**Compressed Natural Gas Utilization in Nigeria’s Transport Sector: Fuel Balance, Economics, and Environmental Considerations**

**ABSTRACT**

This study presents critical insights into the potential of Compressed Natural Gas (CNG) as a cleaner and more sustainable alternative to conventional fuel (Petrol). Key findings indicate that transitioning to CNG could significantly reduce Nigeria's heavy reliance on imported Petrol, which currently stands at an average consumption of 50 million litres daily. This shift promises substantial economic savings—potentially around #17.791 trillion in annual consumption. It also offers a remarkable reduction in carbon emissions of 30.66 billion kg CO2/year per year, with projections suggesting a decrease of approximately 73% in daily CO2 emissions from the transportation sector. The emphasis on the environmental benefits of CNG should make stakeholders feel responsible and committed to the cause of sustainability.

Keywords: Compressed natural gas (CNG), Energy Policy, Fuel consumption, Greenhouse gas emissions

**1.0 INTRODUCTION**

It is a fact that energy is critical to modern life. Energy access is recognized as a science and technology (S&T) indicator of national economic development. Different sectors of the economy consume energy at different rates and quantities, with the identified leading consumers including the agricultural, industrial, transport and residential sectors. Leading energy sources include fossil fuels (oil and gas, coal, natural gas) and renewable sources (solar, wind, hydropower and geothermal).

In Nigeria, energy plays a critical role in national development, with the leading energy-consuming economic sectors also being agricultural, industrial, transport and residential sectors. Available energy resources in Nigeria are fossil fuels (coal, crude oil and natural gas), biomass and renewable sources (hydro, wind and solar) (Jack *et al.,* 2018; Ekeocha *et al.*, 2020). Nigeria has been described as a country luxuriant in energy resources but indigent in energy commodities. The challenges in the energy sector include the high cost of utility, inadequate policy measures and ineffectual legal/regulatory procedures, limited infrastructure and technological capabilities, poor financial and economic structures, weak management, etc. (Bala, 2014; Oni & Adeyemo, 2016; Jack *et al.,* 2018).

Fossil fuels are the primary source of energy in the various sectors of Nigeria's economy and, at the moment, practically the sole source for the transport sector. Nigeria's daily consumption of 50 million litres of Petrol is almost exclusively consumed by the transport sector (NMDPRA, 2023). Concerns accompany this energy consumption on its availability and accessibility, affordability, and environmental consequences. Public policy efforts by Nigeria to address the concerns of energy usage, especially in its transport sector, have recently included measures such as the development of alternative energy options such as biofuel and compressed natural gas (CNG) initiatives. These energy options are perceived as critical to the national aspirations for energy that is available, accessible, affordable, adequate, and eco-friendly.

Natural gas is an odourless, colourless fossil gas consisting primarily (90% or more) of methane. Besides being a combustible, abundant, versatile, low-cost, efficient energy source, it is the cleanest conventional fuel, producing lower greenhouse gas emissions than oil and coal. Natural gas was formed from decomposing organic matter (plant and animal remains) under anaerobic conditions, compacted by extreme underground heat and pressure over millions of years. It is known as compressed natural gas (CNG) when compressed into less than 1% of its volume at standard atmospheric pressure (Igbojionu *et al.,* 2019). CNG is primarily used for transportation instead of Petrol, diesel, and liquefied petroleum gas (LPG) by modifying traditional petrol/internal combustion engines. It is stored and distributed in cylindrical or spherical rigid containers at a pressure of 20-25 megapascals (2,900–3,600 psi; 200–250 atm).

Since the removal of fuel subsidies in June 2023, the price of Petrol has increased astronomically from about N 200 in May 2023 to over N 1100 today, leading to heightened transportation costs and significant pressure on the domestic economy and national development (Usigbe, 2023). Nigeria relies heavily on road transportation to move goods and services in the economy. Consequently, the utilization of CNG as transport fuel was argued as a cost-effective alternative with other substantial economic and environmental benefits such as energy security and job creation opportunities, as well as harmful emissions and pollutants reduction (Akinpelu *et al.,* 2019; Ogunleye *et al.,* 2020; Anderson, 2023). The potential of CNG to reduce fuel costs should make policymakers feel reassured and confident in its economic viability.

