TALLINNA TEHNIKAÜLIKOOL
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DEPARTMENT OF MATERIALS SCIENCE

POSSIBILITIES OF COMPRESSED NATURAL GAS VEHICLE DEVELOPMENT IN LAGOS STATE ROAD TRANSPORT SYSTEM, A VIABLE CONCEPT FOR NIGERIA ROAD TRANSPORT SYSTEM

"Master Thesis"

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Materials and Processes of Sustainable Energetics

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KEEMIA- JA MATERJALITEHNOLOOGIA TEADUSKOND
MATERJALITEADUSE INSTITUUT

Surugaasi sõidukite arendamise võimalused Lagose transpordisüsteemis, võimalik juurutamine Nigeeria transpordistektorisse"

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2016

Declaration

I hereby declare that this master thesis is my original investigation and achievement, submitted for the master degree at Tallinn University of Technology has not been submitted for any degree or examination.

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Oyeniyi Matthew Jolayemi

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List of Abbreviations and Acronyms

TCF	Trillion cubic feet
NOAA	U.S. National Oceanic and Atmospheric Administration
NGC	Nigerian Gas Company
WAGP	West African Gas Pipeline
TSGP	Trans-Saharan Gas Pipeline
LPG	Liquefied Petroleum Gas
AG	Associated Gas
NAG	Non Associated Gas
NLNG	Nigerian Liquefied Natural Gas
CNG	Compressed Natural Gas
NNPC	Nigerian National Petroleum Corporation
OPEC	Organization of Petroleum Exporting Country
ASB	Annual Statistical Bulletin
CDIAC	Carbon Dioxide Information Analysis Center
SCF	Standard Cubic Feet
UNFCCC	United Nations Framework Convention on Climate Change
CH_4	Methane
CO_2	Carbon dioxide
GHG	Green House Gases
SO_4	Sulphur dioxide
U.S	United States
NO	Nitrogen Oxides

DRN	Declared Road Network
BRT	Bus Rapid Transit
LAHA	Lagos State House of Assembly
PHCN	Power Holding Company of Nigeria
WRPC),	Warri Refinery and Petrochemical Company
PHRC	Port Harcourt Refinery and Petrochemical Company
KRPC	Kaduna Refinery and Petrochemical Company
PMS	Premium motor spirit
AGO	Automotive Gas Oil
HHK	House Hold Kerosene
ATK	Aviation Turbine Kerosene
BSCF/D	Billion standard cubic feet of gas every day
ELPS	Escravos to Lagos Pipeline System
MMSCF/D	Million standard cubic feet for every day
GSPA	Gas Sale and Purchase Agreement
NGV	Natural Gas Vehicle
GGE	Gasoline Gallon Equivalent
DGE	Diesel Gallon Equivalent
MPG	Miles Per Gallon
VMT	Vehicle Miles Traveled
KM/L	Kilometre Per Litre
L/100	Litre per 100 kilometre
LAMATA	Lagos Metropolitan Area Transport Authority
UITP	International Association of Public Transport
UATP	African Association of Public Transport

MMSCFD	Million Standard Cubic Feet per Day
PM	Particulate Matter
CO	Carbon monoxide
TSP	Total Suspended Particles
NOx	Nitrogen oxide compounds
SO_2.	Sulphur Dioxide
CG	Conventional gasoline
CD	Conventional diesel
ROI	Return of Investment
NEITI	Nigerian Extractive Transparency Initiative
ANG	Associated Natural Gas

1.0 Natural Gas in Nigeria

Nigeria, as the largest holder of Natural gas in Africa, also have a significant ranking in the world, being ninth largest holder of Natural gas in the world, had in 2013, produced 1.35 TCF (trillion cubic feet) of dry natural gas, this makes her to be among the world's top 30 producer of Natural gas [29]**.** According to Charles Asekhame Odumugbo 2010 [9], 182 TCF (trillion cubic feet) was estimated as Nigeria gas reserves, and with an anticipated growth rate of more than 70% by 2025, the country's gas sector has demonstrated to have the capability of being a key player in the new worldwide Natural gas market. Tragically, even with this tremendous gas reserve, very little have been proficient in the terms of utilization, with hereby still making the enormous side of this natural gas unutilized.

1.1 Gas Flaring

Basically, for safety purposes during exploration, Oil and gas industries are in no doubt releases gases into the atmosphere and this have mostly be a common phenomenon in exploration practice. Gas flaring is one of such major process, and it involves controlled combustion of natural gas in the course of normal oil and gas operations, which same thing is known as Venting that involves the release of gases into the atmosphere during production [78].

1.2 Gas Flaring Practice in Nigeria

Nigerian department of petroleum resources in the year 2007 reported cases of 117 gas flaring sites in the Niger-Delta region. It had been the preferred options of oil companies to by-pass the idea of re-injection, rather it (the company) flares its associated gas to lessen expenses and avoid paying a huge fine. More so, inadequate gas infrastructure had given avenue for gas flaring to thrive. About 75% of gas is therefore flared while 12% re-injected. In spite of the fact that Nigeria government declared a law to battle gas-flaring, gas flaring remains an issue on account of lacking implementation because of low punishments forced for infringement and the giving of exceptions to oil organizations that flare gas [17]**.**

As it is also stated by the U.S. National Oceanic and Atmospheric Administration (NOAA), Natural gas flared in Nigeria represented 10% of the total sum flared globally in 2011. Most Natural gas reserves are situated in the Niger Delta region of Nigeria. The Natural gas industry is

additionally influenced by the same security and administrative issues that influence the oil sector [29].

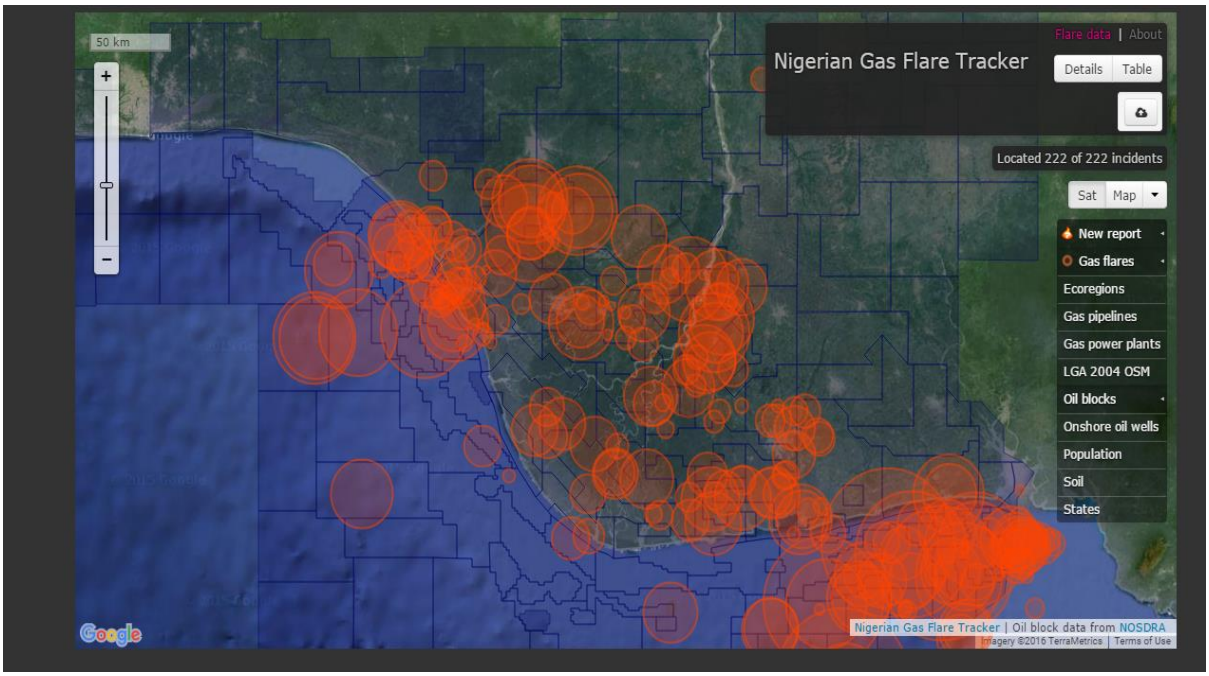


Figure 1.0 Nigeria – Delta Region, Nigeria: Gas flaring site satellite image from a satellite [19]

Figure 1.1 Flare stacks burn off gas at a natural gas processing plant [93]

1.3 Nigeria Strategic intent to eliminate Gas flaring

To subside flaring, the country started endeavours to exploit the associated gas (AG) for natural gas NG international trade, domestic power generation and transportation, and as industrial feedstock. Those major utilization of the gas also include the activities incorporating the Nigeria Liquefied Natural Gas Limited (NLNG) that has traded outside the country (export) more than 3.7 trillion cubic feet (TCF) of LNG [52]**,** the Oso Condensate Natural Gas Liquefaction, the Brass River LNG – the principal offshore LNG plant (Alexander's Gas and Oil Connections, 2003), the Olokola LNG plant, the Escravos Gas Projects for LPG and the Escravos Gas-to-Liquids facility. There are three gas turbine power plants (Afam, Egbin and Okpai) and two gas-fired warm plants (Ughelli and Sapele) and 17 different gas power plants at different phases of development. There also exists various pipeline project which links to the outside (international) incorporating the 678 km West African Gas Pipeline (WAGP) which keeps running from Nigeria to Ghana and the proposed Trans-Saharan Gas Pipeline (TSGP) which is expected to terminate in Algeria. Local pipeline projects, incorporate the Oben-Geregu pipeline which is to supply a power Plant, the Obiafu-Obrikom-Oben pipeline proposed to associate the western and eastern parts of the nation, and the Escravos to Lagos Pipeline System which would expand supply ability toward the South Western part of the nation [57].

These activities have added to the diminishment in the rate of gas flared from 77% in 1990 to 23% in 2012 (NNPC, 2001, 2013). In any case, satellite pictures demonstrate that the total volume flared has increased [85]**.**

Improper priority: on Natural gas utilization, Nigeria stepped on the development of the provincial and global export markets at the expense of domestic use, as showed by the WAGP and NLNG export out terminals which were created ahead of local distribution system. This prioritized the global market advancement than the local and domestic supply. Making national intrigue a priority ahead of regional base is a basic achievement as found in Argentina, Pakistan and Brazil [57].

1.4 Past effort towards Alternative Fuel System

The government owned establishment, which is the Nigerian Gas Company Limited (NGC) which is completely laid with the charge of gas transmission, deal and sales, and with a domestic company went into a joint venture understanding in 2007 to set up a chain of CNG refilling stations. The pilot scheme being set to began in Benin City, in the Niger Delta district, where gas is produced. While the targets included the retrofitting of 50,000 gasoline and diesel vehicles in the initial four years and the development of 8–10 CNG stations, 50 km of steel pipeline and 2 retrofitting workshops in the initial two years. As toward the end of 2013, seven years after the beginning of the test case program, just the objective for conversion workshops has been met [57].

1.5 Purpose of Research

To end the recurring fuel crises, boost good economic policy and the control of emissions from petrol and diesel vehicles over the cities of Nigeria, we need to evaluate and implement a good and sustainable alternative fuel for our road transport system, with CNG, I proposed to replacing current gasoline and diesel fuel which are the main road transport fuel in Nigeria. The Prospects and analysis of potential natural Gas Vehicle (NGV) implementation as a means of road transportation in Nigeria Cities, using Lagos Metropolis for my pilot study enlightens us on how the government of Nigeria can begin a medium scale startup of the use of Natural Gas Vehicle, and that it will be both doable and coherent for the Nigeria government to finance such vehicles on a national scale. This replacement is to enhance the increased domestic use of natural gas as an alternative to current fossil fuel (gasoline and diesel), which will also enable us to diminish to total extinction the problem of gas flaring, and adequately utilize our natural resources for the benefit of our society.

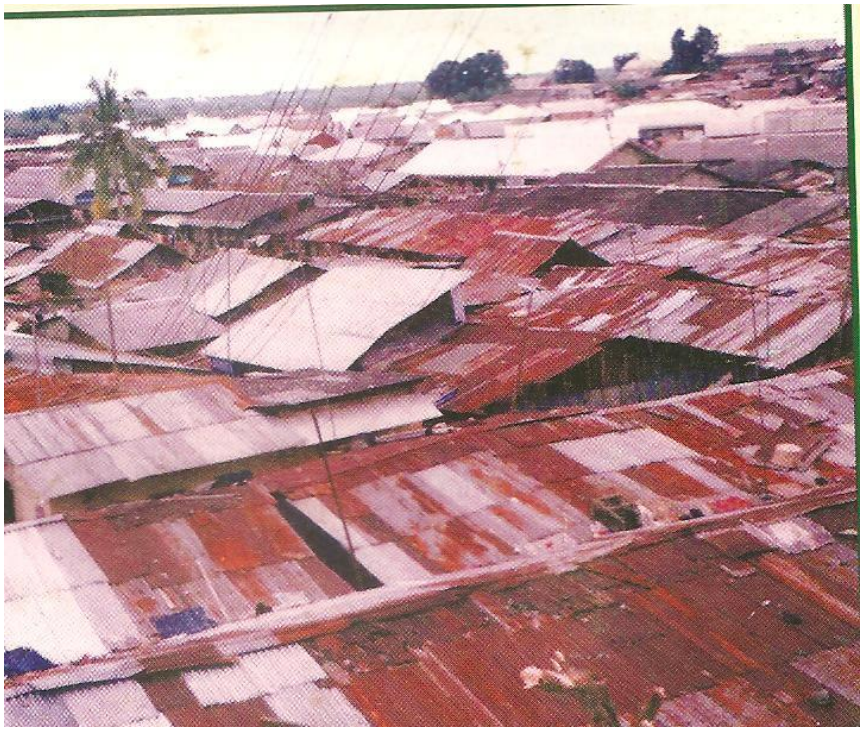
2.0 General Environmental Implication of Gas Flaring

The environmental issues brought about by flaring are principally global, yet to some degree likewise regional and nearby. For instance, flaring/venting amid oil production operations discharges CO_2, methane and different types of gasses which add to an unnatural weather change bringing about atmosphere change, and this influences the natural quality and wellbeing of the region of the flares. This discredits duties made by nations under the United Nations Framework Convention on Climate Change (UNFCCC) and, Kyoto Protocol [20]**.** Worldwide natural effect is because of the blazing of related or arrangement gas, which produces carbon dioxide (CO_2) and methane (CH_4). These discharges expand the convergence of green house gasses (GHG) in the air, which thus adds to a dangerous global [7].

2.1 Niger-Delta Situation, Nigeria

Corrugated rooftops in the Niger Delta district of Nigeria have been eroded by the structure of the acid rain that falls as a consequence of flaring activity in that vicinity. The essential drivers of the corrosive downpour is as a result of sulfur dioxide (SO_2) and nitrogen oxides (NO) which join with air dampness to produce sulfuric acid and nitric acid individually. Size and natural logic in the business have exceptionally strong positive effect on the gas-flaring-related CO_2 discharge [24]. This nullifies responsibilities made by countries under the United Nations Framework Convention on Climate Change (UNFCCC) and Kyoto Protocol [20].

Figure 2.0: Cluster of zinc roofs with various degree of rusting/caving-in From Impact of Gas-Flaring on the Quality of Rain Water, Groundwater and Surface Water in Parts of Eastern Niger Delta, Nigeria [4].



As indicated in a meeting with a town head, from one of the neighborhood groups living around the gas flaring station, the repulsive odour, roaring noise and exceptional warmth exuding from the gas flaring are dehumanizing the same number of them, not only that, but also they are presently experiencing skin infections, tumour, ear issue, respiratory issues, for example, asthma and bronchitis. He affirmed that these sicknesses were unfamiliar to them and are conceivable brought on by consistent flaring of gas in the region. The effect of gas flaring on nature and wellbeing of host groups in Niger Delta, is of extraordinary concern [4].

2.2 Other sources of Air Pollution in Urban Cities of Nigeria

The release of exhaust coming from cars, lorries and all types of road vehicles into the air is one of the significant causes of air contamination in Nigeria particularly in the urban cities where many individuals owns a vehicles for transportation on urban roads. There is fast urbanization in the significant urban areas of Nigeria which is joined by rising vehicle owners, and numerous vehicles plying the road. And thus increments in the continuous release of fumes which causes air pollution [58]**.** This is especially the case amid time of substantial vehicular movement that outcomes into traffic congestion. Several studies and research carried out on environmental studies throughout the years demonstrated that vehicle fumes or smoke has brought about air

contamination which crushes the air quality in urban areas such as Lagos, Ibadan, Kano, Kaduna, and even Abuja the Federal Capital [74].

In Table 2.0, this demonstrated the average Greenhouse Gas Emission by different transport modes per Kilometer in Lagos. Contributions from Pedestrians and bicycle per Kilometer are unimportant. The highest contributions originate from Heavy Duty Multiple Engine Trawlers (1127/km), Heavy Duty Multiple Engine Aircrafts (506/km) and Heavy Duty Trucks (757/km). Regular Motor Cycles (36/km) and Tricycles (59/km) do add to Greenhouse Gas Emission as well. Be that as it may, there are more vehicles on the roads, which implies, more emissions than there are from different types of transport modes. In this manner, all in all, Diesel Busses, Light Trucks and Heavy Duty Trucks are the real sources of emissions from transportation modes [35].

