Compressed Natural Gas: A Dual Solution to Nigeria's Environmental and Economic Issues

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ABSTRACT

Compressed Natural Gas (CNG) presents a promising solution to address two of Nigeria's most pressing challenges: environmental degradation and economic instability. This paper assessed *Compressed Natural Gas: A Dual Solution to Nigeria's Environmental and Economic Issues*, examining the interface between environmental and economic challenges while exploring the forces shaping Nigeria's landscape. Relying on secondary data and descriptive analysis, the study reveals that as Nigeria undergoes economic growth, it faces increasing air pollution—particularly from vehicular emissions—reflecting the early stages of the Environmental Kuznets Curve (EKC) theory, which posits that environmental degradation initially worsens with economic development but improves as income levels rise and cleaner technologies are adopted. In this context, CNG emerges as a cleaner, more sustainable alternative to petroleum-based fuels, offering lower carbon emissions and a reduced environmental footprint in the transportation sector. Furthermore, through the lens of Energy Transition Theory, the paper situates CNG as a transitional fuel that can bridge Nigeria's shift from high-carbon energy sources to a more diversified, low-carbon energy future. The potential for job creation, local production, and enhanced energy diversification positions CNG as a catalyst for sustainable economic growth. By tapping into abundant domestic natural gas reserves, Nigeria can reduce its dependence on imported fuels, stabilize energy prices, and promote long-term energy security. The paper concludes with recommendations emphasizing that the dual benefit of environmental sustainability and economic enhancement makes CNG a critical component of Nigeria's future development strategy. It also discusses the feasibility of CNG adoption, evaluating its environmental impact, economic potential, and the necessary infrastructure investments required to make it a viable national solution.

Keywords: Compressed Natural Gas (CNG), environmental degradation, economic instability, energy, petroleum

INTRODUCTION

Compressed Natural Gas (CNG) is a form of natural gas that has been compressed to less than 1% of its volume at standard atmospheric pressure. The gas, primarily composed of methane (CH_4), is stored in high-pressure cylinders, making it a highly efficient fuel for various applications, including transportation, industrial use, and power generation (International Energy Agency, 2022). Unlike traditional fuels, CNG is a clean-burning, alternative energy source, producing fewer emissions such as carbon dioxide (CO_2), nitrogen oxides (NOx), and particulate matter, thus contributing to reduced air pollution and lower greenhouse gas emissions. The compression process makes it more practical for storage and transport over long distances, as natural gas is typically delivered via pipelines or in compressed form for vehicles (International Energy Agency, 2022).

Globally, CNG has seen significant adoption in recent decades, especially in regions looking to reduce their reliance on oil-based fuels and lower the environmental impact of their energy consumption. CNG is primarily used in transportation, with many countries transitioning their vehicle fleets to run on compressed natural gas. As of recent estimates, over 28 million vehicles worldwide are powered by CNG, with countries like Iran, Pakistan, Argentina, and India leading the adoption (International Energy Agency, 2022).

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CNG buses in Shenyang, China, offer the most favorable economic and environmental outcomes for urban public transit, whereas diesel vehicles serve as a practical choice for taxis (Geng et al., 2013). CNG has quickly emerged in Pakistan as a fuel for transportation, providing environmental advantages, economic gains, and alleviating gas shortages, although challenges persist due to increasing demand and regulatory concerns (Khan & Yasmin, 2014).

CNG's growing relevance can be attributed to several factors: its environmental advantages over gasoline and diesel, its cost-effectiveness due to lower fuel prices in some regions, and the increasing availability of infrastructure for refueling. As the world seeks to reduce carbon emissions and address climate change, CNG serves as a viable intermediary in the transition toward cleaner energy sources.

Furthermore, CNG is becoming an increasingly important alternative to conventional fuels in many parts of the world. According to a report by the International Gas Union (2023), the global consumption of natural gas, including CNG, is expected to continue growing as more countries invest in gas infrastructure, renew their vehicle fleets, and promote sustainable energy policies.

The introduction of CNG to Nigeria was motivated by the need to diversify energy sources and reduce the nation's dependence on imported petroleum products. Nigeria, a major oil and gas producer, has abundant natural gas resources, but until recently, these resources were underutilized in the transportation sector. The Nigerian government began exploring CNG as an alternative fuel for vehicles in the late 1990s, with the aim of reducing harmful emissions and addressing the country’s energy challenges (Idigbe, 2020).

In 2002, the Nigerian National Petroleum Corporation (NNPC) and other stakeholders launched the country's first CNG fueling station in Abuja, signaling the beginning of the CNG adoption movement. This was part of broader efforts to promote natural gas utilization across sectors, supported by policies that incentivized the conversion of vehicles to CNG (Idigbe, 2020).

