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Bridging the Fuel Divide: A Comparative Economic and Environmental Analysis of Compressed Natural Gas and Automotive Gas Oil for Sustainable Transportation in Nigeria

ADAOBI STEPHENIE NWOSI-ANELE[1], KAINE BENE CHINWAH[2]
[1]*Department of Petroleum Engineering, Rivers State University, Port Harcourt, Rivers State, Nigeria*
[2]*Department of Chemical/Petrochemical, Rivers State University, Port Harcourt, Rivers State, Nigeria*

Abstract- This study presents a comparative economic and environmental analysis of Compressed Natural Gas (CNG) and Automotive Gas Oil (AGO) as transport fuels in Nigeria. The research combined quantitative modelling of vehicle fuel costs, lifecycle greenhouse gas (GHG) emissions, and total cost of ownership (TCO) with scenario sensitivity analysis, supported by qualitative insights on adoption barriers and stakeholder perspectives. The results indicate that CNG offers substantial economic advantages, with per-kilometer fuel costs 65–80% lower than AGO under current Nigerian price conditions and payback periods on conversion investments typically within one to two years. Environmentally, CNG reduces direct combustion CO_2 emissions by approximately 36% per 100 km and significantly lowers NO_x, SO_2, and particulate matter, yielding major air quality and health co-benefits in urban centers. The study also highlights macroeconomic and social benefits, including reduced dependence on imported refined products, foreign exchange savings, job creation in local industries, and improved public health outcomes. Nonetheless, risks related to infrastructure deficits, policy uncertainty, methane management, and public perception must be mitigated through robust regulation, blended financing, and phased deployment strategies. Overall, CNG represents a pragmatic transition fuel for Nigeria, capable of enhancing energy security and sustainability while delivering immediate cost and health benefits, provided upstream emissions and infrastructural challenges are addressed.

Keywords- Economic Analysis; Energy Transition; Natural Gas; Sustainable Transportation

I. INTRODUCTION

Energy remains one of the most fundamental enablers of economic prosperity. Historically, countries within the Organization for Economic Co-operation and Development (OECD) have sustained high levels of industrialization and economic development in part because of stable access to affordable energy resources [1]. Conversely, many developing economies have struggled with unreliable or expensive energy supplies, limiting their potential for industrial expansion, agricultural modernization, and efficient transportation. Reliable energy access is not only an economic catalyst but also a prerequisite for achieving multiple Sustainable Development Goals (SDGs), particularly those relating to poverty reduction, health, and climate action.

Globally, the bulk of energy demand is concentrated in industry, residential, commercial buildings, and transportation, which together account for more than 85% of total energy use [2]. Within this mix, transportation is especially significant. It consumes close to 28% of global final energy, with road vehicles responsible for the majority of this share. The sector also accounts for nearly one-quarter of energy-related carbon dioxide (CO_2) emissions, positioning it at the center of climate change debates [1].The reliance of transport on petroleum-based fuels such as Automotive Gas Oil (AGO, or diesel), has persisted for decades due to their high energy density, ease of transport, and well-established distribution networks.
However, the cumulative environmental and economic consequences of their dominance are increasingly evident. Combustion of these fuels generates significant amounts of CO_2, nitrogen oxides (NO_x), sulfur dioxide (SO_2), carbon monoxide (CO), and fine particulate matter ($PM_{2.5}$). These emissions contribute not only to global warming but also to worsening urban air quality and higher incidences of respiratory and cardiovascular diseases [3]. In addition, the volatility of international oil markets

makes petroleum fuels subject to frequent price swings, creating fiscal and social instability in economies heavily dependent on imports.

Recognizing these challenges, many countries have intensified efforts to de-carbonize transportation by adopting cleaner, cost-effective, and more sustainable fuels. Among several alternatives such as biofuels, hydrogen, and electric mobility, Compressed Natural Gas (CNG) has emerged as a transitional option with immediate benefits. CNG consists primarily of methane, which has a higher hydrogen-to-carbon ratio than petroleum fuels. This property enables more efficient combustion and significantly lower emissions of CO_2, NO_x, and particulate matter [4]. In addition, CNG vehicles often produce less engine noise and have longer engine lifespans because of cleaner combustion. Beyond environmental considerations, CNG presents notable economic and strategic advantages. Countries with abundant domestic natural gas reserves can reduce dependence on imported petroleum products, stabilize fuel costs, and improve energy security.

Evidence from India, Iran, and Pakistan demonstrates that large-scale adoption of CNG can lower consumer fuel expenses, reduce urban smog, and extend the operational life of vehicles [5]. These experiences illustrate that natural gas, while not fully renewable, can serve as an important bridge fuel in the transition to a low-carbon energy system. Nigeria occupies a paradoxical position in the global energy system. Despite being one of Africa's leading crude oil producers, the country depends heavily on imported refined petroleum products due to chronic underinvestment and inefficiencies in its domestic refining capacity [6]. PMS and AGO together account for over 70% of national petroleum consumption, leaving Nigeria highly exposed to fluctuations in global oil prices and the fiscal burden of fuel subsidies. For instance, periods of elevated global crude prices have consistently strained the national budget, depreciated foreign reserves, and triggered inflationary pressures on household consumption.