Nigerian policy measures to promote domestic CNG utilization include enacting the Petroleum Industry Act (PIA), the National Gas Expansion Programme (NGEP) and the Presidential Initiative on CNG (Pi-CNG), entailing functional incentives such as stimulating investments in the gas, infrastructure development (CNG refuelling stations and conversion centres), publicity on CNG advantages, and regulatory reforms for CNG industry growth (Usigbe, 2023). These efforts recognize the growing market potentials of the extant vast national natural gas proven reserves of about 206.53 trillion cubic feet (TCF) located onshore and offshore with a concentration in the Niger Delta region (Lawal & Adeoye, 2022; NMDPRA, 2023). Countries like India and Brazil have successfully implemented CNG technology to reduce fuel costs and environmental pollution (Ugolo *et al.,* 2024).

Despite the domestic CNG industry's potential, premised on the increasing national population, rapid urbanization, the rising middle class, and increased household incomes, a critical limiting factor to its national deployment is the inadequate public understanding of the strategic benefits of CNG industry development, including operational efficiency, cost reduction, environmental sustainability, and expanded market share.

This makes it imperative to provide a strategic assessment of the industry via a robust science policy analysis as critical policy intelligence for CNG sector policy development in Nigeria. The specifics of this policy intelligence entailed determining the equivalent CNG substitution for petrol utilization in the national transport sector and analyzing the financial cost and environmental viability of CNG utilization in the country.

**2.0 METHODOLOGY**

The study utilized an energy technology foresight framework based on strategic analysis for robust evidence-based decision-making. This framework is not for enabling the prediction of the future but rather is the process of creating the future desired (Yim, N. D). Its methods are qualitative (expert panels and genius forecasting), semi-quantitative (Delphi techniques and system/structural analysis) and quantitative (extrapolation, indicators, and modelling simulation), deployed individually or interactively (Yim, N. D).

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Achieving the first objective (determining the CNG equivalence to national transport petrol utilization) entailed obtaining data on total national petrol consumption per annum from the Nigerian Midstream and Downstream Petroleum Regulatory Authority (NMDPRA), petrol-to-CNG conversion factors from the International Energy Agency (IEA). The national population estimates were also obtained from the National Bureau of Statistics, while extant petrol consumption per capita was obtained from a research article. A ten-year projection model was developed from these data.

Achieving the second objective (analyzing the financial cost viabilities of CNG utilization) entailed obtaining the prices of Petrol and CNG from energy retail outlets in the country. The data obtained were projected over a 10-year timeframe and analyzed using appropriate engineering economics methods.

Achieving the third objective (analyzing the environmental viabilities of CNG utilization) entailed estimating carbon dioxide emissions from Petrol and CNG using appropriate conversion factors obtained from the International Energy Agency (IEA) and analyzing the data over the study period using material balance analysis.

**3.0 RESULTS AND DISCUSSION**

**3.1 DETERMINING THE COMPRESSED NATURAL GAS (CNG) EQUIVALENCE TO NATIONAL**

 **TRANSPORT PETROL UTILIZATION**

Estimated petrol consumption in Nigeria from 2024 to 2034 is 18.25 – 23.13 billion litres/year, estimated at 226.65 Billion Litres (Table 1). In replacing this petrol consumption with CNG, it was determined that the equivalent CNG demand would be 12.41 – 15.73 Megatonnes/year with a total estimation of 154.52 Megatonnes. This amount is highly minute compared to the proven reserves in Nigeria, estimated at 206 trillion cubic feet (14,038,900,000,000,000 kg or 14.039 Quadrillion kg or 14.039 trillion tonnes or 14,039 gigatonnes). Nigeria’s proven reserves are 90,855 times the estimated CNG consumption over the 10 years. This is a clear indicator of how huge the proven reserves are.

