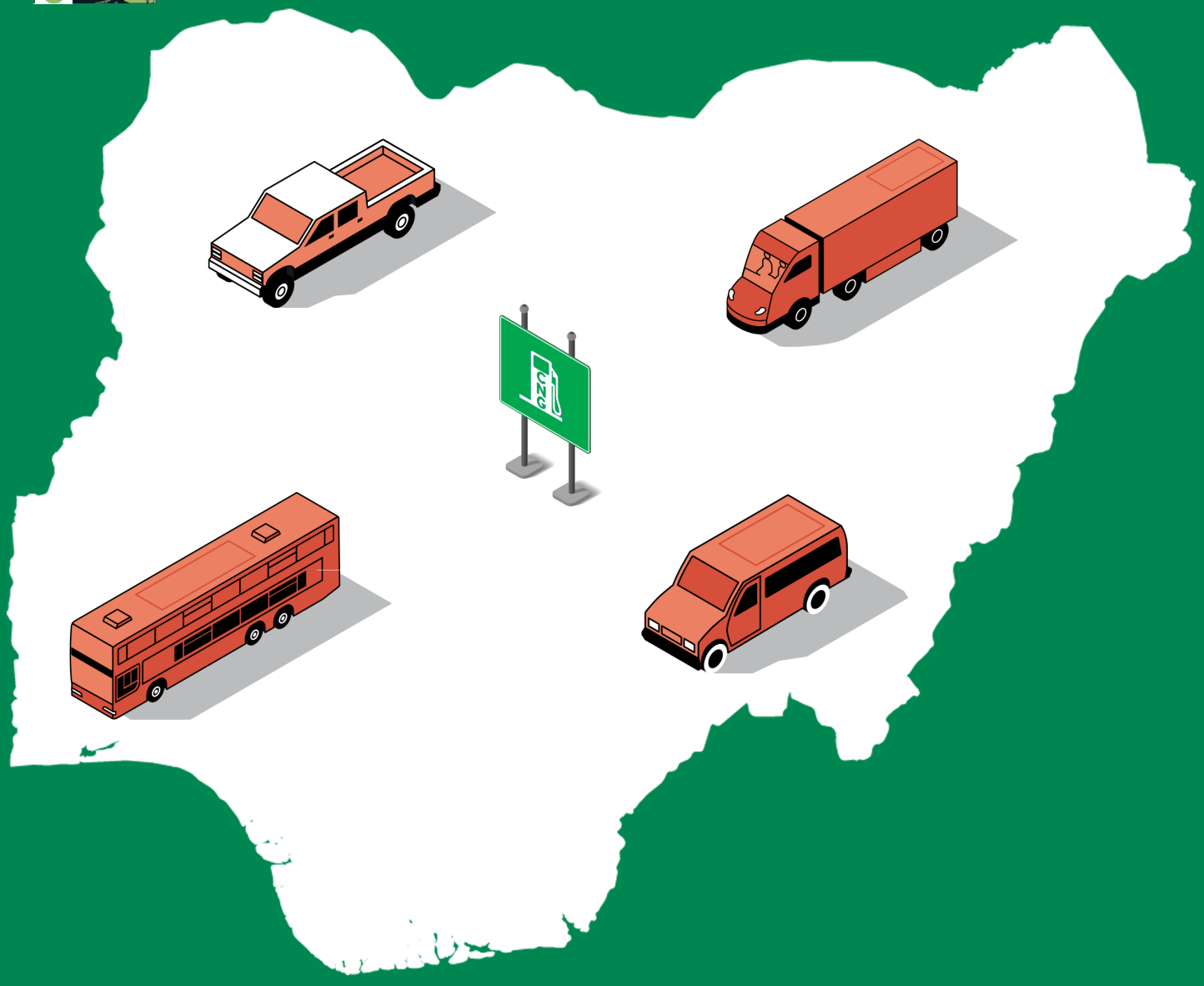


POLICY BRIEF

OPPORTUNITIES FOR CNG-BASED TRANSPORTATION PROGRAMME IN NIGERIA

POLICY BRIEF

OPPORTUNITIES FOR CNG-BASED TRANSPORTATION PROGRAMME IN NIGERIA

Authors: Anumita Roychowdhury, Priyanka Chandola and Vivek Chattopadhyaya

Editor: Akshat Jain

Design and cover: Ajit Bajaj and Sanjit Kumar

Production: Rakesh Shrivastava and Gundhar Das

Policy Brief: Opportunities for CNG-Based Transportation Programme in Nigeria

Prepared by Centre for Science and Environment (CSE), India for the Federal Ministry of Transportation (FMoT) and Federal Ministry of Environment (FME), Federal Republic of Nigeria

We are grateful to the FMoT and FME of the Federal Republic of Nigeria for the opportunity to collaborate as a knowledge partner to develop this Policy Brief: Opportunities for CNG-Based Transportation Programme in Nigeria

The Centre for Science and Environment is grateful to the Swedish International Development Cooperation Agency (Sida) for their institutional support.

Contents

1. Imperatives of CNG programme for transportation in Nigeria

There is considerable interest in implementing a compressed natural gas (CNG) programme for city-based transportation systems and to leverage and harness locally available natural gas in Nigeria. Both energy security concerns and the need to mitigate local air pollution and reduce exposure to vehicular emissions underpin this interest. This can help to reduce dependence on fuel imports as well as cut down toxic emissions from a large ageing vehicle fleet running on diesel and gasoline.

Currently, the Government of Nigeria is assessing the implementation and expansion of the natural gas programme in different sectors. From that perspective, the Federal Ministry of Transportation that is responsible for framing the policies related to transportation systems, especially public transport strategies in Nigeria, has begun evaluation of the CNG strategy for application in city-based transportation.

In view of the fact that India has considerable experience in establishing CNG programmes for city-based transportation systems, the Federal Ministry of Transportation has collaborated with the Centre for Science and Environment (CSE) to inculcate the learnings from Indian cities and assess the local imperatives of Nigeria to chalk out the roadmap for implementation of this programme. This is also supported by the Federal Ministry of Environment, Nigeria, that is working on the framework for clean air action plans and has initiated deliberations on clean fuels and CNG. CSE is also contributing to that process.

This assessment therefore captures the status of the policy action on CNG in Nigeria and the learning from the CNG programmes in Indian cities. This has primarily focussed on the experience of the capital city of Delhi in India that has implemented one of the largest CNG programmes in the country. In addition, this assessment has also reviewed the current imperatives of Nigeria that can help to shape implementation strategies in the cities of Nigeria.

Based on this assessment, pathways have been reviewed that include the need for regulatory mandate; emissions and safety regulations for new technology

and technology pathways; plans for city gas distribution systems and refuelling networks; quality control of vehicle conversion; and fiscal strategies and emissions benefits to inform policy development.

Nigeria is yet to implement the Euro IV emissions standards for both vehicles and fuels. It is recognized that CNG will be an important transition fuel in this scenario. In fact, most of the vehicles are second hand imports and very old. CNG substitution can help leapfrog to much cleaner emissions compared to the conventional fleet as was noticed during the early stages of implementation in India. With access to large natural gas reserves, Nigeria has an opportunity to maximize this benefit.

In 2019, the Government of Nigeria adopted the National Action Plan (NAP) to reduce Short-Lived Climate Pollutants (SLCPs). This has aimed to reduce 75 per cent of $PM_{2.5}$ emissions by 2030. The 22 key measures listed for action include regulation and enforcement of vehicle emission standards, eliminating gas flaring, and targeted adoption of CNG buses in Nigeria as the transportation sector measures. It has proposed conversion of 25 per cent of all buses to CNG by 2030. The government has initiated work on this front. In fact, the transport sector is targeted for five specific measures which include: renewal of the urban bus fleet in Lagos; adoption of CNG buses in Nigeria; introduction of low-sulphur diesel and gasoline; elimination of high emitting vehicles that do not meet vehicle emission standards; and reduction of vehicle journeys by car through a transport modal shift.

The government is now embarking on a comprehensive CNG programme and policy. This is an opportunity to define the scope and design of the programme to maximize emissions and energy security benefits. This can comprehensively define the mandate, emissions regulations for CNG vehicles, technical regulations for quality control rules for CNG conversion, establishment of refuelling infrastructure, safety rules, and gas pricing policy, among others.

Emissions of both toxic air pollutants and heat trapping CO_2 emissions can be reduced from CNG vehicles to provide substantial public health and climate change benefits. However, there are concerns around methane leakage from refining, distribution and refuelling systems that can trap heat and contribute to global warming. Efforts will therefore have to be made to minimize the unintended fall out of this interim solution of using this transition fuel. The ultimate solution to both local air pollution and heat trapping methane emissions is large-scale transition to zero tailpipe emissions.

However, this detailed discussion on CNG programme is being done with a caveat that Nigeria is planning its CNG programme at a time when it also has an opportunity to adopt vehicle electrification programme for targeted zero emissions transition. Therefore, it may be helpful to plan both the transitions in synergy by establishing clear vehicle segment-wise targets and priority to optimize investments.

Lessons from Indian cities: As cities of Nigeria are embarking on a CNG programme for vehicles, it will be helpful to understand the experience and draw lessons from some of the established programmes in Indian cities. It is particularly important to understand the transition to CNG bus programme which was also an important priority focus of the Indian programme.

The CNG programme in Indian cities was driven by the concern over air pollution and toxic exposure to diesel emissions. Indian cities had embarked on the CNG programme at a time when its mainstream diesel and gasoline vehicles were languishing and were extremely polluting in the absence of effective emissions regulations for vehicles and fuels. There was the added interest of strengthening the energy security of the country. The available emissions data in India had shown that switching to CNG could enable leapfrogging to much cleaner emissions levels compared to gasoline and diesel vehicles. At the time of the introduction of the CNG programme in Delhi, the tested emissions data from the vehicle certification agency Automotive Research Association of India (ARAI) had shown that the particulate emissions from a Euro II compliant diesel bus could be 46 times higher than its CNG counterpart.

The emissions gains and the attendant air quality benefits have been the key rationale and justification for promoting this fuel substitution programme in India. The Indian CNG programme had primarily targeted to replace the most polluting segments on the road that included diesel-based high-mileage public transport buses and para transit. This approach has provided the maximum emissions benefits.

While the emissions gains were substantial, introducing a new technology and fuels also required an ecosystem level change. As this new technology had to penetrate the market and compete with the mainstream technologies of diesel and gasoline, more enabling mechanism had to be adopted. This needed investment plans for gas pipeline to have adequate number of online high pressure refuelling systems; a regulatory mandate for targeted replacement of diesel and gasoline vehicles with CNG to create critical mass of demand; technical and emissions

regulations for new product development; and regulations for retrofitment and conversion of on-road vehicles along with quality control of conversion, inspection and maintenance programme, safety regulations for vehicles and gas cylinders, and a fuel pricing policy to keep the cleaner fuel more cost effective.

These are the range of interventions that had to be addressed for a successful implementation of the programme. This programme in Delhi was directed by the Supreme Court of India in response to the ongoing public interest litigation on air pollution mitigation.

The entire implementation process has created a strong learning curve that can be educative and needed for experience sharing among the cities in the developing world embarking on a similar programme. This policy brief aims to capture that learning.

Way forward in Nigeria

Nigeria has an immense opportunity to leverage its locally available natural gas reserves to build a robust CNG programme to counter the pollution impact of the large fleet of old and ageing vehicles on diesel and gasoline that do not conform to any mandated emissions standards currently.

Steps have already been taken to implement this programme and it is at the crossroads for further expansion. This initiative is expected to contribute towards the implementation of the 2019 NAP to reduce SLCPs to achieve 75 per cent reduction in $PM_{2.5}$ emissions by 2030. This has categorically asked for targeted adoption of CNG buses to make them 25 per cent of all buses by 2030. Combining CNG programme with the augmentation of the bus programme is a win-win strategy as this augments public transport services based on clean fuels and provides both emissions and mobility gains.

Prioritize key cities for implementation of city gas distribution system: It is necessary to prioritize key cities with large volumes of traffic and high rates of motorization to implement the CNG programme. Gas pipeline development at the city level is critical to have efficient refuelling systems to support large volume of vehicles. This will require appropriate forecasting of volume of demand to design the refuelling system. It is necessary to establish the maximum number of online stations linked to the pipeline directly.

Need mandate for targeted replacement of other fules with CNG in different vehicle segments for critical mass of demand: A mandate for targeted replacement and transition to CNG is needed for creating critical mass of demand to make the investment in CNG infrastructure efficient. It is not possible to create a sizeable market based on incremental and natural rate of growth. New technologies require a time-bound mandate for targeted vehicle segments for adequate market penetration. Already the NAP has asked for a dedicated CNG bus programme and has targeted 25 per cent of the bus stock to be on CNG. This is an important strategy to eliminate toxic diesel emissions from the bus segment and also create critical mass of demand to make the market viable.

Prioritize transition of high-mileage and more polluting vehicles to maximize emissions gains: The emissions gains can be maximized if high-mileage vehicles—including public transport and para transit—along with more polluting heavy-duty vehicles on diesel are prioritized for targeted transition. Fleet-wise targets are needed for planned transformation. Buses as a priority segment will require special attention.

Need emissions standards and safety regulations for CNG vehicles: As Nigeria is promoting local manufacturing and assembly of vehicles, emissions standards and regulations are needed for proper uptake of technology approaches and to define the technology pathways for best emissions gains. Emissions and technical regulations, and testing for certification of vehicles are necessary to establish a good programme. Nigeria has adopted Euro II emission standards. But the CNG programme can be linked to higher targets of Euro IV emissions standards that can also force adoption of improved diesel and gasoline technologies.

Need monitoring and compliance framework for CNG conversion programme: As Nigeria is also allowing conversion of on-road vehicles with the help of conversion kits, this requires special attention. As the Indian experience shows, lack of quality control of conversion, and the absence of audits and certification of conversion workshops can increase the risk of leakage and safety. It is necessary to certify the conversion kits by make and model of vehicles. Some technical assessment will be needed for conversion of very old vehicles that are imported into the country. Nigeria needs a scrappage programme to identify the end-of-life vehicles that need to be scrapped and cannot be converted. In fact, in India, Delhi took the decision of not converting old diesel buses to CNG and mandated purchase of only new CNG buses. However, for three-wheelers and cars/taxis, conversion techniques have been adopted. This requires a certification system for

conversion kits and periodic audit of the conversion workshops for quality control. Emissions and safety standards will have to be mandated for all of them.

Need framework for safety regulations and monitoring: It is necessary to adopt a framework for monitoring and inspection of safety related aspects of CNG vehicles to eliminate fires and other hazards. Some of the bus-burning incidents during the initial years of the Delhi programme were carefully investigated to ensure uptake of remedial measures. Bus manufacturers were directed to correct the defects related to wiring harness, exhaust manifolds, cylinder heads, etc. With tough safety regulations, field-based root cause analysis and corrective measures, the quality of the programme can be greatly improved. Safety regulations are needed for periodic testing of CNG cylinders in the vehicles as well. This requires testing centres to carry out these pre-defined tests.

Need adequate and appropriate refuelling network for CNG dispensation: Nigerian cities will be well advised to set up pipelines for city gas distribution so that a dense network for CNG refuelling and dispensation can be built. Pipeline-based dispensation system can ensure proper and consistent pressure for refuelling of CNG that can fast-track refuelling. Any tanker-based refuelling system that cannot maintain consistent high pressure during refuelling can be very inefficient and can slow down refuelling. Inadequate supply network and compression and dispensing capacity of refuelling station can make refuelling inefficient leading to long queues of vehicles. Refuelling network also requires adequate geographical coverage. Particularly, public buses require dedicated refuelling systems inside the bus depots to ensure smooth operation of buses and to reduce dead mileage of buses and time wasted in refuelling. This planning is critical for successful operations in cities of Nigeria.

