International Journal of
Science and Engineering Investigations vol. 10, issue 110, March 2021
Received on March 19, 2021 ISSN: 2251-8843

Comparative Techno-Economic Analysis of Compressed Natural Gas as Automotive Fuel With Diesel and Petrol

I. A. Abdullahi[1], M. K. Oduola[2]
[1]Nigerian Gas Processing and Transportation Company Limited, Port Harcourt, Nigeria
[2]Department of Chemical Engineering, University of Port Harcourt, Nigeria
([1]abushahid.abdullahi2@gmail.com, [2]koyejo.oduola@uniport.edu.ng)

Abstract- In this study, a comparative techno-economic analysis of Compressed Natural Gas (CNG), Automotive Gas Oil (AGO) and Premium Motor Spirit (PMS) has been carried out. CNG was converted to Diesel Gallon Equivalent and Gasoline Gallon Equivalent based on their lower heating values. Two vehicles were selected; Light Truck and Car both with a ten-year service life. Cost of fuel required per year was calculated and compared for both fuels along with the entire cash flow analysis. In addition, CO_2 and NO_2 emissions were estimated and compared for the various alternatives under consideration. It was discovered that the payback period of CNG Retrofitting cost and Benefit Cost Ratio were 1.77 years and 5.66 for the Truck; 1.37 years and 7.30 for the Car, respectively. The cost of fuel per kilometre was obtained for the Truck on AGO as ₦21.21, CNG ₦9.01, while for the car on PMS it was ₦19.73 and on CNG ₦10.05 after the payback period. This gives a cost saving of ₦12.19 (57%) for the Truck and ₦9.68 (49%) for the Car. The total cost saving achieved for the entire service life of the vehicles was ₦1,927,877.22 for Truck and ₦1,507,274.09 for the car. NPV for investment in retrofitting were positive for both vehicles. 21.13% and 20.09% of CO_2 emission reductions were achieved for the Truck and Car while 18.85% and 7.45% reduction of NO_2 for the same vehicles. Based on the results obtained, economic benefit of either 31 to 57% or 31 to 49% cost savings as well as CO_2 emission reductions of 21.01% or 20.09%; and NO_2 Emission reduction will be achieved by switching from AGO or PMS to CNG respectively.

Keywords- *Automotive Fuel, Compressed Natural Gas, CO_2 Emission, Renewable Energy*

I. INTRODUCTION

As the world is moving towards green alternative energy sources which are environmentally friendly, cleaner, safer, and available, Nigeria as a global player has to join the train. Nigeria has not been able to produce its required needed automotive fuels: Automotive Gas Oil (AGO, commonly known as diesel) and Premium Motor Spirit (PMS, popularly known as petrol). This situation has economic, social and security implications in addition to the environmental effects of these fuels. In 2018, for instance, the Nigerian refineries produced a total of 745,720,418.00 litres of PMS and 400,815,546.20 litters of AGO respectively [1]. According to NNPC Annual Statistic Bulletin of 2018, the average capacity utilization of the three refineries was 7.97% in 2018 [2]. The daily average consumption of automotive fuels was PMS 50.16 million litters and 13.01 million litres of AGO [2]. With these figures Nigeria was able to produce only 4.07% of PMS and imported 95.93%, while for AGO 8.44% was produced and 91.56% imported. Nigeria has a shortfall of automotive fuels to import. This importation consumed the scarce forex needed for the other important need of industrial spare parts, machineries, and other needs. Also, this situation export jobs to other countries which Nigerians need and is detrimental to the development, stability, and security of the nation.