The environmental implications of Nigeria's fuel consumption pattern are equally significant. Rapid urbanization, combined with extensive reliance on PMS and AGO for road transport, has intensified air pollution levels in major cities such as Lagos, Port Harcourt, and Kano. The World Bank [7] notes that Nigeria is among the largest methane emitters globally, with transport playing a growing role in national greenhouse gas (GHG) inventories. At the same time, the health burden associated with fossil fuel emissions—ranging from asthma to premature mortality—is becoming increasingly costly in socioeconomic terms. Yet, Nigeria possesses vast reserves of natural gas, estimated at more than 200 trillion cubic feet [8]. These reserves remain underutilized, as gas flaring and limited domestic infrastructure constrain full exploitation. Harnessing this resource for transportation offers a strategic pathway to reduce dependence on imported fuels, cut emissions, and strengthen energy security. Accordingly, the federal government has initiated policies and pilot programs to promote CNG adoption in road transport, including the "National Gas Expansion Programme" launched in 2020. These efforts are also aligned with Nigeria's climate commitments under the Paris Agreement, which include a pledge to reduce GHG emissions by 20% by 2030, with conditional targets of 45% reduction given adequate international support [9].

Despite clear potential, CNG penetration in Nigeria remains marginal. Several structural and policy challenges inhibit widespread uptake [10]. First, the country has very limited CNG refueling infrastructure, making access highly inconvenient for most motorists [11]. Second, vehicle conversion costs are relatively high, especially for private owners with limited disposable income [10]. Third, gaps in regulatory frameworks and inconsistent incentive mechanisms reduce investor confidence in building new refueling networks. Finally, public awareness of CNG's economic and environmental benefits is still low, contributing to consumer hesitation [12]. Without evidence-based analysis to demonstrate tangible benefits over existing fuels, stakeholders remain reluctant to commit resources to CNG adoption. Most existing studies on Nigeria's transport energy mix either focus on supply-side issues such as refining deficits and subsidy reforms—or treat CNG adoption in qualitative terms. What is missing is a comprehensive, comparative analysis that evaluates both the economic and environmental implications of shifting from AGO to CNG. Specifically, there is limited empirical evidence that quantifies cost savings, carbon emissions reductions, and broader sustainability outcomes associated with CNG adoption in the Nigerian context.

This research seeks to fill that gap by conducting a detailed comparative analysis of Compressed Natural Gas and Automotive Gas Oil as fuels for Nigeria's road transport sector. The study evaluates both the direct economic dimensions (fuel costs, operating expenses, infrastructure needs) and environmental implications (GHG emissions, air pollutant reductions). In doing so, it aims to provide policymakers, investors, and the academic community with robust insights into whether CNG can serve as a viable, sustainable, and cost-effective alternative to AGO. The significance of this work lies in its potential to inform Nigeria's ongoing energy transition strategy. At a time when the removal of fuel subsidies has elevated consumer fuel prices and heightened interest in alternatives, rigorous evidence on the economic competitiveness of CNG is urgently needed. Furthermore, the environmental benefits of switching to a lower-carbon fuel can support Nigeria's commitments under its Nationally Determined Contribution (NDC) while also addressing urban air pollution. By bridging economic and environmental considerations, this study contributes to the global discourse on sustainable transportation and provides actionable insights for Nigeria and other developing economies facing similar challenges.

A study by Chao [13] compared the pollution levels of various automobiles using gasoline, AGO, LPG, and CNG as automobile fuels. The result of the study as illustrated in table II and III points to CNG as the most environmentally friendly fuel emitting less NOX, CO, CO2 and UCH than other transportation fuels.

Table I. Pollution levels of various transport fuels

Fuel/ emission	CO_2	UHC	CO	NO_x	SO_x	PM
Petrol	22000	85	634	78	8.3	1.1
Diesel	21000	21	106	108	21	12.5
LPG	18200	18	168	37	0.38	0.29
CNG	16275	5.6	22.2	25.8	0.15	0.29

II. MATERIALS AND METHODS

This study employs a literature review and a comparative framework to evaluate the economic and environmental performance of Compressed Natural Gas (CNG) relative to Automotive Gas Oil (AGO) in Nigeria's transportation sector.

All data used in this study were obtained from publicly available, credible sources. No personal or proprietary data were collected. Results are reported transparently with clear assumptions to ensure reproducibility

The methodology integrates economic cost modeling, emission accounting, and sensitivity analysis to provide a holistic assessment. The approach is structured as follows: (i) research design, (ii) data sources, (iii) economic assessment, (iv) environmental assessment, (v) sensitivity analysis, and (vi) analytical framework with equations, tables, and sample calculations.