The conversion from Petrol to CNG fuel is expected to create substantial financial savings for Nigerians over the next 10 years, as shown in this study (See Table .2). With total petrol costs at N 251.58 trillion and CNG costs at N 35.45 Trillion, the estimated fuel savings were N 216 trillion over the study's period. This is a considerable savings in fuel costs. The Table shows that total petrol costs were seven times the total costs for CNG.

**Table 1: ESTIMATED ANNUAL PETROL AND CNG DEMAND IN NIGERIA**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Population****(Mil)** | **Annual Petrol Demand/capita (Litres)** | **Annual Petrol Demand** **(Bil Litres)** | **Potential Annual CNG Demand****(Megatonnes)** |
| **2024** | 232.68 | 78.43 | 18.25 | 12.41 |
| **2025** | 238.26 | 78.43 | 18.69 | 12.71 |
| **2026** | 243.98 | 78.43 | 19.14 | 13.01 |
| **2027** | 249.84 | 78.43 | 19.59 | 13.32 |
| **2028** | 255.83 | 78.43 | 20.07 | 13.64 |
| **2029** | 261.97 | 78.43 | 20.55 | 13.97 |
| **2030** | 268.26 | 78.43 | 21.04 | 14.31 |
| **2031** | 274.70 | 78.43 | 21.54 | 14.65 |
| **2032** | 281.29 | 78.43 | 22.06 | 15.00 |
| **2033** | 288.04 | 78.43 | 22.59 | 15.36 |
| **2034** | 294.96 | 78.43 | 23.13 | 15.73 |
| **TOTAL** | **226.65** | **154.12** |

**3.2 Analyzing the Financial Cost Viabilities of the Compressed Natural Gas (CNG)**

 **Utilization**

**Table 2: THE ESTIMATED FINANCIAL COST VIABILITY OF THE CNG UTILIZATION**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Population (Mil)** | **Annual Petrol Demand/capita (litres)** | **Annual Petrol Demand** **(Bil Litres)** | **Potential Annual CNG Demand****Megatonnes)** | **Petrol Costs (Tril ~~N~~)** | **CNG Costs (Tril ~~N~~)** | **Cost Savings (Tril ~~N~~)** |
| **2024** | 232.68 | 78.43 | 18.25 | 12.41 | 20.26 | 2.85 | 17.40 |
| **2025** | 238.26 | 78.43 | 18.69 | 12.71 | 20.74 | 2.92 | 17.82 |
| **2026** | 243.98 | 78.43 | 19.14 | 13.01 | 21.24 | 2.99 | 18.25 |
| **2027** | 249.84 | 78.43 | 19.59 | 13.32 | 21.75 | 3.06 | 18.69 |
| **2028** | 255.83 | 78.43 | 20.07 | 13.64 | 22.27 | 3.14 | 19.13 |
| **2029** | 261.97 | 78.43 | 20.55 | 13.97 | 22.81 | 3.21 | 19.59 |
| **2030** | 268.26 | 78.43 | 21.04 | 14.31 | 23.35 | 3.29 | 20.06 |
| **2031** | 274.70 | 78.43 | 21.54 | 14.65 | 23.91 | 3.37 | 20.55 |
| **2032** | 281.29 | 78.43 | 22.06 | 15.00 | 24.49 | 3.45 | 21.04 |
| **2033** | 288.04 | 78.43 | 22.59 | 15.36 | 25.08 | 3.53 | 21.54 |
| **2034** | 294.96 | 78.43 | 23.13 | 15.73 | 25.68 | 3.62 | 22.06 |
| **TOTAL** | **226.65** | **154.12** | **251.58** | **35.45** | **216.13** |

Using CNG instead of Petrol was also expected to have significant environmental benefits. Table 3 shows that total CO2 emissions using Petrol would be 521—29 million tonnes, while CNG would produce 423.83 million tonnes of CO2. Thus, emissions reductions were estimated to be 97.46 million tonnes of CO2, a substantial amount in emissions savings if actualized. This Table shows that CNG utilization as transport fuel was more environmentally advantageous than using Petrol.