Gasoline is a complex mixture of hydrocarbons with boiling range from 100^0F to 400^0F. To improve gasoline quality some components are added. The quality improved by the addition of some components are, high antiknock, starting ease, quick warming, low tendency to vapour lock and low engine deposit. Gasoline is produced in two or three grades from refineries, unleaded regular gasoline, premium grade gasoline and super premium grade gasoline. Antiknock performance is the major difference between regular and premium grade gasoline [3]. To produce a gasoline, various components are blended. The components are light straight run gasoline (Isomerate), catalytic reformate, catalytically cracked and hydrocracked gasoline, alkylate, n-butane and additives. The additives are methyl tertiary butyl ether (MTBE), ethyl tertiary butyl ether (ETBE), tertiary amyl methyl ether (TAME) and ethanol in addition to antiknock chemicals [3]. Diesel fuel is formed from hydrocracked stocks and has a boiling range of 360^0F to 600^0F. It is use in trucks and buses with high-speed engines. Wider boiling range diesel is formed by blending naphtha, kerosene with cracked oils from fluid catalytic cracking unit and coker unit. The specification concerned in diesel are flash point, sulphur content, distillation range. Cetane number or Cetane index, per cent aromatics and cloud point [3].

Compressed Natural Gas (CNG) is a fuel obtained by compressing a natural gas to less than its 1 per cent volume at standard atmospheric pressure volume or 3600PSIA. It is used as an alternative automotive fuel with compressed natural conversion kit or compressed natural gas engine. Among its physical properties, noteworthy are its colourless and odourless, cleanliness and clean burning attribute, low carbon monoxide emission and absence of particulate matter emission. CNG is stored in cylinders at high pressure while LNG is a liquid form of natural gas at a low temperature (cryogenic temperature). Comparing production cost, LNG has higher production cost than CNG due to the need of cryogenic condition in storage. Compressed natural gas has advantages over other fuels in terms of emissions, costs, safety record, flexibility, and abundant reserves [4].

Ram [5] stated:

1. CNG is a lightweight gas with a high ignition temperature and at normal temperature and pressure rapidly disperse into atmosphere.
2. CNG has high octane number of 130, therefore, it does not need additives or anti-knock agents.
3. CNG has the lowest pollutants emission as compare to other fuels.
4. PMS has a problem of cold starting due to the fact that it has to vaporize before starting while CNG has better cold starting characteristics.
5. CNG engines have longer life span than other engines.
6. Using CNG gives longer time interval for engine oil replacement as compare to other engines.

Energy consumption from various sources increase due to concern on energy security, environmental pollution of using fossil fuel and high oil price, this encourages the increase in use of non-fossil renewable energy sources and natural gas. Government encouragement in using non-fossil energy sources in many countries, encourage energy users to look for alternative clean energy especially renewable energy which is the fastest growing source of energy.

Nigeria is the largest gas reserve holder in Africa with 200.79 TCF of Gas reserve [1]. In 2018 Nigeria produced 2,909,143,56 MSCF of Gas in which 2,587,853.31,764 MSCF (88.96%) was utilized and 321,290.35 MSCF (11.04%) was flared. In 2019, the gas production was 2,864.93 Billion Cubic Feet (BCF) out of which 2,620.58 BCF (91.47%) was utilized and 244.35 (8.53%) BCF was flared. Average refining capacity utilization was 2.53% [6]. Nigeria gas utilization is based on domestic consumption in generating power, industrial feed stock and export.

The world has 28,540,819 populations of Natural Gas Vehicles (NGVs) with 33,383 refuelling stations [7]. Natural gas vehicles have the lowest harmful emissions than the other fossil fuels as several studies around the world confirmed. They also have lower environmental hazards and when leaked, the fuel dissipates into the atmosphere rather than spilling onto the ground [8]. However, Honda Civic GX is the world cleanest internal combustion natural gas vehicle production line car; it is available in United States and was reported to have produced exhaust emission cleaner than the air going into the engine when tested in high polluting areas [9].

The automotive fuels used PMS and AGO have serious environmental implication and consequences. The world is moving towards more environmental-friendly and economically viable alternatives. It is imperative to look at possible alternatives to these conventional fuels.

This paper is aimed at carrying out a comparative techno-economic analysis of compressed natural gas as automotive fuel with diesel and petrol. The objectives are to find out the technical economic benefits of using CNG as automotive fuel compare to AGO and PMS along with the environmental benefit to gain by using CNG as automotive fuel.