Since its introduction, the usage of CNG in Nigeria has grown, especially in urban areas, where the transportation sector has been facing challenges related to fuel scarcity, high fuel costs, and environmental pollution. A significant boost to this growth was the launch of the National Gas Expansion Programme (NGEP) by the Nigerian government in 2020. The programme aims to promote CNG adoption in the transport sector by expanding refueling infrastructure, making the fuel more accessible to Nigerian drivers (Idigbe, 2020).

Despite these efforts, challenges remain fully capitalizing on CNG's potential, including the need for extensive refueling infrastructure and consumer awareness. However, with a growing focus on sustainability and energy diversification, CNG presents a promising solution to Nigeria’s energy and environmental issues, offering an opportunity to reduce emissions, create jobs, and enhance energy security (Akinwale et al., 2023).

Cng as an Alternative Energy Source

Compressed Natural Gas (CNG) is increasingly being recognized as a viable alternative to traditional fuels like petrol and diesel. It offers several advantages, including lower emissions, cost-effectiveness, and energy efficiency, which are crucial for Nigeria as the nation looks for sustainable solutions to address energy challenges. Below is an exploration of CNG in various milieus in Nigeria.

How CNG Compares to Traditional Fuels (Petrol, Diesel)

CNG is widely regarded as a cleaner and more efficient alternative to traditional fuels such as petrol and diesel. Several key differences highlight the advantages of CNG:

Environmental Impact: CNG is significantly cleaner compared to petrol and diesel. It emits fewer pollutants, including carbon dioxide (CO_2), particulate matter, sulfur oxides (SOx), and nitrogen oxides (NOx), which are major contributors to air pollution and health problems. CNG produces approximately 25-30% less CO_2 emissions than petrol and diesel (U.S. Department of Energy, 2020). CNG combustion produces lower levels

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of CO_2, CO, and hydrocarbons (HC) in comparison to conventional fuels, enhancing its efficiency and environmental advantages (Kyando et al., 2024) (Tica et al., 2019).

Energy Content: While CNG has a lower energy density than petrol and diesel, it is still considered efficient because its cleaner combustion leads to fewer maintenance requirements for engines. The adoption of CNG in vehicles results in a notable decrease in NOx emissions, which are detrimental pollutants linked to diesel and petrol engines (Tica et al., 2019). The lower energy density is offset by its lower cost per unit of energy, making it a more cost-effective choice for consumers.

Cost: CNG is typically cheaper than petrol and diesel. This is especially important in countries like Nigeria, where fuel prices can fluctuate and put pressure on the economy. In many cases, the operating cost of vehicles running on CNG is significantly lower than those using traditional fuels. Engines powered by CNG achieve a 12.7% reduction in fuel consumption and incur 56% lower fuel expenses compared to gasoline engines, resulting in a 29% decrease in environmental impact and related costs (Sahoo and Srivastava, 2021).

Production and Distribution of CNG in Nigeria

Nigeria is well-positioned to benefit from CNG due to its large natural gas reserves. CNG has benefits such as reduced pollution, increased productivity, efficiency, safety, and energy security as an alternative fuel for automobiles in Nigeria (Ibeneme and Ighalo, 2020). The production of CNG in Nigeria involves the extraction and processing of natural gas, which is then compressed and stored in high-pressure cylinders for use in vehicles.

Natural Gas Reserves: Nigeria has the 9th largest proven natural gas reserves in the world, estimated at over 200 trillion cubic feet (Tcf) (International Gas Union, 2020). Nigeria's natural gas reserves could greatly improve its energy composition and lower expenses, yet the current rate of utilization and export opportunities is progressing slowly (Nwaoha and Wood, 2014). However, much of this gas has historically been flared rather than utilized for domestic use or export.

Infrastructure: The infrastructure for CNG distribution in Nigeria is still in its nascent stages. As of 2023, there are a few CNG refueling stations in Nigeria, primarily located in Lagos, Abuja, and Port Harcourt (Tcf) (International Gas Union, 2020). The government and private sector are gradually investing in expanding the network of refueling stations.

Challenges: The primary challenges to the widespread distribution of CNG in Nigeria include the high initial cost of setting up refueling stations, the need for reliable storage and transportation infrastructure, and the limited availability of CNG-powered vehicles.

The adoption of compressed natural gas (CNG) as a transportation fuel in Nigeria has been slow, with only 0.1% of vehicles utilizing it despite a national fleet exceeding six million (Ogunlowo et al., 2018). This limited adoption is attributed to several challenges, including a lack of economic incentives for both vehicle conversion and the establishment of CNG refueling stations. Furthermore, the absence of cooperation between NNPC Gas Marketing Limited and gas distribution companies hinders the widespread distribution of CNG in the country (Oruwari et al., 2024).

Despite these challenges, the potential benefits make CNG an attractive option for Nigeria’s energy future.