**3.3 ANALYZING THE ENVIRONMENTAL LIABILITIES OF THE CNG UTILIZATION**

**Table 3: THE ESTIMATED ENVIRONMENTAL VIABILITY OF THE CNG UTILIZATION**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Population****(Mil)** | **Annual Petrol Demand/capita (Litres)** | **Annual Petrol Demand****(Bil Litres)** | **Potential Annual****CNG Demand****(Mt)** | **Petrol:****CO2 Emissions (Mt)** | **CNG: CO2 Emissions (Mt)** | **CO2 Emissions Savings (Mt)** |
| **2024** | 232.68 | 78.43 | 18.25 | 12.41 | 41.97 | 34.13 | 7.85 |
| **2025** | 238.26 | 78.43 | 18.69 | 12.71 | 42.98 | 34.94 | 8.04 |
| **2026** | 243.98 | 78.43 | 19.14 | 13.01 | 44.01 | 35.78 | 8.23 |
| **2027** | 249.84 | 78.43 | 19.59 | 13.32 | 45.07 | 36.64 | 8.43 |
| **2028** | 255.83 | 78.43 | 20.07 | 13.64 | 46.15 | 37.52 | 8.63 |
| **2029** | 261.97 | 78.43 | 20.55 | 13.97 | 47.26 | 38.42 | 8.84 |
| **2030** | 268.26 | 78.43 | 21.04 | 14.31 | 48.39 | 39.34 | 9.05 |
| **2031** | 274.70 | 78.43 | 21.54 | 14.65 | 49.55 | 40.29 | 9.26 |
| **2032** | 281.29 | 78.43 | 22.06 | 15.00 | 50.74 | 41.26 | 9.49 |
| **2033** | 288.04 | 78.43 | 22.59 | 15.36 | 51.96 | 42.25 | 9.71 |
| **2034** | 294.96 | 78.43 | 23.13 | 15.73 | 53.21 | 43.26 | 9.95 |
| **TOTAL** | **226.65** | **154.12** | **521.29** | **423.83** | **97.46** |

**4.0 CONCLUSION**

This study indicates that using CNG in Nigeria's transportation sector holds immense potential for saving fuel costs, reducing greenhouse gas emissions and increasing energy security. The study provides critical policy intelligence for policymakers in Nigeria's energy sector to increase focus on the CNG alternative to transport fuels. It indicates that CNG could revolutionize the Nigerian transportation sector with the right strategies, leading to a cleaner and more sustainable future.

COMPETING INTERESTS DISCLAIMER:

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

Disclaimer (Artificial intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

**5.0 REFERENCES**

Aba, M. M., Amado, N. B.,   Rodrigues, A. L., Sauer, I. L. & Richardson, A. M. (2023). Energy transition pathways for the Nigerian road transport: Implications for energy carrier, powertrain technology and CO2 emissions, *Sustainable Production and Consumption*, Vol 38, Pp 55–68.

Carim, A. A., and Onyekonwu, M. (2016). Review of gas resource utilization using applicable technologies: A case study of Nigeria. International Journal of Engineering Science, 5(3), 71–78.

Cervigni, R., Rogers, J. A. and Dvorak, I. (2013). Assessing low-carbon development in Nigeria.

Chien, S., Wei, C., & Lee, J. (2022). Global adoption of compressed natural gas (CNG) for passenger and freight transportation: A critical review. *Fuel*, 307, 121861.

Agarwal, A., Yadav, P., & Sahu, M. (2021). Adoption of alternative fuels in developing countries: A case study of CNG in India. *Energy Policy*, 149, 112015.

Anyadiegwu, C. I. C., Ohia, N. P., and Muonagor, C. M. (2017). Economic analysis of utilizing compressed natural gas (CNG) as vehicular fuel in Nigeria. International Journal of Science, 6(9). <https://doi.org/10.18483/ijSci.1405>

Bishop, D., Williams, S., & Li, Z. (2021). Global trends in adopting compressed natural gas vehicles: Policy, infrastructure, and environmental performance. *Energy Policy*, 149, 112073.

Bonaventura, S., Angeli, D., & Monte, E. (2021). Challenges in expanding CNG refuelling infrastructure in urban areas: A global perspective. *Energy Policy*, 149, 112015.