II. METHODOLOGY

A. *Tank-to-Wheel Analysis*

A Tank-to-Wheel analysis on equal basis for CNG, AGO and PMS was carried out. Price of AGO and PMS per liter obtained from NNPC retail station were used. CNG price per 1SCM was obtained from NIPCO PLC. CNG was converted to Gasoline Gallon Equivalent (GGE) and Diesel Gallon Equivalent (DGE) based on their lower heating values. A data on kilometer distance covered by vehicle using AGO and PMS were obtained from Energy Information Administration (EIA) [10].

Average distances travelled per year of 18848.637 km for Light Truck (Vehicle that uses AGO), 18095.464 km for Car (Vehicle that uses PMS) were taken to be the distance the vehicles covered per year. The cost of fuel required to travel the distances based on equivalent fuel for both fuels (AGO, CNG and PMS) were calculated and compared. Cash flow analysis for the fuel cost and cost effectiveness were carried out. CNG conversion cost was incorporated and taken out from the CNG cost benefit.

A statistical hypothesis was set, and t-test was carried out for both vehicles with 5% significance level($\alpha=0.05$) for confirmatory of the significant or otherwise of the saving cost of fuel achieved per kilometre . The hypothesis test was carried out by the use of XLSTAT Software. The hypothesis set was:

Null hypothesis H_0: There is no difference between the two mean prices of the cost of fuel per kilometre.

Alternative hypothesis H_1: There is difference between the two mean prices of the cost of fuel per kilometre.

The greenhouse gasses pollutants (CO_2, CH_4 and NO_2) that contributed to the global warming and adding negative effects to the air quality by using these fuels were calculated and compared. The Tier 1 method of [11] were used to determine the greenhouse (CO_2 ,CH_4 and NO_2).

B. *Procedure for the Conversions between M^3 of CNG and Gallon Equivalents of GO and PMS*

The conversion of CNG to Diesel Gallon Equivalent (DGE) and Gasoline Gallon Equivalent (GGE) is based on the Lower Heating Value(LHV) of the fuels. This relationship GGE=CNG*0.877(100cf) and GGE=Diesel gal*1.155 [12].

$$GGE = CNG\ ccf \times 0.877 \quad (1)$$

$$GGE = Diesel\ gal \times 1.155 \quad (2)$$

C. Amount of DGE and GGE to be used

Two types of vehicles were selected to be used, Light Truck and Car. Light Truck uses AGO (Diesel), and the Car uses PMS (Gasoline). The Truck travelled 18848.64 km per year and the Car travelled 18095.46 km per year. Table 1 shows the km covered by AGO and PMS.

TABLE I. DISTANCE (KM) COVERED BY AGO AND PMS [13].

Fuel Type	Fuel Economy (Miles/Gallon)	Fuel Economy (Km/Litre)
AGO	24.4	10.374
PMS	18.2	7.738

$$x_i = \frac{Kilometre\ Covered\ per\ Annum}{12\ Months} \quad (3)$$

Where:

x_i= Monthly kilometre covered by the vehicle

i= Vehicle type(Truck and Car)

From Table 1, 1 litre of AGO will cover a distance of 10.374 kilometre.

$$x_1 = x_i \times \frac{1}{Distance\ covered\ by\ 1\ litre\ of\ fuel} \quad (4)$$

Where:

X_1= Amount of Diesel needed per month(litres)

$$x_2 = x_1 \times \frac{Gallon}{3.7884\ litres} \quad (5)$$

Where:

X_2 = Amount of Diesel Gallon per month

Amount of CNG per month(cf) equivalent to the number of Diesel Gallon per month (x_3), from Equation (1)

$$CNG(ccf) = \frac{GGE}{0.877} \quad (6)$$

where ccf= 100 cubic feet

Substituting Equation (2) into Equation (6)

$$x_3 = Diesel\ gal \times 131.6987 \quad (7)$$

For the Car, it uses gasoline and will cover a travel distance of 18095.464 kilometre per year.

$$x_4 = \frac{18095.464}{12\ month} \quad (8)$$

Where x_4 = Monthly km covered by the car.