The Role of Natural Gas Reserves in Nigeria’s Energy Mix

Natural gas has the potential to play a central role in Nigeria’s energy mix, especially as the country seeks to diversify its energy sources and reduce its reliance on oil. The role of natural gas reserves in Nigeria's energy strategy includes:

Domestic Energy Supply: Nigeria's vast natural gas reserves are underutilized for domestic power generation. Nigeria burns more gas each year than the entire output of its electric power generation, underscoring the

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necessity for alternative methods of gas utilization (Ede and Johnson, 2001). While natural gas is a significant source for electricity generation (about 60% of the electricity in Nigeria comes from natural gas-fired plants), much of the gas is still flared. CNG offers an opportunity to utilize this flared gas for transportation and industrial purposes, reducing waste and increasing efficiency.

Export Potential: Nigeria is one of the top exporters of liquefied natural gas (LNG), but much of its natural gas production is aimed at international markets. Nigeria is a significant exporter of liquefied natural gas (LNG) in the international market, alongside countries like Australia, Qatar, Malaysia, and Russia (Ulchenko, 2022). By increasing domestic use of natural gas, Nigeria could improve its energy security and reduce its dependence on imported fuels.

Economic Impact: Utilizing natural gas for domestic energy needs, such as CNG production, could stimulate job creation, infrastructure development, and lower overall energy costs. Using natural gas for household needs, including gas for energy, home heating, and the petrochemical sector, has the potential to decrease the unemployment rate, support diversification, and lessen environmental pollution in Nigeria (Mojeed et al., 2021). This is important for Nigeria, which faces energy access challenges and high costs for electricity and fuel.

Theoretical Framework

This paper is founded on the Environmental Kuznets Curve (EKC) Theory and Energy Transition Theory. The EKC hypothesis suggests that environmental degradation worsens in early economic development stages but improves once a certain income level is reached, as societies demand cleaner technologies (Grossman and Krueger, 1995; Dinda, 2004). In Nigeria, reliance on fossil fuels has led to significant environmental problems (Akinbami, 2001), but the adoption of Compressed Natural Gas (CNG) offers a cleaner alternative that supports both economic growth and environmental improvement, aligning with the EKC model. Energy Transition Theory explains how energy systems shift over time from high-carbon to low-carbon sources, driven by innovation, policy, and environmental pressures (Sovacool, 2016). Given Nigeria's oil dependency and environmental challenges (Eleri et al., 2012), CNG provides an opportunity to diversify the economy and reduce emissions. Thus, integrating EKC and Energy Transition theories, the framework argues that CNG adoption offers a pathway to both economic resilience and environmental sustainability.

Environmental Benefits of Cng in Nigeria

Natural Gas, particularly Compressed Natural Gas (CNG), is increasingly seen as a cleaner alternative to traditional fossil fuels such as petrol and diesel. Its adoption in Nigeria offers significant environmental benefits, which are essential for addressing various ecological challenges the country faces. The key benefits include:

Reduction of Greenhouse Gas Emissions (GHGs)

CNG is a fossil fuel, but it is considered cleaner than traditional liquid fuels such as petrol and diesel. The combustion of CNG produces fewer greenhouse gases (GHGs), primarily carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), compared to other fuels. CNG emits about 20-30% less carbon dioxide (CO_2) than petrol and 40% less than diesel, making it a crucial alternative in Nigeria's effort to curb climate change.

In addition to reducing CO_2 emissions, CNG generates significantly lower levels of particulate matter (PM), carbon monoxide (CO), and other air pollutants that contribute to climate change. The reduction in CO_2 emissions helps Nigeria in meeting its carbon reduction targets outlined in the Paris Agreement, particularly in the energy and transportation sectors.

A study by the *International Energy Agency* (IEA) highlights that the shift towards natural gas, including CNG, could contribute substantially to the reduction of GHG emissions globally, as it replaces coal and oil in the energy mix (IEA, 2020).

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Improvement in Air Quality and Public Health

The use of CNG in vehicles significantly improves air quality by reducing harmful emissions that contribute to urban air pollution. In major Nigerian cities such as Lagos, Abuja, and Port Harcourt, high levels of air pollution from vehicle emissions, particularly from diesel-powered vehicles, have caused severe public health issues, including respiratory diseases, heart problems, and premature deaths.

By replacing diesel and petrol with CNG, harmful pollutants like particulate matter (PM), nitrogen oxides (NOx), and sulfur oxides (SOx) are substantially reduced. According to the *World Health Organization* (WHO), air pollution in Nigeria is responsible for thousands of deaths annually, many of which could be prevented through cleaner vehicle technologies like CNG (WHO, 2020). The adoption of CNG also enhances public health by improving respiratory conditions, reducing cardiovascular diseases, and decreasing the number of premature deaths linked to air pollution.

Role of CNG in Mitigating Deforestation and Reducing Firewood Use

In many rural areas of Nigeria, firewood remains a primary source of energy for cooking, contributing significantly to deforestation. The reliance on firewood not only depletes the country's forests but also exacerbates land degradation and environmental degradation. Transitioning to CNG as a cleaner cooking and energy source offers a potential solution to reduce this dependence. Rana (2024) posited that transitioning to Compressed Natural Gas (CNG) as a more environmentally friendly option for cooking and energy can greatly decrease reliance on conventional fossil fuels, providing a sustainable alternative that helps lower carbon emissions and enhances fuel efficiency.