Table 2.0: Average Greenhouse Gas by Transport Mode Per Kilometer. The pollutions generated from transport and traffics mix together with emissions in Lagos [35].

Mode of Transport	**Green House Gas Emission/Vehicle/Km (in metric ton carbon equivalent [MTCE])**
Pedestrian	Negligible
Bicycle	Negligible
Motor Cycle	36
Tricycle	59
Gasoline Car	82
Diesel Car	146
Gasoline Mini Bus	235
Diesel Mini Bus	328
Gasoline Bus	405
Diesel Bus	**480**
Light Truck	**344**
Heavy Duty Truck	**757**
Average Engine Boat	383
Train/Railway Locomotives	396
Average Engine Vessel	430
Heavy Duty Multiple Engine Trawler	1127
Light Double Engine Aircraft	438
Heavy Duty Multiple Engine Air Craft	506

Additionally, there is a sure connection between's the volume of vehicles and the emissions experienced in the Metropolis. As the quantity of vehicles is increasing so additionally the measures of Greenhouse Gasses noticeable all around will increase as well. The quantity of

vehicles was 1.33 million in the year 1992 yet increased to 1.83 million, 20 years after, 2010 that is, by about 59.35% and the discharge expanded by 60.24% [35].

In 20years, between the period 1992 and 2010, the quantity of vehicles on the roads multiplied thus likewise the measure of emissions from this source. It is similar to thusly that, in light of current circumstances, both might be more than twofold in the following two decades.

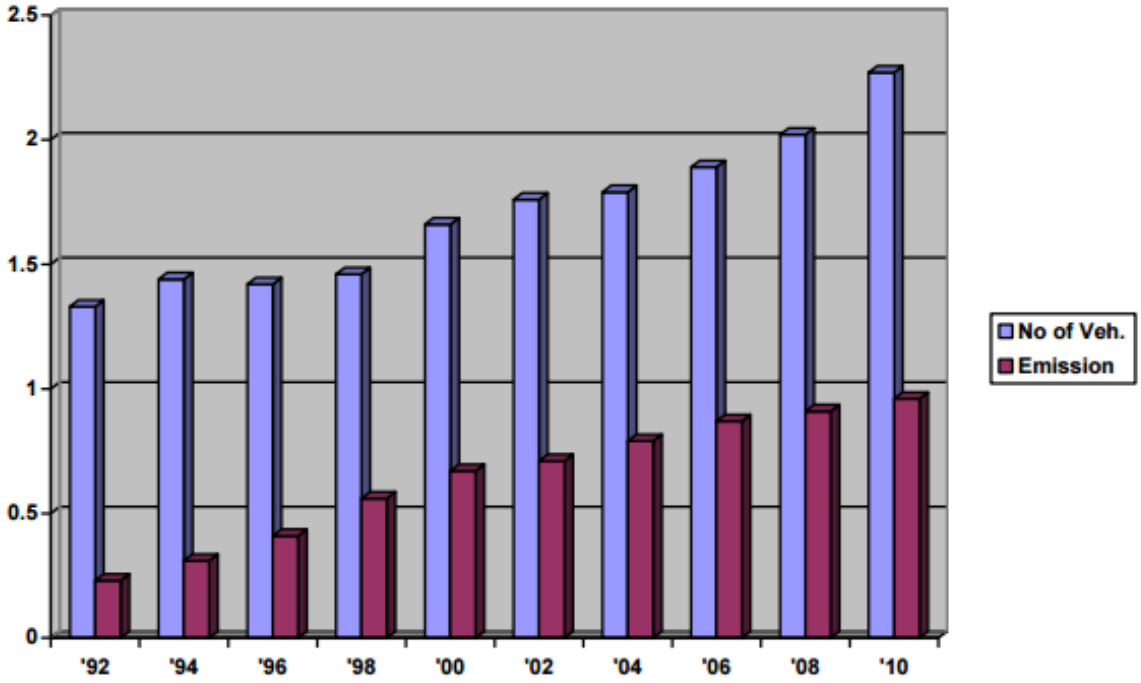


Figure 2.2 Number of vehicle and emission increase [35]

2.3 Population Size and Influence

Population growth rate: The amount of individuals in a given area and the level of economic exercise correspond the measure of energy expended in the vehicle segment. The growth rate in Nigeria is put at around 3.2 % in 2008. This suggests that Nigerian population which was evaluated to be at around 154 million in 2009 is anticipated to be 227 million in 2020 at a direct growth rate of 3.2%. This pattern demonstrates that vehicle ownership will rise, more buses will be purchased, and higher number of tone-kilometer freight vehicles will come onboard. All these will expand the energy demand in the country [64].

2.4 Lagos State Profile

Lagos State has a high human populace of between 18 to 23.8 million and the development rate is between 4.7%-8.2% every year. It is normal that there would be an increment to 30million people by 2020 [37].

2.41 Road network in Lagos, Nigeria

Lagos State has a total road network of 5000km comprising of 675km of Federal roads and 4,325 km of State and Rural roads. 632km of roads in the metropolis falls under the Declared Road Network (DRN). In addition, the State has about 30km of rail network. The mode of Transportation is classified into three: Road, Rail and Water [48].

2.42 Vehicle Registration Statistics, Lagos State

In this way, it is expected that states with high quantities of vehicles with vast gasoline capacity will have larger amounts of fuel utilization than those with less such vehicles. The quantity of gasoline utilizing vehicles registered as a part of every state is intermediary variable for the number of vehicles working inside every state. In any case, vehicles registered in every state are in no way, shape or form the total number available for use. This is on the grounds that some individuals register their vehicles outside their place of residence arrangement either for social identification proof with their place of inception or to lessen the expense of registration [10].

DATA FOR LAGOS STATE MOTOR VEHICLES LICENSES RENEWAL, YEAR 2012

The assessed figure of motor vehicles licenses renewed in the State for the year 2012 was 723,595. This showed a downward trend compared with the relating figure of 758,958 in 2011. The 2012 figure indicated a decrease of 35,363 or 4.66% against 2011 figure.

Motor vehicles licenses renewed for private use in 2012 numbered 585,293 or 80.90% while 100,360 or 13.87% and 34,181 or 4.72% of the total were renewed for Commercial and Corporation use respectively. A total of 562,360 or 77.72% of the vehicles licenses renewed for private use in 2012 were Saloon/Station wagons while 32,929 or 4.55% of the same brand of vehicles had their licenses renewed for commercial use. Minibuses and Omnibuses, accounted for 17,712 or 2.45% and 638 or 0.09% respectively. Renewal of licenses figure for Government vehicles and Mission/Schools were 1,231 or 0.17% and 1,662 or 0.23% respectively of the total vehicles licenses renewed in year 2012 [36].

Saloon/Station wagon vehicles numbering 623,968 constituted 86.23% of the total vehicle licenses renewed in 2012 while Minibuses and Omnibuses recorded 47,828 or 6.61% and 1,435 or 0.20% respectively of the total figure renewed during the year. Vans, Pick-up recorded 14,322 or 1.98% while Lorry/Truck accounted for 33,434 or 4.62% of the total figure during the year.

Table 2.1 Newly- Registered Motor Vehicles by type of Vehicles and type of Ownership, Lagos State: 2012 [36]

TYPE OF VEHICLES	TYPE OF OWNERSHIP					TOTAL
	Private	Commercial	Government	Mission/ School	Corporation	
Saloon/Station wagon	228384	13373	500	675	10472	**253,404**
Van, Pick-up	1599	3345	44	16	813	**5,817**
Lorry/Truck	259	11594		8	1717	**13,578**
Minibus	7193	11280	70	176	705	**19,424**
Omnibus	259	217	4	33	70	**583**
Tanker	1	101			8	**110**
Tractor		51			1	**52**
Trailer	1	30			1	**32**
Tipper	1	767		2	94	**864**
Total	**237,697**	**40,758**	**618**	**910**	**13,881**	**293,864**

TYPE OF VEHICLES	NUMBER OF VEHICLES REGISTERED ANNUALLY																
	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Saloon/Station wagon	22082	12,511	10,529	12,104	27,729	112,600	127446	95,326	57,826	70,496	118,099	156,858	202,042	166,207	188,515	218,528	######
Van, Pick-up	1,163	345	367	361	341	1,269	1876	1,523	1,146	1,460	3,616	6,149	7,084	6,995	7,203	6,155	5,817
Lorry/Truck	634	237	358	344	494	4,016	4791	3,526	1,723	1,780	4,175	6,357	9,987	13,296	11,690	12,478	13,578
Minibus	4,138	1,580	1,573	1,920	3,175	14,529	15469	10,897	6,292	6,988	14,290	17,124	19,244	22,351	30,232	20,420	19,424
Omnibus	605	305	36	98	256	552	833	366	202	162	485	116	392	434	1,541	611	583
Tanker	3	9	5	7	1	16	12	2	6	16	30	61	94	83	40	62	110
Tractor	6	16	5	13	29	41	46	42	25	17	50	73	77	81	97	88	52
Trailer	13	8	6	9	16	53	88	96	70	49	216	172	157	322	782	36	32
Tipper						20	59	55	86	110	304	532	845	1029	863	1,095	864
Total	28,644	15,011	12,879	14,856	32,041	133,096	150,620	111833	67376	81078	141265	187442	239922	210798	240,963	259,473	######

Newly Registered Motor Vehicles by Type of Vehicle and Year of Registration, Lagos, 1991- 2012. (table 2.2. and 2.3.) [36]

TYPE OF OWNERSHIP	NUMBER OF VEHICLES REGISTERED ANNUALLY																
	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
PRIVATE	21892	12205	10073	11260	25944	107555	121646	91669	53322	67246	109436	138592	181632	153781	186,429	196987	237697
COMMERCIAL	3616	1482	1057	1544	2270	13078	15651	9700	5879	5766	17446	19484	28425	32490	32,978	43641	40758
GOVERNMENT	131	73	87	86	204	320	373	148	216	268	571	1061	651	1170	892	445	618
MISSION/SCHOOL	134	17	53	76	105	370	419	365	258	235	332	1097	843	890	875	747	910
*CORPORATION	2871	1234	1609	1890	3518	11773	12531	9951	7701	7563	13480	27208	28371	22467	19,789	17653	13881
TOTAL	**28644**	**15011**	**12879**	**14856**	**32041**	**133096**	**150620**	**111833**	**67376**	**81078**	**141265**	**187442**	**239922**	**210798**	**240,963**	**261484**	**293864**

2.43 The Lagos Bus Rapid Transit (BRT)

Africa's first Bus Rapid Transit (BRT) scheme started operations on March 17, 2008, in Lagos, Nigeria. Called "BRT-Lite", it is a type of the BRT framework, however it is not of the most noteworthy particular like the TransMilenio in Bogota or the Brisbane South East Bus way, both of which cost about $6 million for every kilometer. This new type of the BRT plan is gone for conveying a transport system that will address the issues of local users, while enhancing subjects' personal satisfaction, economy efficiency, and security inside an unmistakably characterized budget [13].

The first phase of the Lagos BRT, which is now running from 'Mile 12 through Ikorodu Road and Funsho Williams Avenue up to CMS' (22 km separation) began, runs a 16 – hour operations from 6.00 a.m to 10 p.m. consistently. The framework utilizes 220 buses to move more than 200,000 passengers every day. In the most recent five years of operations, the BRT framework has moved more than 400 million passengers. The operation is guided by a set of directions directed by the Lagos State House of Assembly (LAHA) and passed into law by the previous Governor, Mr. Babatunde Raji Fashola (2007 – 2015). The pilot BRT Lite plan has performed respectably since operations started in March 2008;

- Average Load factor of 800 passengers carried per bus daily
- Average daily trip per day is 5
- Average waiting time is 15 minutes
- Average speed is 30km/h [92].

Other execution status which are: Average voyage time of 55mins, Fleet capacity utilization is 95% Average passenger kilometer for every day is 5, Kilometers per bus every day is 220 [77]**.**

Financing the Operating Fleet

Two differentiating approaches were taken to financing the substantial buses required for the BRT-Lite framework. In the first approach, 100 new buses were secured by the private sector with no immediate public assistance. In the second approach, 120 transports were secured by a

state-owned organization and afterward rented to the private sector administrator (an extra 40 transports were operated directly by the state-owned company) [13].

Figure 2.3(a) A typical picture of a BRT bus operating in Lagos: [94,95]

Based on the fact that 6 million individuals living in the catchment of the BRTLite passage, three target group were distinguished: Those who had no vehicles and have a singular option of public transport and who might be essential recipients of the BRT-Lite framework (roughly 65 percent of the total catchment). The individuals who had vehicles however were hesitant user, and who, under the right set of situation, would utilize the BRT-Lite framework (around 25 percent). The super rich, who might not be BRT-Lite framework user but rather who might have a solid voice thus would have the capacity to spread influence and may profit by the decongestion effect of the new framework (roughly 10 percent) [13].

Figure 2.3(b) boarding a BRT bus in Lagos [96]

Emissions from BRT

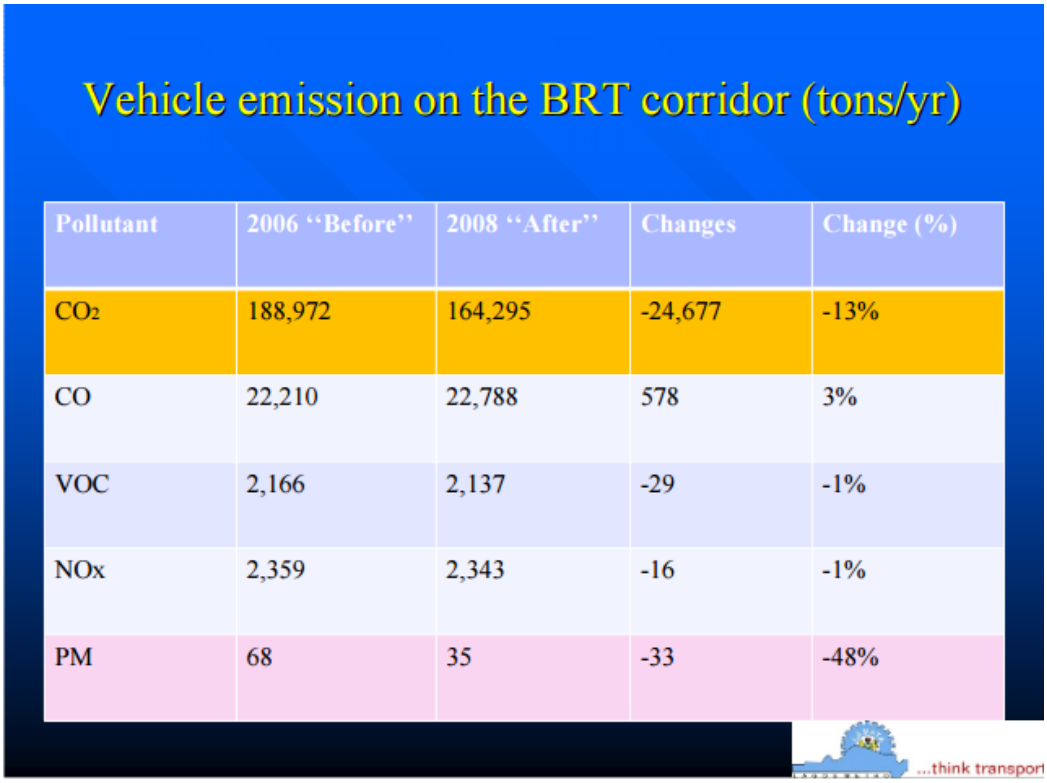


Figure 2.3(c) Vehicle Emission on the BRT corridor **[77].**

The BRTlite has not been able to bring to halt, or entirely reduce significant amount of CO_2 concentration released into the surrounding, since it also utilizes petroleum product as it is so despite some reduction in the level of CO_2 generated. But rather it does not invalidate the workability of the system. The system can be transformed also to work on CNG.