From Table 1, a litre of PMS will cover 7.738km.

$$x_5 = x_4 \times \frac{1}{7.738} \quad (9)$$

Where x_5 = Amount of gasoline litres consumed per month.

The amount of gasoline gallon consumed per month(x_6)

$$x_6 = x_5 \times \frac{Gallon}{3.7884\ litres} \quad (10)$$

The amount of CNG(cf) equivalent to the number of gasoline gallons consumed(x_7) per month is

$$x_7 = x_6 \times \frac{1}{87.7} \quad (11)$$

D. Cost of CNG, AGO and PMS per travelled distance covered

The cost of Diesel (AGO), Gasoline (PMS), Diesel Gallon Equivalent and Gasoline Gallon Equivalent of CNG were calculated based on NNPC retail price and NIPCO Plc price of CNG [14,15]. Table 2 presents the price of AGO and PMS and Table 3 is the price of CNG and retrofitting cost.

TABLE II. PRICE OF AGO AND PMS [15].

Fuel Type	Cost of fuel (₦/litre)
AGO	220
PMS	159

TABLE III. PRICE OF CNG AND RETROFITTING COST [14].

Cost of CNG(₦/1M^3)	95
Retrofitting Cost(₦)	250,000 to 300,000

The annual cost of fuels consumed is obtained as follows:

$$C_{mi} = x_{mi} \times Price\ of\ fuel \quad (12)$$

where:

C_{mi} = Cost of fuel per month

X_{mi} = Amount of fuel consumed per month

i= Fuel type

$$C_{ai} = C_{mi} \times 12 \quad (13)$$

where:

C_{ai} = Cost of fuel per year

E. Estimation of Economic Indexes

Cost of fuel per kilometre

$$C_{fiv} = \frac{C_i}{D} \quad (14)$$

where:

C_{fiv}= Cost of fuel per kilometre

C_i = Annual cost of fuel

i= Fuel type

v= Vehicle type

D= Distance travelled per year

$$Payback\ period = \frac{Initial\ investment}{Uniform\ annual\ benefit} \quad (15)$$

$$Benefit\ Cost\ Ratio = \frac{CNG\ Cost\ saving}{Retrofitting\ Cost} \quad (16)$$

F. Net Present Value(NPV)

$$NPV = \sum_{i=1}^{n} \frac{Cash\ flow\ i}{(1+r)^i} - Initial\ Investment \quad (17)$$

where: r= Interest rate; n= Number of periods; i= Cash flow

G. Estimation of Greenhouse Gases

$$E_p = \sum_i [Fuel_i \times EF_i] \quad (18)$$

where:

E_p = Emission of pollutant (kg)

p= CO_2, CH_4 and NO

i= Fuel type used (TJ)

EF_i=Emission factor (kg/TJ) (Table 4) [12].

TABLE IV. EMISSION FACTORS [12].

Fuel Type	Emission Factors(Kg/KJ)		
	CO_2	CH_4	NO_2
Diesel	74100	3.9	3.9
Gasoline	69300	33	3.2
CNG	56100	92	3.0

III. RESULTS AND DISCUSSION

A. Comparative Economic Analysis of the Automotive fuels

The vehicles are assumed to be run for ten years services life. The cost of the fuels under study: diesel (AGO), gasoline (PMS), through the DGE and GGE respectively of CNG were calculated based on NNPC retail price and NIPCO Plc price of CNG. The results are presented and compared in Tables 5-6 and Figs 1–4. Table 5 and 6 are the yearly amounts of fuels consumed by the different fuel fired vehicles.

The cash flow is the amount of money spent on various fuels, cost of retrofitting from conventional fired technology to CNG fired technology was added in the CNG fuel cost. Table 7 presents the cash analysis for the various vehicles. The retrofitting cost was amortized from the savings gained by switching from other fuels (AGO/PMS) to CNG powered vehicle.