CNG can be used in compressed natural gas-powered cookstoves, providing an efficient and cleaner alternative to firewood. By offering an accessible, affordable, and cleaner energy source, CNG reduces the need for wood cutting, thereby slowing down deforestation. Furthermore, it helps reduce the carbon footprint associated with traditional biomass burning, which releases black carbon (soot) that contributes to climate change.

The Nigerian government, through initiatives like the *National Energy Policy* and various clean cookstove programmes, has recognized the importance of transitioning from biomass to cleaner alternatives. CNG, as part of this shift, can help mitigate the environmental impacts of deforestation while providing a sustainable energy alternative.

Contribution to Nigeria's Commitments in International Climate Agreements (e.g., Paris Agreement)

As a signatory to the *Paris Agreement*, Nigeria has committed to reducing its greenhouse gas emissions and transitioning to a more sustainable, low-carbon energy future. CNG plays a pivotal role in these efforts, especially as the country seeks to diversify its energy sources and reduce reliance on high-emission fossil fuels like coal and oil.

Nigeria's *Nationally Determined Contributions (NDCs)* under the Paris Agreement include efforts to reduce GHG emissions by 20% unconditionally and by up to 45% conditionally by 2030, largely focusing on renewable energy and energy efficiency. The use of CNG in transportation, industries, and even as a domestic cooking fuel, fits within this framework by contributing to lower emission levels, particularly in urban centers where vehicle emissions are a significant concern.

Nigeria, which is a signatory to the Paris Agreement, has committed to a 20% unconditional reduction in emissions by 2030 and a conditional reduction of 47%, with a goal of achieving carbon neutrality by 2060 through initiatives such as the Energy Transition Plan and the Climate Change Act of 2021 (Johnson et al., 2024).

Additionally, the adoption of CNG aligns with Nigeria's broader commitment to promoting energy efficiency and cleaner technologies, a key area in the NDCs. According to the *International Gas Union* (IGU), natural

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gas, including CNG, can help bridge the gap between fossil fuels and renewables by offering a lower-carbon energy option (IGU, 2021).

Economic Benefits of Cng for Nigeria

Natural Gas, particularly Compressed Natural Gas (CNG), has the potential to significantly transform Nigeria's economy. With its vast reserves of natural gas, Nigeria is well-positioned to harness this resource for economic growth (International Energy Agency, 2023). The following outlines the various economic benefits of CNG for Nigeria:

1. Job Creation through the CNG Sector (Production, Distribution, and Infrastructure)

The development of the CNG sector in Nigeria offers significant opportunities for job creation across various stages, from production to distribution. Jobs can be created in the following areas:

Production and Processing: Establishing CNG production plants, including facilities for extraction, compression, and storage, will require a skilled workforce. This includes engineers, technicians, and labourers.

Distribution: CNG transportation infrastructure, such as pipelines, refueling stations, and vehicles, will generate employment opportunities in logistics, marketing, and sales.

Infrastructure Development: Building CNG fueling stations, refitting vehicles for CNG usage, and maintaining existing infrastructure will create jobs in construction, installation, and maintenance services.

2. Cost Savings for Consumers and Businesses

CNG offers a cheaper alternative to traditional fuels like petrol and diesel, which are more expensive due to importation costs. By switching to CNG:

For Consumers: CNG vehicles are generally more fuel-efficient, and the cost per kilometer is lower than that of petrol and diesel. As a result, households and individuals can save significantly on transportation costs.

For Businesses: Companies that rely on transportation (e.g., logistics firms, public transport providers) can also cut operational costs. For instance, businesses can reduce their fuel expenditure by adopting CNG-powered fleets. This would improve their profitability and potentially lead to lower prices for goods and services, benefiting the broader economy.

3. Reduced Dependence on Imported Fuels and the Promotion of Domestic Energy Production

Nigeria's over-reliance on imported petroleum products (such as petrol and diesel) for energy needs places a strain on its foreign exchange reserves and increases vulnerability to global fuel price fluctuations (Nigeria National Petroleum Corporation, 2023). CNG, being derived from domestic natural gas, presents a solution to this issue:

Reduction in Fuel Imports: By increasing the use of CNG for transportation and industry, Nigeria can decrease its dependence on costly fuel imports, saving valuable foreign exchange and stabilizing the national economy.

Promotion of Domestic Energy Production: The development of CNG infrastructure supports the local natural gas industry. This leads to enhanced exploration, extraction, and utilization of the country’s abundant natural gas reserves, promoting the growth of domestic energy production.