Address pricing and taxation of CNG to keep cleaner fuels effectively cheaper than mainstream fuels: Nigeria has already adopted a fuel pricing policy that keeps the price of diesel fuel—that causes more toxic emissions—more expensive than gasoline. This is a good practice in Nigeria. This needs to be further expanded to ensure that the price of CNG remains the cheapest among all the mainstream fuels. This will require a favourable taxation policy. This is also needed to reduce the cost pressure on public transport services.

Vehicle inspection and maintenance programme: While a robust vehicle inspection and maintenance programme is needed for all genres of vehicles, it is particularly important for the CNG fleet. This helps to introduce CNG leakage testing, maintenance of the logbook to record all repairs and promotes preventive

maintenance practices. Regular tests (quarterly tests, annual fitness tests and third party checks) help to improve the quality of the programme and minimize safety hazards.

Need institutional oversight for quality control and implementation of the programme: There is need for multidepartment oversight committee for coordinated action and to oversee the various aspects of the programme.

Need skill building to create jobs in the sector: The wide range of technical regulations and repair and maintenance practices that are needed to implement the CNG programme have strong potential for skill building and job creation. This is an important spinoff that needs to be leveraged.

2. Opportunity in Nigeria: Access to natural gas

Nigeria is located in West Africa, on the Gulf of Guinea. It shares its borders with Benin, Niger, Cameroon and Chad Republic. Nigeria has the largest natural gas reserves in Africa. The country ranks 9th globally in proven gas reserves.[1] It was the 5th largest exporter of liquefied natural gas (LNG) in the world in 2018. About 982 billion cubic feet (Bcf) of LNG was exported. LNG exports accounted for about 6.5 per cent of LNG traded globally. Spain, India and France were the top three importers of LNG.

In 2017, the total primary energy consumption in the country was about 1.5 quadrillion British thermal units and 97 per cent was derived from natural gas, petroleum and other liquids. According to the Oil and Gas Journal, the country had an estimated 200.4 trillion cubic feet (Tcf) of proved natural gas reserves in 2019. Around 1.6 Tcf of dry natural gas (marketed natural gas production) was produced during 2019.[2] It increased to 206 Tcf of gas reserves and 600 Tcf of unproven reserves. About 7.8 Bcf is produced per day. Domestic consumption in power generation and industrialization is only 1.2 Bcf per day.[3] Nigeria's domestic natural gas consumption in 2019 was about 15 billion cubic metres (bcm) and it is expected to increase to some 20 bcm by 2030 (see *Table 1: Proven crude oil and natural gas reserves* and *Table 2: Gas production and utilization*).

Natural gas supplies are located in the Niger Delta and Lagos. There are plans to expand their exploration and extraction and bring it to Abuja and Kano. Security challenges in the Niger Delta are a concern. Gas flaring is also a concern. About 261 Bcf of natural gas was flared in 2018 making it the 7th largest natural gas flaring country. Gas flaring needs to be stopped to enable its utilization. PWC estimates that Nigeria's economy lost N233 billion to gas flaring in 2018 and environmental cost to Nigeria amounts to N28.8 billion annually.

Nigerian Liquefied Natural Gas Company is the biggest natural gas operator in the country. It began exploration and production in 1999. Efforts are being made to make use of the reserves of associated gas and reduce flaring. Nigeria's natural gas industry is also affected by the same security and regulatory issues that affect the crude oil industry (see *Graph 1: Annual natural gas production and consumption in Nigeria in billion cubic feet*).

Table 1: Proven crude oil and natural gas reserves

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Crude oil (mbbl)	36.375.26	36,022.22	37,138.83	37,070.86	37,448.25	37,062.06	37,453.00	36,182.00	36,971.91	36,890.00	36,910.00
Gas (bscf)	180,331.17	182,606.78	180,616.85	180,376.31	187,268.38	186,476.82	193,354.99	198,711.27	200,902.20	203,449.26	203,056.10

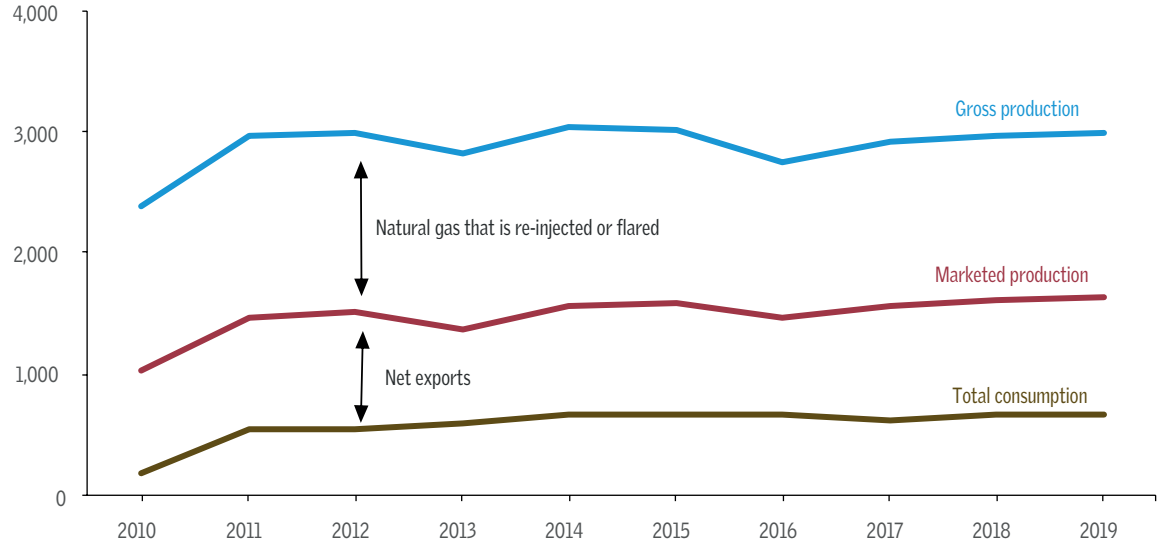
Source: Annual Statistical Bulletin, NNPC

Table 2: Gas production and utilization (in bscf)

	Gas produced	Gas used as fuel	Gas sold to third parties	Gas to NGC	Gas re-injected	Gas for LPG/ NGL/EGTLAS feedstock to EPCL	Gas for LNG	Total gas utilized	Gas flared	Percentage flared
2011	2,400.40	104.54	786.84	101.56	348.33	38.61	313.09	1,781.37	619.03	25.79
2012	2,580.17	115.68	875.46	72.17	462.88	47.19	329.86	1,991.50	588.67	22.82
2013	2,325.14	128.52	606.54	129.89	638.51	56.08	300.88	1,916.53	408.61	17.57
2014	2,485.65	151.14	705.04	178.45	625.59	35.81	391.37	2,199.88	285.76	11.50
2015	2,929.85	159.1	1,017.21	133.54	727.46	41.91	421.19	2,588.48	341.37	11.65
2016	2777.70	147.44	431.53	-	-	130.69	1,007.91	2,465.32	312.47	11.25
2017	2,901.63	139.44	421.94	-	-	106.82	1,119.65	2,543.93	357.70	12.33
2018	2,836.55	134.65	430.21	25.31	760.12	104.76	1,099.42	2,554.47	282.08	9.94
2019	2,864.93	147.08	427.43	27.84	788.69	97.30	1,132.24	2,620.58	244.35	8.53
2020	2,729.10	140.25	478.72	-	698.38	121.51	1096.89	2,535.75	193.13	7.08

Source: Annual Statistical Bulletin, NNPC

Graph 1: Annual natural gas production and consumption in Nigeria in billion cubic feet



Source: US Energy Information Administration

The current mix of transport fuels—gasoline, diesel and CNG: According to the Petroleum Products Pricing and Regulatory Agency (PPPRA), 19 billion litres of petroleum products were imported in 2019, equivalent to USD 8.7 billion. Gasoline and diesel are the main transport fuels. Estimated average daily consumption in 2020 was 60,000,000 litres of gasoline and 14,133,866 litres of diesel. Natural gas component in terms of actual consumption is still very small.

Currently, natural gas is primarily used for power generation and as an industrial fuel. Majority is used in the power sector by independent power plants and for commercial captive power generation. Eighty per cent of the power generation is from gas and the remaining from oil. NIPCO Plc is currently constructing a pipeline from Ibafo-Sagamu-Ibadan to provide CNG to industries.[4]

Improving local utilization of natural gas in the transportation sector is also important to address energy security. Fuel import is increasing in the country. According to Nigeria Bureau of Statistics, gasoline import increased from 17.3 billion litres in 2017 to 20.14 billion litres in 2018 and 20.89 billion litres in 2019. Petroleum import cost was reported to increase three times from N289.46 billion in the first quarter of 2019 to N837.67 billion by second quarter.[5]

Status of pipeline infrastructure: The Nigerian Gas Processing and Transportation Company (NGPTC), a subsidiary of the NNPC, owns the main natural gas pipeline transport infrastructure including the Alakiri–Obigbo–Ikot Abasi Pipeline (the eastern network), the Escravos–Lagos Pipeline System (the western network) and the proposed Ajaokuta–Kaduna–Kano gas pipeline connecting the north.

Domestic gas utilization is expected to increase with the completion of the AKK project in 2023. The NGPTC has also granted franchises to private parties such as Shell Nigeria Gas, Gaslink Nigeria Limited and Falcon Corporation Limited for the development of gas distribution infrastructure in specified markets on a build, own, operate and transfer basis.

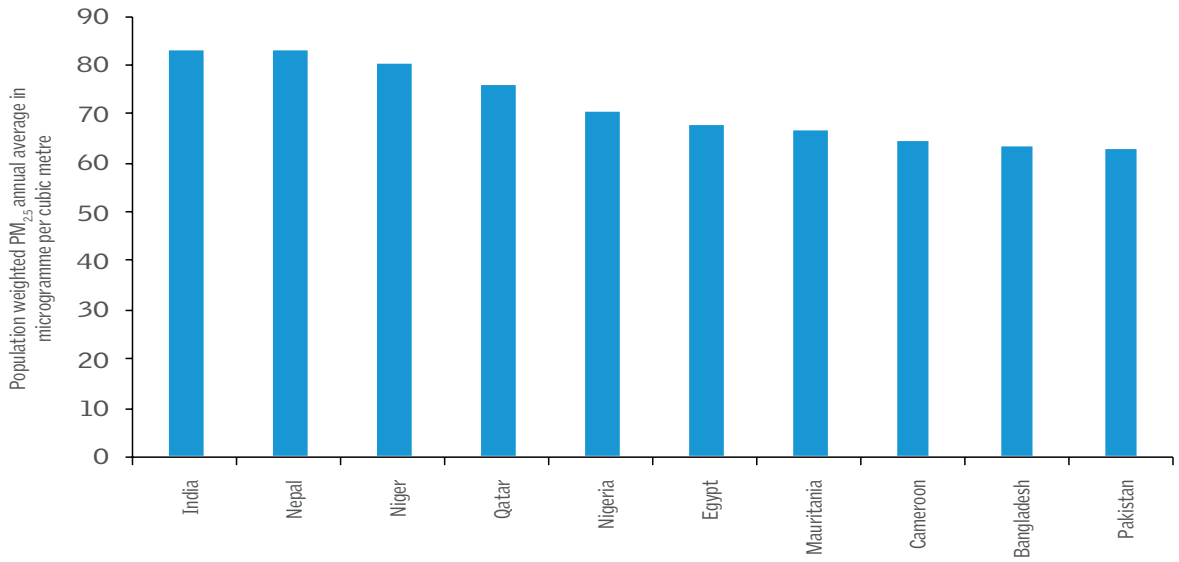
Cities of Nigeria are connected to pipelines or through land transport of CNG. The geographical spread of city gas distribution shows that Benin and Lagos have CNG supply and vehicles are running on CNG in these cities. The Department of Petroleum Resources has plans to build 9,000 filling stations across the country. This therefore raises the questions of how this can be leveraged for expanding a well-planned CNG programme for vehicles in cities.

3. Air pollution imperatives of CNG programme in Nigeria

Air pollution is a serious concern in Nigeria, with particulate pollution being of utmost concern in Nigerian cities. The earliest and the first ever smog episode in Lagos which lasted for more than six hours was reported way back in October 2005 when people around Lagos woke up to a hazy atmosphere that was very unusual. Some schools around Maryland, Ojota, Anthony and Ikeja had to shut down and children were sent back home. This led Lagos Metropolitan Area Transport Authority (LAMATA) to facilitate the Lagos Air (vehicular emission) Quality Monitoring Study (LAQMS) in February 2007.

The report on State of Global Air 2020 has shown that Nigeria is amongst the top ten countries globally with the highest $PM_{2.5}$ exposure (population-weighted $PM_{2.5}$ annual averages). The $PM_{2.5}$ annual average in Nigeria is more than 70 $\mu g/m^3$ (see *Graph 2: Top 10 countries with highest population-weighted $PM_{2.5}$ annual averages*).

Graph 2: Top 10 countries with highest population-weighted $PM_{2.5}$ annual averages

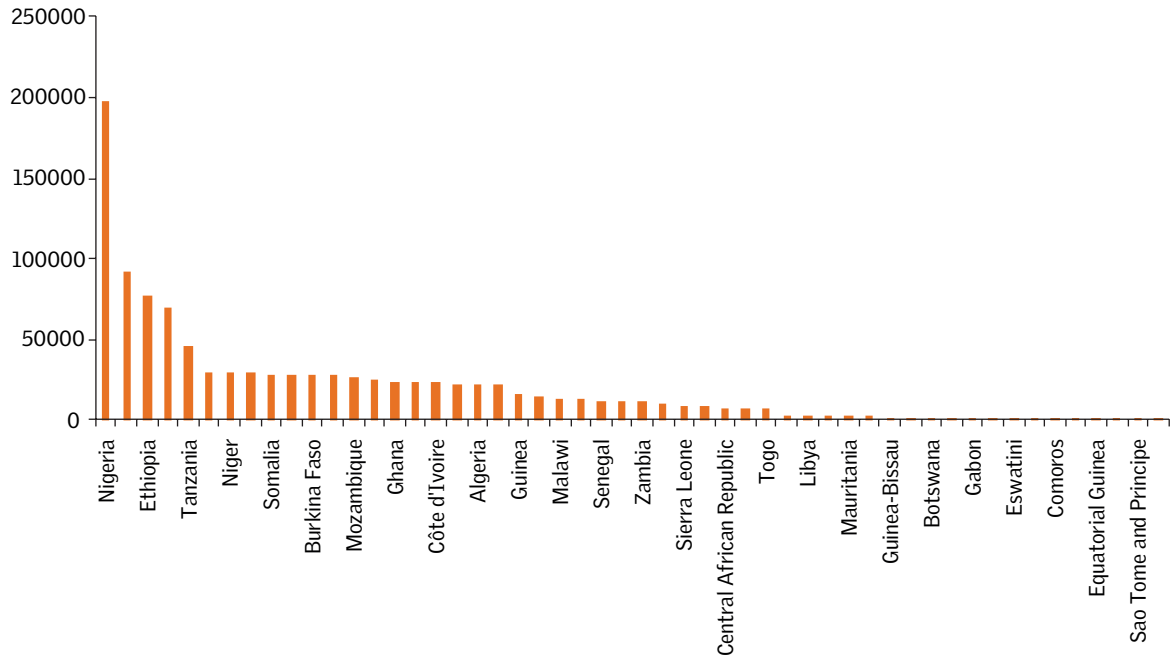


Source: CSE based on SoGA 2020 report

The 2016 WHO database on particulate pollution reported air quality monitoring data of 12 Nigerian cities. All cities in Nigeria had an annual mean of PM_{10} and $PM_{2.5}$ above the WHO guideline. Nigerian cities such as Onitsha, Kaduna, Aba and Umuahia were among four of the 20 African cities that reported worst air quality in the world. Onitsha was the most polluted in terms of PM_{10} and reported the highest (594 $\mu g/m^3$) PM_{10} levels. PM_{10} levels in Onitsha were 30 times higher than the WHO annual PM_{10} guideline of 20 $\mu g/m^3$. PM_{10} levels in cities exceeded the WHO guidelines by about 4 to 30 times. Kaduna had highest $PM_{2.5}$ levels (90 $\mu g/m^3$). The $PM_{2.5}$ levels in cities exceeded the WHO guidelines by about 2 to 9 times. Earlier, the 2016 edition of The Little Green Data Book of the World Bank showed that 100 per cent of the Nigerian population was exposed to $PM_{2.5}$ levels exceeding WHO guidelines. The 2015 edition of the same publication however stated that 94 per cent of the population was exposed to $PM_{2.5}$ exceeding WHO guidelines.