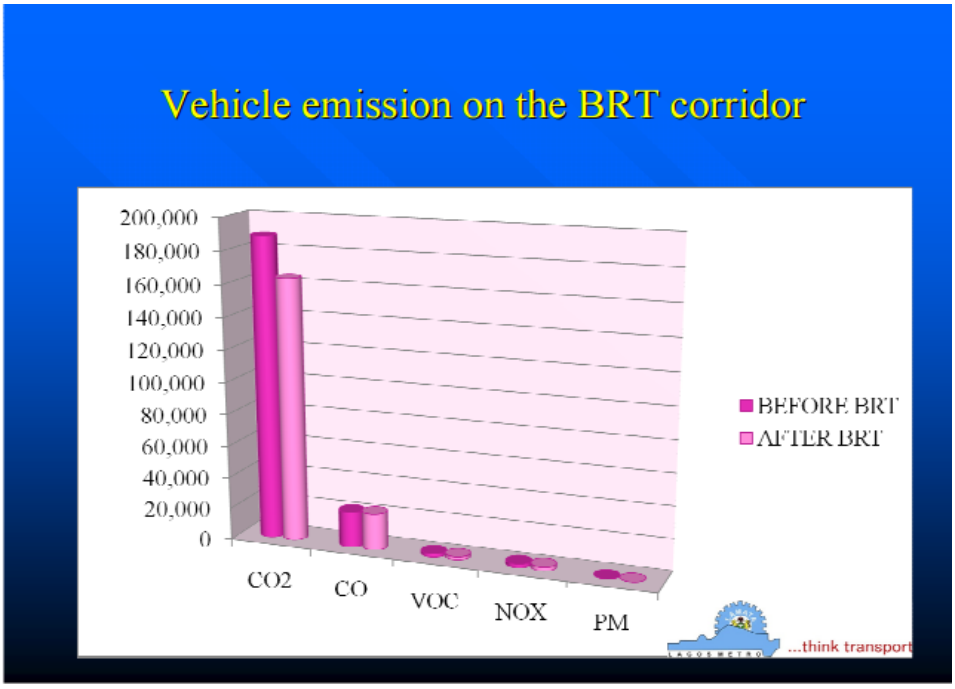


Fig 2.3(d) Vehicle emission on the BRT corridor [77]

2.5 Why considering the option for Alternative Fuel in Nigeria

2.51 Conventional Fuel Situation in Nigeria

The significance of petrol as material products and services can't be lost. It is important to the point that any thought of a conceivable shortage or inaccessibility of the item will undoubtedly spell fate for the economy of the country [75].

Reoccurring challenges

Fuel scarcity is an unpleasant situation in Nigeria. It is extremely problematic to the Nigeria economy. In many instances, the most complex issue arising repeatedly is the way to make petrol available at all times for local consumption, down to earth experience throughout the years have demonstrated that it has not been simple for Nigeria to locate a supportable answer for continuous and extended shortage of petrol in the country, yet petrol scarcity remained an

undefeatable macroeconomic beast in Nigeria. Note that several intervention and stages have been made and are still on the search to address the situation, but yet the issue, however the solution is far from insight. From the era of military administration to the regime of democratic administration, diverse procedures, for example, yearly pivot maintenance of the refineries and importation of refined petrol to supplement local production have been received with no positive effect. The issue has turned into an intermittent difficulty in the country's economy. The circumstance is turning out to be more mind boggling and sensational particularly given the present security challenges confronting the country [75].

2.52 Highlighted Causes of Fuel Scarcity in Nigeria

Lopsided maintenance of the refineries, People's view of state owned enterprise, Smuggling of petroleum items, Pipeline vandalization, incessant Strike by oil workers, Pricing of petroleum items, Continued close down of the Nigerian national petroleum organization stops in Enugu and Aba [56].

2.53 Refinery Problem issue

The Nigerian Federal Government, through its organization, the Nigerian National Petroleum Corporation (NNPC), is in charge of the four existing crude oil petroleum refineries in Nigeria. The four refineries comprises of the Warri Refinery and Petrochemical Company (WRPC), Old Port Harcourt Refinery, The New Port Harcourt Refinery and Petrochemical Company (PHRC) and Kaduna Refinery and Petrochemical Company (KRPC), with a combined installed capability of 445,000 barrels for each day. Each of these refineries is a subsidiary organization under the administration of the NNPC. Petroleum items have, for around two decades now, been supplied to the Nigerian market sector from two sources: domestic crude oil refineries and imports. The split between the two modes was intensely reliant on the availability of the local crude oil refining facilities. The failure of the NNPC refineries to arrive at local demand for petroleum products particularly the premium motor spirit (PMS), has meant an overwhelming dependence of the Federal government of Nigeria on importation to meet local demands. Notwithstanding the importation to support local production, the local utilization of petroleum products in the nation is low. These refineries are at present not able to take care of domestic demand of 300,000 barrels of oil for every day [30].

Table 2.4 Crude oil refining capacity in Nigeria [30].

Plant	Date of commissioning	Installed capacity (barrels/day)
Old P/Harcourt	1965	60,000
New P/Harcourt	1989	150,000
Warri	1978	125,000
KADUNA	1980	110,000
Total		445,000

2.54 Effect of Fuel Scarcity in Nigeria

Nigeria, there is a various negative impact of incessant increment in the price of crude petroleum on the economy. This is on account of whatever happens in the oil sector influences every other sectors of the economy and by implication; it influences the large scale monetary strategies of the nation. Premium motor spirit (petrol) is required to power vehicles which farmers and non-agriculturists expected to move themselves and their merchandise from their homes to their places of exploration. So also, petrol is expected to control creating sets in the country in light of the fact that electrical energy supply from Power Holding Company of Nigeria (PHCN) is not regular and has been depicted in numerous quarters as epileptic [56].

In this way, the irregular supply of petroleum items prompts artificial inflation in the economy. This is on account of products and individuals are moved over a topographical space at higher expense and this effect adversely on real income which happens to be the real determinants of interest of people in the nation. Incessant fuel hike in Nigeria, appears to be unabated, based on the frequencies of its event. The profile of petrol price increase demonstrates that more than twenty-five of such cases have happened somewhere around 1978 and mid 2009. This circumstance has unleashed untold hardship on Nigerians and has influenced costs of rural items and in addition produced products. Numerous individuals have subsequently come about to storing of fuel items in their homes. The result of this conduct is the uncontrolled flame episodes which wreck properties and lives every time there is lack of fuel in the nation.

2.55 PETROLEUM PRODUCTS MOVEMENT IN NIGERIA

Petroleum product circulation is in this manner concerned with the transportation of refined petroleum from the refinery to the last buyers through different locations of delivery in the country. In the Nigeria circumstance, the pipelines and product Marketing Company (PPMC) is in charge of the wholesale supply, appropriation and promoting of petroleum products in Nigeria. Up to this point, the petroleum products available for conveyance were through an elaborate, network of about 4,000 kilometers of pipelines connections associated with 21 broadly distributed depots all over the country. The products might be gotten from the four domestic refineries or in case of a supply deficit from foreign refineries by method of importation. Apart from pipelines, other methods are the use of some twenty marine tankers which are utilized to ship from the coastal refineries of Warri and Port-Harcourt, overwhelming products, and different products are of high demand and transferred to Lagos metropolis [11].

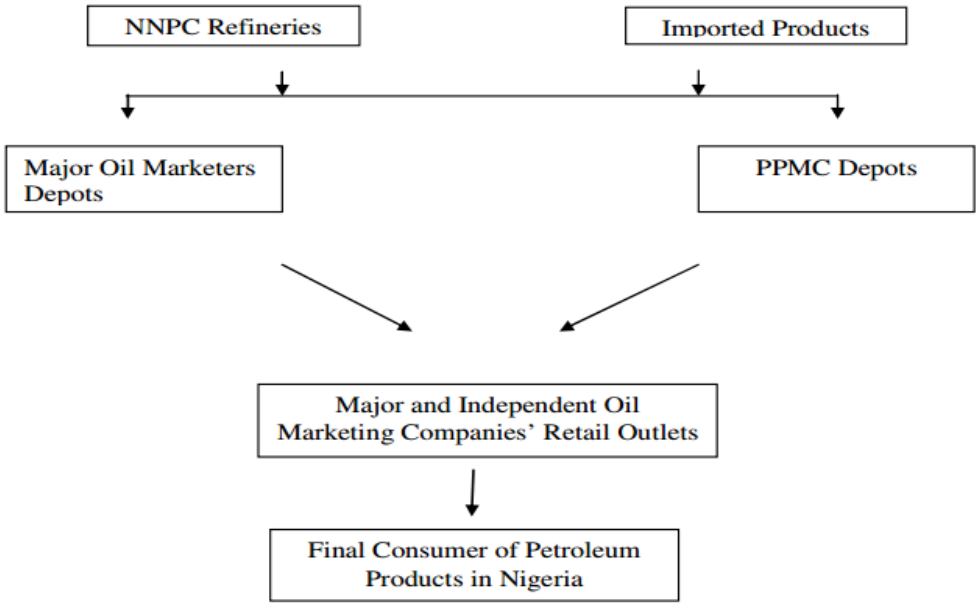


Figure 2.4(a) Source: The physical flow of products: the retail route used by major and independent companies in Nigeria. [50]

2.56 Average Conventional Oil Daily Consumption in Nigeria

The total of 23,883.83 million liters of petroleum products was distributed nationwide, making an average daily consumption in the country to be 47.67 million liters of Petrol Motor Spirit (PMS), 8.82 million liters of Automotive Gas Oil (AGO), 7.90 million liters of HHK (House Hold Kerosene) and 1.04 million liters of Aviation Turbine Kerosene (ATK). In which out of the

volume appropriated, Nigeria National Petroleum Corporation (NNPC) Retail outlets took care of 1,672.43 million liters which is around 7.00% of the volume [51].

Petrol cars in Nigeria were driven 77% further on average than diesel cars. The main contributing factor is petrol state subsidies, which make driving petrol cars cheaper on average. It's also the reason for continuous increase in amount of petrol cars on Nigerian roads [89].

2.57 Average Daily Gasoline Supply in Lagos

During one of the recent fuel scarcity in Nigeria, March-April, 2016, a statement credited to the NNPC corporation spokesman, Mr Ohi Alegbe, who said "The corporation noted that, to achieve the eradication of recent fuel scarcity in the state, truck-out to filling stations in the Lagos area has been increased from the regular 245 (8.05 million litres) to 295 trucks per day (9.7 million) while truck-out to fuel stations in Abuja from Suleja deport that has been stepped up to 210 trucks per day (6.9 million litres) from the regular Supply of 160 trucks per day" [90].

2.58 Retail Outlet of PMS AND Diesel in Nigeria

These are the breakdown of Retail Outlets for petroleum products in all the States of the Federation, (a total of 24,226 outlets), namely [15]:

S/N	STATE	NOS OF PETROL STATIONS
1	ABIA	778
2	ABUJA	303
3	ADAMAWA	390
4	AKWA-IBOM	784
5	ANAMBRA	695
6	BAUCHI	385
7	BAYELSA	68
8	BENUE	635
9	BORNO	913

10	CROSS RIVER	550
11	DELTA	742
12	EBONYI	190
13	EDO	465
14	EKITI	210
15	ENUGU	697
16	GOMBE	291
17	IMO	867
18	JIGAWA	298
19	KADUNA	1,126
20	KANO	1,034
21	KATSINA	442
22	KEBBI	526
23	KOGI	385
24	KWARA	827
25	LAGOS	1,751
26	NASSARAWA	348
27	NIGER	522
28	OGUN	2,207
29	ONDO	743
30	OSUN	970
31	OYO	1,657
32	PLATEAU	552

Table 2.5 Department of Petroleum Resources, 2014 Oil and Gas Annual Report Nigeria [15] .

2.6 Natural Gas Transportation

At the point when Natural gas is not used, it is commonly a waste, and to stay away from wasting such economical resources, we have to find a means to utilize it. Means to transport it needs to be set up with a specific end goal to make utilization of it easy. There are alternatives of transportation in the event that it will be consumed far from point of the gas collection. Natural gas can be transported either by pipeline or tanker, however the most efficient and famous means is pipeline. Furthermore, the choice of pipeline is generally favoured when it is for the most part utilized for business action on everyday schedule. Despite what might be expected, it might be an exceptionally costly stride when pipeline alternative is considered, and there ought to be the position of making a decent cost determination and computation when pipeline is viewed as [53]**.**

The gas dispatcher must modify supply and demand in particular circumstances through a proper sequencing of equipment which is both expensive to run and keep up. Pipeline transportation has transformed into an imperative technique for moving common gas and with the advancement of business sector and broad intrigue, an extensive number of pipeline have been laid. Along these lines, in moving inconceivable measure of this fuel from the accumulation station to the refinery and to transportation and dissemination organization finally to the customers, it can be gone through pipeline. In its progression, colossal venture of capital is for the most part essential. The dominant part of these costs is related to two key fragment, pipeline system and cost related to compressor station [53].

2.7 Nigerian Gas Company (NGC)

The Nigerian Gas Company Limited (NGC) was set up in 1988 as one of the 11 subsidiaries of the Nigerian National Petroleum Corporation (NNPC). It is conferred on with the obligation of building up an effective gas industry to completely serve Nigeria's energy including our industrial feedstock needs through an incorporated gas pipeline system furthermore to export natural gas and its subsidiaries toward the West African Sub-area.

The organization was at first settled to effectively accumulate, treat, transmit and market Nigeria's natural gas and its by-product to important industrial and utility gas distribution organizations in Nigeria and neighboring nations. NGC Strategic Business Direction and rationality has been investigated to concentrate on Transmission, Distribution and Marketing of Natural Gas, Implement full commercialization, investing in feasible Gas Supply ventures for

business manageability. Keep up and grow the business, whilst guaranteeing sheltered and productive use of our introduced limit [49].

As indicated by Nigerian Gas Company (NGC), it has a total capacity of its equipment contain more than 1,250 kilometers of pipelines extending from 4" to 36" in measurement with a general configuration limit of more than 2.5 billion standard cubic feet of gas every day (bscf/d), 16 compressor stations and 18 metering stations. The equipments and facility represent a present asset base of more than $105.5 million business contact [49].

2.71 Existing and Proposed Natural Gas Distribution Network in Nigeria

Domestically, just industrial sector and clients are at the present being considered in the gas distribution systems in Nigeria. This began as far back as 1960 with sales of gas to industrial clients in Port Harcourt. Right away, the gas distribution systems are around 1100 km and majority of which is claimed by Nigeria Gas Company (NGC) covers the western and eastern parts of the nation. The Escravos to Lagos Pipeline System (ELPS) in the west, possessed by NGC, is around 514 km long and makes gas accessible for commercial ventures in the territory [32].

For proficient domestic market growth and elimination of routine gas flaring by the set year, the current gas markets should be extended while the proposed national natural gas pipeline network should be far reaching. The example of the present electricity national grids in which every state of the nation is connected could be adopted. Additionally, expansion of administration to private homes and inns could help request, as found in the figure beneath [32].

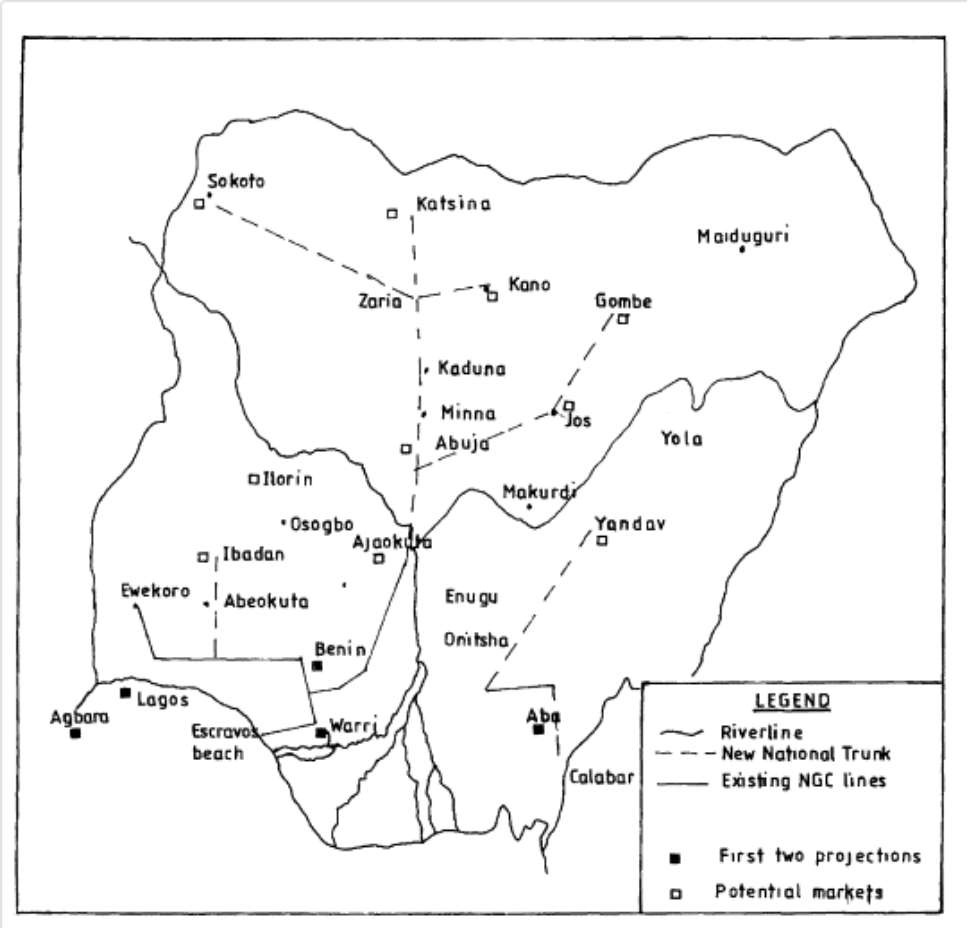


Figure 2.5 proposed national natural gas pipeline network [32].