4. The Potential of CNG to Boost Nigeria's Energy Independence

CNG offers an important pathway toward greater energy independence for Nigeria. With its large natural gas reserves (the 9th largest in the world), the country is in a prime position to leverage CNG as a critical energy resource:

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Energy Security: Using CNG as a primary fuel source can help diversify Nigeria's energy supply, reducing reliance on oil exports and imported refined products. This makes the country's energy security more resilient to global supply chain disruptions and volatile international markets.

Sustainable Energy Development: By focusing on CNG as part of a broader energy transition, Nigeria can contribute to global efforts toward cleaner energy sources. This would enhance Nigeria's energy profile and attract investment in sustainable energy initiatives, such as renewable energy development.

5. Revenue Generation through the Commercialization of Natural Gas

Nigeria's vast natural gas reserves present a significant opportunity for economic growth through the commercialization of natural gas. By promoting the use of CNG, the country can achieve substantial revenue gains in several areas:

Export Earnings: CNG infrastructure development opens up opportunities for Nigeria to export compressed natural gas, which is increasingly in demand globally. This can generate significant foreign exchange revenues and strengthen Nigeria's position as a leading energy exporter.

Tax Revenues: The commercialization of natural gas and the development of the CNG sector will create a range of economic activities that generate taxes and royalties for the government. These could be reinvested into public services and infrastructure development, further driving economic growth.

Private Sector Investment: The growing demand for CNG will encourage private sector investment in the gas industry, providing an economic boost and creating opportunities for public-private partnerships. This will help attract global energy companies to Nigeria, which will further increase tax revenues and economic output.

Cng Infrastructure Development in Nigeria

Compressed Natural Gas (CNG) has been identified as a cleaner and more cost-effective alternative to traditional fuels in Nigeria. The country, blessed with abundant natural gas reserves, has the potential to transition towards a more sustainable energy model, reducing environmental pollution and enhancing energy security (Nigerian Gas Association, 2020). The development of CNG infrastructure, including fueling stations, vehicles, and pipelines, is central to achieving this goal. However, several challenges and opportunities remain in expanding CNG infrastructure in Nigeria.

1. Current State of CNG Infrastructure in Nigeria

As of now, Nigeria's CNG infrastructure is still in its early stages of development. The country has made significant strides in adopting CNG, primarily for transportation purposes, but the coverage and capacity remain limited compared to global standards (Federal Government of Nigeria, 2017).

CNG Stations: There are currently a small number of CNG fueling stations in Nigeria, predominantly concentrated in urban areas like Lagos, Abuja, and Port Harcourt. According to the Nigerian Gas Association (NGA), there are approximately 30 CNG stations nationwide. However, this is inadequate given the potential demand for CNG across the country, especially in metropolitan areas.

Vehicles: The use of CNG-powered vehicles in Nigeria is growing, though it is still relatively low compared to the number of vehicles running on petrol and diesel. Some commercial vehicles, especially buses, are being retrofitted to use CNG, but there are challenges in scaling this up. The government has introduced programs aimed at promoting the conversion of existing vehicles to CNG, but these programs face obstacles related to funding and public awareness.

Pipelines: Natural gas transportation through pipelines is limited and not as expensive as needed for a comprehensive CNG distribution network. While there are major gas pipeline projects, such as the West African Gas Pipeline (WAGP) and Trans-Nigeria Pipeline, their reach does not sufficiently cover all areas where CNG fueling stations are required.

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2. Government and Private Sector Roles in Infrastructure Development

Both the government and private sector play essential roles in developing CNG infrastructure in Nigeria.

Government's Role:

Policy and Regulation: The Nigerian government has supported CNG infrastructure development through various policies, including the National Gas Policy (2017), which promotes the use of gas as an alternative fuel. The government has also introduced incentives, such as tax breaks and reduced import duties on CNG-powered vehicles and equipment.

Funding and Investment: Through government agencies like the Nigerian National Petroleum Corporation (NNPC) and the Department of Petroleum Resources (DPR), the government has provided funding and support for gas infrastructure development. In 2020, the government allocated funding for the establishment of CNG stations under the Nigeria Gas Expansion Programme (NGEP).

Public Awareness and Education: The government has been involved in awareness campaigns to educate citizens on the benefits of CNG and its role in reducing emissions and environmental degradation.

Private Sector's Role:

Investment in Infrastructure: Private companies, including oil and gas corporations like Shell Nigeria and Chevron, have shown interest in investing in CNG infrastructure. They have the capital, technology, and expertise to develop and manage CNG stations.

Public-Private Partnerships (PPP): Collaborations between the government and private sector are essential to the development of CNG infrastructure. This partnership model could help scale up the number of stations and expand pipeline networks.

3. Challenges in Expanding CNG Infrastructure

While there is clear potential for growth, several challenges hinder the rapid expansion of CNG infrastructure in Nigeria:

Funding and Investment: Despite the advantages of CNG, financing is a significant obstacle. Building CNG stations, retrofitting vehicles, and developing pipelines require substantial investments, which may deter both government and private sector involvement without proper incentives or financing models. Limited access to capital markets and the high cost of infrastructure development are key challenges.