Particulate pollution causes 0.197 million deaths in Nigeria which is the highest among African countries (see *Graph 3: Air pollution deaths in Africa*).

Graph 3: Air pollution deaths in Africa



Source: SoGA 2020 Report

4. Special challenge of vehicular pollution in Nigeria

Within this context, motorization and vehicular pollution assume great significance. Even though Nigeria is in its early stages of growth and the legacy vehicle stock is still small compared to other rapidly growing developing countries, the pace is picking up especially in the major urban centres. In Lagos, Nigeria, it is estimated that if the ownership rates grow from 0.05 to 0.06 per capita between 2010–25, there will be an 80 per cent increase in vehicle numbers.

Nigeria has effectively curbed dieselization of personal vehicle fleet with fuel pricing policy. Higher price of diesel fuels has helped lower the use of diesel cars in Nigeria. Nigeria is the best-practice country in terms of fuel pricing; the price of gasoline is kept effectively cheaper than that of diesel. This has helped eliminate dieselization of cars and kept the share of diesel consumption fairly low. Share of diesel consumption in total fuel consumption is only 16 per cent.[6]

This is a critical step as the country imports mostly used and old vehicles. Since these old vehicles are based on old diesel technology and use poor quality fuel, it would have significantly escalated public health risk. Diesel consumption in the region is largely driven by the high share of commercial, freight and public transport that is not easily substitutable. Diesel use in buses and trucks is also high and this segment attracts more new vehicles. Nigeria needs clean diesel and emissions standards for vehicles.

It is important to address diesel emissions as poor-quality diesel harms public health and climate. The International Agency for Research on Cancer of the WHO has reclassified diesel exhaust in Group 1 of carcinogens for definite links to cancer, putting it in the same bracket as tobacco. The European emissions standards that Africa and Asia follow allow diesel cars to emit three times more nitrogen oxides and several times more particulate matter compared to gasoline cars. Moreover, new science has now implicated black carbon, the dark fraction of particulate matter, for enhancing climate impacts as well. Most of the diesel particulate core is the dark matter that absorbs light and heat and warms up the climate and fouls up our lungs.

Thus, use of high-sulphur diesel, outdated vehicle technology and expansion in road-based freight traffic have added to the local health as well as global climate

risks. Also, as high-income countries now aim to phase out diesel cars from city centres and are even planning a complete ban on diesel cars in the future, there are additional concerns that a huge fleet of discarded diesel cars and SUVs from these countries will get dumped in Africa.

Nigeria, therefore, will have to quickly move to clean fuel and stringent emission standards to address diesel emissions from all sources. Data from studies carried out in other parts of Africa such as that by Demiss Alemu of the Addis Ababa Institute of Technology and the Federal Transport Authority in 2012 show that dieselization is pushing the light-duty vehicles market towards bigger engine sizes in African markets which consume more diesel and generate more emissions. This has serious implications for their air quality and public health. African countries will have to adopt improved fuel quality and emissions standards to curb dieselization.

Emission standard roadmap for vehicles in Nigeria: Without its own well-established vehicle-manufacturing base, Africa has become hugely dependent on vehicle imports. But Nigeria is setting up its assembly capacity now. This requires adoption of improved emission standards for vehicle manufacturing and fuel quality to enable adoption of improved technology and fuel quality. Adopting emission standards and fuel quality roadmaps is important to curb toxic emissions from vehicle stock. Clean fuel is the critical first step to bring more advanced vehicle technology and reduce emissions.

Nigeria moved towards adopting low sulphur fuel and issued a notification for low-sulphur diesel (50 ppm) and gasoline (150 ppm) in April 2017. However, implementation was delayed. In fact driven by the ECOWAS there is a regional level consensus to implement low-sulphur fuel and adoption of Euro IV emission standards.

The country should adopt Euro IV emission standards. Nigeria has adopted clean vehicles and fuels regulations like other countries in the ECOWAS region. However, according to media reports, gasoline and diesel remain 20 and 30 times higher than the standards. But, as noted earlier, Nigeria has a unique strategy for curbing dieselization. In Nigeria, diesel is priced higher than gasoline. This has been effective in stopping dieselization of cars.

It is important to note that lack of local refining capacity in Nigeria hampers production of low-sulphur fuels. Despite having 2.5 million low-sulphur content and high API gravity daily barrels of crude oil drilled from the Niger Delta by

Shell, Chevron, Exxon and other energy giants, Nigeria has to import refined high-sulphur (1,000 ppm) cheaper fuels from Europe. As the state-owned refineries are non-functional, the country has to import and the fuels are exported back to Nigeria.

The imported fuels are blended (dewatering, re-gassing and desulphurization) as per Nigeria's standard as set by the SON for cost optimization.[7]

There is however hope from new local refineries which are being set up and are expected to boost low-sulphur fuels production. The government in November 2020 commissioned the first phase of a 5,000 bpd modular refinery in Ibigwe, Imo State which is expected to produce 271 million litres of kerosene, diesel, naphtha and HFO annually. Others include Dangote-owned 650,000 bpd refinery in Lagos expected to be completed this year and a 200,000 bpd refinery owned by BUA to be set up in Akwa Ibom.[8]

It is important to link fiscal solutions with stringent emissions standards. Fiscal strategy for clean fuel fund (direct tax incentive for import of clean fuel; differentiated retail prices for clean and dirty fuel and revenue from higher tax to go to clean fuel fund; and even a small tax on each litre of fuel sold can help to offset costs) and additional and differentiated tax on all cars can help bring more revenue for clean fuel fund. It is more cost effective to design and implement the complete system in one step.

Emission benefits of CNG transition in Nigeria: CNG use in vehicles will help to leapfrog to improved emissions levels. Nigeria can learn and benefit from Delhi or the larger India CNG programme. Mass emissions data for local CNG vehicle fleet and gasoline and diesel fleet in Nigeria is not available.

This fuel substitution strategy based on CNG can provide substantial emissions benefits. A parallel can be drawn from the Indian experience. When Delhi had taken the decision to implement CNG programme, there were virtually no mass emissions standards in India. And when the implementation of the CNG programme started in 2000–01 India had just about adopted the Euro II emissions standards for all fuel types. Emissions data from India at that point of time showed considerable emissions benefits from the CNG programme, especially if it replaced diesel. Both CNG and diesel buses meeting Euro II emissions standards were tested by the vehicle certification agency, ARAI. A Euro II diesel bus emitted 46 times higher particulate matter compared to a Euro II CNG bus (see *Table 3: Emissions results of Euro II CNG and diesel buses in India*). Emissions reduction

potential also depends on the quality of conversion and level of vehicle technology. CNG programme has continued to provide emissions benefits through the successive stages of emission standards that India has adopted subsequently. This is discussed in later sections.

Table 3: Emissions results of Euro II CNG and diesel buses in India

Type of bus	CO	HC	NO_X	PM
	Gram/kilometre (g/km)			
Euro II diesel bus on 500 ppm sulphur fuel + DOC	1.45	0.29	6.24	0.35
Euro II diesel bus on 350 ppm sulphur fuel + DOC	0.65	0.15	5.85	0.11
Euro II diesel bus on 50 ppm sulphur fuel + CRT	1.42	0.04	13.58	0.009
Euro II CNG bus + three way catalytic converter	3.18	1.455	5.35	0.0065

Source: Automotive Research Association of India and The Energy Research Institute, India, 2006

5. Energy security and cost savings

Nigeria has deep interest in strengthening energy security and making the energy transition cost effective. Several estimates have been carried out to understand the cost of transition to the CNG programme and its economic benefits. A technical and economic analysis of using CNG as fuel for public transportation on the Port Harcourt–Onitsha express road was used as a case study. It was found that though high capital investment will be required for purchasing CNG vehicles and building infrastructure, it would still be economically viable and will take less than 5 years to break even.

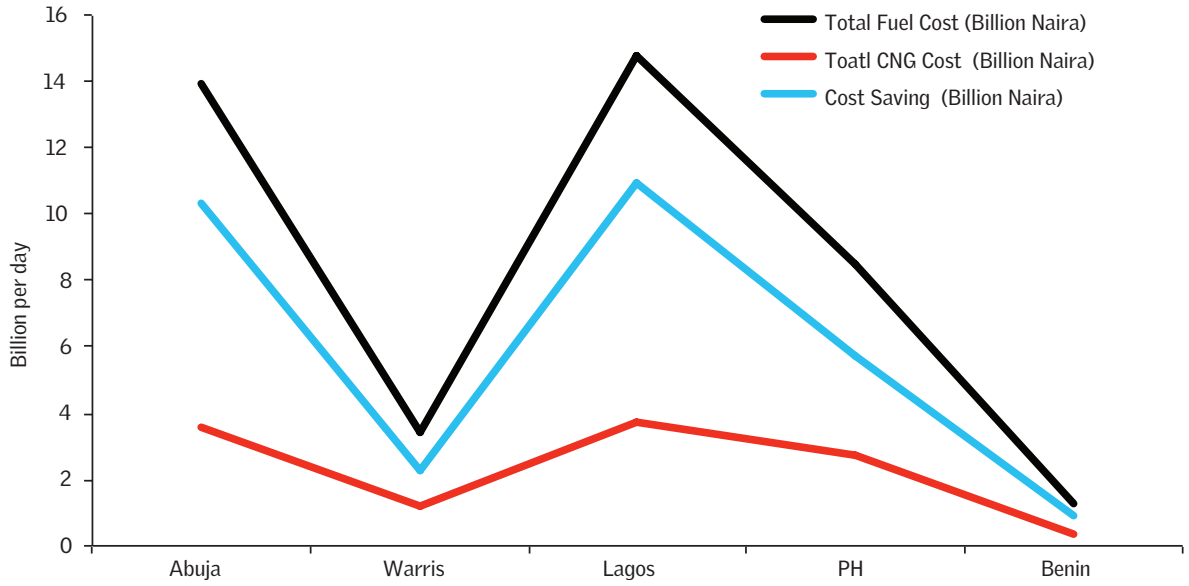
Another study considered a motorist covering an average of 100 km every day in a CNG car. It amounted to savings of N1,143 per day and N34,284 monthly and conversion cost to be recovered before the end of the sixth month. In addition, savings of N211,402 were to be made from the sixth month to end of first year and annual savings of N411,408 thereafter.[9]

According to estimates available from UNEP, if 40 per cent of vehicles in Nigeria switch to CNG, the government can save 28 per cent of foreign exchange spent on the import of 1.02 billion litres of fuels per year. Even cities can secure savings. In Abuja, Abuja Investment spends 13.9 billion Naira on AGO per day. The use of CNG vehicles would reduce the cost to 3.6 billion Naira, saving 10.4 billion Naira per day. Similarly, in Lagos, CNG use can reduce the the amount spent on fuel per day to 3.8 billion Naira from 14.8 billion Naira per day spent on AGO used by Lagbus and BRT, thereby saving 11 billion Naira. In another commercial hub, Port Harcourt, savings of 5.7 billion Naira per day are possible (see *Graph 4: Cost-saving benefits with CNG use in Nigerian cities*).

According to another estimate, 3 trillion Naira will be saved per year if Nigeria switches from gasoline to CNG. Tunji Adeniji, former president of Independent Petroleum Marketers Association of Nigeria (IPMAN), had estimated massive savings using his converted CNG Toyota Hilux truck. While it cost N7,000 to fuel at Ibafo and another N7,000 at Lokoja to reach Abuja, this trip would have cost N25,000 on gasoline in the same vehicle to Lokoja and another N25,000 from there to Abuja. Conversion leads to 40 per cent savings in energy cost for car owners.[10]

Cost effectiveness of this fuel transition is yet another driver of change in Nigeria.

Graph 4: Cost-saving benefits with CNG use in Nigerian cities



Source: Batatunde Bakare 2016, Alternative Fuels: Compressed Natural Gas, Paper presented at the Workshop on Promotion of Low Sulphur Fuels in ECOWAS Sub-region, UNEP, June 15-16, Abuja

6. Policy measures in Nigeria

In 2019, the NAP to reduce SLCPs, was adopted to reduce 75 per cent of $PM_{2.5}$ emissions by 2030. This had listed 22 key measures, including regulation and enforcement of vehicle emission standards, switching to cleaner fuels for cooking, eliminating gas flaring, and reducing emissions from crop burning and livestock. This NAP to reduce SLCPs lists targeted adoption of CNG buses in Nigeria as one of the transportation sector measures and has proposed conversion of 25 per cent of all buses to CNG by 2030. The government has initiated work on this front.

Transport sector is targeted for five specific measures which include: 1) Renewal of the urban bus fleet in Lagos; 2) Adoption of CNG buses in Nigeria; 3) Introduction of low-sulphur diesel and gasoline; 4) Elimination of high emitting vehicles that do not meet vehicle emission standards; 5) Reduction of vehicle journeys by car through a transport modal shift (see *Table 3: Transport measures adopted in the National SLCP Plan*).

The government is now embarking on a comprehensive CNG programme and policy. This is an opportunity to define the scope and design of the programme to maximize emissions and energy security benefits. This can comprehensively define the mandate, emissions regulations for CNG vehicles, quality control rules for CNG conversion, establishment of refuelling infrastructure, safety rules and gas pricing policy, among others.

Nigeria launched the National Gas Expansion Programme (NGEP) in December 2020. It planned to convert 1 million vehicles by 2021. Not much information is available about the progress made. There are reports that some government vehicles have also been converted to CNG. Monitoring of quality of conversion and emissions status after conversion, along with ensuring the availability of required CNG infrastructure is of utmost importance. Nigeria has a special challenge as majority of the vehicle fleet is old.

The Central Bank of Nigeria (CBN) has introduced a 250 billion Naira intervention facility to help stimulate investment in the gas value chain.[11] The Minister represented by the Senior Technical Adviser on Referendum in Autogas Technicians Training and Certification programme in November 2021 is reported to have said that the money was already in the coffers of the CBN and those interested in opening conversion centres could access it. It was reported

that conversion kits were not available in Nigeria and need to be imported. The conversion cost is around 200,000 Naira.[12]

The government gave approval for the CNG project in Benin in March 2007. NIPCO Gas was formed as Joint Venture Company between NIPCO, an indigenous downstream petroleum and gas operator, and Nigerian Gas Company Limited (NGC) to implement the CNG project. More than 5,600 vehicles were converted to CNG. Fifteen CNG stations set up by NIPCO Gas are operational in Benin. There are plans to construct 15 more stations.

A mega CNG station was commissioned at Ibafon in Ogun state. This was set up for converted CNG vehicles and industrial supply. Sixty-seven NIPCO Gas CNG cascades supply CNG to industries in Ibafon. The Ibafon CNG station along with a city gas station has a larger compressing facility (12,000 SCMT) for loading CNG to the nearby industries.[13] While more than 4,000 vehicles had already been converted to CNG in Benin in Edo State, over 500 vehicles are operating in Lagos.[14] In Benin City of Edo state, over 50 per cent of taxi operators have converted to CNG. Use of natural gas has translated into significant savings for taxi drivers.