2.72 Expansion of domestic gas distribution network

Several distribution plans are put in place to advance Nigerian consumption of natural gas. The proposed $745-million Ajaokuta-Abuja-Kaduna pipeline will convey gas to central and northern Nigeria, while the proposed $552-million, Aba-Enugu-Gboko pipeline will convey natural gas to portions of eastern Nigeria. The Lagos State government and Gaslink Nigeria Limited (Gaslink), which is a local gas distribution company, are building up an experimental run project to convey natural gas to nine private neighborhoods in the state. Gaslink as of late started supplying gas to almost 30 industrial customers in Lagos Ikeja industrial [22]**.**

2.73 Existing Pipeline Gas Distribution to Lagos

Presently in Lagos, Gas distribution, Gas is directly distributed to industries and power sectors, and it has not been invented into large scale use as a means of Transportation in Lagos, and in greater part of Nigeria. The existing Lagos Pipeline system is therefore below:

The Escravos-Lagos pipeline system (ELP), it has a capacity of 800 MMscfd [54].

Gaslink Nigeria Limited

Gaslink Nigeria Limited is a backup of Oando Plc and the establishment under which we advance the circulation and use of natural gas in the more prominent Lagos zone. Gaslink is the pioneer and one of only a handful few organizations in Nigeria required in the channeling and conveyance of natural gas to industrial, private and commercial buyers. Gaslink works a 20 year Gas Sale and Purchase Agreement (GSPA) with the Nigeria Gas Company. Gaslink has effectively staged and executed the development of around 100km of natural gas pipeline appropriation system from the Nigerian Gas Company city gate in Ikeja, to cover the Greater Lagos Area including Ikeja, Apapa and their environs. Gaslink right now conveys more than 60 million standard cubic feet for every day (mmscf/d) of gas to more than 150 clients on the Greater Lagos gas dispersion system network, with the ability to convey up to 101 million standard cubic feet for each day (mmscf/d) [54].

2.8 Natural Gas as an alternative Fuel

The utilization of Natural gas as an alternative fuel is gaining popularity all over the world. Very abundance supply is growing in the North America, on a proportional energy premise; it costs not as much as fuel and diesel in current costs. It is thusly obvious that of all contrasting options to petroleum, natural gas has accomplished the best and speediest level of commercialization, and has a portion of the best prospects for close term development. [83].

2.81 Compressed Natural Gas (CNG) Overview

Natural gas, in its compressed form (CNG) is turning into the subject of interest today, as the combustion of gasoline and diesel fuels result in the emanation of harmful toxins which debilitate the very survival of life in this planet [68]**.**

As an example of gases, Natural gas has a low energy density with respect to other fuels. The regular burning properties of Natural gas are gives in **Table 2.6** By and large, 0.921 m^3 of Natural gas has the same energy content as 1.12 L of gasoline. This makes utilization of Natural gas as a transportation fuel at surrounding temperatures and pressure unfeasible. In this way, to utilize Natural gas as a transportation fuel, it must be either compacted or compressed into the liquid form, to expand its volumetric energy density [14].

Table 2.6 Compressed Natural gas characteristics [14].

CNG Characteristics	Value
Vapour density	0.68
Auto Ignition	700˚C
Octane rating	130
Boiling point (Atm. Press)	-162˚C
Air-Fuel Ratio (Weight)	17.24
Chemical Reaction With Rubber	No
Storage Pressure	20.6Mpa
Fuel Air Mixture Quality	Good
Pollution CO-HC-NOx	Very Low
Flame Speed m per sec	0.63
Combust. ability with air	4-14%

Compressed Natural Gas (CNG) is made by compressing methane to less than 1% of its volume under standard atmospheric condition. It is a scentless, tasteless gas that is gotten from gas wells or in coupled with oil products [84]**,** CNG has been utilized broadly as an option of fuel for the automotives industry. A vehicle can be changed over to keep running on CNG fuel through a straightforward procedure of internal alteration, and inside various investigation and analysis, one can inspect the expenses and advantages of this conversion procedure, including its effect upon the general prosperity of the populace as connected to growing issues of contamination in the environment.

Chemistry and Combustion of Compressed Natural Gas (CNG)

Natural gas (NG) is made up basically of methane (CH_4) however much of the time, it contains smaller quantities of ethane, propane, nitrogen, helium, carbon dioxide, hydrogen sulfide, and water vapour. Methane is the key segment of Natural gas. Regularly more than 90% of natural gas is methane [69].

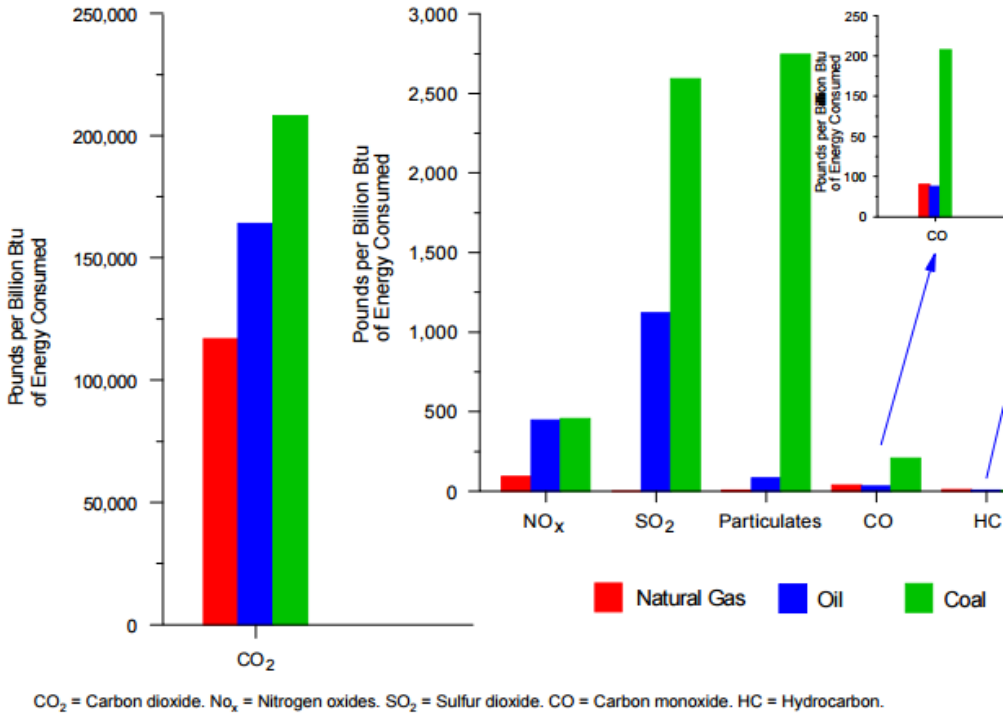
2.82 CNG Fuel Characteristic

The octane rating of Natural gas is around 130, implying that motor engines could work at compression proportion of up to 16:1 without "knock" or explosion. A significant number of the car manufacturer effectively assembled transportation with a natural gas fuelling framework and consumer does not need to pay for the expense of conversion units and required accessories. In particular, natural gas altogether diminishes CO_2 emissions by 20-25% contrast with gasoline since basic chemical structures of natural gas (essentially methane – CH4) contain one Carbon compared with diesel ($C_{15}H_{32}$) and gasoline (C_8H_{18}) [62, 72]. Like methane and hydrogen is a lighter than air sort of gas and can be mixed to diminish vehicle emission by an additional 50%.

2.83 CNG and Environmental Friendly Nature

As indicated by **Lave et al., 2000** [38], the compressed natural gas vehicles show noteworthy potential for the diminishment of gas emissions and particulates.

Air Pollutant Emissions by Fuel Type



CO_2 = Carbon dioxide. No_x = Nitrogen oxides. SO_2 = Sulfur dioxide. CO = Carbon monoxide. HC = Hydrocarbon.

Figure 2.6 ***Source:*** *Energy Information Administration (EIA) [18], Office of Oil and Gas. Carbon Monoxide: derived from EIA, Emissions of Greenhouse Gases in the United States 1997, Table B1, p.*

When Natural Gas is combusted, the gas produces around 20% less CO_2 for each unit of energy than the burning of gasoline, recommending that the complete substitution of gasoline controlled vehicles with CNG controlled vehicles could diminish transportation sector of CO_2 emissions by around 20%. In any case, it is assessed that the genuine level of greenhouse gas emissions reduction from the transportation sector because of the adoption of CNG vehicles is possible to be generally modest.[34].

2.84 Advantage of CNG over Fossil Fuel

It is the only fuel less expensive than gasoline or diesel, it has inherently brought down air pollutions and emissions, it has lower greenhouse emissions, its utilization prolongs petroleum supplies [69]. The emittable pollutions coming out because of burning of natural gas are far less in volume and number than those from the combustion of some other fossil fuel. This happens partially in light of the fact that natural gas is all the more easily and completely combusted, and to some extent since natural gas has less impurities than the other hydrocarbons fuels. For instance, the measure of sulfur in natural gas is much when compared to that of coal or oil [18].

2.85 Chemistry of Emissions

Given the stoichiometric formula for the combustion of gasoline (octane),

$$2C_8H_{18} + 25O_2 \longrightarrow 16CO_2 + 18H_2O$$

It is known that every 1 mol of fuel that is burned will lead to approximately 8 mol of CO_2. Using this ratio and the atomic weight of each atom in the chemical formula leads to the conclusion that for every pound of fuel burned 3.08 pounds of carbon dioxide is produced. The specific gravity of gasoline is 0.75g/ml at STP [16], or 6.259 lbs, indicating that one gallon of gasoline will produce about 19.3 lbs. of CO_2. Information about the fuel efficiency and the vehicle miles traveled (VMT) of the fleet can then be used to compute the approximate number of gallons that the fleet will consume in a given year.

Similarly, the chemical formula for the combustion of natural gas (methane),

$$CH_4 + 2O_2 \rightarrow 2H_2O + CO_2$$

Consolidated with data on the atomic weights of each of the chemicals permitting figuring that the proportion of CO_2 produced when natural gas is combusted, by weight, will be 2.743. At long

last, the National Institute of Standards and Technology (NIST), "1 Gasoline gallon [US] proportionate (GGE) compressed natural gas (CNG) would yield 15.5 lbs. of CO_2. These calculations demonstrate that switching from the combustion of gasoline to the combustion of natural gas could represent 19.6% diminishment in CO_2 emissions [34].

2.9 Natural Gas Vehicle (NGV)

Natural gas has for some time been viewed as an option fuel for the transportation sector. Most NGVs work utilizing CNG. This compressed form of gas is stored in a tube shaped storage capacity tank, in a comparative manner to a gasoline fuel tank, joined to the back, top, or undercarriage of the vehicle. A CNG tank can be filled in a comparable way, and in a comparative measure of time, as a fuel tank. NGVs offer numerous advantages, from enhancing general wellbeing and improving the environment ambient air, to helping the move to fuel cell vehicles [71].

2.91 Benefit of NGV

When we compare NGV powered vehicles with the vehicles powered by conventional diesel and gas, NGVs can fundamentally lower the quantity of harmful emissions, for example, nitrogen oxides, particulate matter, and harmful and cancer-causing contaminations. NGVs can likewise lessen emissions of carbon dioxide, the essential greenhouse gases. NGV and natural gas infrastructure advancement can encourage the move to this technology. Notwithstanding the huge contrast in volumetric energy density amongst gasoline and CNG, the effect of CNG energy density on engine performance is less dramatic. As a gas, it has little cold start issue, Its higher octane rating takes into account higher engine compression proportions than can be utilized with gasoline alone. Higher compression ratio takes into account higher power and fuel effectiveness. In any case, for the same compression proportion, the measure of natural gas air/fuel blend that can be blazed in every cylinder stroke is 10–15% not exactly for gasoline. Because of this, there is a 10– 15% loss of engine output power [71].

2.92 Factors Necessary for NGV Development in Nigeria Market

Pipeline Distribution for Natural Gas

A sufficient natural gas supply is an essential for creating NGVs, and most progressive NGV markets are concentrated in nations with rich natural gas reserves, for example, Iran, Pakistan, Argentina, Brazil, China and India. These nations all have enormous natural gas resources and the majority of their domestic interest for gas could be fulfilled by domestic supply [6]**.** Yet, more than simply having rich resources, countries with improved NGV market likewise have advanced framework – in particular pipelines and refueling stations – to convey the gas to purchasers. Indeed, even in nations rich in natural gas, resources are typically amassed in a couple of regions. With a specific end goal to guarantee viable supply of natural gas, it is essential for governments to venture in and build or enhance natural gas pipelines at the early period of NGV advancement, or offer incentives urging private investor specialists to do as such [87].

2.93 Refueling Station

Apart from pipelines, the easy of availability of natural gas refueling stations is additionally vital to NGV advancement. Customers regularly base their buying choices partly in light of whether there is an adequate number of refueling stations around their home or work environment. This was true in Canada, where NGV market advancement at first profit by the rapid development of refueling stations [59] later, a diminishment in interest in refueling stations brought about Canada's NGV business sector to falter [31]**.** Until as of late, an absence of refueling base slowed down compressed natural gas (CNG) light business vehicle improvement in the U.K. [33].

The fuel can be made available at open filling stations in public places, private fleet facilities or even homes where natural gas pipeline appropriation is accessible. Public natural gas stations have dispensers that are comparative in design to gasoline or diesel dispensers and have practically identical filling times. Private facilities are utilized by committed fleet(s) and are either quick fill or time-fill (i.e., tanks are filled over an amplified timeframe) [39].

Type of Refueling Station

The expense of the significantly more basic strategy for refueling NGVs around the world — a refueling station with fuel delivery equipment practically identical to that found at gasoline stations — relies on upon the kind of fuelling equipment used: fast fill or time-fill. At the point when a high-pressure storage framework is consolidated with a vast compressor in a fast fill

station (the most practically identical setup to gasoline refueling), the expense is higher than in a time fill framework, which has no storage system and a smaller, less costly compressor. As indicated by Doug Horne of the Clean Vehicle Education Foundation, expense is specifically identified with station usage; generally, the bigger the station and the higher the use, the lower the expense per gasoline gallon equivalent (GGE) delivered (Horne 2009). Cost per GGE is most vital to end user since that is the thing that they see as an expense for operating their [39]. When consumers refuel their CNG vehicles in the USA, the CNG is usually measured and sold in GGE units. This is fairly helpful as a comparison to gallons of gasoline [65].

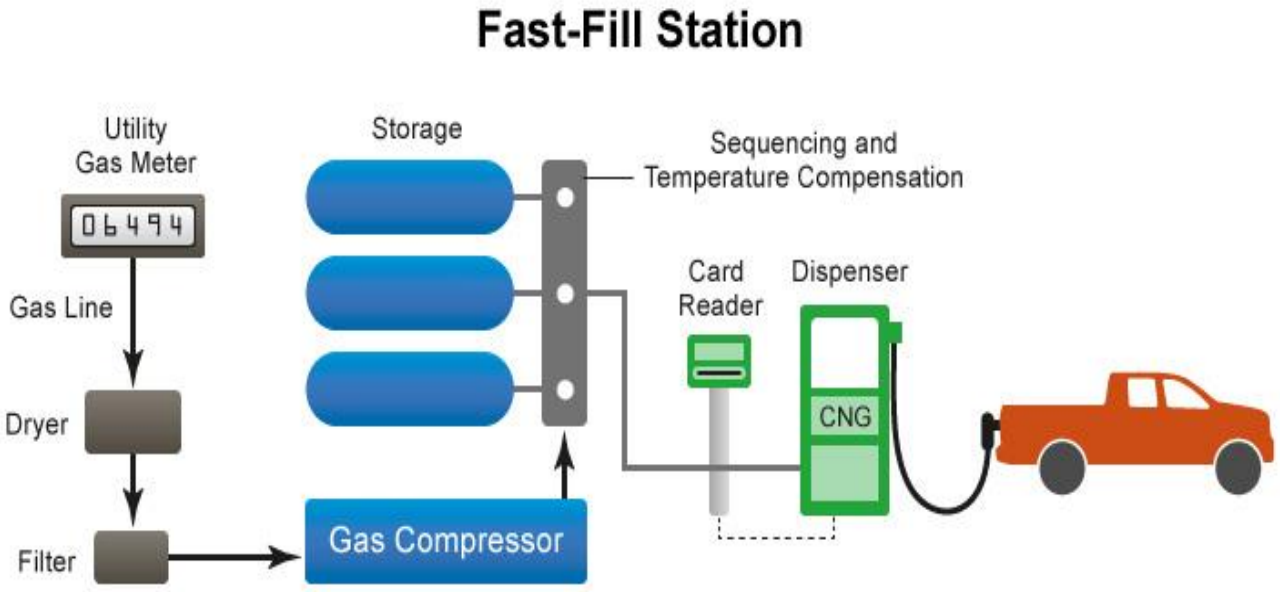


Figure 2.7(a) [65].

Fast-fill: Generally, fast fill stations are most appropriate for retail circumstances where vehicles arrive randomly and need to fill up rapidly. The space expected to store the equipment measures about the extent of a parking space. CNG can likewise be delivered by means of dispenser alongside gasoline or other alternative fuel available to dispense. Fast fill stations get fuel from a local utility line at a low pressure and afterward utilize a compressor on location to compress the gas to a high pressure. After it is compressed, the CNG moves to a progression of storage vessels so the fuel is accessible for a snappy quick fill up. Drivers topping up at a fast fill station experience comparative fill times to a gasoline filling station—under 5 minutes for a 20 gallon equivalent tank. CNG at fast fill stations is regularly stored in the vessels at a high

servicing pressure of (4,300 psi), so it can deliver fuel to a vehicle speedier than the fuel coming directly from the compressor, which conveys fuel at a lower volume. Drivers utilize a dispenser to fill CNG into the tank [65].

