

Assessing the Viability of CNG Conversion as a Sustainable Alternative Fuel Source for Vehicles in Nigeria

BY

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1.0 INTRODUCTION

The Sustainable Development Goals (SDGs) provide a comprehensive framework for global action, urging all nations and stakeholders to collaborate to address a wide range of global challenges and promote sustainable development worldwide (Olayide, 2016). Goal 7 specifically focuses on ensuring access to clean and affordable energy, recognizing its pivotal role in various sectors, including agriculture, business, communications, education, healthcare, and transportation (United Nations Sustainable Development, 2023). In response to the global and national calls for affordable and clean energy, there is an imperative to shift our focus towards alternative energy sources, with natural gas emerging as a promising contender.

1.1 What is a Natural Gas Vehicle (NGV)?

A Natural Gas Vehicle (NGV) is an alternative fuel vehicle that relies on Compressed Natural Gas (CNG) as its primary source of energy. These vehicles operate much like conventional petrol and diesel vehicles, using a combination of compressed air, fuel, and heat to produce combustion, converting chemical energy into mechanical energy. Notably, natural gas is renowned for its clean-burning properties, affordability, and the range of environmental and monetary incentives it offers. NGVs fall into three categories:

- **Dedicated:** Vehicles exclusively powered by natural gas.
- **Bi-fuel:** Light or medium-duty vehicles capable of using both natural gas and petrol interchangeably.
- **Dual fuel:** Heavy-duty vehicles that simultaneously use natural gas and diesel blends.

NGVs substantially reduce greenhouse gas emissions compared to traditional vehicles, with reductions of up to 30%. Carbon monoxide emissions are reduced by 90% - 97%, carbon dioxide emissions by 25%, and nitrogen oxide emissions by up to 60%. These reductions have

a tangible impact on air quality, reducing smog and harmful pollutants, ultimately contributing to a healthier environment.

1.2 How Do CNG Vehicles Work?

Compressed Natural Gas (CNG) is stored in specialized tanks or cylinders within the vehicle. This gas remains in a gaseous state and is typically stored at the rear of the vehicle. A pressure regulator within the fuel system reduces the high-pressure gas to a level compatible with the engine's fuel injection system. The fuel is then introduced into the intake manifold or combustion chamber, where it mixes with air and is compressed and ignited via a spark plug.

Liquefied Natural Gas (LNG), on the other hand, involves super-cooling natural gas to approximately -260°F, turning it into a liquid state, and storing it in cryogenic tanks onboard the vehicle. LNG offers a higher energy density than CNG, making it suitable for heavy-duty trucks requiring extended ranges. However, LNG fueling demands specialized clothing and training compared to CNG, though it requires less refueling time.

1.2.1 Advantages of Natural Gas Vehicles

In addition to being an environmentally friendly option, NGVs offer various advantages:

- **Cleaner:** NGVs burn cleaner than gasoline and diesel vehicles, significantly reducing greenhouse gas emissions.
- **Cheaper:** Natural gas is cost-effective compared to traditional fuels like petrol and diesel.
- **Availability:** As it is produced and processed locally, natural gas guarantees a more reliable supply.
- **Quieter:** NGV engines are quieter than their gasoline counterparts.

- **Lower Operating Costs:** NGVs have lower operating costs and maintenance expenses.
- **Less Wear and Tear:** Natural gas is less corrosive to vehicle engine parts, increasing engine longevity.

1.2.2 Disadvantages of Natural Gas Vehicles

While NGVs offer numerous benefits, they do have some limitations:

- **Speed:** NGVs may not match the speed performance of gasoline-powered vehicles.
- **Large Tanks:** The need for a large storage tank can reduce trunk space.
- **Lower Performance:** NGVs may have lower mileage efficiency due to the additional weight of the natural gas tank.
- **Limited Refueling Stations:** Natural gas refueling stations are less common than traditional ones, limiting the travel range of NGVs.
- **Non-Renewable:** Despite its abundance, natural gas is still a non-renewable fuel source.

