1 per US gallon |

**Source: [12]**

**Table 3: Fuel Consumption Rate and Cost for 28 days in a Month**

| Fuel Type | Monthly Fuel Consumption (L) | Monthly Fuel Cost (N) | Monthly Fuel Cost ($) |
|---|---|---|---|
| CNG | 280 (scf) | 30,800.00 | 73.33 |
| LPG | 344.4 | 108,761.52 | 258.96 |
| gasoline with subsidy | 403.2 | 66,528.00 | 158.40 |
| gasoline without subsidy | 403.2 | 186,278.40 | 443.52 |

The daily savings from fuel cost was evaluated using the difference in the daily cost of fuels for each fuel type evaluated. Results of the daily cost savings from using natural gas fuels against gasoline are presented in Table 3.4. Further economic analysis was conducted by generating the cash flow data when using the various fuels. The net present value (NPV) which is the measure of profitability of a project was evaluated using the annual fuel cost savings as revenue inflow. The payback period was also calculated using the initial cost of investment (cost of converting the vehicle) and the cost savings on the fuels. The payback period is given as equation 4.0. A sensitivity analysis was conducted to evaluate the influence of fuel cost on the profitability of using these gases as an alternative to premium motor spirit in vehicles. The results of the sensitivity analysis are discussed in the next section.

$$Pay\ back\ period = \frac{cost\ of\ vehicle\ conversion}{cost\ savings\ on\ fuel} \quad (4.0)$$

**Table 4: Daily Cost Savings on Fuel**

| | Daily Fuel Cost savings (N) | | Daily Fuel Cost savings ($) | |
|---|---|---|---|---|
| | Gasoline with subsidy | Gasoline without subsidy | Gasoline with subsidy | Gasoline without subsidy |
| CNG | 1,276.00 | 5,552.80 | 3.03 | 13.22 |
| LPG | -1,508.34 | 2,768.46 | -3.59 | 6.59 |

## 3.0 Results and Discussion

### 3.1 Fuel Consumption Evaluation

The monthly fuel consumption for the various fuel types was evaluated for the assumed distance of 100km daily for 28 days in a month. The fuel economy factor for the various fuel types was adopted from relevant publications. Figure 11.0 shows the monthly fuel consumption per kilometre when the various fuels are used on a vehicle driving 100km daily for 28 days. Gasoline has the highest monthly fuel consumption rate with a total monthly consumption of 403.2 litres. This is followed by LPG with monthly fuel consumption of 344.4litres and CNG with a consumption rate of 280scf. Studies have shown that when driving at an average speed of 100km/hr, gasoline consumed more energy than LPG. This is attributed to the gas properties having the rate of flame speed faster than gasoline. Report shows that the use of CNG resulted in a remarkable lower fuel consummption compared to gasoline[34]. The reason for this is explained by the high heating value of CNG when compared to gasoline (12% higher). This high heating value allows it to produce an almost equivalent but lesser output power. As such, CNG consumes less energy per unit power produced compared to gasoline under the same engine operations. CNG has also been found to offer better mileage when compared to gasoline for mid-size passenger cars [11].