A. Research Design

The study adopts a quantitative comparative approach that models the total cost of ownership (TCO) and lifecycle greenhouse gas (GHG) emissions of CNG and AGO vehicles. Calculations are performed per 100 km of vehicle operation and then scaled to annual and multi-year horizons to capture both individual and fleet-level implications. The model accounts for direct fuel consumption, upstream methane leakage (for CNG), and conversion costs for CNG retrofits.

B. Data Sources

1. Fuel prices:
2. Energy densities: AGO (35.8 MJ/L), CNG (40 MJ/SCM).
3. Emission factors: U.S. EPA and IPCC guidelines for CO_2, NO_x, SO_2, and $PM_{2.5}$.
4. Methane leakage assumptions: 0.2%, 1%, and 3% of throughput, consistent with IEA methane studies.

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5. Vehicle performance data: Typical fuel consumption rates for diesel vehicles in Nigeria's light- and medium-duty categories.
6. Conversion costs: Industry estimates for bi-fuel retrofits ($266.67–$400.00)

C. Economic Assessment

The economic analysis evaluates fuel cost per 100 km, annual fuel savings, and payback periods for vehicle conversion to CNG. A 5-year ownership horizon is assumed. For a more comprehensive comparison, TCO incorporates not only fuel expenses but also conversion costs, maintenance, and potential infrastructure expenditures. Costs are annualized to reflect long-term impacts.

Diesel fuel cost per 100 km:

$$Cost_{100,d} = P_d \times v_d \quad (1)$$

CNG fuel cost per 100 km:

$$Cost_{100,g} = P_d \times V_g \quad (2)$$

Annual savings:

$$S_{year} = \left(Cost_{100,d} - Cost_{100,g}\right) \times \frac{K_{year}}{100} \quad (3)$$

Payback period:

$$Payback = \frac{C_{conv}}{S_{year}} \quad (4)$$

D. Environmental Assessment

Environmental impacts are quantified in terms of CO_2 emissions, methane leakage (CO_2-equivalent), and local air pollutants. The combustion and upstream emissions are modeled separately.

Energy demand per 100 km:

$$E_{100} = v_d \times ED_d \quad (5)$$

CNG volume equivalent:

$$V_g = \frac{E_{100}}{ED_g} \quad (6)$$

Combustion CO_2 emissions

Diesel:

$$CO_{2_{100,d}} = EF_d \times v_d \quad (7)$$

CNG:

$$CO_{2_{100,g}} = EF_g \times V_g \quad (8)$$

Methane leakage:

$$M_{CH_4} = \rho_{CH_4} \times V_g \quad (9)$$

$$M_{leak} = L \times M_{CH_4} \quad (10)$$

$$CO_{2e_{leak}} = M_{leak} \times GW\rho_{CH_4} \quad (11)$$

$$CO_{2e_{100,g}} = CO_{2_{100,g}} + CO_{2e_{leak}} \quad (12)$$

E. Sensitivity Analysis

Sensitivity tests assess the robustness of results under varying conditions:

Fuel price variability: AGO ($0.53–$0.8/L), CNG ($0.13–$0.27/SCM).
Vehicle efficiency shifts: ±10% around baseline fuel economy.

Methane leakage scenarios: 0.2%, 1%, 3%.
Annual distance travelled: 5,000–50,000 km per year.
These tests capture uncertainty and highlight thresholds where CNG's economic and environmental advantages may weaken.

F. Baseline Assumptions

Table II. Baseline assumptions

Parameter	Symbol	Value	Unit	Source
Diesel retail price	P_d	$0.65	$/L	[14]
CNG retail price	P_g	$0.15 – $0.25	$/SCM	[15]
Diesel consumption	v_d	6.0	L / 100 km	[16]
Energy density diesel	ED_d	35.8	MJ/L	[17]

Energy density CNG	ED_g	40.0	MJ/SCM	[17]
CO_2 factor diesel	EF_d	2.68	kg/L	[18]
CO_2 factor CNG	EF_g	1.91	kg/SCM	[19]
Methane density	ρ_{CH4}	0.717	kg/SCM	[20]
GWP of CH_4	GWP_{CH4}	28	—	[18]
Conversion cost	C_{conv}	~$335.00	$	[21]
Analysis horizon	T	5	Years	Defined

Table III. Cost per 100 km

Fuel / Scenario	Result ($ / 100 km)
Diesel (AGO)	$3.89
CNG ($0.15/SCM)	$0.82
CNG ($0.25/SCM)	$1.36

Table IV. Combustion CO_2 emissions per 100 km

Fuel	Result (kg CO_2 / 100 km)
Diesel (AGO)	16.08
CNG	10.26

Table V. Methane leakage impact (CNG lifecycle emissions)

Leakage rate	Lifecycle CO_2e (kg/100 km)
0.2%	10.47
1%	11.34
3%	13.49

Table VI. Payback

User type	Annual km	Annual savings ($)	Payback (years)
Private	15,000	$460.29	0.72
Commercial	30,000	$920.58	0.36

III. RESULTS

This section presents and discusses the outcomes of the comparative economic and environmental assessment of Compressed Natural Gas (CNG) and Automotive Gas Oil (AGO) for sustainable transportation in Nigeria. The discussion integrates the quantitative findings derived from the methodology with broader implications for Nigeria's energy security, environmental sustainability, and policy direction.