1.3 Other Forms of Alternative Vehicle Fuels

In addition to natural gas, Nigeria should invest in researching and developing various alternative fuels for transportation and other industrial uses to ensure long-term energy sustainability. These alternative fuels include:

- **Electricity:** Used to power electric vehicles (EVs), battery-electric vehicles (BEVs), and plug-in hybrid electric vehicles (PHEVs). EVs can charge their batteries directly from the grid, offering energy security and emissions benefits.
- **Hydrogen/Fuel Cell:** Fuel cell electric vehicles (FCEVs) use hydrogen to produce electricity, emitting only water vapor and warm air.

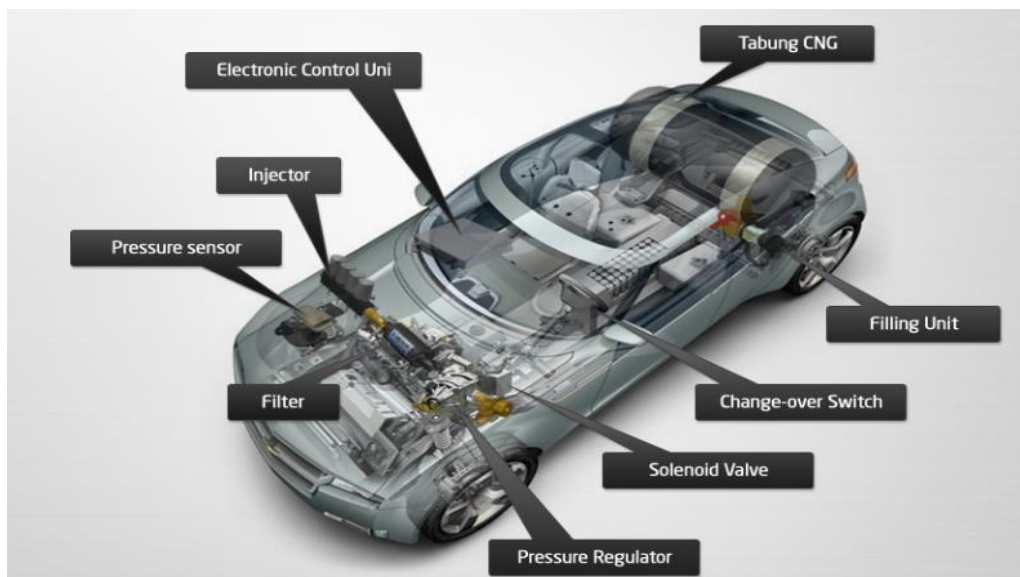
- **Biodiesel:** A renewable fuel produced from vegetable oils, animal fats, or recycled grease, suitable for diesel vehicles.
- **Renewable Diesel:** Chemically identical to petroleum diesel, produced from fats and oils.
- **Ethanol/Flex Fuel:** A renewable fuel made from plant materials like corn, commonly blended with petrol.

1.4 Parts Required for CNG Conversion

To convert a petrol vehicle to CNG, specific components are necessary. These include:

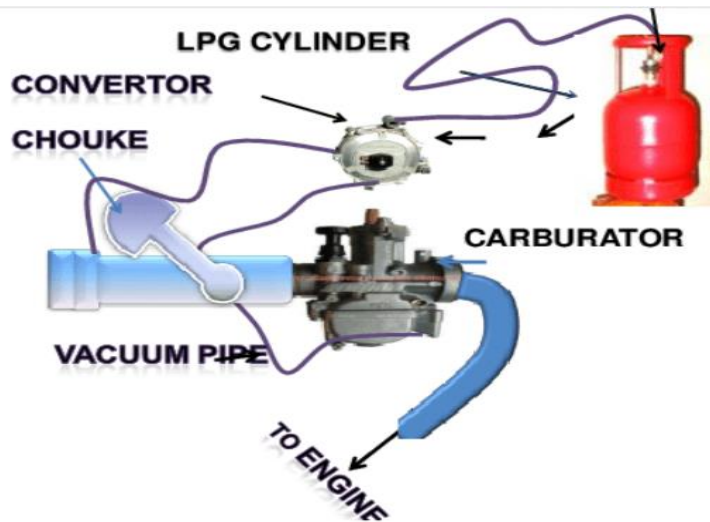
- Air/Gas Mixer
- Pressure Regulator
- High-Pressure Line
- CNG Filling Valve
- CNG Tank
- Manometer
- Selector Switch (Petrol/CNG)
- Emulator
- Heating System