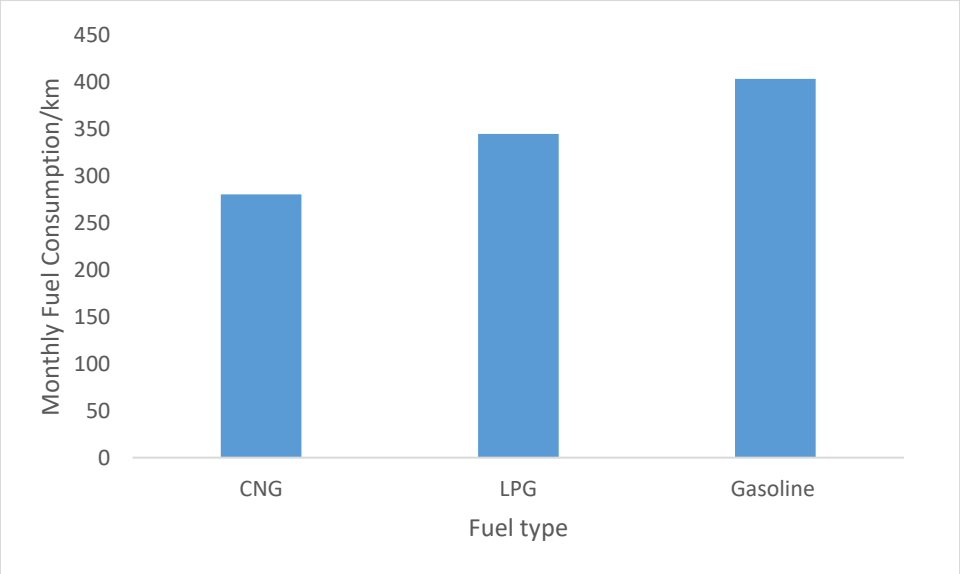


**Figure 8.0: Monthly Fuel Consumption**

### 3.2 $CO_2$ Emission Determination

Using the $CO_2$ emission factor provided by the Intergovernmental Panel on Climate Change (IPCC) as shown in Table 3.2, the annual $CO_2$ emission for the various fuels was calculated and presented as Figure 12.0. The average annual $CO_2$ emission from a typical vehicle is 4,600kg per year (Environmental Protection Agency, 2018). From this study, gasoline has a higher $CO_2$ emission relative to the gas fuels with CNG having the least annual emission of 178.08kg of $CO_2$ per scf of CNG. Studies have shown the $CO_2$ emissions from natural gas fuels to be consideraly lower than the emissions from gasoline, (5% reduction in this study) (Koay *et al.*, 2019). Conventionally, natural gas fuels have lower $CO_2$ emissions (6% - 11% lower) when compared to gasoline[27].