Logistics and Distribution: One of the major hurdles is the logistics of transporting compressed natural gas. Given Nigeria's vast size and poor road infrastructure in some regions, delivering CNG to remote areas remains difficult. Furthermore, the lack of an extensive pipeline network for natural gas distribution poses a bottleneck.

Public Awareness and Adoption: Public awareness of the benefits of CNG remains low. Many Nigerians are more familiar with petrol and diesel, and there is a reluctance to switch to CNG, primarily due to a lack of information about its cost savings and environmental benefits. Additionally, the conversion of vehicles to CNG requires both financial investment and technical expertise, which can be barriers for individual vehicle owners.

Regulatory Hurdles: Despite progress in policy development, Nigeria's regulatory framework for gas utilization is still evolving. There are often delays in permitting and approvals for the establishment of new CNG stations, further slowing down the infrastructure rollout.

4. Potential Partnerships and Investment Opportunities for CNG Infrastructure

Given the challenges mentioned above, there is a significant opportunity for strategic partnerships and investments in Nigeria's CNG infrastructure sector.

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International Investment: Global energy companies and investors can play a crucial role in developing Nigeria's CNG infrastructure. Companies with expertise in gas distribution and infrastructure, such as Total Energies, ExxonMobil, and Shell, could collaborate with the Nigerian government to enhance infrastructure and expand the CNG network (OPEC, 2023). International financial institutions, such as the World Bank and the African Development Bank, could provide funding and technical support for infrastructure projects.

Private Sector Innovation: Local private sector players, particularly those in the automotive, transport, and gas industries, have the potential to drive CNG infrastructure development. There are opportunities for local gas suppliers to set up small-scale CNG stations, especially in underserved regions. Additionally, companies specializing in vehicle conversion and retrofitting can tap into the growing demand for CNG-powered vehicles.

Public-Private Partnerships (PPPs): Nigeria could benefit from structuring PPPs where private companies finance, build, and operate CNG infrastructure, while the government provides regulatory support and guarantees. This approach can reduce the financial burden on the government and accelerate infrastructure development.

Local Content and Employment Creation: Investing in local content, such as setting up local CNG vehicle conversion centers and manufacturing facilities for CNG-related equipment, can create jobs and stimulate economic growth. The development of CNG infrastructure would not only benefit the environment but also improve the local economy through job creation and new business opportunities.

Policy Framework and Government Initiatives of Cng in Nigeria

Effectively implementing CNG in Nigeria demands a coordinated strategy that includes government participation, legal structures, collaborations with the private sector, and a focus on enhancing refueling and retrofitting facilities (Ugolo et al., 2024).

1. Nigeria's Policies on Energy Transition and Renewable Energy

Nigeria has been making concerted efforts to transition from fossil fuel dependence to more sustainable energy sources. The country’s policies have increasingly focused on adopting cleaner energy solutions to address the environmental concerns associated with petroleum and coal-based power generation.

National Energy Policy (2003): This policy outlines the nation's commitment to diversifying its energy mix, with an emphasis on clean energy technologies. Natural gas, being abundant and relatively cleaner than oil, plays a crucial role in Nigeria's energy transition.

National Renewable Energy and Energy Efficiency Policy (2015): This policy highlights renewable energy sources like solar, wind, and hydropower but also includes natural gas, which is considered a key transition fuel toward lower carbon emissions.

Nigeria’s Energy Transition Plan (2021): This document sets out Nigeria’s goals for reducing carbon emissions and enhancing energy access through cleaner energy systems, with an emphasis on both natural gas as a transitional fuel and the promotion of renewable energy sources.

2. Government Support for CNG Adoption (Subsidies, Incentives)

The Nigerian government has recognized the importance of transitioning to cleaner energy sources and has put in place several initiatives to encourage the adoption of CNG in vehicles and industries, they include:

Subsidies for CNG Conversion: The Nigerian government has offered financial incentives, such as subsidies, to facilitate the conversion of petrol and diesel vehicles to CNG-powered ones. These incentives are often provided through partnerships with private companies and international development agencies (Federal Government of Nigeria, 2021).

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Tax Incentives: To promote the adoption of CNG in transportation, the government has introduced tax reliefs for CNG vehicle manufacturers, as well as companies involved in setting up CNG refueling stations (Federal Government of Nigeria, 2021).

Promotion of Infrastructure Development: Government initiatives such as the National Gas Expansion Programme aim to increase the availability of CNG fueling stations across the country, which supports widespread adoption in the transport sector. The government has also worked with both state-owned and private entities to develop infrastructure (Federal Government of Nigeria, 2021).

Public-Private Partnerships (PPP): The government has encouraged partnerships between public and private sector players to boost the availability of CNG-powered vehicles and refueling stations. This has led to the establishment of CNG fueling infrastructure in major cities like Lagos, Abuja, and Port Harcourt (Federal Government of Nigeria, 2021).