A. Multi-scenario Fuel Cost Results

Table VII. summarizes fuel cost per 100 km across three vehicle consumption classes (4, 6, and 8 L/100 km) and a range of AGO and CNG retail prices. Values are in United State Dollars ($) and computed exactly from the baseline energy densities (AGO = 35.8 MJ/L, CNG = 40 MJ/SCM).

Table VII: Cost per 100 km ($) — selected scenarios

v (L/100 km)	AGO price ($/L)	CNG price ($/SCM)	Vg (SCM/100 km)	Cost AGO ($/100 km)	Cost CNG ($/100 km)	CNG as % of AGO
4.0	0.53	0.13	3.58	2.13	0.48	22.4%
4.0	0.65	0.15	3.58	2.59	0.55	21.2%
4.0	0.65	0.20	3.58	2.59	0.72	27.6%
4.0	0.65	0.25	3.58	2.59	0.91	34.9%
6.0	0.65	0.13	5.37	3.89	0.72	18.4%
6.0	0.65	0.15	5.37	3.89	0.82	21.2%
6.0	0.65	0.20	5.37	3.89	1.07	27.6%
6.0	0.65	0.25	5.37	3.89	1.36	34.9%
8.0	0.80	0.27	7.16	6.40	1.91	29.8%

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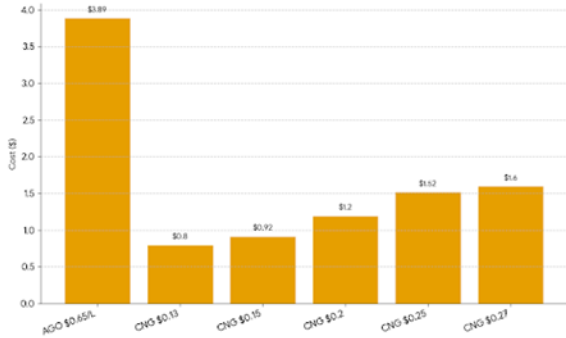

Fig. 1. Fuel Cost per 100km for v = 6L/100 km ($)

Fig. 1. shows the fuel cost per 100 km for the baseline vehicle consumption (v = 6.0 L/100 km) at AGO = $0.648/L and the range of CNG prices included in the analysis for a selected scenario from the full scenario matrix.

B. Emissions Results: Combustion and Lifecycle (Methane Leakage)

Table VIII. presents combustion CO_2 and lifecycle CO_2-equivalent for CNG under different methane leakage rates. Calculations assume v = 6.0 L/100 km, combustion emission factors EFd = 2.68 kg CO_2/L and EFg = 1.91kg CO_2/SCM, methane density 0.717 kg/SCM, and methane GWP100 = 28

Table VIII. CO_2 and CO_2e per 100 km (v = 6.0 L/100 km)

Scenario	CO_2 (AGO)kg/100 km	CO_2 (CNG combustion) kg/100 km	Leak %	CH_4 leaked kg/100 km	CO_2e leakage kg/100 km	CNG lifecycle CO_2e kg/100 km
Baseline (no leak)	16.08	10.257	0.0	0.0000	0.0000	10.257
Low leak	16.08	10.257	0.2	0.00770	0.2156	10.4726
Medium leak	16.08	10.257	1.0	0.03850	1.0781	11.3351
High leak	16.08	10.257	3.0	0.11551	3.2342	13.4912

The figure below visualizes selected scenarios of AGO combustion versus CNG lifecycle under the three leakage assumptions from the full lifecycle emissions matrix.