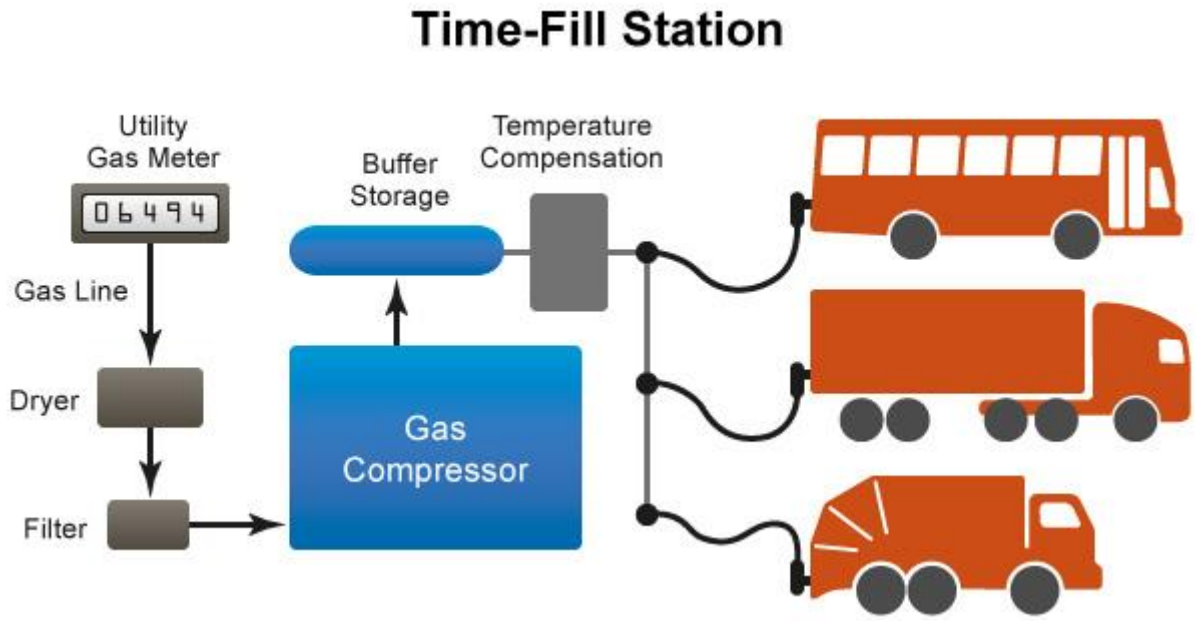


Figure 2.7(b) [65].

Time-fill: Time-fill stations are utilized principally by fleets, and it work best for vehicles with vast tanks that refuel at a central area consistently at night. Time-fill stations can likewise function well also for small applications, for example, a fueling appliance at a driver's home. At time fill station, a fuel line from utility conveys fuel at a low pressure to a compressor on location. Not at all like fast fill stations, vehicles at time-fill stations are generally filled straightforwardly from the compressor, not from fuel stored in tanks. The time it takes to fuel a vehicle relies on upon the quantity of vehicles, compressor size, and the measure of buffer storage. Vehicles may take a few minutes to numerous hours to fill [65].

2.94 Fuel Economy

The fuel economy of an automobile is the fuel efficiency relationship between the distance traveled and the amount of fuel consumed by the vehicle. Consumption can be expressed in terms of volume of fuel to travel a distance, or the distance travelled per unit volume of fuel

consumed. One extra parts of fuel economy information critical to note is the structure in which the information is accounted for—in particular, the units. Overwhelmingly, it is most normal to see fuel economy information reported in efficiency (e.g., miles per gallon [mpg] or kilometers per litre [km/L]) or fuel utilization (e.g., liters per 100 kilometers [L/100 km]) [5].

A report by Maduekwe , Uduak Akpan and Salisu Isihak (2015) in Table 2.7. Shows the information of registered vehicles, average annual distance and the efficiency of the fuel in the vehicles as indicated by engine type for Lagos State Metropolis. For vehicles fleets of both gasoline (petrol) and diesel engine types, e.g. saloon and Station Wagons, their study appointed 85% of the total number of enrolled and registered vehicles to gasoline type engines. According to them, they showed that 'it was in accordance with the study conducted by LAMATA, furthermore, some of their values were acquired from the International Association of Public Transport (UITP) and African Association of Public Transport (UATP), while Fuel efficiency information utilized by them, was gotten from the study led by **Shabbir et al. (2010)** [70], [44].

Table 2.7: Values used for base year (2011) (Annual kilometres per unit Vehicle, Lagos)

Types of Vehicles	Registered vehicles (including renewal and new registration)(V_{it})	Avg. Annual Distance (VKm_{kt})	Fuel efficiency km/litres
Light Duty Vehicles (LDV)			
Private (including govt., missions/schools, businesses)			
Saloon/Station Wagon			
Gasoline	675563	4260	11
Diesel	119217	4260	10
Motorcycles			
Gasoline	31767	3000	40
Public/commercial			
Saloon/Station Wagon			
Gasoline	53500	4260	14
Diesel	9441	4260	10
Motorcycles			
Gasoline	64228	3000	40
Heavy Duty Vehicles (HDV)			
Private (including govt., missions/schools, businesses)			
Lorry/Truck			
Diesel	14394	73920	3
Minibus/Omnibus			
Diesel	27523	73920	3.5
Tanker/tractor/trailer/tipper			
Diesel	1189	52000	3
Van, pick-up			
Gasoline	7868	72000	20
Diesel	1388	72000	10
Public/commercial			
Lorry/Truck			
Diesel	34583	73920	3
Minibus/Omnibus			
Diesel	55024	73920	3.5
Tanker/tractor/trailer/tipper			
Diesel	3838	52000	3
Van, pick-up			
Gasoline	12668	72000	20
Diesel	2236	72000	10

Source: *International Association of Public Transport (UITP) and African Association of Public Transport (UATP) (2010); Shabbir et al (2010)*

Mileage patterns and specific fuel consumption are important indicators in determining vehicles which are best suited for the substitution of diesel fuel and gasoline by CNG [23].

3.0 ECONOMICAL VALUE OF CNG

Nations that have adopted CNG as an alternative fuel, has some price benefits attached to it especially when compared with conventional fuel, as it can be seen in table 3.0 below

Retail fuel prices (US $) in top 15 CNG user countries (Table 3.0)

Rank	Country	Gasoline	Diesel	CNG per liter gasoline equivalent	CNG per liter Diesel equivalent
1	Iran	0.42	0.17	0.3	0.34
2	Pakistan	1.02	0.79	0.72	0.8
3	Argentina	1.44	1.44	0.33	0.39
4	Brazil	1.72	1.11	0.92	1.05
5	China	1.05	0.98	0.56	0.63
6	India	1.38	0.85	0.6	0.69
7	Italy	2.03	1.85	0.85	0.95
8	Colombia	1.31	0.96	0.8	0.92
9	Uzbekistan	1.03	0.98	0.3	0.34
10	Thailand	1.25	1.06	0.27	0.32
11	Bolivia	0.83	0.66	0.3	0.29
12	USA	1.02	1.12	0.6	0.68
13	Armenia	1.31	1.19	0.49	0.56
14	Bangladesh	0.79	0.56	0.27	0.29
15	Egypt	0.33	0.2	0.07	0.09
Average	1.13	0.93	0.49	0.56	

Table 3.0 analyzes the retail fuel costs in US $ for the monetary year 2011–2012 in top 15 CNG user nations. It can be deduced that CNG pump price by and large on the average by 50% lower than the gas and diesel price in many nations that have had effective NGV implementation. The rapid growth of CNG vehicles in the most recent decade particularly in Asia-pacific locale was for the most part due to this less fuel cost of CNG with respect to gas/diesel [45].

Also according to Muhammad Imran Khan , Tabassum Yasmin, Abdul Shakoor (2015) [45]**,** the economics of running the CNG vehicles vis-à-vis its operation on petrol/Diesel has been worked out at the average global fuel price for the fiscal year 2011–2012. Their results as presented in **Fig. 3.0**

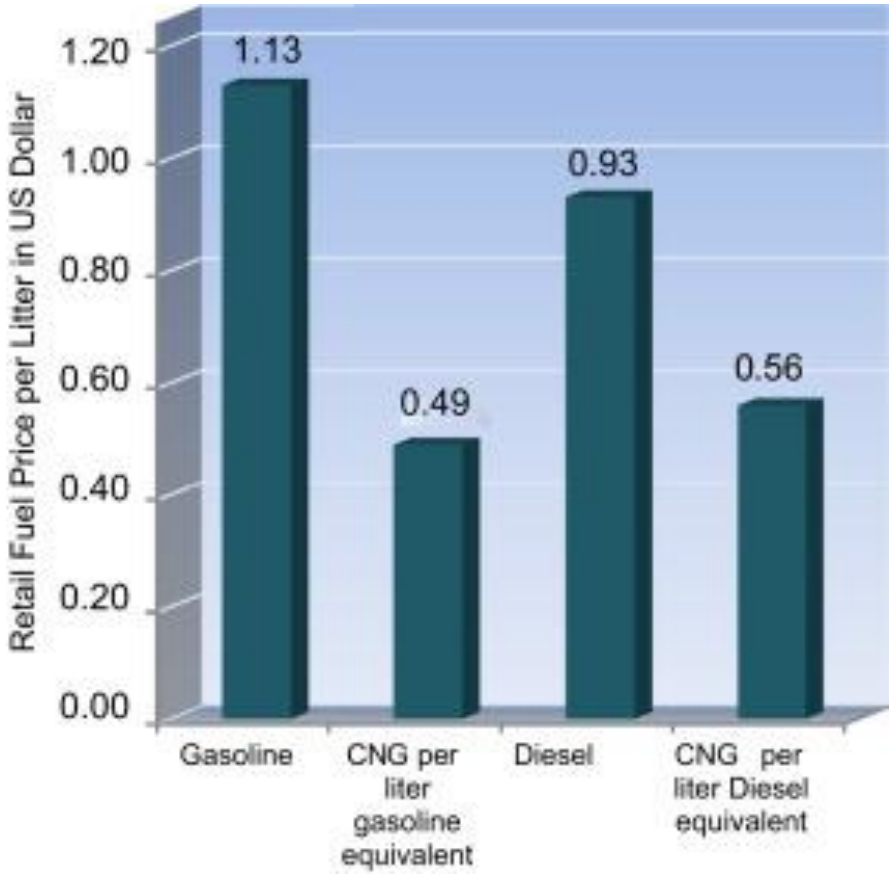


Figure 3.0 average global fuel price for Fiscal Year 2011 – 2011 [45].

Table 3.1 Cost Comparison CNG vs Other Fuel [45].

Description	**CNG**	**Gasoline**	**Diesel**
Vehicle type	Bus	Bus	Bus
km travelled per annum per vehicle	80,000	80,000	80,000
Total annual consumption of fuel in liters (consider unit of 'N m^3' in case of CNG)	36,184	39,400	32,000

Description	CNG	Gasoline	Diesel
Retail fuel price per liter US $ (consider unit of 'N m^3' in case of CNG)	0.52	1.02	0.92
Annual fuel cost (US $)	18,816	40,188	29,440
% Fuel cost saving CNG vs gasoline	113%		
% Fuel cost saving CNG vs diesel	57%		

CNG industry has grown fundamentally at an extraordinary rate of around 52.5% per annum amid the most recent couple of years. Right now the nation has 6.167 million total number of register vehicles [60] out of which there are 3,100,167 (89%) vehicle has been running on CNG while the rest, which incorporates transports, trucks, and bikes, three wheelers and so on, are utilizing gasoline and diesel.

3.1 Growth of CNG in Pakistan

The CNG industry in Pakistan has seen a gigantic development in the most recent decade, by goodness of agreeable government strategies and the key pretended by CNG station/vehicle owners. At present, it is stands first on the planet.

Table 3.2 Statistics of Pakistan's CNG industry (Statistics and Europe, 2013) [45].

Total NGV population (other than ships, trains and aircraft)							CNG stations	
Total NGVs	LD + MD + HD Vehicles	LD Vehicles	MD + HD Buses	Other	% of total vehicles in the country	% of total NGVs worldwide	Total	% of total CNG stations worldwide
3,100,167	2,920,167	2,919,500	667	180,000	89.14%	19.12%	3330	15.84%

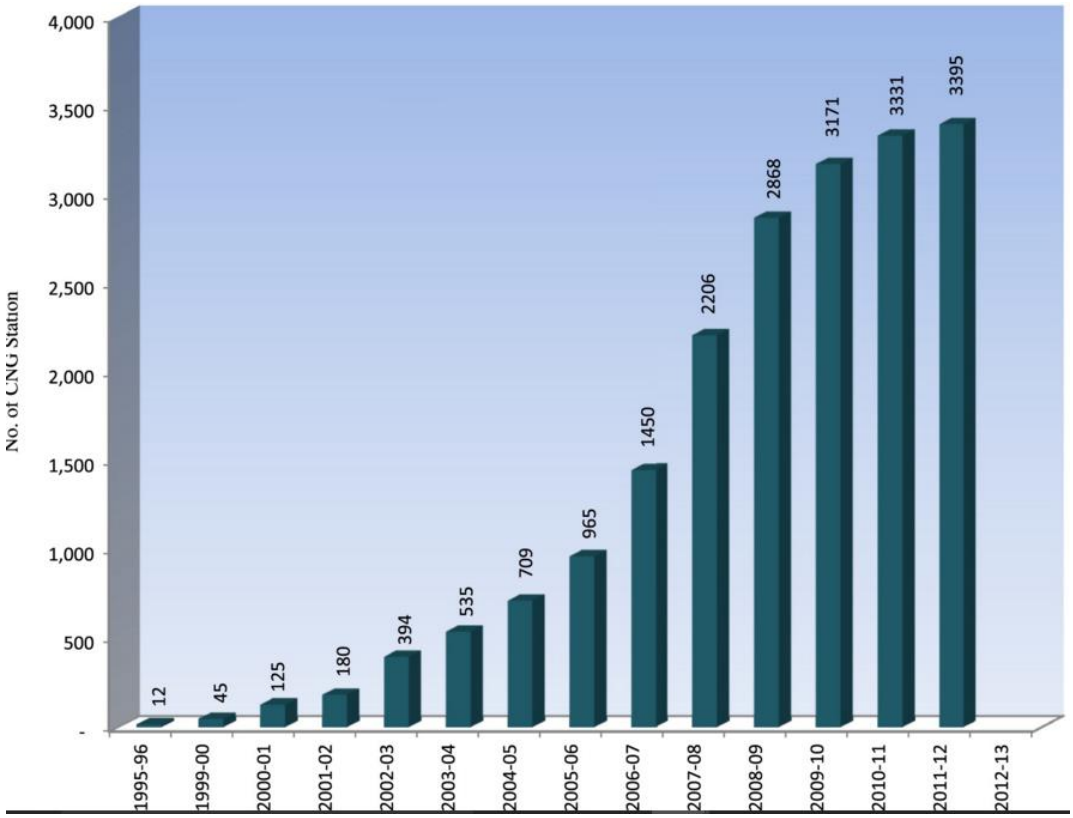


Figure 3.1 shows bar Chat of Number of CNG station against Year in Pakistan [45]

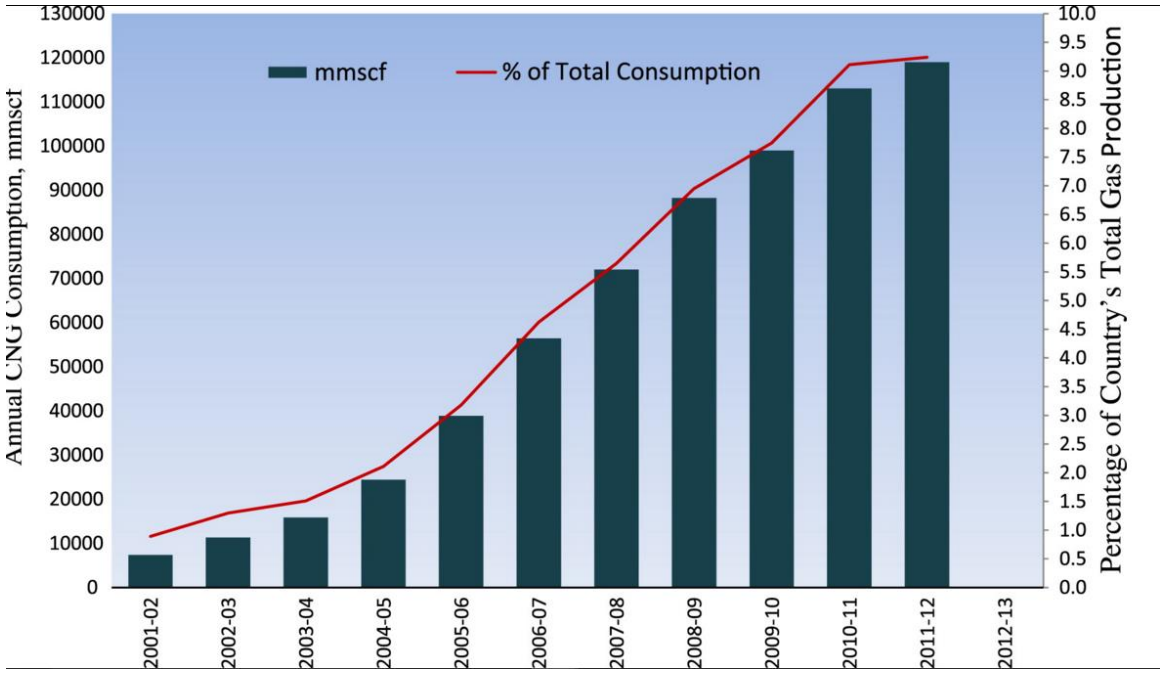


Figure 3.2 shows plot of Yearly Amount of CNG consumption in MMSCFD: Million Standard Cubic Feet per Day in Pakistan. [45].