NIPCO has also laid 51 kilometres of gas pipeline in Benin to distribute CNG to the seven stations in the city and built capacity to dispense 500 standard cubic metres and dispense to no fewer than 20,000 vehicles.[15]

At present there are two stations operating in Abuja. These are along the airport road and Kubwa expressway and owned by the NNPC.[16]

The areas that need more attention include framing of emissions regulations; adoption of safety standards and periodic testing of CNG cylinders; guidelines and audits of conversion workshops and vehicle inspection; and maintenance programme for quality control; and certification of conversion kits, among others.

As per 2017 National Gas Policy, the gas sector will require diversified use of natural gas beyond the power sector. In order to rally private sector participation in gas utilization, the PIA provides up to ten years tax holiday for gas companies, which is incremental to the five years maximum, earlier provided by the replaced law.

The pump price of gasoline was N145 per litre as of August 2021. Nigeria spent a total of N905.27 billion to keep the pump price of gasoline at this rate. On the other hand, CNG without subsidies was between N100 and N110 per standard cubic meter (equivalent of a litre).[17]

Table 3: Transport measures adopted in the National SLCP Plan

SLCP abatement measures	Target
1. Renewal of urban bus fleet in Lagos	5,000 new buses in Lagos and Danfo buses fully replaced by 2021
2. Adoption of CNG buses in Nigeria	25 per cent of all buses converted to CNG by 2030
3. Introduction of low-sulphur diesel and petrol	50 ppm diesel fuel introduced in 2019; 150 ppm gasoline introduced in 2021
4. Elimination of high emitting vehicles that do not meet vehicle emission standards	Euro IV limits met by all vehicles by 2030
5. Reduction of vehicle journey by car through transport modal shifts	500,000 daily journeys shifted from road to rail and waterways

Source: Nigeria's National Action Plan (NAP) to reduce Short Lived Climate Pollutants (SLCPs), Federal Ministry of Environment, Federal Republic of Nigeria, 2019, p vi

Gas is seen as the future for the country. According to Mele Kyari, Group Managing Diretor of NNPC, the country is struggling with supply of gas and there is difficulty filling the network across the country with gas. If the supply is weak, it will affect prices. Kyari is reported to have said, 'Supply mechanism for gas in the country, especially LPG, is weak. That is why there are collaborations extensively to extract value from our gas resources and make it available to the market. Once supply becomes high, prices will be captured by the development.'[18]

Several gas discoveries in Nigeria with large acreages have remained undeveloped. Many operators attribute this to the "unfriendly pricing" regime for locally produced natural gas. This specifies uncompetitive price of $2.50/MMBTu of gas for thermal power generators, and $1.50 for chemical process plants such as methanol, ammonia and urea. These prices are considered uncompetitive when compared to gas prices in the international market.

However, in a notable shift, the new PIA provides that natural gas shall be supplied to power sector consumers at $3.20/MMBTu, with a further provision for annual price reviews. Similarly, gas-based industries will be supplied within a price band of $0.90–$3.20, which is significantly higher than the price in the pre-PIA era. Beyond the "non-cost reflective" natural gas pricing regime, which was widely seen as a deterrent for upstream investments, many other acreage holders in Nigeria are simply limited by lack of finance, as well as operational constraints relating to inadequate pipeline infrastructures for gas transmission.

To address funding challenges, which rank high among the numerous problems limiting the gas sector, the new Act provides for the establishment of a

government-owned fund that can help finance private sector projects through equity participation. The Midstream and Downstream Gas Infrastructure Fund (MDGIF) is both novel and essential as it could lower the funding barrier for private sector projects and equally provide some level of de-risking by virtue of sovereign equity participation.

Retrofitment of vehicles and new CNG vehicles: The focus is on conversion of on-road vehicles. However, some manufactures are coming up with new vehicles. Innosan, an indigenous vehicle manufacturer, has unveiled the 55-seater IVM city bus, the first indigenously manufactured CNG vehicle. Hundred such city buses are being manufactured for NNPC.[19]

As part of the NGEP, one million vehicles were targeted for conversion. Lagos state plans to convert 25 per cent of its 4 million vehicles over a four-year period. The plan will also involve the deployment and roll out of LPG and CNG conversion centres in partnership with OEMs and the rolling out of autogas dispenser on the forecourts and standalone autogas stations across five divisions of Lagos State.[20]

The average cost of conversion of a gasoline vehicle to CNG is estimated to be USD 400. The government would require 1.32 trillion Naira to convert its 8 million public vehicles.[21] Innosan announced plans in October to help owners convert their gasoline vehicles to CNG.[22] Not much information is available in the public domain on after-market conversion or on procurement of conversion kits and quality control of the programme.

There was however confusion with the cost of conversion as the government initially announced that it would be free. According to Mele Kyari, one million cars will be powered by autogas free of charge. 'Select NNPC stations across the country will offer free conversion of some cars to enable them to run on LPG or CNG and there are currently 80 locations in the country capable of fuelling the vehicles,' he said.[23]

However, payment plans regarding the conversion kits were detailed out by Justice Derefaka, Technical Adviser on Gas Business and Policy Implementation to Minister of State for Petroleum, reiterating that the conversion is not totally free. He is reported to have said that the cost varies and it depends on the cylinder of the vehicle. For a typical SUV cylinder, it is a bit higher, but on an average it is around N200,000 to N250,000. This is for a four-cylinder vehicle but it becomes a little bit higher for a six-cylinder SUV vehicle. [24]

Explaining further, he said that the owner of the car would partner with the bank and then the bank would agree with the conversion centre to convert the customer's car for free but not free in its entirety. The installer will put some form of mechanism that each time the gas is bought a certain amount would be deducted to pay for the conversion kits. The conversion kit's cost will be covered in five to seven months.[25] A survey by BusinessDay showed that conversion kit costs between N350,000 and N450,000.[26] However, there is no information on the number of conversions and their quality.

An Autogas and Natural Gas Vehicles (ANGV) Committee, a sub-committee of the NGEP, has been formed by the government to drive adoption of gas as an alternative fuel for vehicles in the country. Mohammed Ibrahim, chairman of the committee, was quoted saying in a gathering of major CNG and LNG stakeholders that increased utilization of CNG/LNG would provide a conducive environment for investors and CNG/LNG could be employed to power passenger cars and city buses. The Committee also met with major fuel station owners in Abuja to discuss modalities for inclusion of CNG dispensing facilities in their stations.[27]

As Nigeria builds momentum to expand its CNG programme, well informed policy measures can help to create a robust and an effective programme.

7. CNG programme in India: The learning curve

The early phase of the CNG programme in Nigeria can tap the learning curve from some of the established city-based CNG programmes for vehicles in India. The issues, challenges and concerns are the same. Like in Nigeria, CNG programme in India has been an opportunity to tide over the problem of highly toxic emissions from the conventional diesel and gasoline vehicles, especially those meeting weak emissions standards, and leapfrog to much cleaner emission levels with the fuel substitution strategy.

However, this transition needed an ecosystem approach to establish proper systems, regulations and infrastructure to support the programme and maximize emissions benefits. This needed addressing emissions and safety regulations to influence the technology pathways, vehicle certification system, certification of CNG conversion kits and retrofitment for different vehicle segments, quality audits of the conversion workshops, CNG refuelling infrastructure and addressing CNG pricing. Each of these strategies had to be addressed at the early stages.

The objective of this section is to capture some of the learning from the CNG programmes in India, particularly the programme in Delhi that has implemented one of the largest CNG programmes in the country.

Genesis of CNG programme in Indian cities

The CNG programme for the transportation sector was largely catalysed by the air pollution concerns and mitigation action in cities, even though it was also seen as an important energy security measure.

The early genesis of a large-scale CNG programme for vehicles can be traced to Delhi and Mumbai, the mega cities of India. Mumbai's programme was initially driven by public policy and also strong commercial interest of the large taxi fleet to utilize substantially cheaper CNG fuel compared to gasoline that was the key fuel for taxis in the city. Much later, Bombay High Court had intervened to direct conversion of the freight vehicles in the city to CNG as a pollution control measure.

The situation in Delhi was different. A very small-scale CNG programme had started in Delhi during the early nineties when Delhi was connected with the main trunk pipeline and gas supply for industrial use had started in its vicinity. A

couple of CNG stations were set up and voluntary conversion had started. Delhi's CNG programme was driven more by air pollution concerns and to sidestep the problem of diesel pollution to reduce toxic exposures in the city.

Delhi captures a very important learning curve not only for the rest of India but also all other cities in developing countries embarking on this programme. Success of the Delhi programme led to further expansion that helped to broaden the ambit of city gas distribution to include other cities of India.

The mandate for CNG programme in Delhi: CNG programme in Delhi is an outcome of the policy action to control air pollution and to protect public health. This was catalysed by the directive from the Supreme Court of India that was hearing an ongoing public interest litigation on air pollution since 1985. Initially, only voluntary conversion to CNG was envisaged, especially targeting the car fleet owned by the government, in addition to mandating the use of catalytic converters in cars and introducing unleaded gasoline in 1995.

The major impetus for more accelerated action on CNG came from the public campaign for clean air and health that gathered momentum towards the later part of the nineties. In January 1998, following a directive from the Supreme Court, an empowered multi-stakeholder body, Environment Pollution (Prevention and Control) Authority (EPCA), was formed to advise the Court on pollution control measures and also monitor implementation of court orders. Then onward, a spate of ruling on CNG as well as other measures for vehicular pollution control followed in Delhi.

The Supreme Court order of 28 July 1998 was in response to the recommendations of EPCA and its deliberations with the Government of Delhi. This had laid down the foundation of the CNG programme in Delhi.

On 28 July 1998, the Supreme Court of India ordered the following:

- *Replacement of all pre-1990 autos and taxis with new vehicles on clean fuels by 31 March 2000*

- *Financial incentive for replacement of all post-1990 autos and taxis with new vehicles on clean fuels*

- *No eight-year-old buses to ply except on CNG or other clean fuels by 1 April 2000*

- *Entire city bus fleet to be steadily converted to single fuel mode on CNG by 31 March 2001*

- *Gas Authority of India Ltd (GAIL) to expedite and expand from 9 to 80 CNG outlets by 31 March 2000*

A significant element of this order is that except buses for which the Supreme Court had very specifically directed single mode on CNG, it gave the option of CNG or other clean fuels for all other vehicles—three-wheelers and taxis. In fact, the acceptable clean fuels were subsequently defined by the court as follows:

The hydrocarbon fuels are inherently polluting and hence such fuels cannot be regarded as 'clean fuels' and totally non-injurious to health. The effort is to constantly improve the fuel and engine technology of automobiles to reduce the effect.

(i) *However, among these fuels, CNG, LPG and Propane can be regarded as environmentally acceptable fuels.*

(ii) *To get better emission control in petrol-driven vehicles, it is necessary to improve fuel quality, use catalytic convertors and ensure that fuel is not adulterated.*

(iii) *In view of the special measures needed for pollution control in the NCT of Delhi, low sulphur diesel with 0.05 per cent (500 ppm) sulphur cannot be regarded as an environmentally acceptable fuel.*

(iv) *In the context of NCT of Delhi, there is need to bring public passenger transport (city buses, autos, taxis) as early as possible on CNG. For vehicles which cannot be converted to CNG for practical reasons, 0.05 percent sulphur diesel may be permitted as a Transitional Fuel for a limited period of time to be kept as short as possible for public health reasons.*

(v) *Ultra-low sulphur diesel (with 0.001% sulphur) and low PAH content in combination with Continuously Regenerating Traps (CRT) and catalytic convertors can be regarded as environmentally acceptable fuel in the NCT.*

Thus, the option of clean diesel with 10 ppm sulphur was acceptable in Delhi even then but clean diesel was not available in India.

Thus, the CNG programme in Delhi was introduced two decades ago to reduce particulate pollution, especially toxic emissions from diesel fuel. A series of Supreme Court directives since 1998 in public interest litigation on air pollution led to the introduction of one of the largest ever natural gas vehicles programmes for public transport. CNG vehicles have replaced diesel-run buses, taxis, autos, and small commercial vehicles. The CNG programme has been further scaled up for nearly the entire commercial vehicle fleet of the city. CNG stations have increased from the original nine to more than 500 stations in Delhi-NCR. Over the past few years, taxis as part of aggregator companies like Ola and Uber have become the preferred modes of public transport in Delhi-NCR. Except the all-India tourist permit taxis, all these taxis are required to run on CNG. Overall, CNG has been widely expanded to all key commercial vehicle segment over the years. Furthermore, now since several cities of India have CNG programme, consumers have more options to choose from in terms of models/makes and vehicle usages.

Mandate for other cities of India: Subsequently, in January 2003, the Central Pollution Control Board (CPCB) released air pollution data of 22 polluted cities in the country. In the hearing of 14 August 2003, the bench observed that though the air quality had improved considerably in Delhi since 1996, particulate pollution in other cities was turning into a crisis.

Thus, the Supreme Court widened the ambit of the same air pollution case in Delhi to include seven more polluted cities—Bangalore, Hyderabad, Chennai, Ahmedabad, Kanpur, Lucknow and Solapur. The cities of Mumbai and Kolkata were not included as their respective High Courts were already hearing public interest litigation in those cities. These cities included CNG programmes in their respective plans. The cities that did not have access to CNG like Bangalore and Chennai have listed LPG programme. In its ruling of 5 April 2002, the Supreme Court also stated, 'The Union of India will give priority to the transport sector including private vehicles all over India with regard to the allocation of CNG.'

The Supreme Court had emphasized the importance of CNG as "*unadulterable gaseous fuel*". With these orders the Supreme Court has established an unprecedented principle that gas allocation would have to accord priority to the transport sector to address the air pollution and public health crisis in cities.

India is at a crossroads today as far as the natural gas vehicle programme is concerned. The older CNG programmes of Delhi and Mumbai are now fully established in terms of scale of the market and refueling infrastructure. There is also now considerable scope of expanding the programme to a much larger number

BOX: TIMELINE OF KEY ACTIONS ON VEHICLES IN DELHI

1994–95: Introduction of catalytic converters and unleaded petrol

1996: 5000 ppm sulphur diesel introduced

1998: Pre-mix 2T engine oil mandated for 2-stroke engine vehicles

Phasing out of old commercial vehicles that are older than 15 years

Start of Delhi Metro construction.

Fuel testing laboratory set up to inspect fuel quality in the city.

1999: Diesel sulphur reduced to 2500 ppm

Bharat Stage-I (Euro-I) standards for private vehicles implemented

Restricting the plying of goods vehicles during the day

2000: Bharat Stage-II (Euro II) emission norms for all private vehicles

Diesel and petrol with 500 ppm sulphur content mandated for private vehicles

Replacement of all pre-1990 three-wheelers and taxis with vehicles on CNG begun

Phasing out of buses more than 8-years-old and conversion to CNG begun

2001: Bharat Stage-II (Euro II) emission norms for all commercial vehicles by October

The sulphur content of diesel further reduced to 500 ppm with effect from October

Replacement of all post-1990 three-wheelers and taxis with vehicles on clean fuels

Number of CNG vehicles increased

2002: 94 CNG stations established by March

All diesel buses phased out and replaced with CNG buses

Number of CNG vehicles increased further

EPCA proposed that CNG retail price should be kept lower than diesel to provide economic incentives to vehicles being replaced

16,340 non-destined trucks turned away from entering Delhi (July–November).