Fig: 1.0: CNG Conversion Kit



Source: CGS, 2023

Fig 1.1 LPG to Gas Conversion Kit



Source: (Rama et al., 2018)

1.5 Types of CNG Kits

There are two main types of CNG kits available for cars, namely **Factory-fitted CNG Kit** and **Aftermarket CNG fuel Kit**

1.5.1 Factory-Fitted CNG Kit

Installed by the vehicle manufacturer during production, these kits are exclusive to specific vehicle models and do not void the vehicle's warranty.

1.5.2 Aftermarket CNG Fuel Kit

These universal kits can be installed in various vehicle models, providing cost savings. However, they may void the vehicle's warranty.

1.6 Natural Gas Vehicle Conversion Kits

for almost all modern petrol vehicles sold in Nigeria. They provide a practical solution for vehicle owners looking to switch to natural gas fuel. These conversion kits also offer a cost-effective way to extend the lifespan of vehicle engines, as natural gas is less corrosive to engine components.

1.6.1 Conversion Kit Components

Natural gas conversion kits typically consist of several components:

- **Regulator:** Controls the flow of natural gas from the tank to the engine, ensuring the right pressure.
- **Filling Nozzle:** Used for refueling the vehicle with compressed natural gas.
- **High-Pressure Tubing and Fittings:** Transport natural gas from the tank to the engine.
- **Pressure Gauges:** Monitor gas pressure within the system.
- **Closed-Loop Feedback System:** Helps maintain optimal air-fuel ratios.
- **Emulator:** Adapts the vehicle's electronic systems for natural gas operation.
- **Time Advance Processor:** Ensures precise ignition timing.
- **Fuel Change-Over Switch:** Allows the driver to switch between natural gas and petrol.
- **Additional Hardware:** Such as hoses, hose clamps, wiring, straps, mounting straps, screws, and fittings.

1.6.3 Conversion for Fleet Vehicles

For fleet owners, converting multiple vehicles to natural gas can lead to significant cost savings over time. While natural gas vehicles may have a shorter driving range compared to diesel or gasoline vehicles due to the lower energy density of natural gas, additional storage tanks can be installed to increase range. The key to realizing these savings lies in factors such as the average distance traveled by the fleet, infrastructure costs for refueling, and other considerations. The payback period varies, but over the lifespan of the vehicles, lower operating and maintenance costs typically offset the upfront conversion expenses.

1.7 Conversion of 2/3 stroke engine

Converting a 2/3 stroke engine to natural gas can be a complex and costly process. It may involve replacing the engine's cylinders, pistons, and valves with ones designed for natural gas use. Additionally, the engine's fuel injection system and exhaust system may need to be modified to accommodate the change in fuels. While this conversion can provide improved emissions and fuel efficiency, it may not be worth the investment for smaller or older engines. It's important to consult with an experienced mechanic or engineer before undertaking such a project.

Detailed study of 2 stroke 3 wheeler CNG engine has not been conducted so far. It may be possible to develop a bi-fuel (CNG/Gasoline) single cylinder air cooled 200 cc, 2 stroke engine for 3 Wheeler application. This engine is an air cooled SI engine converted to operate on CNG fuel with electronic ignition system. An additional feature is the ability to change the spark ignition timing w.r.t. speed and type of fuel selected. The engine variables optimized included the compression ratio and the Ignition timing. The spark plug, lubrication oil, Cat-Con, First stage and second stage CNG pressure regulators, Gas-air mixer, Venturi size and power screw

was some of the hardware selected and optimized suitable to CNG operation without compromising the base petrol performance. It was observed that the induction system optimization plays an important role in meeting the power performance and THC emission targets due to scavenging. Engine can be optimized with a three-way Palladium based catalytic converter (instead of Pt based Cat Con) to meet proposed BS-III norms (Shanmugam et al., 2009)

Fig 1.4: 2/3 Stroke Engine Conversion Kit



1.8 Cost /benefit Analysis

The cost of converting a vehicle to run on compressed natural gas varies based on several factors, including the type of conversion kit, the vehicle's make and model, and labor costs. Factory-fitted kits are generally more expensive than aftermarket options, but they offer greater safety and don't affect the vehicle's warranty. Aftermarket kits, while more affordable, may void the vehicle's warranty and require professional installation to ensure safety and compliance with regulations.