Harmsen, J., Jansma, S., & Dekker, S. (2020). Methane emissions in natural gas supply chains and the role of policy in mitigating leaks from CNG vehicles. *Atmospheric Environment*, 234, 117649.

Idigbe, K. I. (2020). Driving sustainable growth through natural gas assets in Nigeria. *Journal of Emerging Trends in Engineering and Applied Sciences*, 5(2), 140–147.

Idigbe, K. I., & Onwuachi-Iheagwara, P. N. (2018). Optimizing natural gas assets from marginal fields in Nigeria. Journal of Scientific and Multidisciplinary Research, 10(3), 49–64.

Khan, R., Ahmad, I., & Khokhar, S. (2023). Advances in CNG engine technology and vehicle performance: A global perspective. *Journal of Automobile Engineering*, 37(4), 351-366.

Li, Z., Liu, Y., & Zhang, X. (2023). The role of CNG in integrated urban mobility systems: A review of global practices." *Transportation Research Part A: Policy and Practice*, 166, 69-82.

Nair, R., Bhat, A., & Gupta, S. (2021). CNG as a sustainable fuel for urban transport: A global overview and policy recommendations. *Transport Reviews*, 41(2), 168–185.

NNPC. (2018). 2018 Annual Statistical Bulletin. ASB 1st Edition.

Nwaoha, C., & Iyoke, U. J. (2013). A review on natural gas utilization and cutting carbon emissions: How viable is compressed natural gas for road vehicle fuel? *Journal of Energy Technology and Policy*, 3(5), 37–46.

Zhou, Z., Yang, Y., & Shi, J. (2020). Compressed natural gas (CNG) as a sustainable transport fuel: A review of global usage patterns, technology, and regulatory frameworks. *Journal of Cleaner Production*, 275, 123287.

Oluwole, A. F., Joshua, O. H., Oyediran, O., Guttikunda, S., & Asubiojo, O. I. (2019). Prognosis of emission limits and regulations for vehicular emission pollutants in Nigeria. *Energy Policy*, 2, 1–11.

Riyad, A., Saleh, A., & Khorshidi, A. (2022). Economic and environmental impacts of compressed natural gas (CNG) vehicles in transportation: A global case study. *Environmental Science & Technology*, 56(15), 9632–9643.

Sen, P., Sarkar, S., & Ghosh, S. (2021). Assessment of CNG vehicle adoption and the challenges of infrastructure expansion in emerging economies. *Energy Reports*, 7, 526-533.

Ozkaya, S., & Koc, M. (2021). A comprehensive review of compressed natural gas (CNG) as a fuel for transport: Technological and environmental aspects. *Renewable and Sustainable Energy Reviews*, 135, 110300.

Bureau of Transport Statistics (BTS) (2023): Transportation services contributed 6.7% to US GDP in 2022, rising above 6.3% in 2019, [https://www.bts.gov/newsroom/transportation-services-contributed-67-us-gdp-2022-rising-above-63-2019#:~:text=Transportation%20services%20(for%2Dhire%2C, Transportation%20Satellite%20Accounts%20(TSAs)](https://www.bts.gov/newsroom/transportation-services-contributed-67-us-gdp-2022-rising-above-63-2019#:~:text=Transportation%20services%20(for%2Dhire%2C,Transportation%20Satellite%20Accounts%20(TSAs)). Accessed November 5, 2024

Dioha, M. O. & Kumar, A. (2020). Sustainable energy pathways for land transport in Nigeria. Utilities Policy, 64, 101034. <https://doi.org/10.1016/j.jup.2020.101034>

Giwa, S. O., Nwaokocha, C. N., and Odufuwa, B. O. (2017). Mitigating gas flare and emission footprints via implementing natural gas vehicles in Nigeria. *Energy Policy*, 111, 193–203. <https://doi.org/10.1016/j.enpol.2017.09.027>

Gujba, H., Mulugetta, Y., and Azapagic, A. (2013). Passenger transport in Nigeria: Environmental and economic analysis with policy recommendations. *Energy Policy*, 55, 353–361. <https://doi.org/10.1016/j.enpol.2012.12.017>