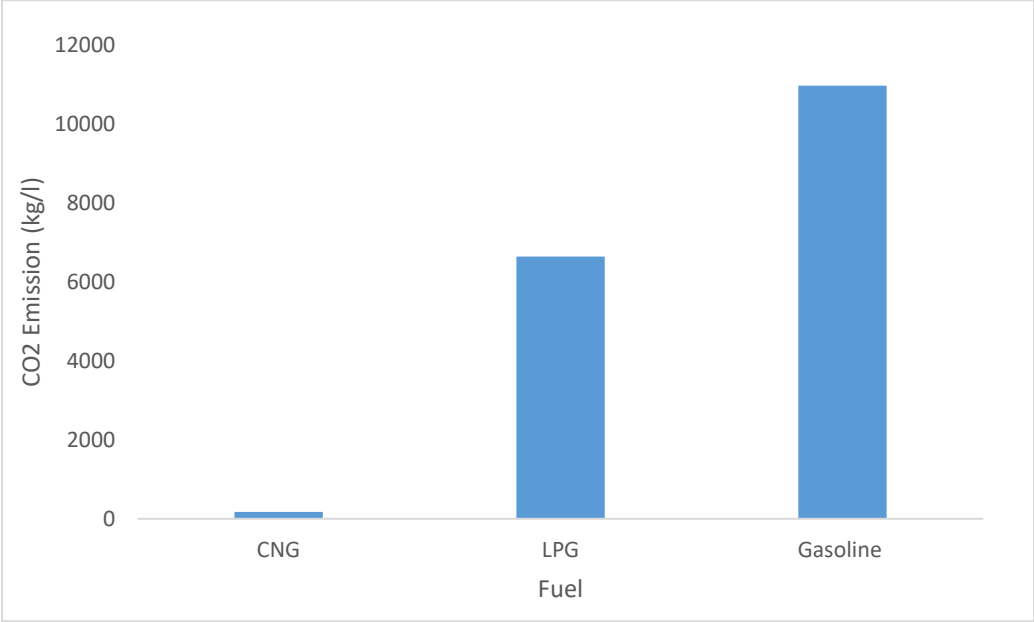


**Figure 9.0: Annual $CO_2$ Emission**

### 3.3 Cost Savings on Fuels

The monthly fuel cost savings for each natural gas fuel against gasoline were calculated as presented in Figure 13.0. Results showed relatively higher cost savings when CNG and LPG are used as alternatives to unsubsidized gasoline fuel. As high as N155,478.40 could be saved on fuel costs in a month from using compressed natural gas over unsubsidized gasoline. This is directly caused by the relatively lower cost of CNG to other fuel types. Over the years, the price of liquid petroleum fuels has always been higher than the price of natural gas fuels around the world [32], [3]. From the results, it can be observed that LPG fuel had a better fuel cost savings when used as an alternative to unsubsidized gasoline in Nigeria.

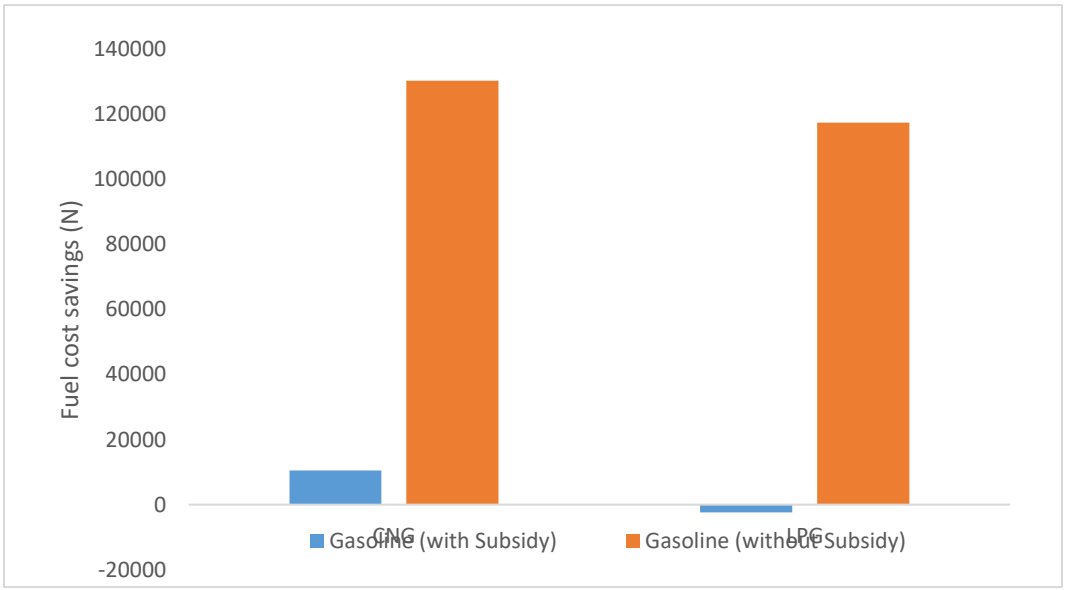


**Figure 10.0: Monthly fuel Cost Savings**

### 3.4 Economic Analysis (Cash flow and payback period)

The cost savings from CNG fuel (at CNG price of N110/scf and gasoline price of N165/ltr) was used as the revenue inflow to generate the cash flow presented in Table 4.1. Considering the initial cost of converting the vehicle as the capital expenditure (CAPEX) the cumulative cash flows were generated and the payback time was calculated. The payback time is the time at which the initial cost of investment will be recovered from the cost savings on fuels. The payback period for using CNG as an alternative was approximately 7 months. This implies that the cost savings from using CNG fuel as an alternative to gasoline would be enough to recover the initial cost of converting the vehicle to CNG-driven in about 7 months. The NPV which is a core element of economic analysis as it indicates the profitability of a project was evaluated at 5% and 10% discount rate. The NPVs obtained from the fuel cost savings of using CNG as an alternative fuel were both positive values; N729,425.91 and N532,756.12 for 5% and 10% respectively. At the price of N315.80/litre of LPG and N165/litre of gasoline used in this study, the NPV on using LPG as an alternative to gasoline is negative because there are no cost savings on using LPG at that price. Positive values of NPV signifies that a project is viable and worth investing in. The payback time for CNG from this study is in range with data from published literature taking into cognizance the year of publication and change in the price of fuels [35].