TABLE V. AMOUNT OF AGO AND PMS CONSUMED PER YEAR

Fuel Type	Amount of Fuel (Litre/year)	Amount of Fuel (Gallon/year)
AGO	1,816.91	479.60
PMS	2,338.52	617.24

TABLE VI. AMOUNT OF DGE AND GGE CONSUMED PER YEAR

Fuel	DGE	GGE
CNG	(cf)	(m^3)
	63,162.52	1,788.56

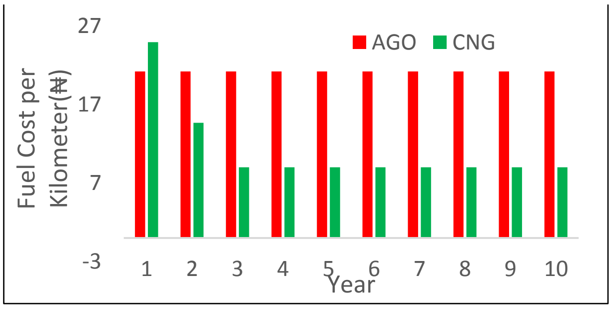

Figure 1. Cost of fuel per kilometre comparison for Truck

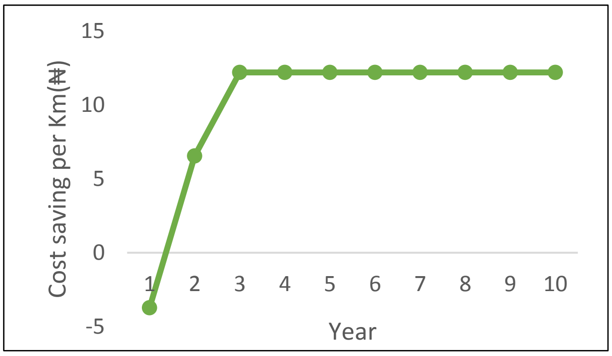

Figure 2. CNG Cost Saving per kilometre for Truck

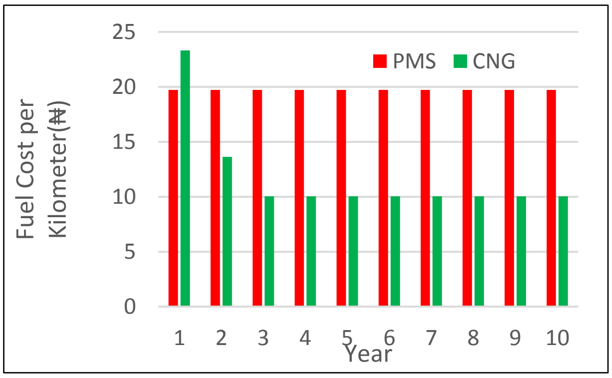

Figure 3. Cost of fuel per kilometre comparison for Car

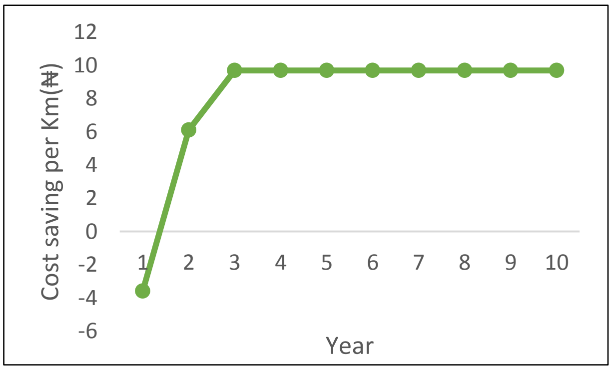

Figure 4. CNG Cost Saving per kilometre for Car.