3. Regulations and Standards for CNG Use in Vehicles and Industries

The Nigerian government has implemented specific regulations to ensure that CNG is used safely and efficiently in vehicles and industries. These regulations cover vehicle modifications, infrastructure development, and operational standards.

National Petroleum Act: This act includes guidelines for the exploration, production, and use of natural gas in Nigeria. It sets the groundwork for the legal framework governing the CNG industry (National Petroleum Authority, 2021).

CNG Conversion Guidelines: The Department of Petroleum Resources (DPR) has developed standards for the conversion of vehicles from gasoline and diesel to CNG, ensuring that the conversion process is safe and that vehicles comply with environmental standards (National Petroleum Authority, 2021).

Safety Standards for CNG Infrastructure: Nigeria has adopted international best practices for the design, construction, and operation of CNG refueling stations to ensure public safety. The standards include requirements for storage tanks, compressors, and fueling dispensers. CNG stations incorporate various systems, including gas metering, purification, and compression units, designed to meet international safety standards, while essential safety equipment, such as shut-off valves and gas drying systems, is crucial for preventing accidents and ensuring safe refueling operations (Erokhov, 2022).

Regulation of CNG Vehicle Emissions: The government has imposed stringent emission standards for vehicles to ensure that CNG-fueled vehicles contribute to a reduction in greenhouse gas emissions. These regulations align with global standards such as the Euro 6 emissions regulations (National Petroleum Authority, 2021).

4. Role of the Nigerian National Petroleum Corporation (NNPC) in Promoting CNG

The Nigerian National Petroleum Corporation (NNPC) plays a significant role in Nigeria's push toward adopting CNG as an alternative fuel (Federal Ministry of Power, Works, and Housing, 2015).

Gas Supply and Distribution: NNPC, as the state-owned oil corporation, is involved in the exploration, production, and distribution of natural gas in Nigeria. NNPC Ltd is transformed to a commercial entity with a mandate to explore and produce more oil and gas for export and domestic utilization, promoting industrialization and economic growth (Obaje et al., 2022). The corporation is responsible for ensuring a steady supply of natural gas to CNG refueling stations across the country.

Partnerships and Investment: NNPC has partnered with both local and international stakeholders to expand the infrastructure needed for CNG adoption. This includes investing in CNG distribution networks, refueling stations, and promoting public awareness.

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National Gas Expansion Programme: Through this programme, NNPC has actively promoted the use of CNG for transportation, domestic use, and industrial applications. The program seeks to make CNG more accessible to the average Nigerian by lowering fuel costs and reducing the nation's carbon footprint.

Research and Development: NNPC supports research into improving the efficiency of CNG-powered engines and the development of new technologies that facilitate the use of natural gas in various sectors.

Challenges in Adopting Compressed Natural Gas (Cng) In Nigeria

The adoption of Compressed Natural Gas (CNG) as an alternative fuel source in Nigeria faces several challenges that hinder its widespread use. These challenges span cultural, technical, financial, logistical, and perceptual barriers. Understanding and addressing these concerns is crucial to ensuring the successful integration of CNG into the country's energy landscape.

1. Cultural and Consumer Behaviour Challenges

Cultural perceptions and consumer behaviour play a significant role in the adoption of CNG in Nigeria. The traditional preference for gasoline and diesel-powered vehicles is deeply entrenched in the Nigerian automobile market. This is compounded by a general resistance to change, as consumers are often skeptical of new technologies or fuel sources due to concerns over unfamiliarity and reliability. Moreover, CNG vehicles are seen as relatively new in Nigeria, and consumers may hesitate to switch from more familiar fuel types to CNG, despite the potential environmental and cost benefits (Agboola, 2022).

Further, the limited availability of CNG-powered vehicles and refueling stations creates a barrier. This scarcity fosters consumer uncertainty about the long-term viability of CNG adoption, leading many to stick with conventional fuels. Cultural attitudes toward energy consumption and vehicle ownership also influence the willingness to transition to alternative fuels like CNG (Nigeria Bureau of Statistics, 2023).

2. Technical and Safety Concerns Around CNG Usage

While CNG is widely recognized as a cleaner and more environmentally friendly fuel alternative, technical and safety concerns remain a significant barrier. CNG requires specialized storage and handling due to its high pressure, which can raise fears about its safety, particularly in a country with inconsistent maintenance practices. There are concerns about the risk of explosions or fires in case of accidents or improper installation of CNG cylinders in vehicles (Akinmoladun and Olatunji, 2023).

Furthermore, the lack of a well-established infrastructure for refueling CNG vehicles creates technical challenges. The relatively low number of CNG fueling stations across Nigeria means that many vehicle owners may find it difficult to access refueling points, limiting the practicality of CNG as an everyday fuel source (Alabi and Williams 2021).