**Table 5: Monthly Cash Flow from fuel Cost Savings of CNG over Gasoline**

| Month | **C**ash Flow (NGN) | **C**ash Flow (USD) | Cumulative C**ash** F**low** (NGN) | Cumulative **C**ash Flow (USD) |
|---|---|---|---|---|
| 0 | (250,000.00) | (595.24) | | |
| 1 | 35,728.00 | 85.07 | (214,272.00) | (510.17) |
| 2 | 35,728.00 | 85.07 | (178,544.00) | (425.10) |
| 3 | 35,728.00 | 85.07 | (142,816.00) | (340.04) |
| 4 | 35,728.00 | 85.07 | (107,088.00) | (254.97) |
| 5 | 35,728.00 | 85.07 | (71,360.00) | (169.90) |
| 6 | 35,728.00 | 85.07 | (35,632.00) | (84.84) |
| 7 | 35,728.00 | 85.07 | 96.00 | 0.23 |
| 8 | 35,728.00 | 85.07 | 35,824.00 | 85.30 |
| 9 | 35,728.00 | 85.07 | 71,552.00 | 170.36 |
| 10 | 35,728.00 | 85.07 | 107,280.00 | 255.43 |
| 11 | 35,728.00 | 85.07 | 143,008.00 | 340.50 |
| 12 | 35,728.00 | 85.07 | 178,736.00 | 425.56 |

### 3.5 Sensitivity Analysis

A sensitivity analysis was conducted on the price of gas fuels. A general fixed price was considered for both gas fuels. The cost savings on using these natural gas fuels at a gas price of N50, N100, N150 and N200 was evaluated. The resulting NPV from the various price scenario was evaluated. Figure 14.0 and 15.0 shows the sensitivity analysis results reflecting the effect of gas price on the economics of using natural gas fuels. The influence of gas price on the fuel cost saving is shown in Figure 14.0. It can be observed that significant cost savings were recorded for CNG for all price scenarios up to N200/scf. However, LPG was observed to only record significant cost savings at gas prices up to N150 as no cost savings were recorded at gas price of N200. The gas price

sensitivity analysis was extended to the NPV as well. Figure 15.0 reflects the effect of gas prices on the net present value of investing in CNG and LPG as alternative fuels to gasoline. Both CNG and LPG recorded positive values of NPV for gas prices between N50 and N150 indicating that an investment in these gases as alternative to gasoline would be profitable if gas prices were maintained within these price range. Negative NPV values were observed for LPG at gas price of N200 explaining that an investment in the use of LPG at a gas price of N200 would not be viable and reasonable. Considering that more volume of natural gas fuels is required to travel the same distance compared to the equivalent volume of gasoline due to the difference in their energy equivalent, the continuous use of the natural gas fuels would not be favourable to an average vehicle owner at higher gas prices. Studies had earlier confirmed that an investment in gas fuel was very sensitive to fuel prices[31].