3.2 Environmental aspect of CNG program in Pakistan

Because of rapid industrial growth, urbanization and subsequently increment in traffic volume in the course of the most recent couple of decade's underdeveloped nations like Pakistan have experienced substantial increments with respects to emissions and pollution of the atmosphere [41]. In Pakistan, as in numerous other nations, traffic is a noteworthy reason for abnormal amounts of contamination in the urban communities [40]. There are no precise commitments for controlling the vehicle emissions in Pakistan, which brought on more than 90% of the atmospheric pollution [66]**.** Pakistan's National Conservation Strategy Report expresses that the normal Pakistani vehicles, discharges 20 times more hydrocarbons, 25 times more carbon monoxide and 3.5 time more NOx in grams per kilometer than the average vehicles in the United States [61]. The report expresses that urban air pollution cause around 22,700 unexpected losses of life for each year in the nation [61]**.** The vast majority of the Pakistani urban areas are reeling under basic levels of NOx and particulate matter pollution. There are intense public nervousness about health impacts of diesel related fine particulate matter, and other air poisons. These stresses are upheld by the studies in India and epidemiological studies conducted in different other nations that have assortment of health disasters connected with particulate matter in defenseless populaces, including sudden deaths, hospital emergency, respiratory illnesses and changes in pulmonary function. Investigation of encompassing poison levels previously, then after the fact the execution of CNG system in the country demonstrates noticeable decreases in particulate mattern, PM , carbon monoxide CO, carbon dioxide CO_2, total suspended particles TSP, nitrogen oxide compounds NOx and sulphur dioxide compound SO_2.

On the general account for over 3.2 million NGVs in the country, there is corresponding decline in the transport emission as highlighted in Table 3.3 [25].

Decline in the transport emission due to CNG program.

S. no.	Emissions	Kg/Km
01	Carbon dioxide – CO_2	355
02	Carbon monoxide – CO	7680
03	Oxides of Nitrogen – NO_x	6080
04	Hydrocarbons – HC	896
05	Particulate matter – PM	7616

3.21 Money Saving Advantage of CNG

The development of CNG vehicles is chiefly because of the money saving advantages of CNG over gas/diesel fuel. In Pakistan CNG is much less expensive compared with petrol and diesel. The expense for the operation of CNG vehicles opposite its operation on gasoline/diesel has been done at the present fuel price in the country. The outcomes are duplicated and demonstrated as follows. The examination is illustrated utilizing the calculations below:

Current Price of CNG = Rs. 65/kg

Current Price of Gasoline = Rs. 105/Lit

Current Price of Diesel = Rs. 104/Lit

Now on the basis of energy equivalent

1 kg of CNG = 1.4 L of Gasoline And on the basis of engine compression ratio

1 L of Diesel = 1.4 L of Gasoline [46]

3.3 China CNG programme and Benefit

Fuels examined include the conventional gasoline, diesel, liquefied petroleum gas, compressed natural gas, wheat-derived ethanol, corn-derived ethanol, cassava-derived ethanol, sugarcane-derived ethanol, rapeseed-derived biodiesel and soybean-derived biodiesel." **Renewable and Sustainable Energy Reviews, 13, (2009).** Among their outcomes is the chart below, which shows that CNG is altogether lower in life cycle greenhouse gas emissions than conventional gasoline (CG) or conventional diesel (CD), which are the two most prominent energizes utilized as a part of China [63]

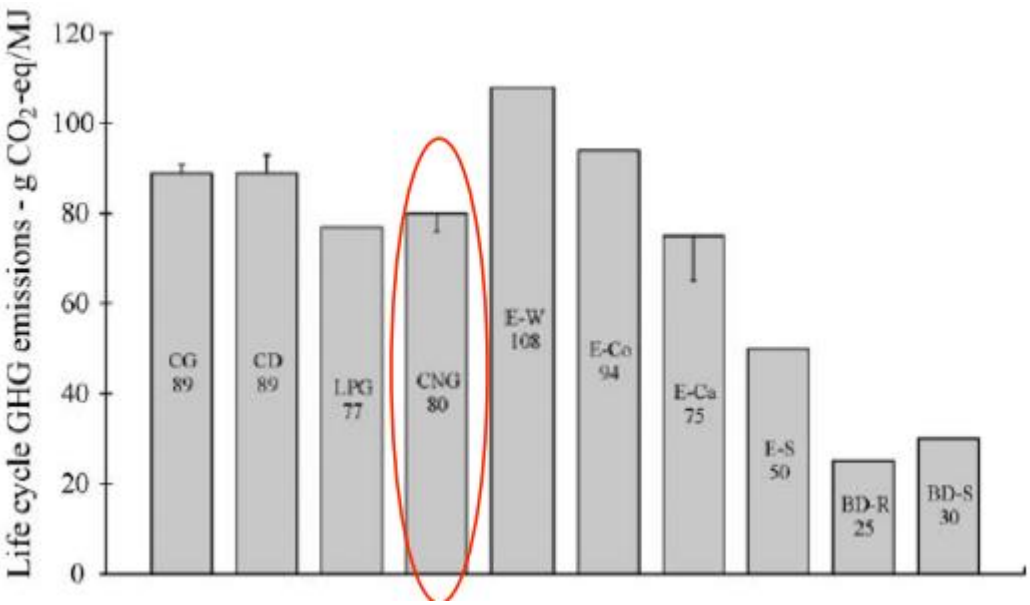


Figure 3.3 Life Cycle GHG Emissions for Each Fuel in China [63]

3.4 USA benefit from CNG fuel system

Points of interest to NGV's is the incorporation of the cost of fuel being $1.50 to $2.00 not as much as gasoline on a per gallon equivalence basis. Home-fueling choices are available to consumers that give extra convenience to vehicle owners. As indicated by the Natural Gas Vehicle Association of America (2012), replacing a much older vehicle with a newer NGV can give the accompanying decreases in emissions of:

• Carbon monoxide (CO) by 70%–90%

• Non-methane organic gas (NMOG) by 50%–75%

• Nitrogen oxides (NOx) by 75%–95%

• Carbon dioxide (CO2) by 20%–30%

As it was reported by the Energy Management Institute that, from 2004 to 2007, natural gas was 48.6% less costly than gasoline. All the more as of late, the percentage difference has reduced. There are changes in cost price based on the location inside the U.S [34]

4.0 NGV Project Management and Implementation Planning

Replacing conventional fuel and diesel vehicles with natural gas vehicles (NGVs) and CNG is a better alternative for Nigeria, if Nigeria seek to proffer a timely solution to gas flaring and greenhouse gas emissions both nearer and far into the future. Because we have the population and adequate vehicles to utilize locally a significant number of natural gas which is being flared regularly and coupled with the fact that we do export large quantity of natural gas into the international market. Therefore, dreaming about switching to NGV vehicle on Nigeria road is not far- fetched. On the premise of city-level information, the reasoning here supplies information to enable a decisive idea put forward to the implementation of Natural Gas Vehicle on a large market scale in Nigeria, starting with Lagos metropolis.

4.1 Strategy to enhance the development and usage of CNG in NGV in Lagos, and in Nigeria

Taking a hint from the idea of NGV method of implementation as it was done in China, according to Hongxia Wang et al., 2015, We have to embrace the procedure they used as proposed: (1) enhance natural gas delivery framework across the city; (2) sensibly decrease the relative price of natural gas compared to gasoline; (3) offer preferences to minimum income and medium-sized urban communities and towns, establishing natural gas refueling stations in these zones; and (4) advance the utilization of NGVs in the private division [26].

It will be a good practice to carry out gradual implementation through certain number of stages in the implementation of large scale CNG fleet into Nigeria system road transportation. It is therefore necessary to start from a little market product to a large scale market. Both natural gas vehicles and stations. Therefore, in the preliminary phase, a moderate number of filling stations should be put on ground, based on feasibility study, even if we look beyond pursuing the immediate economic efficiency, future profitability and return will be considered in the case study.

Now after the success of first phase of implementation, we can proceed further into the second phase of introducing more facilities as part of building a viable network for full scale CNG implementation in Lagos.

4.12 The optimization framework

By the adoption of method utilized in Switzerland for the starting of CNG programme in their country, and it delivered an expected and credible result, as being reported by Martin Frick et al., 2007 [43], we need to make the right choose of surveying and mapping out a prospective area in Lagos state to site CNG filling station, which as to be open to market, easy accessibility and sale opportunity. For each of the prepared progressive stages for the CNG programme, it is expected that future stations will be coordinated into a portion of the 1751 existing filling stations in Lagos according to total gasoline retail outlet in Lagos. It is sensible to consider set of areas that will mirrors the requests of the consumers regarding availability and accommodation, and also those of local government as far as open acceptability.

4.13 Engineering Principles of Modified Engine

Outline of Engine Conversion process, if retrofitting conventional fuel parts to natural gas in vehicles meant for road transport. This can be accomplished by bringing into the market sector new vehicles ex-factory plant replaced with CNG engines, or as an initial step, by transforming engines of existing vehicles to CNG. To bring in natural gas as a fuel for road transport through the change of vehicles to CNG, the accompanying alternatives are conceivable: (a) Modification of a gas (Otto cycle) motor to CNG burning (supposed transformation to a committed fuel); (b) Modification of a gasoline to either CNG or gas (two way/bi-fuel) ignition; (c) Conversion of a diesel motor to devoted CNG (sparkle ignition) ignition; and (d) Conversion of a diesel motor to double fuel (gas and diesel consolidated) combustion [23].

4.2 Cost-Benefit Analysis Framework

The primary main thrust in the improvement of a CNG conversion programme and advancement of a CNG business sector is user economics aspects. There must be adequate direct reserve funds in working expenses for vehicle administrators to consider transforming from the recognizable gasoline and diesel vehicle operation to "new fuel". The essential necessity for the improvement of market through fuel cost saving funds is a sizeable difference between the cost of CNG and that of diesel to draw in vehicle operators. Furthermore, CNG station operators and gas wholesalers must have the capacity to make adequate benefit out of this new pursuit [23].Vehicles which will give the most beautiful cost savings benefit by converting from diesel or gasoline fuelling to CNG will show the following attributes:

(a) High annual mileage resulting in high total fuel consumption;

(b) High specific fuel consumption resulting in high total fuel consumption;

(c) Low vehicle age so as to obtain maximum return from the conversion during the remaining life of the vehicle;

(d) Low total cost of conversion to CNG;

(e) Adequate standard of maintenance;

(f) Operating patterns around available distance of a CNG filling station or along a very much defined route which will be overhauled by CNG stations; vehicle fleets, e.g. urban buses, operating from a station are in this manner perfect candidates;

(g) Operating pattern which permit incessant refueling to minimize the amount of CNG cylinders which are a high cost item [23].

This group can be used as target Market for starting NGV

Table 4.0: Example of target vehicles for CNG conversion [2].

Vehicle Class	**Class Definition**
Motor Rickshaw	3 – wheel passenger vehicle
Motor Car	Cars, Taxis, Jeeps and all other light vehicles
Wagons/Minibus	Wagons and Vehicles with seating capacity less than 20 passengers
Van/Pick-up	Goods vehicles up to one tone capacity
Bus	Seating capacity of more than 20 passengers

Current Fuel Price in Nigeria as listed in Table 4.1 [80, 91,]

Row Number	Entity	Gasoline ($)	Diesel ($)
Row 1	Current Price per litre in Nigeria (April 2016)	**$0.45**	**$0.79**
Row 2	Current Price per (US gallon Equivalence) in Nigeria	**$1.71**	**$2.97**
Row 3	NIPCO CNG Price per litre ($) for GGE & DGE	**$0.28** CNG per litre for GGE	**$0.32** CNG per litre for DGE ($0.28 x 1.14GGE)
Row 4	NIPCO CNG Price per U.S Gallon ($)	**$1.06** CNG per U.S GGE ($0.28 x 3.78)	**$1.21** CNG per U.S DGE ($0.32 x 3.78)

Footnote:

Unit of Nigeria Currency is Naira (₦)

1 Dollar @ ₦ 196 Central Bank of Nigeria Exchange Rate (1/5/2016) [8].

1 Gallon of Gasoline Equivalent (GGE) of the CNG contains 3.78 liquid litres of Petrol (United States)

1 Gallon of Diesel Equivalent (DGE) of the CNG contains 3.78 liquid litres of Diesel (United States)

Gasoline and Diesel unit of measurement in Nigeria is expressed in Litre (1dm ^{3} of fluid)

Gasoline Gallon Equivalents (GGE) is 1.14 Gallon gasoline to 1 Gallon of Diesel equivalent

A leading indigenous downstream operator, the Nigerian Independent Petroleum Company (NIPCO) Plc, had a task of carrying out pilot study on the possible use of CNG in Nigeria road transportation sector, starting in 2007, though the company, faced with many challenges, has not until now gotten a convincing outcome to persuade Nigeria government to adopt the NGV system. NIPCO also reported in Nigeria Daily Newspaper, (Nigeria Tribune September 9, 2015(NIPCO laments challenges confronting CNG usage in Nigeria). Price of CNG from

NIPCO, ₦55 ($0.28) per standard cubic feet (scuf) of gas is equivalent to one litre of petrol which currently sells at ₦87 ($0.45) with government subsidy [80]**.**

My research proposal begins with Table 4.2 figures and entities as described in each box

Specification for NGV Small Scale Startup in Lagos	**Proposed Number of entity**	**Price and Quantity Information**
TOTAL AMOUNT OF VEHICLES (PRIVATE AND COMMERCIAL)	65,000	
Details		
Cars (Private and Commercial)	50000	
Minibus	10000	
Omnibus	4000	
Van	500	
Bus Rapid Transit (BRT)	500	$51,020 per BRT bus procurement (source: LAMATA
Starting Number of CNG Refueling Station	400	
Types of Refueling station	Fast Fill refueling station/ Containerized Refueling Station	
Opening Hour (7am – 10pm), 7days Every week	15hours Daily	
Average Vehicles per Filling Station Daily	163	
Average vehicles per hour	11	
Average gasoline litres equivalent of	6000 litres	6000 litres per station

CNG in a filling station per day		
Total gasoline litre equivalent supply for 400 refueling CNG station daily	2,400,000 litres	(6000litres x 400 stations)
Average Gasoline litre equivalent of CNG per Light Duty Vehicle Daily in Lagos	20 litres	($0.28 x 20) = $5.4 (₦1646.4)
Average Gasoline litre equivalent of CNG per Medium and Heavy Duty Vehicle in Lagos Daily	40 litres	($0.28 x 40) = $11.2 (₦2195.2)
Average Gasoline litre equivalent of CNG refueling per Medium and Heavy Duty Vehicle in Lagos (Commercial) BRT Inclusive	70 litres	($0.28 x 70) = $19.6 (₦ 2724)

Table 4.2: Description of Starting vehicles for CNG programme in Lagos Nigeria

Footnote:

Unit of Nigeria Currency is Naira (₦)
1 Dollar @ ₦ 196 Central Bank of Nigeria Exchange Rate (1/5/2016) [8].
1 Gallon of Gasoline Equivalent (GGE) = 3.78litres of Petrol (United States)
Gasoline and Diesel unit of measurement in Nigeria is Litre
1 US Gallon contains 3.78 litres

In order to implement the specimen above, we need to consider the cost of retrofitting and also the average cost of new NGV vehicles in the categories

4.3 NGV Cost of Retrofitting

Fleets or individuals who are interested in operating CNG- or autogas-powered vehicles have two options: aftermarket conversion of existing vehicles or the purchase of new vehicles already equipped to use an alternative fuel [82]**.** Existing gasoline vehicles can be converted to natural gas vehicles using kits that cost about US $500 – $2,000 [76]**.** Also different conventional fuel vehicle has different cost of retrofitting, like for the instance of Diesel vehicle may have higher cost of retrofitting than their gasoline counterparts.

The initial effect of CNG operation is an increase in the fixed operating costs due to the additional capital required for the conversion to CNG. These costs must be recovered during the remaining life of the buses. As mentioned earlier, conversion of diesel buses is regularly recommended only for vehicles aged three to maximum five years. The remaining economical service life, and thus the pay-back period of the conversion investment, would then be six to seven years. However, for buses running with a high annual mileage, the life cycle of the engine requires a rebuild after approximately four years, necessitating also replacement of some conversion components. In addition, the CNG storage cylinders have normally to be removed and tested after 3 to 5 years (depending on the safety regulations in a country). Thus, the amortisation period should not be longer than four years. On the contrary, bus operators expect a cost recovery after 2 to 3 years [23].