3. Financing and Investment Barriers

The shift to CNG-powered vehicles and infrastructure requires significant investment, which presents a challenge in Nigeria’s volatile economic environment. The cost of converting traditional vehicles to run on CNG, or purchasing new CNG-powered vehicles, is often higher than that of conventional gasoline or diesel-powered vehicles. Many consumers are unwilling to make the upfront investment, particularly given the economic uncertainty and relatively high inflation rates (Daramola and Ojo, 2022).

Additionally, the lack of incentives or subsidies from the government for adopting CNG technology further discourages potential investors and consumers. The Nigerian government has yet to establish clear and attractive financial policies or support for CNG adoption, leaving private investors to shoulder the full burden of development and expansion of the necessary infrastructure, such as refueling stations and conversion facilities (Okunbor and Onifade, 2021).

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4. Logistics and Transportation Issues

Nigeria's underdeveloped infrastructure for CNG poses logistical and transportation challenges. The transportation of CNG requires specialized vehicles and equipment, which are not widely available in the country. The distribution network for CNG is limited, and many regions in Nigeria lack access to the necessary refueling infrastructure. This creates a supply chain issue for CNG vehicles and puts additional pressure on transportation systems to ensure reliable and cost-effective fuel delivery across the nation (Bakare and Sulaimon, 2023).

Furthermore, the lack of consistent and effective regulation for the distribution of CNG adds to the logistical complexity. Without a clear framework for refueling infrastructure development, transportation companies may be reluctant to invest in CNG-powered fleets, further hindering the expansion of the sector (Nigerian Gas Association, 2021).

5. Public Perception and Misinformation about CNG

Public perception and misinformation about CNG further complicate its adoption in Nigeria. Many consumers are misinformed about the benefits of CNG, often perceiving it as an unreliable and unsafe fuel. Some misconceptions include fears about engine performance, fuel efficiency, and the cost-effectiveness of CNG compared to conventional fuels (Nwachukwu, S. and Abubakar, 2022).

Additionally, there is a lack of widespread education on the environmental and economic benefits of using CNG. Media campaigns and educational programs that inform the public about the advantages of CNG are limited, leading to a lack of awareness. This misinformation often exacerbates public reluctance to adopt CNG as an alternative fuel source (Udom and Okafor, 2021).

RECOMMENDATIONS

The following recommendations to the use of CNG in Nigeria is necessary. Promote the adoption of CNG as an alternative fuel source, the Nigerian government should introduce policies that incentivize the adoption of CNG for both industrial and transportation purposes. This can include tax reductions on CNG vehicles, subsidies for CNG refueling infrastructure, and reduced import duties on CNG equipment. Similarly, public awareness about the environmental and economic benefits of CNG, government agencies, in partnership with environmental organizations, should lead campaigns, educating both the public and businesses on the advantages of switching to CNG. Also, to encourage the widespread use of CNG, the government, in partnership with private investors should prioritize the establishment of CNG refueling stations in major cities and along transportation corridors. And more conversion centres to retrofit existing vehicles to run on CNG, making the transition more accessible for vehicle owners and operators. Furthermore, the government should explore public-private partnerships to finance the development of CNG infrastructure. This includes refueling stations, production plants, and vehicle conversion facilities. Such partnerships will help mitigate the high upfront costs and accelerate the transition to CNG usage. To encourage local production of CNG vehicles, conversion kits, and compressors; the government should offer incentives such as tax relief, grants, and access to favourable financing options for manufacturers and suppliers. In addition, the government and private sector should invest in research and development to improve the efficiency and environmental benefits of CNG technologies. This could include efforts to increase the storage capacity, reduce the cost of conversion kits, and develop more efficient CNG engines for a wider range of vehicles. Correspondingly, the government should develop training programmes for technicians, engineers, and other professionals who will be needed to maintain and repair CNG vehicles and infrastructure. Government-backed vocational training institutions can collaborate with CNG industry players to ensure a skilled workforce. Regular environmental assessments should be conducted to monitor the positive effects of CNG adoption on air quality, carbon emissions, and other environmental indicators. This data will help to refine policies and improve public perception. Lastly, the government can seek technical assistance, knowledge sharing, and financial support from international organizations, development banks, and foreign governments that have successfully implemented CNG programmes. Such collaborations can help Nigeria adopt best practices, while also attracting international investors to the sector.

CONCLUSION

CNG presents a significant opportunity for Nigeria to transition towards a cleaner, more sustainable energy future. With abundant natural gas reserves, Nigeria has the potential to reduce its reliance on imported fuels, lower greenhouse gas emissions, and improve air quality, while also enjoying cost-effective and energy-efficient benefits. As the government continues to invest in infrastructure and expand the distribution network, CNG could play a key role in diversifying Nigeria's energy mix and addressing both environmental and economic challenges. Lastly, by prioritizing CNG, Nigeria can reduce fuel import dependency, lower environmental pollution, and make a substantial contribution to achieving its energy goals.

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