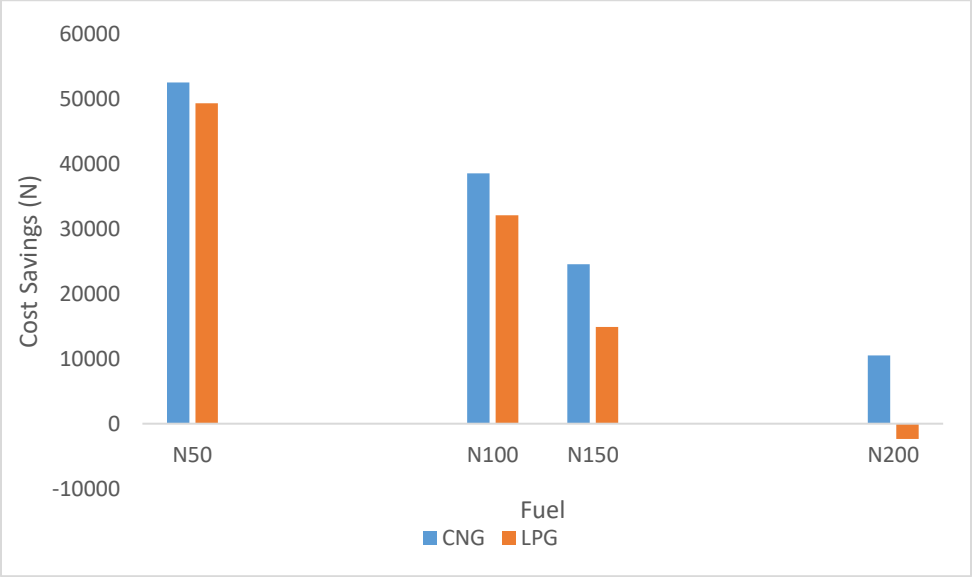


**Figure 11.0: Sensitivity of Fuel Cost Savings to Natural Gas Price**

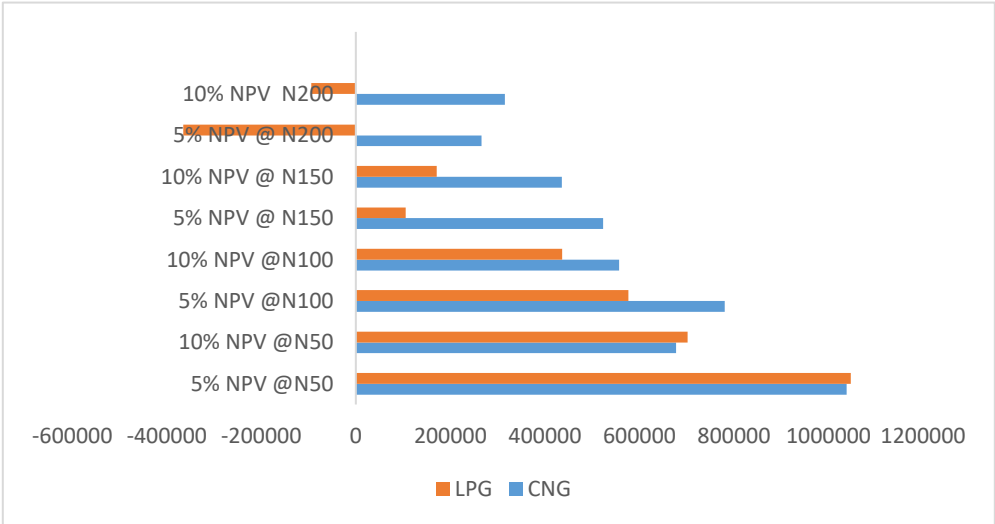


**Figure 12.0: Sensitivity Analysis of NPV to Natural Gas Prices**

## 4.0 Conclusion and Recommendations

This study examined the technical and economic aspects of using CNG, LPG and LNG as alternatives to AGO and PMS in vehicles in Nigeria. The annual CO2 emission from each fuel type was evaluated, the fuel cost savings was calculated and the influence of gas price on the economics of using these gas fuels was also analysed. Results of this study have shown that despite the high initial conversion cost, the use of these gases presents great benefits to the country:

i. The use of natural gas fuels as alternative to gasoline significantly reduces the annual $CO_2$ emissions and would present Nigeria with a chance to reduce environmental pollution.
ii. Adopting natural gas fuels as an alternative to gasoline would offer huge fuel cost savings to vehicle owners enough to recover the initial cost of vehicle conversion within the first few years of operation. However, to achieve this the gas price must be kept lower than the gasoline price.
iii. Following the economic analysis, NPV have shown that investment in natural gas fuels is viable and profitable as long as the gas prices are maintained below the gasoline price.
iv. This study recommends an optimum gas price set at N150. From the sensitivity analysis, investment in natural gas fuel was profitable (with positive NPV) at gas price of N150 and this price is considered not too low as it is above the current price of CNG in the country.