Three lines of metro become operational

2004: Implementation of the revised norms for the PUC certification programme

2005: Introduction of Bharat Stage-III (Euro III) emissions standards for all vehicles

Sulphur content in diesel reduced to 350 ppm and in petrol to 150 ppm

Pilot experiment on the lambda tests in the PUC centres

Decision to register commercial light duty vehicles only on CNG

2006: Detailed investigation and corrective measures initiated to reduce bus fire incidents

After market conversion of diesel buses to CNG buses found serious lapses in conversion practices, remedial measures initiated

2007: Status of natural gas vehicle programme: There were 154 CNG stations fuelling over 1,50,000 vehicles including over 12,000 buses, 72,000 three-wheelers and over 50,000 private cars

Decision to impose a cess on diesel fuel to raise funds for clean air programme

Decision to phase out diesel light duty commercial fleet

2008: Reciprocal Common Transport Agreement among the state for unrestricted movement of vehicles in the National Capital Region prepared and CNG-based vehicles (autos, taxis, buses) promoted

Only CNG operated stage carriage buses originating and terminating in NCR can ply in NCR Area

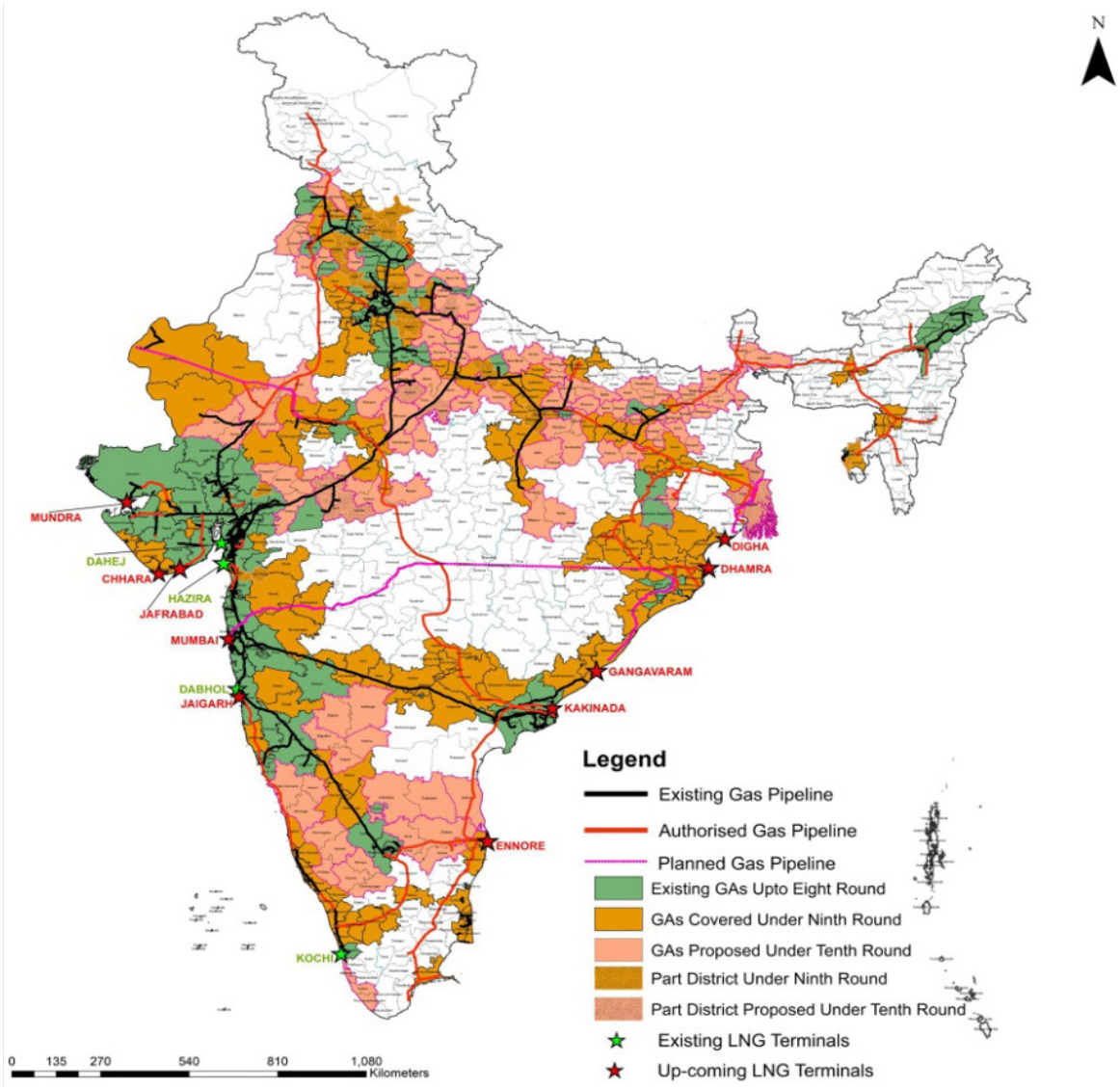
2010 to 2021: CNG programme started to be stabilized, incidences of fire reduced considerably

Expansion of CNG network continued in Delhi-NCR and there are 586 station across the region

of cities. GAIL has plans to expand the national gas grid. There is expansion plan for gas pipeline by GAIL which is adding more cities to the grid (see *Map 1: Gas infrastructure map of India*).

GAIL launched "Project Blue Sky" to implement natural gas programmes in cities through joint venture operations. The model is to form joint ventures with public sector oil marketing companies to set up the infrastructure in cities for supply of gas. Indraprastha Gas Ltd in Delhi, Mahanagar Gas Ltd in Mumbai and Central UP Gas Ltd in Lucknow and Kanpur are such ventures. Similar joint ventures have been formed in several cities already to cater to the retail customers in industry, commercial and automobile sectors.

Map 1: Gas infrastructure map of India



Source: Ministry of Petroleum and Natural Gas

The Union Ministry of Petroleum and Natural Gas (MoPNG) has already issued a notification on policy for development of natural gas pipeline and city or local natural gas distribution network in 2006 to promote both public and private investments. Under this regulatory framework, the Petroleum and Natural Gas Regulatory Board (PNGRB) will have the powers to sanction pipelines and city gas distribution (CGD) network. The state governments will be responsible for facilitating timely completion of projects.

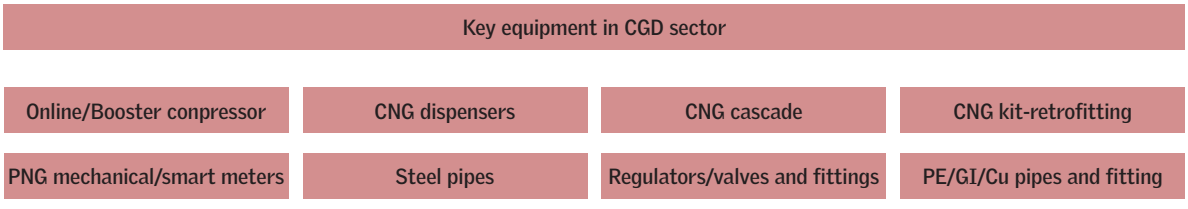
The state governments also prepare plans for the city distribution network. They prioritize the cities and local areas based on environmental concerns, industrial fuel requirement, etc. The big challenge is to set up adequate refuelling infrastructure in new cities. This requires proper network planning and implementation. This therefore brings up the question of how CNG network for transport can be made cost effective with an appropriate business model in the new cities.

Currently, the MoPNG along with the PNGRB are focused on development of the natural gas infrastructure in India. PNGRB grants authorization to the entities to lay, build, operate or expand for the development of CGD or local natural gas distribution network.

As of March 2020, there are around 2,000 CNG stations in India. Earlier, the CNG network was in Maharashtra, Gujarat and Delhi-NCR but now it has expanded considerably. Gas distribution pipelines are being expanded in India.. India has planned investments to the tune of Rs 90,000 crore in the next 5 to 7 years in CGD network.

According to MoPNG , CNG use has grown at a CAGR of 14.4 per cent from 2015 to 2019 and it is expected to grow further in years to come. Presently, India has the capacity to meet estimated demand for equipment and spares related to growing CGD sector—which comprises of piped natural gas for residential, commercial and industrial use and CNG for vehicles. This provides opportunity for setting up of new facilities and expansion of existing capacities in the country.[28]

Figure 1: Key equipment in city gas distribution sector



Source: Ministry of Petroleum and Natural Gas

Table 4: Current status of CNG programme in India

State/UT(s)	Company name	No. of companies	No. of CNG stations
		(as on 31.03.2020)	
Andhra Pradesh*	Bhagyanagar Gas Limited, Godavari Gas Private Limited, Megha Engineering & Infrastructure Limited	3	66
Assam	Assam Gas Company Limited	1	1
Bihar	GAIL (India) Limited	1	8
Chandigarh, Haryana, Punjab & Himachal Pradesh	Indian Oil-Adani Gas Pvt Ltd.	1	11
Dadra & Nagar Haveli**	Gujarat Gas Limited	1	6
Daman and Diu	Indian Oil-Adani Gas Pvt Ltd.	1	4
Delhi NCT***	Indraprastha Gas Ltd.	1	419
Goa	Goa Natural Gas Private Limited	1	2
Gujarat**	Adani Gas Limited, Vadodara Gas Limited, Charotar Gas Sahakari Mandali Limited, Gujarat Gas Limited, Hindustan Petroleum Corporation Limited, Haryana City Gas (KCE) Private Limited	7	636
Gujarat & UT of Daman and Diu	IRM Energy Private Limited	1	5
Haryana	Adani Gas Limited, GAIL Gas Limited, Haryana City Gas Distribution Limited, HPOIL Gas Private Limited, Indian Oil-Adani Gas Pvt. Ltd., Indraprastha Gas Limited, Hindustan Petroleum Corporation Limited, Haryana City Gas (KCE) Private Limited	8	104
Jharkhand	GAIL (India) Limited		8
Karnataka	GAIL Gas Limited, Indian Oil-Adani Gas Pvt. Ltd., Megha Engineering & Infrastructure Ltd.	3	23
Kerala	Indian Oil-Adani Gas Pvt. Ltd.	1	8
Madhya Pradesh	Think Gas Bhopal Private Limited, Aavantika Gas Limited, GAIL Gas Limited, Indian Oil Corporation Limited, Naveriya Gas Private Limited	5	62
Maharashtra	Gujarat Gas Limited, HPOIL Gas Private Limited, Mahanagar Gas Limited, Maharashtra Natural Gas Limited, Mahesh Gas Limited, Unison Enviro Private Limited	6	370
Maharashtra & Gujarat	Maharashtra Natural Gas Limited	1	5
Odisha	GAIL (India) Limited	1	19
Punjab	Gujarat State Petronet Limited, IRM Energy Private Limited, Think Gas Ludhiana Private Limited, Torrent Gas Private Limited, Bharat Gas Resources Limited	5	33
Rajasthan	Rajasthan State Gas Limited, Torrent Gas Private Limited, Dholpur CGO Private Limited, Adani Gas Limited	4	16
Telangana*	Bhagyanagar Gas Limited, Torrent Gas Private Limited	2	66
Tripura	Tripura Natural Gas Company Limited	1	14

Uttar Pradesh	Adani Gas Limited, Central UP Gas Limited, GAIL (India) Limited, GAIL Gas Limited, Green Gas Limited, Indian Oil-Adani Gas Private Limited, Indraprastha Gas Limited, Sanwariya Gas, Torrent Gas Private Limited, Bagpat Green Energy Pvt. Ltd.	10	306
Uttar Pradesh & Madhya Pradesh	Adani Gas Limited	1	1
Uttarakhand	Indian Oil-Adani Gas Private Limited, Haridwar Natural Gas Private Ltd.	2	5
West Bengal	Great Eastern Energy Corporation Ltd., Indian Oil-Adani Gas Private Limited	2	10
Total			**2,208**

Notes:

1. CNG network has covered most of India barring few states such as Tamil Nadu which do not have the network. Scale of the programme in terms of number of vehicles or number of CNG stations is big in Delhi-NCR, Gujarat, Maharashtra, Utter Pradesh and Haryana

2. Some entities are operating in more than one state. Hence, their number is taken once only

3. *From FY 2019–20, entries for Andhra Pradesh & Telangana are reported separately. Prior to this AP & Telangana were taken together. ** Dadra & Nagar Haveli are reported separately from Gujarat State. *** Delhi contains information for Delhi-NCT only. Remaining entries of the NCR GAs are added in respective states.

4. Total may not tally due to rounding off

Source: Petroleum Planning & Analysis Cell; Petroleum and Natural Gas Statistics 2019–20, accessed at https://mopng.gov.in/en/petroleum-statistics/indian-png-statistics

8. Vehicle segment-wise approach

Each vehicle segment has its own challenges and imperatives while transitioning to new fuels and technology. Each segment requires its own ecosystem of emissions regulations and standards, defined technology pathways, certification and performance verification, safety aspects and inspection, and maintenance for on-road performance.

Each of these aspects needs to be addressed while introducing new technology in the market. Delhi's experience shows that several vehicle-segment wise issues need to be addressed through a spate of regulations and infrastructure development.

Through successive stages of emissions standards (Euro II in 2000, Euro III in 2005, Euro IV in 2010, and Euro VI in 2020) the emission norms for CNG vehicles more or less aligned with gasoline and diesel vehicles in India.

Like in gasoline vehicles, particulate matter is also not regulated in CNG vehicles as particulate emissions are negligible. The Euro VI emissions standards in India have aligned emissions standards for diesel and CNG buses.

There are however differences in hydrocarbon (HC) emission norms for spark ignition engine powered vehicles that are fuelled by gasoline and CNG. In case of CNG vehicles, in addition to HC, which is common with gasoline vehicles, non-methane hydrocarbon is also regulated (See *Table 5: Comparison of structure of emission standard for CNG driven vehicles vis a vis diesel and gasoline vehicles*).

CNG buses

There is a bigger opportunity for emissions gains if the heavy-duty vehicles for mass transport like buses are prioritized for fuel substitutions. This can reduce emissions and exposures considerably. As part of its NAP of 2019 for controlling SLCPs, Nigeria has targeted to have 25 per cent of its bus fleet on CNG. Therefore, understanding the CNG bus programme becomes necessary to tap the learning curve.

Delhi's CNG programme had prioritized moving diesel buses to CNG to reduce toxic diesel emissions. The Supreme Court order of July 1998 had directed that no buses eight or more years old can ply except on CNG or other clean fuels by 1 April

Table 5: Comparison of structure of emission standard for CNG driven vehicles vis a vis diesel and gasoline vehicles

Category	Applicable emission norm
1. Three- and two-wheelers	
OE CNG Category M and N vehicles with GVW ≤3,500kg	Prevailing gasoline norms*
Retrofitment from gasoline; CNG Category M and N vehicles with GVW ≤3500kg	Prevailing gasoline norms
Retrofitment from diesel: CNG Category M and N vehicles with GVW ≤3500kg	Prevailing diesel norms, except PM limit
2. Four-wheelers	
CNG Category M and N vehicles with GVW >3500kg manufactured up to 1 April 2010	Prevailing diesel norms (except PM limit) based on 13 mode steady state engine dynamometer test or 13 mode engine steady state cycle as applicable
CNG Category M and N vehicles with GVW >3500kg manufactured on and from 1 April 2010	Prevailing diesel norms, except PM limit

Note:

1. Mass emission norms for vehicles when operating on CNG shall be same as are applicable for gasoline vehicles with exception that HC shall be replaced by NMHC, where NMHC=0.3xHC

2. Crankcase emission and SHED test are not applicable in CNG mode.

*Vehicles having option for bi-fuel operation and fitted with limp-home gasoline tank of capacity not exceeding 2 litres, 3 litres, and 5 litres respectively on two-wheelers, three-wheelers, and four-wheelers are exempted from emission test, crankcase emission test and SHED test in gasoline mode.

Source: Indian emission regulations booklet, The Automotive Research Association of India

2000 and the entire city bus fleet should be steadily converted to single fuel mode on CNG by 31 March 2001. Simultaneously, the order stated that 10,000 CNG buses will have to be procured to strengthen the city bus service. However, initially, the market shift was slow and subsequently more stringent measures were taken, including imposition of per day penalty on all diesel buses till they were replaced with CNG buses. This finally led to the full establishment of CNG by 2002.

Emission gains from CNG buses: CNG buses had to meet the Euro II emissions standards during the inception of the programme in Delhi. The first generation CNG bus technology meeting Euro II standards was dominated by the conventional stoichiometric CNG engines using mechanical air-to-fuel proportioning and mixing systems with electronic "trim" of the air-to-fuel ratio, based on the feedback from an exhaust oxygen sensor. They were also equipped with three-way catalytic converters (TWC).