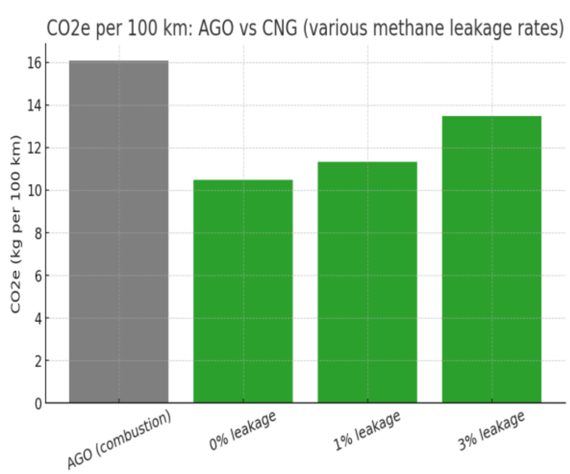

Fig 2. CO_2e per 100 km: AGO vs CNG (various methane leakages rate)

C. TCO and Payback Results

Table VIIII. summarizes annual fuel savings and payback periods for conversion cost $333.33 across vehicle classes and annual mileage profiles. Values use AGO = $0.65/L and CNG prices $0.15/SCM (low) and $0.25/SCM (high) for contrast.

Table IX. Annual savings and payback (conversion cost $333.33)

v (L/100 km)	CNG Price ($/SCM)	Annual Mileage (km)	Annual Savings ($)	Payback Period (Years)
4.0	$0.15	10,000	$173.24	1.92
4.0	$0.15	15,000	$259.86	1.28
4.0	$0.15	30,000	$519.72	0.64
6.0	$0.15	10,000	$289.85	1.15
6.0	$0.15	15,000	$434.78	0.77
6.0	$0.15	30,000	$869.55	0.38
8.0	$0.25	10,000	$303.15	1.10
8.0	$0.25	15,000	$454.72	0.73
8.0	$0.25	30,000	$909.44	0.37

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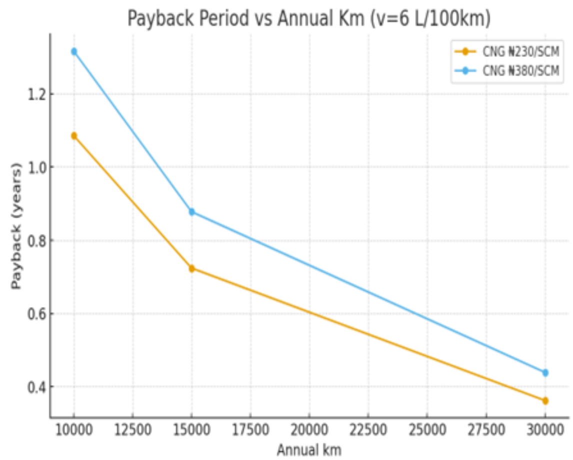

Fig. 3. Payback Period vs Annual km (v = 6 L/100km)

Fig. 3. shows the payback period as a function of annual kilometers for v = 6 L/100 km at CNG prices $0.15 and $0.25 for a select scenario from the total cost of ownership payback scenarios.

IV. DISCUSSION

The comparative analysis demonstrates that Compressed Natural Gas (CNG) offers substantial economic and environmental advantages over Automotive Gas Oil (AGO) in Nigeria's transport sector. Across baseline scenarios for light-duty vehicles, CNG reduces per-kilometer fuel expenditure to between 18 and 35 percent of diesel costs, translating to savings of roughly 65–80 percent depending on prevailing market prices. On the environmental front, combustion emissions from CNG are consistently about one third lower than those from AGO, yielding an average reduction of ~36 percent in CO_2 per 100 km. When lifecycle emissions are considered, the climate advantage remains strong at low methane leakage rates but diminishes as leakage exceeds 3 percent, underscoring the importance of robust monitoring and control. Importantly, total cost of ownership modelling shows that conversion investments can be recovered quickly, often within one to two years, with even faster payback for high-mileage commercial fleets [22]. These results remain robust across sensitivity analyses of fuel prices, vehicle efficiency, and usage patterns, highlighting CNG's potential as a cost-effective and lower-emission alternative to conventional diesel fuels in Nigeria.

The following subsections provide an in-depth interpretation of these findings and situate them in Nigeria's macroeconomic, infrastructural, environmental, and policy context.

A. Microeconomic impacts

The economic case for CNG adoption is compelling for both private motorists and commercial fleet operators in Nigeria. Conversion costs, typically ranging from ~$270 to $400, can be recovered rapidly through fuel savings, with private users driving under 15,000 km annually achieving payback within one to two years under conservative price assumptions. For high-mileage vehicles such as taxis, buses, and haulage trucks, the break-even period can be shortened to a few months, often less than a year, due to their intensive fuel use. These results mirror international experiences, such as in India where fleet operators reported similar recovery times following CNG adoption in urban bus systems. Beyond individual vehicle economics, large-scale fleet conversions generate additional cost advantages by enabling bulk fuel procurement, centralized refueling logistics, and more efficient scheduling of retrofits, all of which reduce per-vehicle costs and downtime. Importantly, concentrated fleet adoption also creates the demand base needed to justify investments in refueling infrastructure and maintenance capacity, generating positive network effects that reinforce the financial viability of CNG. The implications for Nigeria are significant: widespread adoption by commercial operators could deliver immediate cost relief and improve energy security, while private owners would still benefit from long-term savings in an economy where transport expenses account for a substantial share of household budgets.