This study has shown that the present price of CNG (N110 per scf) is reasonable to encourage investment in natural gas fuel vehicles. The current price of LPG is the country is observed to be higher than the current price of gasoline making it not profitable to invest in LPG fuel vehicles. The Nigerian government has made efforts to promote the use of natural gas fuel vehicles in the country, however, this has not been quite successful as this initiative met a corresponding rise in vehicle conversion cost and gas price especially for LPG. It is believed that a deregulation of the sector, encouraging major private players like Dangote, Innoson, etc. to get involved in the business of vehicle conversion would create competition and drive the cost of converting a vehicle from gasoline driven to natural gas driven to an affordable rate for an average Nigerian. Furthermore, it is expected that the initiative of the government to increase participation in flare gas utilization through the ongoing flare gas commercialization programme will increase the gas supply in the country which will have an effect on the gas price to favour investment in natural gas vehicles. Conclusively, a reduced cost vehicle conversion and gas price will translate to an increase in the number of natural gas vehicles in the country. Affordable vehicle fuel cost will mean affordable transportation cost, cost savings and a resulting improvement in the standard of living in the country.

This study has been able to comparatively evaluate and present the economics of using two forms of natural gas fuels (CNG and LPG) as an alternative to gasoline. Previous studies were only able to provide analysis on one form of natural gas fuel either CNG or LPG. The outcome of this study will not just save as an important reference material for further research, it will also reiterate the environmental benefits derived from using natural gas fuels, it will act as a guide/resource material to the government and policy makers in fixing natural gas prices that will favour investment in

natural gas vehicles and further reveals the need by the oil and gas industry to increase investment in gas utilization to provide for the upcoming natural gas vehicle market in Nigeria.