Fig 1.3: Average cost and benefit of CNG Conversion in Nigeria

Vehicle type	Typical conversion cost	Autogas savings	Time to recover
Petrol vehicles	N300,000 – N400,000	N40/km or 40%	9 to 12 months
Tricycles (keke napep)	N100,000 – N200,000	N10 – N15/km or 50% - 75%	3 to 4 months
Vans and lorries	N18 million (cost differential between a gas engine truck and a diesel engine truck).	N360/km	12 months
Others (Petrol generators)	N90,000	N500/hour or 50%	150 –200 hours

1.8 Regulation on CNG Conversion in Nigeria

The successful adoption of compressed natural gas (CNG) as a transportation fuel in Nigeria requires a supportive regulatory framework. Various stakeholders, including the government, need to work collaboratively to overcome obstacles and encourage usage (Ogunlowo et al., 2017).

1.8.1 Legislative Support

To foster the adoption of CNG as an automobile fuel in Nigeria, the government should consider the following legislative measures:

- **Carbon Tax System:** Develop a targeted carbon tax system to incentivize the use of CNG as a cleaner alternative.
- **Market-Based Policies:** Implement market-based policies that promote CNG adoption.

- **Natural Gas Infrastructure:** Invest in a robust natural gas transmission and distribution network.
- **Availability of Refueling Stations:** Increase the availability and accessibility of CNG refueling stations.
- **Subsidies for Vehicle Conversion:** Consider subsidizing vehicle conversion expenses.
- **Bi-fuel/Dual-fuel Vehicles:** Encourage the adoption of bi-fuel and dual-fuel vehicles as an interim solution.

1.8.2 Lessons from Developed Countries

Developed countries have already established regulations to govern CNG conversion processes. These regulations include standards for safety, emissions, and technical specifications. Additionally, certification and licensing of conversion centers or technicians are part of these regulations to ensure compliance. Some countries offer incentives like grants and tax credits to offset conversion costs (Gammie et al., 2015). For instance, in the United States, vehicles converted to CNG must adhere to Federal Motor Vehicle Safety Standards (FMVSS), with mandatory inspections following conversion (Kentucky General Assembly, 2023).

1.8.3 The Need for a CNG Authority

Notably, Nigeria lacks a dedicated organization focused on CNG adoption as a vehicle fuel (Ibeneme & Ighalo, 2020). In contrast, countries like India, Argentina, and Brazil have established agencies to promote CNG usage. In addition to its use as a vehicle fuel, CNG can be utilized for energy generation from organic waste, highlighting both challenges and opportunities (Olujobi et al., 2021).

1.9 Conclusion

Natural gas conversion represents a promising alternative fuel option for Nigeria, offering economic, environmental, and energy security benefits. Leveraging domestic natural gas resources can reduce pollution, enhance energy affordability, and contribute to economic development. To unlock this potential, Nigeria must develop a supportive policy and regulatory framework, invest in infrastructure, and foster collaboration between the government, private sector, and international partners.

2.0 Recommendation

There is an evident need for an increased focus on raising awareness and promoting the adoption of compressed natural gas (CNG) as a viable vehicle fuel source in Nigeria. While commendable efforts are being made through initiatives such as marketing CNG refueling facilities and considering the subsidization of vehicle conversion costs, more assertive measures are required. These include:

1. **Aggressive Public and Media Campaigns:** The government should launch comprehensive public awareness campaigns and engage with local communities through workshops, seminars, and events. These efforts must advocate for CNG adoption and address the economic impact of high petrol prices on the public.
2. **Stakeholder Partnerships:** Collaborations with policymakers, stakeholders, and energy companies should be established to foster the growth of CNG infrastructure and support.
3. **Tax Incentives and Subsidies:** Consider introducing tax incentives and subsidies to promote the adoption of CNG vehicles and encourage investments in CNG infrastructure.