B. Macroeconomic impacts

Although Nigeria is a net exporter of crude oil, it remains heavily dependent on imported refined petroleum products to meet domestic transport demand, a paradox that places sustained pressure on foreign exchange reserves and exposes the economy to international price volatility. Redirecting even a modest share of transport energy consumption from imported diesel to domestically available natural gas could deliver significant macroeconomic benefits. With proven reserves of more than 202 trillion cubic feet of natural gas, Nigeria has ample capacity to supply CNG to its transport sector without reliance on external markets [8]. Scenario modelling indicates that each percentage point of fuel demand shifted to CNG translates into multi-million-dollar reductions in refined product imports, with savings amplified during periods of global oil price shocks. If 20 percent of current diesel consumption were displaced by CNG, the resulting import bill reductions could amount to several billion dollars annually, easing pressure on the balance of payments and exchange rate stability. The World Bank [7] highlights that such reductions in refined product imports are critical for stabilizing the Naira and narrowing fiscal deficits. Beyond foreign exchange savings, lower transport operating costs cascade through the economy by reducing logistics expenses for food distribution, trade, and manufacturing, thereby dampening inflationary pressures. In a context where price instability is frequently fuel-driven, CNG adoption offers not only an energy security dividend but also the potential to enhance competitiveness and moderate inflationary risks over the longer term.

C. Employment and local industry

The expansion of CNG in Nigeria has the potential to generate significant direct and indirect employment across multiple segments of the value chain, including refueling station construction and operations, equipment supply and fabrication, cylinder manufacturing and certification, vehicle conversion workshops, and gas processing and distribution. For instance, projections by the Presidential CNG Initiative [23] indicate that the nationwide rollout of conversion centers and refueling infrastructure is set to create over 25,000 new jobs in technical services and manufacturing. As noted by the National Bureau of Statistics [24], the transport support service sector possesses high absorption capacity for semi-skilled labor, offering a partial remedy to youth unemployment. With appropriate policy frameworks that prioritize local content and capacity development, many of these opportunities could be captured domestically rather than through imports. Small- and medium-sized enterprises (SMEs) stand to benefit particularly by specializing in conversion services, station operations, and related supply chains, thereby broadening the base of inclusive economic participation. At scale, a national CNG program could create thousands of skilled jobs while also supporting the development of a domestic manufacturing base for CNG cylinders, kits, and ancillary technologies. Such a base would not only meet local demand but could eventually supply regional markets, positioning Nigeria as an exporter of CNG technology and expertise. These industrial and employment opportunities are consistent with the objectives of Nigeria's Economic Recovery and Growth Plan (ERGP), which emphasizes diversification, industrialization, and job creation as pathways to sustainable development [25].

D. Greenhouse gas emissions

The emissions analysis underscores that Compressed Natural Gas (CNG) offers a significant opportunity for near-term mitigation, delivering roughly 36% lower combustion-phase CO_2 emissions per kilometer compared to Automotive Gas Oil (AGO). However, the broader climate benefit is highly sensitive to methane leakage across the natural gas supply chain. When leakage is maintained below about 1% (based on $GWP_{100} = 28$), CNG delivers meaningful lifecycle CO_2e reductions of approximately 30–35% relative to AGO. Once leakage rates approach 3%, this advantage narrows considerably and may even disappear, leaving CNG with an equal or worse footprint than diesel. These findings highlight that while CNG adoption can make an important contribution to Nigeria's de-carbonization strategy, its climate case ultimately depends on the integrity of the gas infrastructure. Without robust leak detection and repair (LDAR) programs and stringent upstream emission controls as recommended by the UNEP [26] Global Methane Assessment, the transition risks undermining the very environmental gains it seeks to achieve.

E. Local air quality and public health

The transition from diesel to Compressed Natural Gas (CNG) carries immediate and tangible public health benefits through its impact on local air quality. Unlike diesel, which emits significant quantities of sulfur dioxide (SO_2), nitrogen oxides (NO_x), and fine particulate matter ($PM_{2.5}$), CNG combustion produces negligible SO_2, around 80% lower NO_x, and virtually eliminates particulate emissions. These reductions are particularly consequential in densely populated urban centers such as Lagos and Port Harcourt, where poor air quality is already linked to high rates of asthma, lung cancer, and cardiovascular disease [3]. The near-elimination of particulate pollution, coupled with sharp reductions in NO_x, directly lowers respiratory and cardiovascular risks, thereby reducing hospital admissions, cutting healthcare expenditures, and improving workforce productivity. The Clean Air Fund [27] has estimated that air pollution costs African cities billions of dollars annually in lost productivity and health-related expenses, underscoring the scale of the potential gains. A powerful co-benefit of adopting CNG is thus the immediate local health improvement it delivers, independent of the longer-term climate accounting of methane emissions, making it both an economic and public health imperative for Nigeria's transport sector.