## References

[1] Aaron, O., 2022. Urbanization in Nigeria 2021, Hamburg: Statistica.
[2] Abdullah, N. N. and Govand, A. 2021. An Empirical Analysis of Natural Gas as an Alternative Fuel for Internal Transportation. *International Journal of English Literature and Social Sciences,* 6(1), pp. 479- 485 DOI: https://dx.doi.org/10.22161/ijels.61.64.
[3] Adegoriola, A. E. and Suleiman, I. M. 2020. Adopting Gas Automobile Fuels (LPG and CNG) into the Nigerian Transportation System. *Journal of Economics and Sustainable Development,* 10(14), pp. 12-19.
[4] Anyadiegwu, C., Ohia, N. and Muonagor, C. 2017. Economic Analysis of Utilizing Compressed Natural Gas (CNG) as Vehicular Fuel in Nigeria. *Recent advances in Petrochemical Science,* 3(4), pp. 78 - 84 DOI: 10.19080/RAPSCI.2017.03.555618.
[5] Deri, J. D. 2016. *CNG Economic Analysis for the Fulfillment Of Peak Loads in the Jambi Region of the Country,* Jakarta: Universitas Indonesia.
[6] Emeka, N. O., Chike, O. and Nwabueze, E. 2018. Technological and Economic Evaluation of Conversion of Potential. *Procedia Manufacturing,* Vol. 17, pp. 444-451. doi:https://doi.org/10.1016/j.promfg.2018.07.296.
[7] Elgas 2021. LPG Conversion MPG – LPG Fuel Economy – LPG Average Mileage. Elgas Ltd.https://www.elgas.com.au/autogas-lpg-cars/fuel-cost-savings-autogas-lpg-cars/ Accessed: 29-10-2022
[8] Environmental Protection Agency 2018. *Greenhouse Gas Emissions from a Typical Passenger vehicle,* Washington DC: United States Environmental Protection Agency.
[9] Igbojionu, A., Anyadiegwua, C., Anyanwub, E., Obah, B., and Muonagor, C. 2019. Technical and economic evaluation of the use of CNG as potential public transport fuel in Nigeria. *Scientific African* , 6(2019), https://doi.org/10.1016/j.sciaf.2019.e00212.
[10] Ikechukwu, O. I. and Joshua, O. I., 2020. Implementation of CNG as an Alternative Fuel for Automobiles in Nigeria: Benefits and Recommendations. *International Journal of Engineering Research and Technology,* 9(07), pp. 1516-1522.
[11] HT Auto Desk. 2021. Is CNG the right fuel for your car? Decoding the Dilemma. https://auto.hindustantimes.com/auto/cars/is-cng-the-right-fuel-for-your-car-decoding-the-dilemma-41635143558751.html Accessed: 29-10-2022.
[12] Intergovernmental Panel on Climate Change, 2006. *Guidelines for National Greenhouse Gas Inventories,* Volume 2. Hayama, Kanagawa: Institute for Global Environmental Strategies (IGES).
[13] International Association for Natural Gas Vehicles, 2010. *Natural gas vehicle statistics: NGV count - ranked numerically as at December 2009. US:* International Association for Natural Gas Vehicles.
[14] International Energy Agency, 2017. *The Future of Trucks: Implications for Energy and the Environment,* Paris: IEA, doi:10.1787/9789264279452-en.
[15] International Renewable Energy Agency, 2018. *Global energy transformation. A roadmap to 2050,* Abu Dhabi: International Energy Agency.
[16] International Renewable Energy Agency, 2018. *Renewable energy policy network for the 21st century. Renewable energy policies in a time of transition,* Paris: International Energy Agency.
[17] Ismaila, S., Bolaji, B., Adetunji, O., AdekunlE, N., Yusuf, T., and Sanusi, H. 2013. On Vehicular Emissions of Petrol and Diesel Engines. *Annals of Faculty Engineering Hunedoara- international Journal of Engineering,* 11(3), pp. 177-180.
[18] Jean-Paul, R., 2020. *The Geography of Transport Systems.* Fifth edition New York, USA: Hofstra University. doi.org/10.4324/9780429346323.
[19] Jhawar, P. S. 2022. *Natural gas (CNG) vs. LPG, LNG, RNG and Diesel,* Cummins. https://www.cummins.com/news/2022/05/05/natural-gas-cng-vs-lpg-lng-rng-and-diesel Accessed: 18/10/2022
[20] Koay, L. K., Sah, M. J. and Bin othman, R. 2019. Comperative Study of Fuel Consumption, Acceleration and Emission for Road Vehicle Using LPG or Gasoline. *Advanced Structred Materials,* Vol. 102, pp. DOI: https://doi.org/10.1007/978-3-030-05621-6_6.
[21] Mohabbat, Z., Vahid, P. and Hossein, S. 2017. Technical characterization and economic evaluation of recovery of flare gas in various gas-processing plants. *Energy,* Vol.124, pp. 481-491. doi:https://doi.org/10.1016/j.energy.2017.02.084.