Although fuel savings opportunities exist, the upfront purchase prices of new NGVs are higher than their petroleum-fueled counterparts. The fuel cost savings, however, can overcome the larger investment required, especially for vehicles that have high annual vehicle miles traveled (VMTs) [3].

4.31 CNG STATION ESTIMATION

The operation of natural gas vehicles necessitates a supply network in order to have the vehicles refueled within their operating range. This refueling network can be built up supplementary to the existing network of filling stations for diesel and gasoline. However, these CNG stations will have to be regularly supplied via pipelines or, alternatively, by refueling trucks. It is reasonable to expect that the number of CNG stations will reflect the number of CNG vehicles on the road, particularly when considering the primary target market for the first few years of a CNG programme, i.e., fleets which are likely to have central CNG stations to suit their requirements. However, during the initial stage, it is most likely that CNG stations would be operating below capacity, thus grossly under utilizing the capital investment because of the small number of vehicles converted to CNG [23].

Figure 4.0 I propose the purchase and installation of CNG capacity manufactured by New West technology for the startup of CNG filling station in Lagos

Large Station (1,500–2,000 gge*/day)

Type	Cost Range	Example Applications	Assumptions
Fast-Fill 	$1.2–$1.8 million	• Large retail station serving light- to heavy-duty vehicles such as delivery vans, work trucks, refuse trucks, class 8 tractors, and local fleets, or • Airport station serving light- and medium-duty vehicles such as taxis, shuttle buses, and local fleets**	• Two 300–400 scfm (143–190 gge/hr) compressors • 30 psi inlet gas pressure • 55,000 scf storage (437 gge) • Two dual-hose metered dispensers • Included installation costs are estimated at 50% of equipment costs

Figure 4.0: Margaret Smith, New West Technologies (DOE HQ T**echnical Support)** [42].

Footnote:

1 US Gallon contains 3.78 litres

1 Gallon of Gasoline Equivalent (GGE) = 3.78litres of Petrol (United States)

Investment Cost Estimation for CNG Refueling Station in table 4.3 below

Design and installation of 2000 gge/day	**Cost Per Unit Station**
Capital Project Cost (Site Preparation and Pipe Laying)	$ 200,000
Equipment and Installation	$ 1,000,000
Infrastructure and other expenses	$ 150,000
Total Investment per Unit Station	**$1,350,000**
Grand Total for 400 Unit	**$ 540,000,000**

CNG Price per Gallon (3.78litres)	=	$ 1.06
Operating Costs (cost of running)	=	$ 0.87
Net Profit	**=**	**$ 0.20/gge**

Refueling station capacity of 2000gge/day, if station is running for 360days per year, the return on investment is calculated by

2000 gge/day x 360 days x $0.20/gge = $144,000/yr profit

Return on Investment = $144,000/$1,350,000 x 100% = 10.67% ROI (Return of Investment)

Return of Investment in the term of years = $1,350,000/$144,000 yr profit = 9.3years.

An investment cost of $540 million for the construction of 400 CNG refueling stations according to what I propose. This is a good investment startup up for a gradual implementation process in Lagos State to actualize a rapid CNG master plan. The supply capacity according to the manufacturer's specification, per each is 2000 gallon of gasoline equivalent (GGE). Therefore, 400Units CNG refueling station will be able to supply above daily requirements of 2.4million litres of CNG for 65,000 vehicles daily if each vehicle was to fill up its tank according to the table 4.2

4.4 Estimated Government Revenue on CNG Fuel Market in Lagos

For the Federal Government of Nigeria to expand in its constructions of more CNG refueling stations in more localities in the country, the federal government should implement 10% tax on price per litre of CNG fuel, while those government vehicles (buses and taxis) used for commercial purposes, should be exempted from this CNG tax. If the government have 500 BRT, and 5,000 Taxis which will run on Natural gas fuel for her internal revenue on road transportation to encourage and market the citizens the reason to adopt NGV. This is also a marketing strategy of the government for individuals.

Vehicle Type	**Tax**	**Price per litre**	**Average litre per Vehicle daily**	**refueling Price Per unit vehicle daily**	**Daily Tax income Per vehicle**	**Numbers of Vehicles**	**Tax Revenue of CNG Sale**
Car (Private)	10% Tax	$0.308	20	$6.16	$0.56	45000	$25,200
Car, Taxi(Commercial) Government	No Tax	$0.28	20	$5.6	-	5000	-
Mini Bus (Commercial)	10%	$0.308	40	$12.32	$1.12	10000	$11,200

Omni Bus (Commercial)	10% tax	$0.308	50	$15.4	$1.4	4000	$5,600
BRT (Commercial) Government	No Tax	$0.28	70	$19.6	-	500	-
Total Daily Revenue (Tax)							**$42,000**
Annual Government Revenue (Tax)							**$15,120,000**

Table 4.4 calculated tax revenue for government on vehicle fleets running on CNG

This estimated revenue from the table above, will exactly represent minimum revenue that could be generated by the government annually if the entire retrofitted vehicle in the system are gasoline engine. Definitely, diesel retrofitted vehicles will buy CNG at the price as seen in table 4.1, row 3 and 4 where the refueling price of CNG is different for both GGE vehicles and DGE vehicles. Tax revenue will be more than the calculated revenue, this is a plus for government earning on CNG business.

On the contrary, a decrease in each day revenue may also be possible, if some vehicle owner decides not to use their vehicle for a certain day, due to fault or personal decision and therefore decides to use commercial transportation or possibly due to mechanical fault of the vehicle, whereas the table still indicate the minimum tax profit that will be generated by the government if CNG is implemented with a startup of 65,000 vehicles according to my analysis. In order to enlarge the NGV market, the Government will need to re-invest more on CNG project by constructing more CNG stations until it cover up the entire state. This market development is better achieved, and other states of the federation are not left out.

4.5 Startup Requirement for NGV

Since the CNG proposed market implementation with a moderate startup, it is required that those vehicles that will be retrofitted for the startup, should not be more than 18months from the time of purchase. Those vehicles in the pilot startup group do not include brand new NGV which are directly purchased from the manufacturer, but rather, they are retrofitted vehicle that incur additional spending to refit the engine to NGV. This will enable us to encourage, market, and convince other vehicle owner that still adopt conventional fuel system, to see the reason they

need to migrate to alternative fuel system and retrofit their cars, since we have a larger number of gasoline and diesel vehicles in circulation.

4.6 Simple Payback Period Estimation

One important yardstick to evaluate the economical value of switching to an alternative fuel system is simple payback. Simple payback is obtained by dividing the total incremental expense or the cost of the vehicle by the annual fuel cost savings, this will yield the certain number of years required to pay back the investment on the vehicle converted and benefits obtained in return. All my expenses and savings calculated in this thesis are expressed in currency dollars. Likewise, CNG refueling stations expenses are excluded from this calculation indicated in the subsequent tables below. Simple payback is a central point to consider in any fuel-switching choice [1].

Annual Savings ($) = VMT/MPG*Price Differential – Additional Cost for a CNG Bus due to lower Fuel Efficiency. **Payback in Years** = Incremental Cost/Annual Savings [1].

Table 4.5 Price Differential for Gasoline, Diesel and CNG

	Gasoline	**Diesel**
Current price per Gallon	$1.71	$2.97
Price per Gallon (CNG) market	**GGE of CNG**	**DGE of CNG**
CNG (taxed)	$1.16	$1.33
CNG (untaxed) Government vehicles	$1.06	$1.21
Price Differential	**Gasoline Gallon - GGE of CNG**	**Diesel Gallon - DGE of CNG**
Taxed (Private owners)	$ 0.55	$1.64
Untaxed (Government vehicles)	$0.65	$1.76

Table 4.6 : Simple Payback data

Fleet	Fuel Type	Miles per Gallon Gasoline/ Diesel	Miles per gallon CNG equivalent	Annual Miles Traveled per Vehicle	Cost of Vehicle Maintenance ($¢ per mile)	Annual Incremental Maintenance cost	(Cost of Retrofitting) to CNG vehicle	Total Incremental Cost
Car (Private)	Gasoline	25.87	22.84	18,163.923	5¢	$908.196	$1,500	$2408.196
Taxi(Commercial) Government	Gasoline	32.93	29.08	24,606.299	7¢	$1,722.44	$1,500	$3222.44
Mini Bus (Commercial)	Diesel	8.23	7.23	45,931.759	10¢	$4,593.18	$2500	$7,093.18
Omni Bus (Commercial)	Diesel	8.23	7.23	45,931.759	10¢	$4,593.18	$4000	$8,593.18
BRT (Commercial) Government	Diesel	8.32	7.31	24,606.299	10¢	$2,460.63	$10,000	$12,460.63

Footnote: 126.67 scf = 129,000 BTUs = One standard GGE = 114,000 BTUs,

143.94 scf =146,818.8 BTUs = One Standard DGE

MPG (CNG) equivalent of Gasoline = 0.883 x MPG Gasoline value

MPG (CNG) equivalent of Diesel = 0.879 x MPG Diesel value

Price Differential is used in the calculation of payback period is considered for two groups which are:

- Price difference (Taxed) observed for private owners and Private commercial purposes
- Price difference (Untaxed) Government Vehicle (Taxis and BRT)

Price differential figures in table 4.5

4.7 Variables or Incremental costs: Depreciation is partly variable because increased mileage requires increased vehicle repairs and replacement, and reduces vehicle resale value. Used vehicle price guides **(www.edmunds.com and www.kbb.com)** indicate that mileage-related depreciation typically averages 5-15¢ per mile [81]; this is indicated in a column for each class of vehicles in the table. Variable costs which increase with vehicle mileage. It is the Yearly Cost of Vehicle Maintenance.

4.71 Annual Miles traveled for each class of vehicle are obtained from Table 2.7 and analogy of common distance traveled in Lagos from one end of Lagos state to the other.

- **Private Car Owner (maximum Distance travelled per day)** of a private Car Owner from {Ikorodu, Nigeria, Start Point: Raj Oluwolegbon St, Ikorodu, Nigeria – Ikoyi , Lagos, Nigeria End Point: Thompson Ave, Lagos, Nigeria (40.6km,) Round Trip = 40.6km x 2 = 81.2km (50.45 miles).
- **Car Commercial (distance equivalent to BRT).**
- **Mini Bus and Omni Bus miles traveled:** have have high annual mileage traveled due to rapid loading time and high patronage **(**Table 2.7)
- **Bus Rapid Transit (BRT) 5 times per day km per trip** [92].

Note: 360days for 1year.

Fuel Economy conversion (km/l) conversion to (miles per gallon) was obtained through the use of conversion calculator from **www.thecalculatorsite.com/conversions/fuelconsumption.php [98],** where I converted Fuel economy expressed in kilometer per litre as represented in table (4.6).

As an example, the specific calculation and result in Table 4.7, for a CNG vehicle which covers a distance of 18,163.923 miles per year, with a fuel price differential of $0.55 per gasoline gallon equivalent, 25.87GGE, and 22.84 miles gallon CNG equivalence (values from table 4.6)

4.72 Annual savings

= (18,163.923/25.87 x 0.55) – (18,163.923/22.84 – 18,163.923/25.87) x 1.16 = $276.116

While the **Payback in Years** = Incremental Cost/Annual Savings

= $2408.196/276.116 = 8.7yrs

Table 4.7 demonstrate the annual savings and payback periods for various vehicle class, as obtained using the formula used by **Wyoming Public School Districts (2012)** [1]**,** from alternatives in fuel price differential and vehicle miles traveled.

Fleet type	**Fuel Transition**	**Price Differential**	**Miles Per Year**	**Annual Savings**	**Payback in Years**
Car (Private)	From Gasoline-CNG	$0.55	18,163.923	$278.116	8.7yrs
Taxi(Commercial) Government	From Gasoline-CNG	$0.65	24,606.299	$380.76	8.5yrs
Mini Bus (Commercial)	From Diesel-CNG	$1.64	45,931.759	$8126.3	10.5months
Omni Bus (Commercial)	From Diesel - CNG	$1.64	45,931.759	$8126.17	1.1yr
BRT (Commercial) Government	From Diesel - CNG	$1.76	24,606.299	$4710.75	2.65yrs

From the results of the simple payback analysis shown in table 4.7, among the 5 different classes of fleet, 3 have a payback period less than 5years, the other two vehicle fleets, which belongs to cars that were converted from gasoline to CNG system, have a payback period above 5years. Assuming that each fleet classes in the table, runs on daily bases, on a 10- year replacement cycle averaging 18,000 miles per year, we still have a good payback period for the fuel cost differential between gasoline fuel and CNG which should be at least $1.16 per gallon/GGE to offset the cost ($3222.44) of the CNG cars.

From the result, we can deduce that vehicle that belongs to gasoline converted, would experience a little cost savings because of the minimal fuel cost differentials, especially when it has a low annual mileage. The high annual mileage vehicle is most likely to generate a higher cost savings, which would justify enough reason for fuel switching. The more a gasoline fueled vehicle is driven, the greater the cost savings from using natural gas. All other variables are kept constant, the higher the price differential, the shorter the payback period will apply. Therefore, doubling the fuel price differential will effect on the payback period, by cutting the payback period by more than half. And since Nigeria gasoline price is soaring high on regular basis, and with no certainty of stability, it is much more better to switch gasoline driven vehicle to CNG, and where effective payback period is certain, and also having more positive effect on the environment.

4.8 Initiatives for Natural Gas Vehicle Development in Nigeria

According to **World Bank, 2014** who highlighted economic benefits, environmental considerations, energy security, and natural gas availability are the major drivers for NGV adoption for most countries. There is need for the federal government of Nigeria to make a leading contribution, and introduce a clear policy on alternative fuel, by stirring up its effort to adoption, coordination, and implementation of Natural gas vehicle at large as a means of transportation on our road transport system. It needs to bring together all stakeholders with the aim of inculcating them of the outlined pathways for a fruitful CNG implementation program as it is represented by my sketch in the figure below.

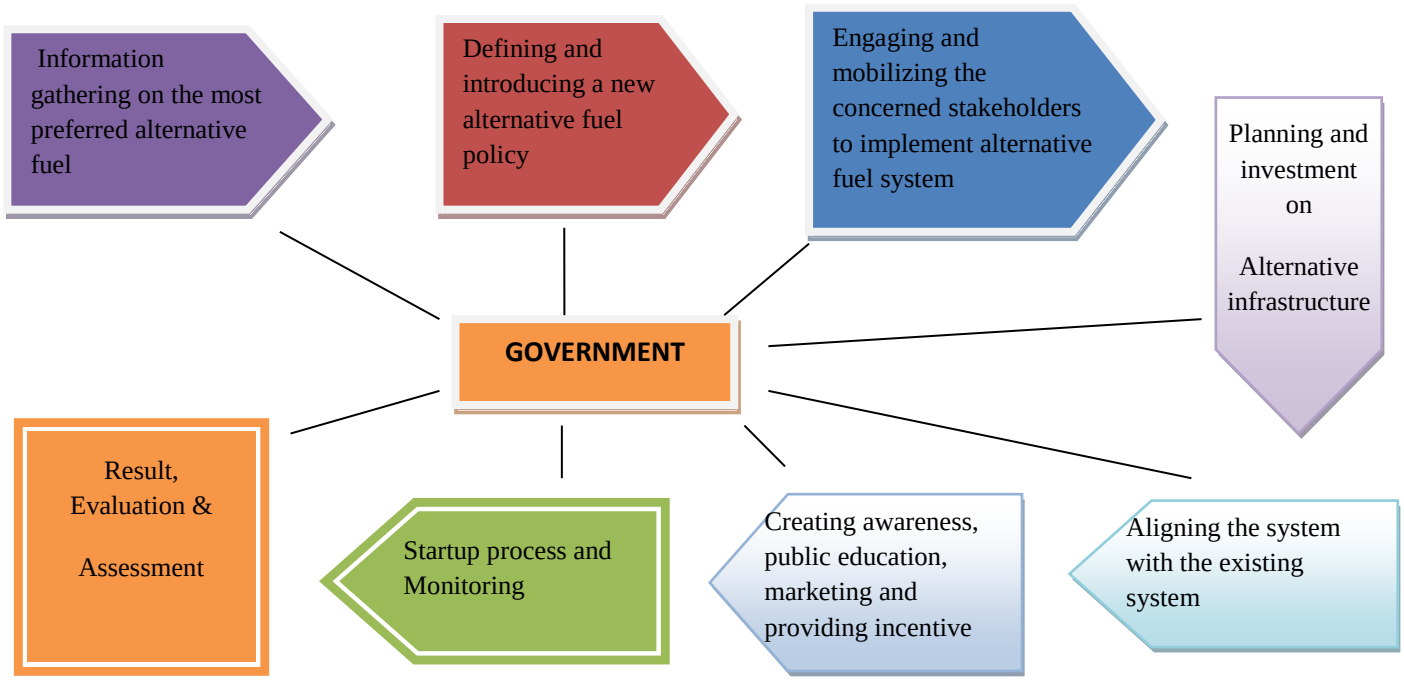


Figure 4.1 innovations to CNG implementation planning in Nigeria

5.0 Conclusion

My research had indicated the benefit of compressed natural gas as a national fuel if implemented in Nigeria, and with more indications of liberating Nigerians from distresses as a result of incessant fuel scarcity. From here, we need to take measurable steps of adopting CNG as our national fuel. This will be a panacea for the current crises in our Oil sector. Even a hope for the populace. A recent fuel scarcity was reported in Nigeria in May, 2016, as the federal government finally announced the complete removal of fuel subsidy on gasoline, due to lots of excess it spends on subsidy payment annually, though it attracted a lot of controversy in the country and faceoff with labour union of Nigeria, but labour union was prevailed upon by the Federal government after a series of economic analysis on how it was not a proper growth to the Nigeria economy system. However, the Federal Government indicated that it will not be able to go further with subsidy payment on gasoline product, and it had called for the complete removal of fuel subsidy. From hence the gasoline pump price has soar high, now being sold at ₦145 ($0.74) per litre. This repeated crises has began since 1980, the issue of fuel subsidy, resulting in epileptic conventional fuel supply from our unfixed refinery, whereby making refined fuel importation inevitable, but fuel importation has not also proffer the required solution due to subsidy payment which had not allowed the government to always agree with the marketer.