F. Risk assessment and mitigation

The major risks associated with large-scale CNG adoption are technical, environmental and institutional. Below are the principal risks and pragmatic mitigation measures.

A comprehensive risk assessment highlights that infrastructure deficits and methane leakage pose the highest threats to successful adoption. The insufficient rollout of refueling stations (Infrastructure Gap) is a high-impact risk that could stall the transition; mitigating this requires blended finance models, such as public-private partnerships and concessional loans, alongside anchor demand guarantees [28]. Closely linked to this is market and policy risk, where reversals on fuel pricing or inconsistent subsidies could undermine investor confidence. To mitigate this high-impact risk, the government must publish a stable, legislated national CNG roadmap and transparent regulatory frameworks that avoid abrupt policy shifts. Technical and safety risks also require proactive management. Methane leakage represents a significant environmental risk; fugitive emissions during production, processing, or refueling could negate climate gains. Mitigation strategies must include mandatory Leak Detection and Repair (LDAR) programs, independent verification audits, and the deployment of continuous monitoring systems. Furthermore, safety and public perception remain a hurdle, as fears regarding cylinder integrity or accidents could slow uptake. This necessitates rigorous certification schemes for cylinders and conversion kits, mandatory periodic inspections, and widespread public education campaigns.

Beyond these primary hurdles, operational and social risks play a critical role. Institutional capacity presents a medium risk, particularly regarding the limited technical expertise available for conversion, inspection, and enforcement. To address this, extensive training programs and certification schemes for technicians and regulators must be established to strengthen the sector's human capital. Supply chain reliability also poses a medium risk, as delays in imported cylinders, kits, or spare parts could disrupt operations. Incentivizing local manufacturing and creating inventory reserves are essential steps to buffer against global supply disruptions. Finally, issues of social acceptance and environmental justice must be addressed. Resistance from users due to conversion costs or lack of awareness can be mitigated through targeted subsidies for early adopters and demonstration projects. Simultaneously, equity-sensitive policies must ensure that the benefits of the transition are accessible to small operators and low-income users, preventing disproportionate economic burdens.

V. CONCLUSION

This research demonstrates that Compressed Natural Gas (CNG) presents a compelling pathway for Nigeria's transport sector, offering clear economic, environmental, and social advantages relative to Automotive Gas Oil (AGO). The quantitative analysis consistently shows that CNG provides large reductions in per-kilometer fuel costs, translating into rapid payback periods for both private vehicle owners and high-mileage commercial fleets. The long-term economic case is reinforced at the national scale, where substituting CNG for imported diesel could save billions of dollars annually in foreign exchange, reduce inflationary pressures from fuel price shocks, and enhance Nigeria's balance of payments. Environmentally, CNG offers immediate benefits by cutting tailpipe CO_2 emissions by more than one third and drastically reducing harmful pollutants such as NO_x, SO_2, and $PM_{2.5}$. These improvements translate directly into lower healthcare costs, improved worker productivity, and reduced mortality from respiratory and cardiovascular diseases, particularly in heavily polluted urban centers.

Thus, CNG represents a pragmatic “bridge fuel” that can deliver immediate economic relief, energy security, and public health benefits while positioning Nigeria for deeper decarbonization pathways in the future. Realizing these opportunities will require deliberate action: investments in infrastructure, a stable and credible policy environment, strict methane management, and broad-based stakeholder engagement. If implemented with foresight and consistency, CNG adoption can make Nigeria’s transport sector more resilient, sustainable, and equitable, while contributing meaningfully to the country’s climate commitments under the Paris Agreement.

REFERENCES

[1] International Energy Agency (IEA), “World energy outlook 2023,” Paris, 2023. [Online]. Available: https://www.iea.org/reports/world-energy-outlook-2023

[2] BP, “Statistical review of world energy 2023,” London, 2023. [Online]. Available: https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html

[3] World Health Organization, “WHO global air quality guidelines: particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide,” Geneva: WHO Press, 2021. https://www.who.int/publications/i/item/9789240034228

[4] S. A. Khan, M. S. Khan, and M. A. Ahmed, “Techno-economic and environmental analysis of compressed natural gas (CNG) as an alternative fuel for transportation,” Energy Reports, vol. 7, pp. 444–453, 2021. https://doi.org/10.1016/j.egyr.2021.07.114

[5] S. O. T. Ogaji, “Natural Gas: A Bridge Fuel to a Sustainable Energy Future in Nigeria,” Journal of Sustainable Energy Development, vol. 14, no. 2, pp. 88–104, 2019.