[22] Monday, U. V. 2011. *The role of gas engineer in actualizing vision 2020,* Port Hacourt:
[23] Morgan, T. 2017. *Autogas Incentive Policies: A Country-By-Country Analysis of Why and How Governments,* Brussels, Belgium: European LPG Association.
[24] National Bureau of Statistics. 2018. *Road Transport Data,* Abuja, Nigeria: National Bureau of Statistics.
[25] Navas-Anguita, Z., García-Gusano, D. and Iribarren, D. 2019. A review of techno-economic data for road transportation fuels. *Renewable and Sustainable Energy Reviews,* Issue 112, pp. 11–26.
[26] NGV Global, 2019. NGV Statistics Updated. David Perry. Washington DC: International Association of Natural Gas Vehicles. https://www.iangv.org/2016/12/ngv-statistics-updated/
[27] NGVAmerica, 2021. *Fleets Run Cleaner on Natural Gas: Emissions and Environmental Benefits of Natural Gas Vehicles,* Washington DC: Natural Gas Vehicles for America.
[28] Ogunlowo, O., Bristow, A. and Sohail, M. 2015. Developing compressed natural gas as an automotive fuel in Nigeria: Lessons frominternationalmarkets. *Energy Policy,* Volume 76, p. 7–17 http://dx.doi.org/10.1016/j.enpol.2014.10.025.
[29] Ogunlowo, O., Sohail, M. and Bristow, A. 2018. Stakeholder consensus on the use of compressed natural gas as automotive fuel in Nigeria. *Case Studies on Transport Policy,* Vol. 6, pp. 613–628 DOI: https://doi.org/10.1016/j.cstp.2018.07.011.
[30] Raslavičius, L., Keršys, A., Mockus, S., Keršiene, N., and Starevičius, M. 2014. Liquefied petroleum gas (LPG) as a medium-term option in the transition to sustainable fuels and transport. *Renewable and Sustainable Energy Reviews,* 32(c), pp. 513-525.
[31] Setiyo, M., Soeparman, S., Hamidi, N. and Wahyudi, S., 2016. Techno-economic Analysis of Liquid Petroleum Gas Fueled Vehicles as Public Transportation in Indonesia. *International Journal of Energy Economics and Policy,* 6(3), pp. 495-500.
[32] Smajla, I., Daria, K., Branko, D. and Lucija, J. 2019. Fuel Switch to LNG in Heavy Truck Traffic. *Energies,* 12(515), p. doi:10.3390/en12030515.
[33] Srinivasan, V., Francis Luther King, M. and Purushothaman, T., 2014. Alternate Fuel - A Literature Review. *Middle-East Journal of Scientific Research* , 22(2), pp. 205-209.
[34] Tabar, A. R., Hamidi, A. A. and Ghadamian, H. 2017. Experimental investigation of CNG and gasoline fuels combination on a 1.7 L bi-fuel turbocharged engine. International Journal of Energy Environ Eng, Volume 8, pp. 37–45 https://doi.org/10.1007/s40095-016-0223-3.
[35] Ubani, E. C. and Ikpaisong, S. U. 2018. Use of CNG as Autofuel in Nigeria. *European Journal of Engineering Research and Science,* 3(10), pp. 66-69 DOI: http://dx.doi.org/10.24018/ejers.2018.3.10.668.
[36] United Nations 2022. *Nigeria Population Growth Rate 1950-2022 | MacroTrends,* https://www.macrotrends.net/countries/NGA/nigeria/population-growth-rate: United Nations-World Population Prospects.
[37] US Department of Energy, 2013. *Case Study – Liquefied Natural Gas,* Chicago: Argonne National Laboratory.
[38] Wilson, N., Maher, A., Thomson, G. and Keall, M. 2008. Vehicle emissions and consumer information in car advertisement. *Environmental Health,* 7(14).
[39] World Bank, 2022. *2022 Global Gas Flaring Tracker Report,* Washington, DC: Global Gas Flaring Reduction Partnership.
[40] World Bank, 2022. Nigeria Urban Population 1960-2022. https://www.macrotrends.net/countries/NGA/nigeria/urban-population Retrieved 2022-10-29.
[41] Yeh, S. 2007. An empirical analysis on the adoption of alternative fuel vehicles: The case of natural gas vehicles. *Energy Policy,* Vol. 35, p. 5865–5875 doi:10.1016/j.enpol.2007.06.012.