The Nigerian Extractive Transparency Initiative, NEITI, released its audit report indicating that the Federal Government of Nigeria had paid about ₦4.5 trillion ($22.6 billion) between 2006 and 2012, a period of seven years, as subsidy on petroleum products imported into the country. The breakdown shows that ₦816.554 billion ($4.1 billion) was paid between 2006 and 2008, ₦3 trillion ($15.1 billion) between 2009 and 2011 and ₦ 690 billion ($ 3.5 billion) in 2012. As it was stated by stakeholder democracy Nigeria “According to our independent analysis based on average domestic fuel consumption, subsidies claimed by fuel marketers cost Nigeria $2.9bn over the year 2014. This is a 400% increase since 2007 and a sum equivalent to 13% of the Federal Budget, passed in April 2015 and this moreover had also been an avenue for fraud by some elements that does bring the government to its knees. Every successive government has not been able to cope It had always arises from one successive government to the other.

If we can therefore covert Natural gas as our main transportation fuel, there will be lots of worthy project that will be invested on in Nigeria, since we do not need to import fuel again, and our refinery capacity will be able to suffice our fuel demand supply of conventional fuel. This will both benefit the government and the populace. And since natural gas need not to be refined, and we need not much effort it, but rather only pipeline transportation mode from the point of exploration is required after imputing some certain treatments on it.

Advantage: CNG price is affordable even if it is not subsidized, it is still cheaper than gasoline and diesel fuel, and so if implemented, a commercial gas pricing framework would sustain domestic utilization and proper investment through natural gas vehicle in sustaining and growing gas supply rather than flaring it. There will be an improved quality of life in the environment, after saving the environment from green house gases produced from gas flaring.

5.1 Recommendation

For government to popularize NGVs in the private and public transportation sector, it has to improve the following:

- Constant natural gas supply, which proves to be a one of the significant factor that affects NGV development.
- Price ratio of natural gas to gasoline/diesel needs to be improved; this is another factor that significantly affects NGV development. The lower the price ratio (i.e. relatively cheap natural gas compared to both diesel and gasoline), the greater the popularity of NGV ownership in the domestic market and the higher the NGV market penetration.
- Promotion policies in private and public transportation are also important for NGV development in Nigeria, developing natural gas refueling stations and other infrastructures, financial supports for retrofitting of vehicles.

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Appendices

The following tables contain relevant figures of Oil exploration data from NNPC as recorded its Annual Statistical Bulletin for gas, gasoline, Diesel, and other conventional Fuel in Nigeria. This data will enable us to understand total volumes, quantities of Oil materials, money worth, amount of money spent on fuel importation, each conventional oil used, gas generated and flared etc. These data are helpful, to enable us to utilize the information on it for planning purpose when adopting Natural Gas as a National alternative fuel in road transport system in Nigeria.

APPENDIX

10 – Year Domestic Refining Capacity Utilization (%)

Years / Refineries	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
KRPC	33.08	8.34	-	19.56	22	20.46	22.17	29.12	29.33	12.90
PHRC	42.18	50.26	24.87	17.84	15	9.17	12.24	11.95	9.18	12.24
WRPC	54.85	3.85	-	38.52	41	43.36	27.99	27.88	35.99	19.28

10 – Year PPMC's Products Import (Metric Tons)

Year / Product	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
PMS	5,482,813	5,407,634	5,792,449	4,596,145	5,988,567	5,031,288	487,375	5,873,996	4,387,019	4,860,813
HHK	671,939	1,081,503	1,335,022	909,542	1,170,993	1,608,464	151,009	2,058,298	2,175,388	2,177,451
AGO	N/A	N/A	N/A	N/A	N/A	N/A	121,297	N/A	86,350	N/A
LPG	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table 1 &2 NNPC 2014 Annual Statistical Bulletin [51]

APPENDIX

10 - Year Average Daily Petroleum Products Distribution ('000 liters)

Year / Product	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
PMS	23,682.91	22,758.86	24,273.43	23,551.33	28,535.05	17,407	15,584.79	13,746.67	43,546.50	47,669.80
HHK	3,804.78	2,538.06	1,466.02	2,534.04	1,987.17	1,832	2,467.69	1,728.65	7,297.59	7,901.70
AGO	6,487.99	4,519.86	3,794.40	3,857.43	3,274	2,409.23	2,679.16	1,854.05	7,755.50	8,819.63

10 – Year PPMC's Domestic Products Sales ('000 liters)

Year / Product	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
PMS	7,224,162	8,846,929	7,725,762	7,206,729	6,876,577	9,090,470	8,042,354	8,391,032	7,822,127	6,913,444
HHK	1,773,771	2,073,820	1,759,121	1,949,837	1,898,722	2,996,467	2,869,296	3,123,279	3,691,371	3,127,256
AGO	2,030,508	1,358,199	626,283	1,273,203	648,417	1,336,361	1,750,465	1,013,223	1,113,305	551,338
LPFO	550,775	255,546	160,150	530,554	403,710	239,595	472,110	498,661	-	-
HPFO	-	-	-	-	-	-	-		-	-

Table 3 & 4 NNPC 2014 Annual Statistical Bulletin [51]

APPENDIX

Petroleum Products Imports: (January – December 2010)

MONTHS	PMS		DPK		TOTAL	
	QTY (MT)	VALUE ($)	QTY (MT)	VALUE ($)	QTY (MT)	VALUE ($)
January	613,773.559	476,666,720.13	172,742.96	133,994,936.48	786,516.52	610,661,656.60
February	656,844.445	532,179,285.34	160,104.19	123,758,891.90	816,948.63	655,938,177.24
March	814,437.876	659,580,459.47	186,550.03	143,990,247.22	1,000,987.91	803,570,706.69
April	443,463.110	375,699,205.59	162,873.52	128,179,681.82	606,336.63	503,878,887.41
May	561,584.023	490,820,859.74	183,851.72	150,979,211.71	745,435.74	641,800,071.46
June	498,747.415	437,056,637.68	73,770.88	64,089,988.36	572,518.30	501,146,626.05
July	118,386.511	101,968,395.08	134,668.69	114,531,699.54	253,055.20	216,500,094.62
August	376,422.308	314,883,192.10	171,421.57	144,838,568.80	547,843.88	459,721,760.90
September	268,013.937	212,762,175.83	98,902.06	79,557,268.84	366,916.00	292,319,444.67
October	377,826.606	304,297,822.21	131,646.02	107,233,438.02	509,472.62	411,531,260.23
November	209,493.272	170,262,494.17	69,368.62	56,046,556.08	278,861.89	226,309,050.25
December	92,295.137	79,284,783.65	62,563.76	51,178,585.83	154,858.90	130,463,369.48
TOTAL	**5,031,288.20**	**4,155,462,030.99**	**1,608,464.02**	**1,298,379,074.60**	**6,639,752.22**	**5,453,841,105.59**

APPENDIX

YEAR	GAS PRODUCED	GAS USED AS FUEL	GAS SOLD TO THIRD PARTIES	GAS TO NGC	GAS RE-INJECTED	FUEL GAS TO EPCL	GAS FOR LPG/NGL (FEEDSTOCK TO EPCL)	GAS FOR LNG	GAS LIFT	TOTAL GAS UTILIZED	GAS FLARED	% Flared
2004	2,082,283,189	71,534,048	239,513,290	72,758,426	332,806,436	9,979,511	47,100,859	410,167,378	11,883,045	1,195,742,993	886,540,196	42.58
2005	2,093,628,859	84,137,982	526,288,967	-	397,744,644	10,339,647	46,337,150	187,287,551	30,177,141	1,282,313,082	811,315,777	38.75
2006	2,182,432,084	76,797,392	629,596,866	-	333,687,178	7,926,235	44,410,804	240,915,583	45,436,202	1,378,770,261	803,661,823	36.82
2007	2,415,649,041	76,524,011	760,747,361	-	354,610,374	9,417,626	34,980,978	368,626,236	51,053,728	1,655,960,315	759,688,726	31.45
2008	2,287,547,344	83,730,016	708,159,550	63,831,255	391,075,575	7,640,304	23,582,179	331,569,374	58,560,235	1,668,148,489	619,398,854	27.08
2009	1,837,278,307	80,573,880	440,941,863	21,021,894	409,848,718	8,086,525	42,401,451	269,095,956	55,956,116	1,327,926,402	509,351,905	27.72
2010	2,392,838,898	72,233,897	857,225,685	167,190,149	21,182,685	493,309,826	5,204,476	25,866,822	169,057,005	1,811,270,545	581,568,354	24.30
2011	2,400,402,880	104,541,241	786,837,515	101,560,670	348,331,140	9,434,734	38,607,385	313,087,278	78,970,059	1,781,370,022	619,032,858	25.79
2012	2,580,165,626	115,677,106	875,458,449	72,166,259	462,875,916	15,367,328	47,186,521	329,863,143	72,904,179	1,991,498,902	588,666,724	22.82
2013	2,325,137,449	128,523,560	606,542,389	129,885,775	638,506,664	9,220,378	56,076,709	300,877,404	46,898,121	1,916,531,001	409,311,430	17.60
2014	**2,524,268,444**	**154,370,682**	**712,296,160**	**178,446,671**	**643,806,744**	**11,006,037**	**38,795,138**	**391,369,174**	**104,577,824**	**2,234,668,430**	**289,600,014**	**11.47**

Table 6 **10 – Year Gas Production and Utilization (mscf) NNPC Annual Statistical Bulletin, 2014** [51].

Résumé (English)

Natural gas is becoming one of the most important resources of energy and currently shares 23% of world primary consumption. The utilization of Natural gas as an alternative fuel is gaining popularity all over the world. It costs not as much as fuel and diesel in current costs. It is thusly obvious that of all contrasting options to petroleum, natural gas has accomplished the best and speediest level of commercialization, and has a portion of the best prospects for close term development.

Compressed Natural Gas (CNG) which is made by compressing methane to less than 1% of its volume under standard environmental condition. It is a scentless, weak gas that is gotten from gas wells or in combined with oil items; CNG has been used comprehensively as an alternative of fuel for the automobile industries. One of the central advantages of CNG is that it gives a wellspring of affordable energy. As the world keeps on utilizing and depending on costly conventional fuel, for example, diesel and fuel, the low cost alternative of CNG gives a discovery of hope. Although the climatic change in the world has been the drive for the continual seeking of environmentally friendly alternative energy, CNG has been one of the best choices of alternative fuel discovered at the appropriate time.

Gas flaring is a questionable environmental concern, since it contributes fundamentally to green house gas (GHG) emissions that are detriment to the surroundings, and moreover, gas flaring can be seen from the perspective of economic dimension as a misuse of important energy resources. The Nigeria instance of gas flaring pulls in consideration overall since it flares more associated natural gas (ANG) than it those it utilizes. The average measure of associated natural gas (ANG) being flared in Nigeria can really meet our energy demand and even many countries that could request for our supply.

The goal of this research is to evaluate the possibility of utilizing the flared natural gas in Nigeria as a source of energy for moving vehicles in the metropolis of Lagos, Nigeria, the most populous city in Nigeria, which case, it will be an eye opening for the overall implementation of Natural Gas vehicle into other Nigeria cities road transport system, this is based on the statistical information of enormous domestic consumption of conventional fuel due to numerous vehicle

plying the road in Nigeria; also for the advantage of taking control of climate change in Nigeria by enlarging domestic utilization of Natural Gas as a good alternative fuel.

In the studies, it enabled us to determine the method of initiating moderate startup of natural gas vehicle (NGV) market in Lagos. From the point of view of information gathered, it enabled us determine how to begin the construction of CNG refueling station, emancipating the return of investment of the refueling stations, and method of future multiplication of CNG system into the current conventional fuel system. Another point of implementation begins with the proposed number of existing vehicles conversion from conventional fuel engine to CNG engine compatibility; which were observed of performance by dividing them into fleets of private car owners, bus rapid transit, and vehicle owners for commercial purposes; with those vehicles formally running on gasoline and diesel fuel.

The result obtained indicated a good payback period for retrofitted vehicles especially for those vehicles that were converted from diesel to CNG compatible; therefore encouraging the decision to use Natural gas vehicle in Nigeria. A good price differential between Compressed Natural Gas and Conventional fuel is the driving force.

Resümee (Estonian)

Maagaas on muutumas üheks olulisemaks energiaallikaks ning tänasel päeval moodustab see 23% kogu maailma primaarenergia tarbimishulgast. Maagaasi kui alternatiivse kütuse kasutamine populaarsus kasvab terves maailmas. Maagaasi maksumus on konkurentsivõimeline nii diisli kui bensiiniga. Arvestades vastandlikke arvamusi võrreldes naftaga, on maagaas saavutanud märkimisväärse turustustaseme kiiremini ning omab lähiperspektiivis häid väljavaateid.

Surugaas (CNG)saadakse metaani komprimeerimisel ning võrreldes normaaltingimustega onvõimalik saavutada kuni 99% mahu vähenemine. Tegemist on lõhnatu ning kerge gaasiga, mida saadakse gaasimaardlatest või kombineeritud nafta produktidest; CNG on laialdaselt kasutatavalternatiivne kütus autotööstuses. CNG peamiseks eeliseks on mõistlik hind ning suur enerigamahukus. Kui maailm kasutab jätkuvalt tavapäraseid kütuseid (diisel ja bensiin), siis alternatiivse kütuse CNG madal maksumus pakub võimalusi ka tulevikuks. Kuigi kliimamuutused üle maailma on olnud impulsiks keskkonnasõbralike alternatiivsete energiaallikate pidevaks otsimiseks, on CNG üks parimatest valikutest praegusel ajal

Gaasi põletamine on keeruline keskkonnaprobleem, kuna see suurendaboluliselt kasvuhoonegaasideheitmete hulka, mis on kahjulikud ümbrusele. Gaasi põletamist võib majanduslikust vaatenurgast pidadaka energiavarude väärkasutuseks. Gaasi põletamine Nigeerias tõmbab rohkem tähelepanu, sestassotsieerunud maagaasi (ANG) põletatakse rohkem kui seda kasutatakse. Keskmine assotsieerunud maagaasi (ANG) kogus, mis Nigeerias põletatakse, täidab nii Nigeeria ning potentsiaalselt ka teiste nõudlust taotlevate riikide energiavajaduse.

Antud uuringu eesmärgiks on hinnata võimalust kasutada põletatavat Nigeeria maagaasi sõidukite kütusena Lagoses (kõige suurema rahvaarvuga linn Nigeerias) ning see võib osutuda esimeseks sammuks NGV (maagaasisõidukite) juurutamiseks teiste Nigeeria linnade transpordisüsteemi; see põhineb statistilistel andmetel, mille kohaselt tarbitakse tavapäraseid kütuseid väga suurtes kogustes (Nigeerias on sõidukite arv väga suur); lisaks võib maagaasi laialdane kasutamine olla eeliseks kliimamuutuste kontrolli saavutamise üle Nigeerias, suurendades kodumaiste alternatiivsete kütuste kasutamist.

Uuringus onkäsitletud meetodit maagaasisõidukite (NGV) turu arendamiseks Lagoses. Kogutud andmed võimaldasid kindlaks teha, kuidas alustada CNG tanklateehitamist, tagastada investeeringuid ning määrata meetodid CNG süsteemi juurutamiseks tavapäraste kütustepõhisesse süsteemi. Teise rakenduspunktinatuleb kindlaks määrata, kui palju olemasolevaid sõidukeid tuleb ümber ehitada tavapärasest mootorist CNG mootoriks; uurimisobjektiks olid nii erasõidukidkui bussid, mis tänasel päeval kasutavad kütusena peamiselt vaid bensiini ning diislit.

Saadud tulem näitas, et moderniseeritud sõidukite puhul on tasuvusaeg kõige lühem (eelkõige sõidukitel, mis on ümberehitatud diiselkütusest CNG-ks); see julgustab Nigeerias ka maagaasi laialdasemalt kasutamist sõidukites. Märkimisväärne hinnavahe CNG ning tavapäraste kütuste vahel on edasiviiv jõud.