4. **Pilot Projects:** Implement pilot projects in specific regions or communities to assess the feasibility and impact of CNG adoption in various contexts.
5. **Educational Initiatives:** Partner with educational institutions to incorporate CNG-related curricula and raise awareness among the younger generation about the benefits of CNG vehicles.
6. **Private Sector Engagement:** Engage with vehicle manufacturers and energy companies to facilitate the availability of CNG-powered vehicles and ensure the development of CNG refueling infrastructure.
7. **Research and Development:** Encourage research and development efforts to enhance the efficiency and affordability of CNG conversion kits, making them more accessible to vehicle owners.
8. **Standardization:** Develop and enforce standardized regulations and safety protocols for CNG conversion and refueling stations to ensure consistent quality and safety across the country.
9. **Incentivize Fleet Conversion:** Target fleet owners and operators by offering incentives to convert their vehicles to CNG

2.1 The Role of NACETEM in the CNG conversion process

At the National Centre for Technology Management (NACETEM), our mandate and mission are centered on advancing science, technology, and innovation management for sustainable development. In line with our commitment to these principles, we recognize the critical importance of Compressed Natural Gas Vehicle (CNGV) adoption in Nigeria. CNGV technology represents a transformative opportunity for our nation, offering economic, environmental, and energy security benefits.

As we strive to fulfill our vision of becoming an internationally recognized center of excellence in science, technology, and innovation management, we are ready to play a pivotal role in facilitating the CNG conversion process. Here are the key recommendations for our involvement:

1. Specialized Training and Skill Development: Drawing upon our status as a Training Centre, we will develop and implement comprehensive training programs tailored to the needs of technicians, engineers, and professionals engaged in CNG vehicle conversion. These programs will be designed in collaboration with international experts, ensuring that participants acquire the knowledge and skills necessary to execute CNG conversions safely and efficiently.

2. Evidence-Based Policy Research and Advocacy: Leveraging our proficiency in policy research, we will embark on rigorous studies to assess the advantages and challenges of CNG adoption in Nigeria. Our research will provide empirical foundations for policy recommendations, advocating for the formulation of supportive policies, incentives, and regulations that foster CNGV conversion. We will emphasize the compelling economic, environmental, and energy security advantages of CNG.

3. Capacity Building in CNG Technology: Collaborating with esteemed domestic and foreign institutions, we will develop postgraduate courses and programs dedicated to CNG technology and management. These programs will be instrumental in producing experts and professionals equipped to spearhead the CNG conversion initiative in Nigeria.

4. STI Databank and Knowledge Dissemination: We will establish and maintain an extensive databank reflecting ongoing efforts in CNG conversion. This databank will be made accessible to the public, government agencies, and potential investors, serving as a vital resource for informed decision-making. This knowledge dissemination will encompass all

facets of CNG technology, including safety standards, best practices, and conversion success stories.

5. STI Policy Formulation and Advisory: At all levels of government – Federal, State, and Local – we will actively participate in the formulation of science, technology, and innovation policies, particularly those related to alternative energy sources like CNG. Our goal is to provide strategic counsel on integrating CNG technology into national energy and transportation policies, advocating for the inclusion of incentives for CNGV conversion.

6. International Collaboration: We will reinforce our collaborations with other countries, especially African nations, in the field of CNG technology and management. By sharing best practices, research findings, and policy insights, we aim to facilitate the seamless adoption of CNG technology on a regional scale. Partnerships with international organizations and institutions renowned for their expertise in CNG technology will be actively pursued.

7. Awareness Campaigns and Stakeholder Engagement: NACETEM will organize a series of awareness campaigns, workshops, seminars, and conferences dedicated to CNG technology and its multifaceted benefits. We will engage with government officials, industry leaders, and the public to raise awareness regarding the advantages of CNGV conversion and to address any misconceptions or doubts.

8. Research and Development Support: Our organization will allocate resources to support research and development initiatives in collaboration with universities and research institutions. Projects aimed at enhancing CNG conversion kits, storage solutions, and safety measures will receive our funding and backing.

9. Quality Control and Certification: We will establish stringent quality control standards and certification programs for CNG conversion facilities and technicians. Ensuring that all

conversions adhere to safety and environmental standards will be a top priority. We will provide certification for compliant facilities and professionals, instilling confidence in the safety and reliability of CNGV conversions.