The tests carried out on the Euro II compliant Indian buses by the ARAI as part of the TERI study found that even the first generation CNG bus technology meeting Euro II emissions standards had significant PM reduction and moderate NO_X

Table 6: Comparative emissions of Euro II diesel and CNG buses in India

Type of bus	CO g/km	HC g/km	NO_X g/km	PM g/km	CO_2 g/km	Km/litre
Euro II diesel bus on 500 ppm sulphur fuel + DOC	1.45	0.29	6.24	0.35	798.7	3.33
Euro II diesel bus on 350 ppm sulphur fuel + DOC	0.65	0.15	5.85	0.11	766.1	3.44
Euro II diesel bus on 50 ppm sulphur fuel + CRT	1.42	0.04	13.58	0.009	781.38	3.36
Euro II CNG bus + three way catalytic converter	3.18	1.455	5.35	0.0065	729.74	NA

Source: The Energy and Resources Institute, 2004, *Fuel Choices for Transport and the Environment*, New Delhi, page 9

emissions advantage compared to their diesel counterparts. The PM levels from the Euro II CNG bus were found to be nearly 46 times lower.

This CNG technology choice seemed appropriate in terms of meeting the objective of particulate emissions reduction, as it could easily and readily make particulate emissions negligible (see *Table 6: Comparative emissions of diesel and CNG buses in India*). The same ARAI tests found that only when diesel engines are fitted with advanced emissions control components and run on very low sulphur fuels, are their emissions comparable with the emissions from Euro II CNG buses.

The emissions test data from ARAI also shows that the NO_X emissions from the TWC equipped CNG bus are also lower than the oxidation catalyst and CRT equipped diesel buses. However, the gap is smaller in the case of NO_X than PM. The natural gas bus programme provided an opportunity to leapfrog to much cleaner emissions in Indian cities when diesel technology was stagnating.

Subsequently, CNG bus technology further evolved through the successive stages of emissions standards—Euro III in 2005, Euro IV in 2010 and Euro VI in 2020. Several technological approaches have been adopted by the bus industry that include lean burn CNG technology to more advanced stoichiometric technology and improved TWC.

Studies have established the emissions benefits of this technology evolution. A detailed study published in 2018 from the Indian Institute of Technology (IIT), Kanpur, confirms once again without doubt that BS IV CNG buses are significantly cleaner and less toxic compared to diesel buses.[29] This study has characterized particulate emissions from diesel engines, gasoline engines, CNG engines and other engine and fuel configurations complying with Euro II, Euro III and Euro IV emission norms. This study has specifically assessed the toxicity and mutagenic

potential of particulate matter emissions from different engines. This has enormous health implications for longer term exposure to emissions from different engines and fuel configurations. While all engines and fuel configurations emit toxins, overall mutagenicity of CNG emissions is lower (see *Table 7: Comparison of mutagenic potential and emissions from different engines meeting different emissions standards*). The key highlights of the difference between diesel and CNG engines that emerges from this study are as follows:

- Particulate matter emitted from diesel engines are higher in mutagenicity, while that from CNG engines are negligible in mutagenicity compared to all other test fuels and engine configurations.

- Toxic group of polycyclic hydrocarbons adsorbed onto CNG particulates were also relatively fewer compared to those from equivalent diesel and petrol engines. This indicates significantly lower toxicity of exhaust compared to others.

- Particulate matter concentrations as well as hazardous chemical constituents such as transition metals were significantly lower from CNG engines.

Table 7: Comparison of mutagenic potential and emissions from different engines meeting different emissions standards

Particulate characteristics	Euro II IDI diesel engine	Euro III CRDI diesel engine	Euro IV CRDI diesel engine	Euro II gasoline engine	Euro IV CNG engine
Mutagenic potential (TA98 with S9)	2	0	1	0	0
Mutagenic potential (TA98 without S9)	2	0	1	2	0
Mutagenic potential (TA100 with S9)	1	0	1	0	1
Mutagenic potential (TA100 without S9)	0	1	0	0	0
PAHs	3	3	1	2	1
Trace metals	2	1	2	1	1
Gaseous emissions	1	1	1	2	2
Particulate morphology	2	1	1	2	1
Physical characteristics of particulate	2	2	2	1	1
Total	15	9	10	10	7

Source: Avinash K. Agarwal et al 2018, Toxicity and mutagenicity of exhaust from compressed natural gas: Could this be a clean solution for megacities with mixed-traffic conditions? Journal Environmental Pollution (Elsevier), 239 (2018) Page 1 to 13

- NO_2 emissions were also lower from Euro IV CNG buses.

The study has concluded that CNG is a comparatively safer fuel compared to diesel and petrol and can offer a cleaner transport energy solution for mega-cities with mixed-traffic conditions.

This published research study in India came after the last unpublished study of the Council for Scientific and Industrial Research (CSIR). This study done jointly by CSIR-IIP-University of Alberta, carried out real world emissions tests on two post-2010 Indian CNG buses in Delhi and two diesel buses including one Canadian make meeting 2010 heavy duty standards fitted with advanced particulate trap and one Indian diesel bus without diesel particulate trap. The measurements were carried out while accelerating and cruising the vehicles.

This study showed that ultrafine particle emissions from Bharat Stage IV Indian diesel bus without particulate traps were 600 to 2,000 times more than the Indian CNG buses. Ultrafines are of 0.1 micrometre size and 25 times smaller than $PM_{2.5}$. They go directly to the blood stream and in conjunction with the finer particles of $PM_{2.5}$ and PM_1 they cause irreparable damage to health.

Indian BS IV CNG buses were already close to or better than the Euro VI emissions standards. The conventional Indian CNG buses have ultrafine particulate number emissions close to the Euro VI standards. While the limit value for particle count under Euro VI emissions standards is 600 billion particles per kWh, the actual observed level in one CNG bus was 278 billion particles per kWh and in the second 950 billion per kWh. This shows the current CNG bus fleet gives Indian cities a much better opportunity to leapfrog to Euro VI emissions standards. In contrast, the current Indian diesel bus was found emitting 1,000 times more ultrafine particle numbers compared to Euro VI limit on transient cycle.

CNG buses performed much better on all other pollutants than diesel buses. Results show that both CO and NMHC emissions from the current CNG buses are close to the limit values of Euro VI norms. CO, NMHC and NO_X emissions from Indian CNG buses are also much better than the Canadian diesel bus meeting tighter emissions standards. The NO_X emissions are actually within the limit values for Euro VI norms on transient cycle. While the actual CO emissions from the Indian diesel bus without trap are 19 times higher, NMHC emissions are 47 times higher, and NO_X emissions are 17 times higher than the limit value for Euro VI emissions standards (see *Table 8: Comparison of key emission parameters CNG and Diesel buses*).

Table 8: Comparison of key emission parameters CNG and Diesel buses

Bus type	CO (g/kwh)	NMHC (g/kwh)	NO_X (g/kwh)	Total particle numbers
Diesel bus				
Acceleration	7.87	7.58	8.42	$6.45x10^{14}$ or 6,45,000 billion
Cruise	2.68	-	7.14	$4.46x10^{14}$ or 4,46,000 billion
CNG bus				
Acceleration	0.43	0.15	0.87	$2.78x10^{11}$ or 278 billion
Cruise	2.2	0.57	0.82	$4.37x10^{11}$ or 437 billion
Euro VI (WHSC)	1.5	0.13	0.4	$6.0×10^{11}$ or 600 billion
(WHTC)	0.4	0.16	0.46	

Source: CSIR

Inspection and maintenance and safety protocol

Yet another lesson from the Delhi CNG bus programme is the need for proper safety regulations for CNG vehicles and refuelling infrastructure.

During the initial stages of the CNG programme in Delhi, inadequate emissions and safety regulations, ineffective enforcement and compliance system, poorly designed refuelling infrastructure, and serious safety risks plagued this programme. And all this had to be addressed.

Around 12 CNG bus fire incidents (including new buses from vehicle manufacturers) were reported during 2001–02. This required immediate corrective action through constant monitoring. This is an example of quality problems arising from implementation of a large-scale NGV bus fleet, from which others can profitably learn. The Delhi programme is an important example of methods adopted to address the quality issues under public scrutiny.

During 2001–02, two studies were commissioned by CSE to investigate the safety of CNG buses operating in Delhi, following the occurrence of a number of bus fires. These were *Status of implementation of CNG as a fuel for urban buses in Delhi* and *Safety of CNG buses in Delhi: Findings and recommendations*). Many quality issues were found throughout the chain of supply from the chassis builder

to the bus operators. They occurred in both OEM new buses, and in the conversion of existing older diesel engines to natural gas operation. Summary of technical flaws noted in OEM CNG buses during 2001–02:

- Damage to high pressure gas piping
- Pulling out of high-pressure gas pipes from fittings
- Failure of PRDs. There was an unusually high number of burst disc failures
- Short circuit in electric wiring creating sparks
- Insufficient flexibility in the high-pressure gas piping

Generally, the conversions were found to have much poorer quality than the OEM vehicles. Irrespective of the type approval certification, variance with the approved specifications was noticed:

- Stress loops at the gas piping from the cylinder were missing
- Clamping of gas pipes was not sufficient in several locations
- The distance between the gas cylinder and the exhaust muffler was less than 75 mm and the heat shield was missing
- Dust protection caps were missing at gas filter inlets

Remedial measures: Since the technology was new, several remedial measures were taken from time to time to ensure that safety protocols are followed. These included fitness checks and additional third-party checks to ensure that road worthiness norms, and safety protocols are followed.

To address these issues, a separate safety council was set up by the Delhi government to deal with CNG related safety issues and carry out "root-cause" evaluations of CNG-related safety problems, identify solutions and ensure implementation. Independent third-party inspection was introduced in which buses identified with flaws were sent back for remedial action. A special checklist for this specialized inspection was prepared. The objective of this programme was to establish inspection of the engine and high-pressure fuel storage system and also improve the interface between the type approval agency and the inspection

centre in the city for feedback and constant monitoring. This inspection is now carried out annually. At the beginning of the programme, the number of buses failing third-party checks was high but it declined thereafter. But the failure rate began to rise once again from 2004 onwards. Clearly, these systems are not being enforced effectively.

Since 2005, a few more fire incidents in CNG buses were reported in Delhi until the episodes during the summer months of 2007. These involved OEM buses. As a result of this, the EPCA directed further technical evaluation and made recommendations on corrective action to eliminate the deficiencies.[30]

The evaluation exposed that many of the earlier problems had persisted. The range of problems identified included bulk/continuous release of gas from the fuel system of the bus and fire triggered by a short circuit in the electrical system or hot spots in the system that created the conditions for fire. Other deficiencies included faulty routing of electric wiring harness, overheating of the engine and excessive lube oil consumption, flaws in exhaust manifold design, problem with engine cylinder heads, etc. Manufacturing deficiencies, coupled with poor maintenance and use of substandard components, aggravated the problem.

A set of remedial measures were recommended and put in place. These involved all parties like the chassis builder, the converter, the Transit Corporation and inspection agencies, in taking corrective action. A mobile inspection and maintenance facility was tasked with carrying out unscheduled and random checks. OEMs were asked to replace the cracked exhaust manifold, remove the 12-volt terminal tapping from the 20-volt battery bank and reroute the wiring harness to separate the gas and electric lines. These took some time to implement.

In fact, many of the deficiencies could have been easily rectified. Damage to high pressure piping from rough roads, for example, could be prevented by use of stone shields, or relocation of tanks and fittings (roof mounted). Pulling out of high-pressure gas pipes from fittings can be prevented by use of stress relieving loops in the gas line. In some cases, PRDs were fitted with stronger burst discs to allow cylinders to be filled to higher pressures to improve the range of the vehicle. The latter is really tampering carried out by the bus operators and should be strongly discouraged and stopped. Electrical short circuits are easily preventable.

To improve the inspection system, maintenance facilities have been instituted in DTC workshops where all buses, including private buses, were scheduled to go for quarterly inspection. Delhi transport department was asked to carry out

unscheduled and random checks. All buses were required to keep logbooks onboard with details regarding inspection and repairs carried out. All buses were asked to register with the authorized service stations for periodic check-ups. It was further noted that some key components including low-pressure and high-pressure regulators, solenoid valves, catalytic converters, etc. would have the registration number of the vehicle embossed on them to prevent use of floating components that are used only at the time of inspection. Testing centres were set up for periodic inspection. A common periodic testing checklist is followed at each of these centres. Audit of periodic testing is being carried out from time to time.

Also, additional measures were taken to ensure that buses were regularly tested for leakage of CNG in depots. It was noticed that safety protocols were not adequately followed in after-market conversion of diesel buses to CNG which led to incidents of buses catching fire. The Delhi government took a decision that only dedicated CNG buses from OEMs will be introduced in the fleet.

EPCA also issued direction to bus manufacturers that ensure safety and optimum performance. Bus manufacturers were asked to carry out all the technical recommendations as detailed out in the report of the expert committee including the specific engineering and technical changes. The manufacturers were told that not implementing these measures would invite strong action. There were specific directions to Delhi Transport Corporation (DTC), the city bus operator, and the transport department to set up mobile vehicle inspection and maintenance (I/M) facilities.

There was a specific direction to the transport department of the NCT of Delhi to ensure that CNG buses, including the converted ones, undergo three comprehensive and improved I/M check-ups once in each quarter of the year at the authorized and designated workshops. The quarterly inspection should include leakage checking, inspection of wiring harness, checking for high tension leads for possible current leakage, checking conditions of hoses, tightness of CNG cylinders mountings, conditions of gas pipes and joints, functioning of all gauges in the instrument panel, inspection of battery cut off switch, current limiting devices, dust cap/plug, etc. The transport department of the NCT of Delhi was also directed to constitute a Steering Committee to oversee the implementation of the entire I/M programme for CNG buses and report to EPCA.

Monitoring of conversion of on-road vehicles: Very serious note was taken of the fact that the conversion agencies had failed to provide after sale service and support for maintenance and repair to the converted CNG buses and their

operators. This seriously compromised the safety features of these buses. Taking note of the problems in the converted CNG buses, EPCA directed that converted buses must undergo periodic inspection once in every quarter of the year at the authorized converters workshops as per approved periodic inspection checklist. The converter agencies needed to submit to EPCA the rate list of key spare parts and components of various subsystems such as the fuel system, electrical ignition system, etc. as also the names and addresses of the authorized suppliers of these spare parts and components.

This was done to curtail the use of spare parts of substandard makes at cheaper prices which can compromise safety. The converter agencies were asked to display in their workshops a price list for various components and fittings as also of various replacement costs. The converter agencies were also asked to give an undertaking that they would provide after-sales service facilities to the converted buses for as long as the buses are on road.

The transport department of the NCT of Delhi was also asked to constitute a steering committee to monitor the periodic inspection and maintenance programme as also the functioning of the converter workshops and the manufacturer authorized workshops. Emphasis was given to inspection and auditing of converter workshops.

The converter workshops were directed to be inspected with regard to the equipment, staff and other facilities available there. The transport department was to notify a four men committee having representation from ARAI, transport department, DTC and an EPCA expert nominee to inspect and audit these workshops.

All these measures led to significant reduction in the number of fire incidents and led to improvement in inspection and maintenance of buses. The bus corporation further initiated annual maintenance contract with bus manufacturers. The present challenge in Delhi is to augment the bus fleet from around 6,000 buses to 11,000 buses (which is considered the demand for buses in the city for public transport).

Subsequently, while conversion of on-road vehicles continued, conversion of on-road public transport buses was discontinued and a decision was taken to buy only new CNG buses from the vehicle manufacturers.

Checking of CNG leakage in CNG buses: The DTC had started operation of CNG Leakage Checking Centres at several bus terminals since 30 January 2006.