[6] Nigerian National Petroleum Company Limited (NNPC), “2023 Monthly Financial and Operational Report (MFOR),” Abuja: NNPC Ltd, 2023.
https://nnpcgroup.com/

[7] World Bank, “Nigeria Development Update (June): Staying the Course,” Washington, DC: World Bank Group, 2024. https://www.worldbank.org/en/country/nigeria/publication/nigeria-development-update-ndu

[8] C. A. Odumugbo, “Natural gas utilization in Nigeria: Challenges and opportunities,” International Journal of Environmental Sciences, vol. 12, no. 4, pp. 110–125, 2021. https://doi.org/10.1016/j.jngse.2010.08.004

[9] Federal Ministry of Environment (FMEnv), “Nigeria’s First Nationally Determined Contribution – 2021 Update,” Abuja: FMEnv, 2021.
https://unfccc.int/sites/default/files/NDC/2022-06/NDC%20INTERIM%20REPORT%20SUBMISSION%20-%20NIGERIA.pdf

[10] C. Ubani and U. Ikpaisong, “Use of CNG as autofuel in Nigeria,” European Journal of Engineering Research and Science, vol. 3, no. 10, pp. 1-6, 2018.
https://doi.org/10.17577/ijertv9is070654

[11] D. O. Bolaji, K. A. Bello, and B. O. Bolaji, “An overview of the progress in the use of compressed natural gas in Nigeria,” Nafta-Gaz, no. 6, pp. 417–423, 2025.
https://doi.org/10.2118/228698-ms

[12] A. E. Adegoriola and I. M. Suleiman, “Adopting Gas Automobile Fuels (LPG & CNG) into the Nigerian Transportation System,” Journal of Economics and Sustainable Development, vol. 11, no. 14, 2020.
https://doi.org/10.7176/jesd/10-14-02

[13] A. K. Chao, “Investigating the strategic impacts of natural gas on transportation fuel diversity and vehicle flexibility,” M.Sc. Thesis, Massachusetts Institute of Technology, 2013.
https://dspace.mit.edu/handle/1721.1/81128

[14] GlobalPetrolPrices, “Diesel prices: Nigeria,” 2025. [Online]. Available: https://www.globalpetrolprices.com/Nigeria/diesel_prices/

[15] Daily Post Nigeria, "Fuel Crisis: CNG retail price benchmarks in Nigeria," 2025. [Online]. Available: https://dailypost.ng/2024/09/06/fuel-crisis-federal-government-announces-cng-retail-price-benc

[16] International Energy Agency (IEA), "Fuel consumption of cars and vans," Paris: IEA, 2019. https://www.iea.org/data-and-statistics/charts/fuel-consumption-of-cars-and-vans-2019

[17] MET Group, "Natural gas vs. diesel: Energy density and efficiency," MET Group Industry Insights, 2021. https://group.met.com/en/mind-the-gap/energy-efficiency/natural-gas-vs-diesel

[18] IPCC, "Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change," Geneva, Switzerland: IPCC, 2014. https://www.ipcc.ch/report/ar5/syr/

[19] U.S. Environmental Protection Agency (EPA), "Greenhouse Gas Emissions from a Typical Passenger Vehicle," 2025. [Online]. Available: https://www.epa.gov/greenvehicles/greenhouse-gas-emissions-typical-passenger-vehicle

[20] The Engineering ToolBox, "Methane - Density and Specific Weight," n.d. [Online]. Available: https://www.engineeringtoolbox.com/methane-density-specific-weight-d_2020.html

[21] Business Intelligence Africa (BIA), "The cost of vehicle conversion to CNG in West Africa," BIA Reports, 2023. https://africa.businessinsider.com/

[22] International Energy Agency (IEA), "World energy outlook 2024," Paris: IEA, 2024 https://www.iea.org/reports/world-energy-outlook-2024

[23] Presidential CNG Initiative, "Strategic Roadmap for CNG Deployment in Nigeria," Abuja: Federal Government of Nigeria, 2024. https://pci.gov.ng/

[24] National Bureau of Statistics (NBS), "Transport Fare Watch and Labor Force Statistics," Abuja: NBS, 2024. https://nigerianstat.gov.ng/

[25] Federal Government of Nigeria, "Economic Recovery and Growth Plan (ERGP): Transforming Nigeria," 2017. https://www.budgetoffice.gov.ng/index.php/economic-recovery-growth-plan-2017-2020

[26] United Nations Environment Programme, "Global Methane Assessment: Benefits and Costs of Mitigating Methane Emissions," Nairobi: UNEP, 2021. https://www.unep.org/resources/report/global-methane-assessment-benefits-and-costs-mitigating-methane-emissions

[27] Clean Air Fund, "The State of Global Air Quality Funding 2023," London: Clean Air Fund, 2023. https://www.cleanairfund.org/resource/state-of-global-air-quality-funding-2023/

[28] African Development Bank, "African Economic Outlook 2024: Driving Africa's Transformation," Abidjan: AfDB, 2024. https://www.afdb.org/en/knowledge/publications/african-economic-outlook