In conclusion, NACETEM is fully committed to driving the successful adoption and implementation of Compressed Natural Gas Vehicles (CNGVs) in Nigeria. These efforts align seamlessly with our vision of becoming a global center of excellence in science, technology, and innovation management for sustainable development. Together with our partners and stakeholders, we will work tirelessly to realize the immense potential that CNG technology offers to our nation.

Frequently Asked Question

I. Natural gas as a vehicle fuel - is this new technology?

Natural gas engines were built during the late 1800s, years before they built the first petrol engine. Therefore, it is not new technology

II. What impact will converting a vehicle have on the original warranty?

Generally, installing aftermarket parts on a vehicle does not affect the original equipment (vehicle) manufacturer's warranty. This is the case when having an aftermarket CNG conversion kit installed on your vehicle by a professional or an accredited expert.

III. Can an engine run on both CNG and petrol?

Yes - but not at the same time. You can run on one type of fuel at a time and change the fuel you are using with a button on the dash near the stirring wheel.

IV. How many kilometers can a tank full of CNG travel?

This would depend on the CNG tank size that is selected for your vehicle conversion.

V. If a vehicle runs out of CNG while driving - what should the driver do?

When the CNG storage tank becomes low on pressure the engine will automatically switch to gasoline. Normally the driver will not notice a change in engine operation when this takes place.

VI. How safe is CNG when used as a fuel for vehicles on the road?

Natural Gas is much lighter than air, so it rises into the atmosphere rapidly if it is released due to an accident. It has a narrow range of flammability. The fuel storage cylinders used in CNG

vehicles are much stronger than petrol fuel tanks as their design is subjected to heat and pressure extremes.

VII. Will CNG harm the engine in any way?

The use of CNG serves to extend the life of lubricating oil as CNG will not contaminate or dilute crankcase oil. Natural gas is not toxic or corrosive.

VIII. Why are exhaust gases non-existent in CNG vehicles?

A major positive aspect of CNG use is that being a natural gas (methane) its exhaust emissions contains just water vapor, no carbon or other particles, and a small quantity of carbon monoxide. Being virtually pollution-free CNG driven vehicles meet the most stringent emission standards worldwide.

IX. Does CNG have a smell?

While natural gas is odorless, an odor is often added as a safety precaution in case of a gas leak.

X. How does a CNG/gasoline bi-fuel vehicle compare to a standard petrol-powered one regarding performance parameters?

Easy starts, steady idling, and smooth acceleration are virtues of CNG-run vehicles. The power loss of 5-15% means that acceleration is slower, which can be negated by fine-tuning the CNG kit, by advancing spark timing to derive the benefit of its high octane rating. Natural gas has a 130 octane rating, compared to the 87 to 96 octane rating of gasoline.

XI. Can a diesel engine be converted?

No, a vehicle powered by a diesel engine can be repowered by switching the diesel engine for a dedicated natural gas engine. The other option is to add compressed natural gas (CNG)

blending capability. This technology, available for some diesel engines, allows the engine to operate on a controlled mixture of diesel fuel and CNG.

XII. Are CNG cylinders safe in vehicle accidents?

A pressurized gas cylinder is probably the strongest component of the vehicle. Vehicles that are destroyed in collisions show the only discernible component being the intact gas cylinder. It is unlikely that cylinders will rupture due to a collision impact. A CNG storage cylinder is many times stronger than a standard petrol or diesel tank installed in a vehicle.

XIII. Are vehicle maintenance needs different from CNG?

Natural gas engines work essentially the same way as gasoline engines. An air-fuel mixture is injected into the intake manifold, drawn into the combustion chamber, and then ignited by a spark plug. Most engine service requirements are very similar and can be handled by a dealer, automotive shop, or trained mechanic.

XIV. How long does it take to install a conversion kit?

Depending on the vehicle, most installations are done in just 8 to 12 hours.

XV. How much does it cost to convert?

There are many factors involved in estimating the cost to convert. It usually costs between N150,000 and N350,000 to purchase the kit needed in converting a vehicle from petrol or diesel engine to CNG engine, depending on the nature and condition of the vehicle.

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