LONG RANGE CNG BUSES

Even after shifting of the entire public transport fleet in the national capital to CNG as per the mandate, inter-state buses coming from other cities to Delhi continued to run on diesel. Delhi Transport Corporation had stopped all its inter-state routes in 2001 due to unavailability of CNG in the neighbouring states. Given the challenges of on-board storage of gas and range limited to 200–250 km per fill only, CNG buses have largely remained confined to intra city transport only.

Mahindra & Mahindra and Agility Fuel Solutions of USA have partnered with IGL for a project on long haul CNG buses, involving introducing the new concept of light weight Type IV composite cylinders in buses. These cylinders are 70 per cent lighter than the Type - I (all steel) cylinders which are being used in India currently. The main advantage of these cylinders is that due to their lighter weight, the number of cylinders can be increased in the vehicle thus creating more storage capacity on-board. The buses which used to carry only 80–100 kg of CNG with steel cylinders can carry 225–275 kg of CNG with new composite cylinders. More storage of CNG means more kilometre range of buses. Buses fitted with Type IV Composite Cylinders have a running range of approx. 800–1000 km per fill of CNG.

IGL has procured five of Mahindra's Type IV buses for Uttarakhand Transport Corporation (UTC) on lease basis. It is possible to have long haul operations through CNG buses. This will also reduce the requirement of frequent refuelling and long queues. Retrofitting with Type IV CNG cylinders is also possible in buses running on other fuels.[31]

State Transport Authority made amendments in the permit condition of stage and contract carriage CNG propelled Omni buses to ensure safety of the commuters and other road users. Now it is mandatory for permit holders to get their vehicles checked for CNG leakage every quarter from the approved centres of DTC. DTC issues a certificate to the vehicle owner, valid for three months from the date of issue. This checking is carried out as per the provisions of Automotive Industry Standards (AIS: 024) in regard to CNG Leakage. In case of leakage, a leakage report is provided to the operator specifying the point of leakage for rectification of the defect. After the rectification vehicles are rechecked. [32]

All these developments therefore indicate the nature of interventions that are needed to build a robust CNG bus programme.

Three-wheelers and taxis

Three-wheelers and taxis are another key component of the CNG programme in Indian cities.. These are the intermediate public transport system and provide high frequency services and are part of last mile connectivity and multi-modal integration. In most cities, especially smaller cities, they provide the bulk of the public transport services. This segment is significantly large in Nigerian cities.

In Delhi, there was a specific direction in July 1998 to replace all pre-1990 autos and taxis with new vehicles using clean fuels by 31 March 2000. Financial incentives were given for replacement of all post-1990 autos and taxis with new vehicles on clean fuels. This was in addition to the number of three-wheelers already having been restricted by the Supreme Court order dated 16 December 1997. This was subsequently lifted with some conditions in April 2010, when Euro III/IV norms were introduced for all vehicles.

The CNG programme also speeded up the transition from two-stroke to four-stroke engine powered three-wheelers. In 2006, the Delhi government issued a policy to replace two-stroke with four-stroke three-wheelers. It was pushed through buy back schemes and more stringent testing of emissions from smoky three-wheelers. The in-use vehicle fitness and emission testing systems were also improved. All these measures promoted four-stroke CNG auto rickshaws meeting improved emission norms.

Similarly, as per the mandate, all taxis registered in Delhi had to convert to CNG. However, those on all India permit and all India tourist permits, which allowed the taxis to travel outside Delhi where CNG was not available, were exempted. Only the local fleet moved to CNG.

In the subsequent years as CNG prices remained cheaper than diesel and gasoline partly as a result of favourable fuel taxation policy, it acted as an incentive for the taxi and three-wheeler operators.

9. Emission standards and certification of new CNG vehicles

India follows equivalent of European emissions norms that are adapted as Bharat Stage emissions standards. When the CNG programme was directed by the Supreme Court of India in 1998, India had not adopted mass emissions standard for vehicles. From 2000 onwards, it has adopted a stepped approach to introducing these standards—initially the tighter standards for the big cities and one step below for the rest of the country. Since then, India has graduated to Euro II emissions standards in 2005, Euro III in 2010, Euro IV in 2015 and Euro VI in 2020. But these standards, except Euro VI emission standards that were introduced in the entire country at one go, were introduced at least five years in advance in Delhi compared to the rest of the country. These standards are called Bharat Stage standards in India. For easy reference, this section will refer to these standards in Euro terms.

All along the way, CNG vehicles had to meet the one step tighter emissions standards that were in force in Delhi. At the time of the introduction of the CNG programme in 2001, CNG vehicles including buses had to comply with the Euro II emissions standards. Currently, these vehicles have graduated to Euro VI level.

In India, certification and standardization of CNG vehicles are governed under the Central Motor Vehicle Rules and detailed regulations published by authorities. Two critical automotive industry standards in this regard are AIS-024 which covers 'Safety and procedural requirements for type approval of CNG/bio-CNG/LNG operated vehicles (dedicated, bi-fuel & dual fuel)' and AIA-028 'Code of practice for use of CNG/bio-CNG/LNG fuel in internal combustion engine vehicles.' These cover the wide gamut of parameters related to emissions, durability, safety and technical integrity of vehicles (see *Table 9: AIS-024 (Version 4) safety and procedural requirements for type approval of CNG/Bio-CNG/LNG operated vehicles*).

Technical specifications of CNG conversion kit (dedicated, bi-fuel and dual fuel) vehicles have been adopted that include specifications for kit, cylinder, valves, pressure regulator, filter, oil pump and lubrication system, high pressure tubing, low pressure tubing, gas-air mixer, gas injector, on-off switch, ignition system &

Table 9: AIS-024 (Version 4) Safety and procedural requirements for type approval of CNG/Bio-CNG/LNG operated vehicles

Description of regulation	Annexures of AIS-024
· Technical specification of CNG/Bio-CNG/LNG kit	Annexure I
· Technical specification of CNG/Bio-CNG/LNG vehicles	Annexure II
· Checklist for fitness tests and certification for in-use vehicles after fitment / conversion to CNG/Bio-CNG/LNG mode	Annexure III
· Safety checks for use of CNG/Bio-CNG/LNG fuels in internal combustion engine vehicles (as per AIS-028) & Indian gas cylinder rules, 2004	Annexure IV
· Criteria to authorize the CNG/Bio-CNG/LNG kit installer and responsibility of vehicle / kit manufacturer / supplier / installer	Annexure V
· Installation certificate for converted CNG/Bio-CNG/LNG vehicle	Annexure VI
· Checklist for third party checking or inspection of built-up CNG/Bio-CNG/LNG buses (new and in-use) before registration	Annexure VII
· Checklist for preventive maintenance of in-use CNG/Bio-CNG/LNG vehicles	Annexure VIII
· Checklist for third party checking / inspection of CNG/Bio-CNG/LNG vehicles (other than CNG/Bio-CNG/LNG buses) before registration (New and In-use)	Annexure IX
· Tests to be carried out by Test CNG/Bio-CNG/LNG Fitment	Annexure X

Source: Ministry of Road Transport and Highways, https://morth.nic.in/sites/default/files/Draft_AIS_024%28Ver5%29Safety_%26_Procedural_Requirements.pdf

wiring harness, interfacing unit, ignition timing advancer, fuel selector switch, dual fuel actuation mechanism and catalytic converter, among others. Technical specifications of vehicles have also been prescribed. For the in-use vehicles, checklist for fitness tests and certification for in-use vehicles after fitment/conversion to CNG mode (dedicated, bi-fuel & dual fuel) have been prescribed.

AIS 028 covers detailed regulations for cylinders (design approval, fittings, location, ventilation, mounting), construction of compartments and specification for materials, installation of cylinders (manifolding), shielding, CNG fuel line, flexibility, trailers and semi-trailers, CNG control equipment, electric wiring, compliance plate, inspection testing and commissioning for installer (leak testing, among others), garaging and repair for installers, construction equipment and vehicles—special requirement and checklist for installation of dedicated, bi-fuel, and dual-fuel vehicles.

As the programme progressed, it needed further improvements in type approval process, durability requirement and on-road monitoring. It was also evident that type approval process at the time of vehicle certification alone cannot guarantee a quality system. For example, use of stress loops in high pressure CNG lines is documented in the Indian type approval requirements under AIS 028 D1, and should have been picked up in the type approval inspection. But initially it was missed. The requirements of AIS 028 D1 were also not well understood. Often the converters were not complying with these requirements. This required strong surveillance.

The new generation regulations therefore also require a skill building and capacity building programme to build capacity and implement the technical regulations.

Moreover, for technology development and type approval of vehicles, additional quality action needs to be considered to prevent the design failure in the first place before release of the vehicle. Getting it right the first time involves a much lower cost than dealing with warranty costs subsequently to correct failures in the field.

Much of what has been observed above could have been prevented through the use of a simple Design Failure Mode and Effects Analysis (DFMEA) process. CSE's review showed that this quality control system is in place in many countries. Going through the whole system provides the opportunity to determine what could possibly go wrong before the vehicle design is released. It is common, however, for company personnel to believe they do not have the time to go through this, but in fact it saves the company time and money in the long run by not having to fix field failures. The DFMEA process should catch missed items.

The DFMEA also catches issues not covered under the type approval process. One example of this is the fuel/air ratio control system. There is a safety check and specifications for a gas/air mixer, but nothing on performance. So, the DFMEA in this case would look at the fuel/air ratio control system to determine possible losses of control, which could result in lean operation causing misfire to occur with subsequent catalyst damage. The DFMEA also flags the need for maintenance of the A/F ratio control system which may be vulnerable to drift. The DFMEA process should be conducted prior to the vehicle being submitted for type approval, and provided as evidence that a quality system is in place, and could be part of the type approval. By taking these steps in the first place, robust designs will minimize field failures and warranty costs.

Ground assessment had also shown that the catalytic converters in the early batches of CNG bus fleet in Delhi were particularly vulnerable as these bus technologies use older distributer ignition systems, and mixer systems for CNG fuel control. Studies show these can have extensive catalyst durability problems when misfire occurs during loss of fuel and spark control. Greater than 2 per cent misfire will kill a catalyst. Under the current emissions regulations in India, the durability requirement for the emissions control equipment has been fixed at a very low level—only 80,000 km. This may amount to replacing catalytic converters almost ten times during the useful life of the vehicles—given the annual mileage of the buses and the fixed age of 15 years for buses.

Experts point out that catalyst technology has advanced considerably in recent years. Advanced thermally stable oxygen storage materials have considerably improved long-term thermal stability.

Achieving durable emissions performance is a combination of calibration technique and catalyst technology. This requires regulatory developments on extended durability requirements for heavy duty vehicles to comply with useful life emissions standards and recall and corrective action. Such approaches have been adopted in the US and other places. It is important to ensure that even as the emissions deteriorate on the new emission control system with mileage accumulation, the emissions must remain below the useful life emissions standards.

10. CNG refuelling infrastructure—pipeline and refuelling stations

Introduction of new vehicle and fuel system requires an ecosystem approach. In addition to introducing vehicles, it is necessary to establish adequate and appropriate network of refuelling stations. A plan for geographical distribution of CNG stations as per needs of public transport and other vehicles is as important as targeted number of CNG vehicles for different segments. In view of this, the original CNG mandate had also included the directive to set up minimum 80 refuelling stations in Delhi.

Initially, the target was inadequately met which led to long queues of CNG vehicles in refuelling stations. One key reason for the long queues was the low pressure of gas at the pumps. There were only a few high compressor stations in the city and most of these were concentrated in a few parts of the city. As of March 2002, Delhi had 94 stations, of which 55 stations were called daughter and daughter booster stations that relied on gas delivered through tanks. These cannot maintain the desired pressure for refuelling and were inefficient. That increased the time of refuelling and also led to long queues. What was needed was an extensive expansion of pipelines within the city to connect the refuelling stations and maintain the pressure and improve overall efficiency (see *Table 10: CNG refuelling infrastructure in the initial phase of the programme in 2002*).

Therefore, it is important to carefully plan and execute the project to meet the CNG requirement. The capacity expansion should be properly planned and the infrastructure development to increase capacity should be in line with the anticipated increase in demand and the addition of equipment should be designed to speed up the gas filling capacity with suitable compressors and appropriate dispensers. Otherwise, consumers will find it difficult to switch over from conventional fuels to CNG.

Since 2002, the total number of CNG stations have increased dramatically in Delhi and these are linked with extensive pipelines. According to the Petroleum Planning & Analysis Cell of MoPNG , there were 419 CNG refuelling stations in Delhi as of April 2020, catering to a fleet size of 0.77 million vehicles.

Table 10: CNG refuelling infrastructure in the initial phase of the programme in 2002

	Number of stations	% of total gas sold in 2001–02
Dedicated DTC Mother Stations	9	23.5
Mother stations	17	44.4
Online Stations	13	17
Daughter Booster stations	29	8.5
Daughter stations	26	6.1
Total	94	

Note:

1. "CNG mother station" means CNG facilities connected with natural gas pipeline and having a compressor meant primarily to fill mobile cascades of daughter station. Such stations may also have stationery cascade for CNG dispensing to vehicles;

2. "CNG online station" means CNG facilities connected with natural gas pipeline and having a compressor primarily to fill stationary cascades for dispensing CNG to vehicles;

3. "CNG daughter station" means CNG facilities not connected to natural gas pipeline. Such CNG dispensing station receives CNG through mobile cascade;

4. "CNG Daughter booster stations" are similar to daughter stations but a booster compressor is installed to increase the pressure above 200 bars once the pressure of the mobile cascade falls below 200 bars. Thus, the maximum amount of gas stored in the mobile cascade is dispensed to the daughter booster station.

Sources: EPCA report: Getting the CNG price right; Gas cylinder rules 2004, accessed at https://dipp.gov.in/sites/default/files/Gas_cylinder_Rule_2004.pdf (3) https://smartutilities.net.in/2017/03/16/daughter-booster-stations/

11. CNG pricing and taxation policy

It is also clear that to make a new fuel and vehicle programme cost effective and to reduce its total cost of ownership to enable it to compete with the mainstream technologies, well designed pricing and taxation policy is needed.

Recognizing this, the Supreme Court directive had taken on board the recommendation that a favourable taxation policy be adopted that will aim for at least 30 per cent price differential between CNG and diesel. In response, the Government of Delhi had waived off value added tax on CNG. This helped in keeping the pump prices lower than diesel.

However, over time the price gap between CNG and diesel fuels has narrowed considerably due to the changes in international fuel prices, though CNG has continued to remain cheaper than diesel. In 2002–03, CNG was cheaper than diesel by about 46.71 per cent. In December 2013, the price differential plummeted to 7.35 per cent. An intervention was made to reduce CNG prices that helped to increase the differential again to about 35 per cent. Of late, the retail prices of petrol and diesel have increased considerably. As on July 2021, CNG was cheaper by 51 per cent compared to diesel and 57 per cent compared to petrol. Delhi has successfully kept the price of CNG comparatively cheaper than competing fuel.

Thus, a pricing policy for cleaner fuels is necessary to promote their use and also to keep public transport services cost effective.

12. Air quality benefits of the CNG programme in Delhi

The air quality benefits of the CNG programme in Delhi are borne out by various studies that have been carried out since the beginning of this programme.

Air quality and public health benefits: The CPCB, the apex air quality monitoring agency in India, has stated that after the implementation of the first phase of CNG programme in 2002, particulate levels dropped by about 24 per cent from the 1996 levels. A study conducted in 2004, by the Washington DC-based Resources For the Future (RFF), found that of all the different interventions made to combat pollution in Delhi, the CNG programme had the maximum impact as buses travel more kilometres and contribute more to the pollution load. A study by Jawaharlal Nehru University found perceptible drop in polycyclic aromatic hydrocarbons—a group of very toxic pollutants—in Delhi's air immediately after the introduction of the CNG programme. The World Bank study of 2004 shows that the first generation measures in Delhi and Mumbai that also include the CNG programmes helped to reduce the number of premature deaths annually—at least 3,629 in Delhi and at least 5,308 in Mumbai.