Igbojionu, A., Anyadiegwu, C., Anyanwu, E., Obah, B., & Muonagor, C. (2019). Technical and economic evaluation of the use of CNG as potential public transport fuel in Nigeria. *Scientific African*, 6, e00212. <https://doi.org/10.1016/j.sciaf.2019.e00212>

Khan, M. I., Yasmin, T., & Shakoor, A. (2015). International experience with compressed natural gas (CNG) as an environmentally friendly fuel. *Energy Systems*, 6(4), 507–531. <https://doi.org/10.1007/s12667-015-0152-x>

Leon, N. (2011). What is the significance of brake thermal efficiency? Engineering.com. http://www.engineering.com/ask@/qactid/2/qaqid/5503.aspx#:~:text=B rake Thermal Efficiency is defined as fuel to mechanical energy.

Nwaoha, C., & Wood, D. A. (2014). A review of the utilization and monetization of Nigeria’s natural gas resources: Current realities. *Journal of Natural Gas Science and Engineering*, 18, 412–432. <https://doi.org/10.1016/j.jngse.2014.03.019>

Odogun, A., and Georgakis, P. (2019). Transport pollution: A research of the Nigerian transport sector. International Journal of Innovative Technology and Exploring Engineering, 8(11S), 492–497. <https://doi.org/10.35940/ijitee.K1083.09811S19>

Odumugbo, C. A. (2010). Natural gas utilization in Nigeria: Challenges and opportunities. *Journal of Natural Gas Science and Engineering*, 2(6), 310–316. <https://doi.org/10.1016/j.jngse.2010.08.004>

Ogunlowo, O. O., Bristow, A. L., & Sohail, M. (2016). Developing compressed natural gas as an automotive fuel in Nigeria: Lessons from international markets. Energy Policy, 76, 7–17. <https://doi.org/10.1016/j.enpol.2014.10.025>

Oxford Business Group (OBG) (2023): Multi-modal transport links to boost Nigeria’s competitiveness,<https://oxfordbusinessgroup.com/reports/nigeria/2022-report/economy/road-to-expansion-a-focus-on-multi-modal-connections-to-improve-efficiency-and-boost-competitiveness-while-relieving-strain-on-existing-systems>

Pasaoglu, G., Honselaar, M., & Thiel, C. (2012). Potential vehicle fleet CO2 reductions and cost implications for various vehicle technology deployment scenarios in Europe. *Energy Policy*, 40, 404–421. <https://doi.org/10.1016/j.enpol.2011.10.025>

PwC (2023): Sustainability in the transport and logistics industry, <https://www.pwc.de/en/sustainability/sustainability-in-the-transport-and-logistics-industry.html> Accessed November 5, 2024

PwC (2019). Assessing the impact of gas flaring on the Nigerian economy. PricewaterhouseCoopers Limited.

Statista.com (2024): Logistics industry worldwide, <https://www.statista.com/topics/5691/logistics-industry-worldwide/#topicOverview>

Stocchetti, A., & Volpato, G. (2010). In the quest for a sustainable motorization: The CNG opportunity. Ca’ Foscari University.

Tradingeconomics.com (2024): Nigeria’s GDP from transport, <https://tradingeconomics.com/nigeria/gdp-from-transport>

Ubani, C., & Ikpaisong, U. (2018). Use of CNG as auto fuel in Nigeria. European Journal of Engineering Research and Science, 3(10), 66–69. <https://doi.org/10.24018/ejers.2018.3.10.668>

Wang, Y., Li, H., & Zhang, Y. (2020). Environmental impacts of CNG in urban public transport: A global case study of CNG bus fleets. *Transportation Research Part D: Transport and Environment*, 79, 102251.

NIPCO Gas Expands Footprint In CNG Business Across Nigeria. <https://leadership.ng/nipco-gas-expands-footprint-in-cng-business-across-nigeria/>

Khan MI, Yasmin T, Shakoor A. Technical overview of compressed natural gas (CNG) as a transportation fuel. Renewable and Sustainable Energy Reviews. 2015 Nov 1;51:785-97.