Climate benefits: It is stated that the programme has also contributed to reducing greenhouse gas emissions. A TERI-ARAI study also showed comparatively lower CO_2 emissions from CNG buses than their diesel counterparts.

Initially, there were also concerns that methane emissions from the CNG infrastructure and vehicles may contribute significantly to the global warming potential of the programme. While that is a concern and needs to be addressed by stopping methane leakage on a lifecycle basis, later studies also pointed out that a lot of that impact can be offset by the fact that the CNG programme helped eliminate black carbon emissions, which are also potent warming agents. A study by British Columbia showed that in comparison with the warming potential of black carbon emissions from the older diesel fleet, CNG was much better. On its own, the estimated CO_2e increase due to switch to CNG could have increased the warming potential of the programme. But when black carbon is taken into account, the switch is at worst carbon neutral. At best, up to 30 per cent reduction in CO_2e has been estimated from this programme.

As noted earlier, with subsequent improvement in vehicle technology through successive stages of Euro IV and Euro VI equivalent emissions standards in India, the emissions benefits from the CNG fleet have been further optimized.

CNG—panacea for fuel adulteration: Fuel adulteration is a serious risk in liquid fuels. It also negates all the gains made through improvements in vehicle technology, especially from the advanced emissions control systems needed to reduce emissions from petrol and diesel. Gaseous fuel is seen as a means to liberate from the evil clutches of adulteration. In fact, the Supreme Court of India observed in its ruling in April 2002 that CNG is an environmentally acceptable fuel and it is non-adulterable.

13. Pathways for a robust CNG programme in cites of Nigeria

Nigeria has an immense opportunity to leverage its locally available natural gas reserves to build a robust CNG programme for vehicles to counter the pollution impact of the large fleet of old and ageing vehicles on diesel and gasoline.

Steps have already been taken to implement this programme and it is at the crossroads for further expansion. This initiative is expected to contribute towards the implementation of the NAP of 2019 to reduce SLCPs to achieve 75 per cent reduction in $PM_{2.5}$ emissions by 2030. The plan categorically asks for targeted adoption of CNG buses such that they form 25 per cent of all buses by 2030. Combining CNG programme with the programme for augmenting buses is a win-win strategy as this improves pubic transport services based on clean fuels and provides both emissions and mobility gains.

Substituting older more polluting fuels with cleaner fuels can help in leapfrogging to much cleaner emissions levels. While its use is being promoted in other sectors, a well-planned city gas distribution system for the key cities of Nigeria can help to create a critical mass of demand for transportation use. This will require a policy and an implementation strategy addressing the technical regulations for product development and retrofitment, quality control of conversion, inspection and maintenance programme, extensive pipeline for setting up of refuelling infrastructure, safety regulations, and a fuel pricing policy.

Prioritize key cities for implementation of city gas distribution system: It is necessary to prioritize key cities with large volumes of traffic and high rates of motorization to implement the CNG programme. Gas pipeline development at the city level is critical to have efficient refuelling systems to support large volume of vehicles. This will require appropriate forecasting of volume of demand to design the refuelling system. It is necessary to establish the maximum number of online stations linked to the pipeline directly.

Need mandate for targeted replacement of other fules with CNG in different vehicle segments for critical mass of demand: A mandate for targeted replacement and transition to CNG is needed for creating critical mass of demand to make the investment in CNG infrastructure efficient. It is not possible to create a sizeable market based on incremental and natural rate of growth. New

technologies require a time-bound mandate for targeted vehicle segments for adequate market penetration. Already the National Action Plan has asked for a dedicated CNG bus programme and has targeted 25 per cent of the bus stock to be on CNG. This is an important strategy to eliminate toxic diesel emissions from the bus segment and also create critical mass of demand to make the market viable.

Prioritize transition of high-mileage and more polluting vehicles to maximize emissions gains: The emissions gains can be maximized if high-mileage vehicles—including public transport and para transit—along with more polluting heavy-duty vehicles on diesel are prioritized for targeted transition. Fleet-wise targets are needed for planned transformation. Buses as a priority segment will require special attention.

Need emissions standards and safety regulations for CNG vehicles: As Nigeria is promoting local manufacturing and assembly of vehicles, emissions standards and regulations are needed for proper uptake of technology approaches and to define the technology pathways for best emissions gains. Emissions and technical regulations, and testing for certification of vehicles are necessary to establish a good programme. Nigeria has adopted Euro II emission standards. But the CNG programme can be linked to higher targets of Euro IV emissions standards that can also force adoption of improved diesel and gasoline technologies.

Need monitoring and compliance framework for CNG conversion programme: As Nigeria is also allowing conversion of on-road vehicles with the help of conversion kits, this requires special attention. As the Indian experience shows, lack of quality control of conversion, and the absence of audits and certification of conversion workshops can increase the risk of leakage and safety. It is necessary to certify the conversion kits by make and model of vehicles. Some technical assessment will be needed for conversion of very old vehicles that are imported into the country. Nigeria needs a scrappage programme to identify the end-of-life vehicles that need to be scrapped and cannot be converted. In fact, in India, Delhi took the decision of not converting old diesel buses to CNG and mandated purchase of only new CNG buses. However, for three-wheelers and cars/taxis, conversion techniques have been adopted. This requires a certification system for conversion kits and periodic audit of the conversion workshops for quality control. Emissions and safety standards will have to be mandated for all of them.

Need framework for safety regulations and monitoring: It is necessary to adopt a framework for monitoring and inspection of safety related aspects of CNG vehicles to eliminate fires and other hazards. Some of the bus-burning incidents

during the initial years of the Delhi programme were carefully investigated to ensure uptake of remedial measures. Bus manufacturers were directed to correct the defects related to wiring harness, exhaust manifolds, cylinder heads, etc. With tough safety regulations, field-based root cause analysis and corrective measures, the quality of the programme can be greatly improved. Safety regulations are needed for periodic testing of CNG cylinders in the vehicles as well. This requires testing centres to carry out these pre-defined tests.

Need adequate and appropriate refuelling network for CNG dispensation: Nigerian cities will be well advised to set up pipelines for city gas distribution so that a dense network for CNG refuelling and dispensation can be built. Pipeline-based dispensation system can ensure proper and consistent pressure for refuelling of CNG that can fast-track refuelling. Any tanker-based refuelling system that cannot maintain consistent high pressure during refuelling can be very inefficient and can slow down refuelling. Inadequate supply network and compression and dispensing capacity of refuelling station can make refuelling inefficient leading to long queues of vehicles. Refuelling network also requires adequate geographical coverage. Particularly, public buses require dedicated refuelling systems inside the bus depots to ensure smooth operation of buses and to reduce dead mileage of buses and time wasted in refuelling. This planning is critical for successful operations in cities of Nigeria.

Address pricing and taxation of CNG to keep cleaner fuels effectively cheaper than mainstream fuels: Nigeria has already adopted a fuel pricing policy that keeps the price of diesel fuel—that causes more toxic emissions—more expensive than gasoline. This is a good practice in Nigeria. This needs to be further expanded to ensure that the price of CNG remains the cheapest among all the mainstream fuels. This will require a favourable taxation policy. This is also needed to reduce the cost pressure on public transport services.

Vehicle inspection and maintenance programme: While a robust vehicle inspection and maintenance programme is needed for all genres of vehicles, it is particularly important for the CNG fleet. This helps to introduce CNG leakage testing, maintenance of the logbook to record all repairs and promotes preventive maintenance practices. Regular tests (quarterly tests, annual fitness tests and third party checks) help to improve the quality of the programme and minimize safety hazards.

Need institutional oversight for quality control and implementation of the programme: There is need for multidepartment oversight committee for coordinated action and to oversee the various aspects of the programme.

Need skill building to create jobs in the sector: The wide range of technical regulations and repair and maintenance practices that are needed to implement the CNG programme have strong potential for skill building and job creation. This is an important spinoff that needs to be leveraged.

Annexure

Some relevant regulations related to CNG vehicles in India

1. Application for CNG Retroftment Centre (RFC)
https://transport.delhi.gov.in/sites/default/files/All-PDF/CNG%20new%20application%20format.pdf

2. Detailed guidelines to set up city gas distribution network
- https://www.pngrb.gov.in/OurRegulation/PNGRB%20Regulations/A.%20CGD%20Network/A.1.%20CGD%20Authorization%20Regulations/CGD%20Auth-Post%20Amendment-30.09.2020.pdf
- http://petroleum.nic.in/sites/default/files/guidelines%20of%20CNG.pdf

References

1. Anon 2021, Nigeria focuses on gas to drive future and lift economy, International Energy Forum. Accessed at https://www.ief.org/news/nigeria-focuses-on-gas-to-drive-future-and-lift-economy

2. Anon 2020, Nigeria, US Energy Information Administration. Accessed at https://www.eia.gov/international/analysis/country/NGA

3. Peter Uzoho 2021, Nigeria slumps to 20th position in natural gas production, all Africa. Accessed at https://allafrica.com/stories/202112140036.html

4. Oladehinde Oladipo 2021, CNG can save Nigeria N3 trn but infrastructure lacking, BusinessDay. Accessed at https://businessday.ng/energy/oilandgas/article/cng-can-save-nigeria-n3trn-but-infrastructure-lacking/

5. Yusuf Akinpelu 2021, Despite govt's repeated promises, importation of dirty fuels continues in Nigeria, The Premium Times. Accessed at https://www.premiumtimesng.com/news/headlines/452486-analysis-despite-govts-repeated-promises-importation-of-dirty-fuels-continues-in-nigeria.html

6. Anon 2017, Developing a roadmap for the adoption of clean fuel and vehicle standards in Southern and Western Africa, International Council on Clean Transportation.

7. Yusuf Akinpelu 2021, Despite govt's repeated promises, importation of dirty fuels continues in Nigeria, The Premium Times. Accessed at https://www.premiumtimesng.com/news/headlines/452486-analysis-despite-govts-repeated-promises-importation-of-dirty-fuels-continues-in-nigeria.html

8. Yusuf Akinpelu 2021, How Nigerians are paying deadly price for Europe's dirty fuel, The Premium Times. Accessed at https://www.premiumtimesng.com/news/headlines/435772-special-report-how-nigerians-are-paying-deadly-price-for-europes-dirty-fuel.html

9. Ubani E. Chikwendu et al 2018, Use of CNG as Autofuel in Nigeria, European Journal of Engineering Research and Science, Vol 3, No 10.

10. Oladehinde Oladipo 2021, CNG can save Nigeria N3 trn but infrastructure lacking, BusinessDay. Accessed at https://businessday.ng/energy/oilandgas/article/cng-can-save-nigeria-n3trn-but-infrastructure-lacking/

11. Anon 2020, Framework for the implementation of intervention facility for the national Gas Expansion Programme, Central Bank of Nigeria

12. Anon 2021, FG sets aside N250bn for autogas vehicle conversion – Minister, Pulse. Accessed at https://www.pulse.ng/news/local/fg-sets-aside-n250bn-for-autogas-vehicle-conversion-minister/lgy17k1

13. Anon (n.d.), Compressed Natural Gas (CNG) Division, NIPCO PLC. Accessed at https://nipcoplc.com/cng-division/

14. Anon 2015, 5,000 Vehicles Use CNG In Nigeria – NIPCO. Accessed at http://www.thetidenewsonline.com/2015/09/02/5000-vehicles-use-cng-in-nigeria-nipco/

15. Oladehinde Oladipo 2021, CNG can save Nigeria N3 trn but infrastructure lacking, BusinessDay. Accessed at https://businessday.ng/energy/oilandgas/article/cng-can-save-nigeria-n3trn-but-infrastructure-lacking/

16. Anon 2022, One year after: FG's autogas plan fails to fly ahead of subsidy removal, FridayPosts. Accessed at https://fridayposts.com/one-year-after-fgs-autogas-plan-fails-to-fly-ahead-of-subsidy-removal/

17. Oladehinde Oladipo 2021, CNG can save Nigeria N3 trn but infrastructure lacking, BusinessDay. Accessed at https://businessday.ng/energy/oilandgas/article/cng-can-save-nigeria-n3trn-but-infrastructure-lacking/

18. Kingsley Jeremiah 2021, Nigeria's gas reserves to hit 230Tcf despite poor utilisation, The Guardian. Accessed at https://guardian.ng/business-services/nigerias-gas-reserves-to-hit-230Tcf-despite-poor-utilisation/

19. Anon 2022, Check out Brand new IVM 6115 from Innoson, the First Locally-made CNG 'Gas-powered' Vehicle in Nigeria. Accessed at https://www.carmart.ng/public/blog/check-out-brand-new-ivm-6115-from-innoson-the-first-locally-made-cng-gas-powered-vehicle-in-nigeria/

20. Anon 2021, Lagos targets conversion of one million vehicles to autogas. Accessed at https://www.erpecnewslive.com/article/14724/lagos-targets-conversion-of-one-million-vehicles-to-autogas-africa

21. Nse Anthony-Uko 2021, Nigeria Needs N1.3trn To Convert 8m Public Vehicles From Petrol To Gas, Accessed at https://leadership.ng/nigeria-needs-n1-3trn-to-convert-8m-public-vehicles-from-petrol-to-gas/

22. Obafemee 2021, Innoson to help owners convert petrol-powered cars to run on cheaper and cleaner CNG, AutoJosh. Accessed at https://autojosh.com/innoson-to-help-owners-convert-petrol-powered-cars-to-run-on-cheaper-and-cleaner-cng/

23. Johnson Uche 2020, N250bn to be spent to find compressed natural gas infrastructure, Nairametrics. Accessed at https://nairametrics.com/2020/12/02/n250bn-to-be-spent-to-fund-compressed-natural-gas-infrastructure/

24. Emmanuel Egobiambu 2020, Vehicle owners to pay N250,000 to convert cars to autogas, Says FG. Accessed at https://www.channelstv.com/2020/12/02/vehicle-owners-to-pay-n250000-to-convert-cars-to-autogas-says-fg/

25. Emmanuel Egobiambu 2020, Vehicle owners to pay N250,000 to convert cars to autogas. Accessed at https://www.channelstv.com/2020/12/02/vehicle-owners-to-pay-n250000-to-convert-cars-to-autogas-says-fg/

26. Oladehinde Oladipo 2021, CNG can save Nigeria N3 trn but infrastructure lacking, BusinessDay. Accessed at https://businessday.ng/energy/oilandgas/article/cng-can-save-nigeria-n3trn-but-infrastructure-lacking/

27. Okechukwu Nnodim 2020, Vehicles: FG inaugurates committee on alternative fuel, Punch. Accessed at https://punchng.com/vehicles-fg-inaugurates-committee-on-alternative-fuel/

28. Anon 2020, Natural Gas: Navigating towards cleaner tomorrow, Ministry of Petroleum and Natural Gas. Accessed at https://mopng.gov.in/files/PdcDocument/NaturalGasDocument.pdf

29. Avinash K. Agarwal et al 2018, Toxicity and mutagenicity of exhaust from compressed natural gas: Could this be a clean solution for megacities with mixed-traffic conditions? Journal Environmental Pollution (Elsevier), 239 (2018) Page 1 to 13

30. (1) EPCA Report No. 30, March 2007, CNG safety: Progress and action taken report, *Mimeo* (2), EPCA Report No. 26, July 2006, Investigations relating to fire hazards and safety in CNG Buses, *Mimeo* (3) H B Mathur, Report on the fire incidents in a converted CNG Bus, 2006, *Mimeo*

31. Anon 2019, Shri Dharmendra Pradhan unveils India's First CNG Bus which can run 1000 Kms in one fill;Says Delhi has witnessed a revolution in shift towards cleaner gas based fuels, PIB Release. Accessed at https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1597433

32. http://dtc.nic.in/content/cng-leakage-checking-centres

Centre for Science and Environment
41, Tughlakabad Institutional Area, New Delhi 110 062
Phones: 91-11-40616000 Fax: 91-11-29955879
E-mail: cse@cseindia.org Website: www.cseindia.org