TABLE VII. CASH FLOW FOR THE AGO, PMS AND CNG VEHICLES

Year	Truck(₦/year)			Car(₦/year)		
	AGO	CNG	CNG Saving	PMS	CNG	CNG Saving
1	399,720.53	469,913.52	-70,192.99	371,824.52	439,345.06	-67,520.54
2	399,720.53	276,444.73	159,614.08	371,824.52	256,865.60	114,958.92
3	399,720.53	169,913.52	229,807.06	371,824.52	189,345.06	182,479.46
4	399,720.53	169,913.52	229,807.06	371,824.52	189,345.06	182,479.46
5	399,720.53	169,913.52	229,807.06	371,824.52	189,345.06	182,479.46
6	399,720.53	169,913.52	229,807.06	371,824.52	189,345.06	182,479.46
7	399,720.53	169,913.52	229,807.06	371,824.52	189,345.06	182,479.46
8	399,720.53	169,913.52	229,807.06	371,824.52	189,345.06	182,479.46
9	399,720.53	169,913.52	229,807.06	371,824.52	189,345.06	182,479.46
10	399,720.53	169,913.52	229,807.06	371,824.52	189,345.06	182,479.46
Total	3,997,205.32	2,105,666.40	1,927,877.22	3,718,245.21	2,210,971.12	1,507,274.09

Comparative Economic Analysis of the fuel costt (Table 8) has indicated that prior to the payback period of Retrofitting; the CNG technology fired vehicles cost more to travel a kilometer. There after saving cost will be achieved. It was observed that after the payback period, CNG Light Truck achieved a cost saving of ₦159,614.08 in the year Retrofitting cost was paid finally. After that ₦229,807.02 will be achieving yearly till the end of the vehicle life service period. A total cost saving of ₦1,927,877.22 was achieved for the entire vehicle service life period (10 years).

CNG car saving of ₦114,958.92 was achieved after the payback period and thereafter a yearly cost savings of ₦182,479.46 will be achieved in the remaining period of the vehicle service life. A total cost savings of ₦1,507,274.09 was achieved for the entire service life of the CNG car (10 years).

However, in terms of fuel cost per kilometer (Table 9), AGO Truck was ₦21.21 per kilometer for the entire service life of the vehicle while CNG Truck cost ₦24.93 for the first year, ₦14.67 for the second year. The cost reduced to ₦9.01 for the remaining service life of the vehicle after the payback period. For each kilometer travelled, a saving cost of ₦12.19 will be achieved. Statistical hypothesis test results for the saving cost were t (18) =2.101, p=<0.0001 at α = 0.05. Since the *p-value* is lower than the significance level alpha we reject the null hypothesis $H_{0,}$ and accept the alternative hypothesis H_1.

The payback period of the Retrofitting Cost was 1.77 years for the Light Truck and 1.37 Years for the Car (Table 10). The Benefit Cost Ratio of Retrofitting was 5.66 for Light Truck and 7.30 for the Car. This means, the benefit of Retrofitting was more than five times the cost of retrofitting the Truck and more than seven times the cost of Retrofitting the Car .For PMS car a kilometer distance travelled cost ₦19.73, while car on CNG cost ₦23.31 for the first year and ₦13.63 for the second year. The cost dropped to ₦10.05 per kilometer after the payback period. Comparatively, a saving cost of ₦9.68 will be achieved per kilometer.

CNG-AGO Cost Ratio was 1.17, 0.69, and 0.43 for the first, second, third year and after the payback period respectively. This translates to a saving cost of 31 to 57% cost saving. CNG-PMS cost ratio was 1.18, 0.69, and 0.51 respectively for the first, second, and after the payback period. This also translates to 31 to 49% saving cost.

TABLE VIII. COMPARATIVE COST OF FUEL PER KILOMETRE FOR THE VEHICLES

Year	Truck(₦/km)			Car(₦/km)		
	AGO	CNG	CNG Saving	PMS	CNG	CNG Saving
1	21.21	24.93	-3.72	19.73	23.31	-3.58
2	21.21	14.67	6.54	19.73	13.63	6.10
3	21.21	9.01	12.19	19.73	10.05	9.68
4	21.21	9.01	12.19	19.73	10.05	9.68
5	21.21	9.01	12.19	19.73	10.05	9.68
6	21.21	9.01	12.19	19.73	10.05	9.68
7	21.21	9.01	12.19	19.73	10.05	9.68
8	21.21	9.01	12.19	19.73	10.05	9.68
9	21.21	9.01	12.19	19.73	10.05	9.68
10	21.21	9.01	12.19	19.73	10.05	9.68

TABLE IX. FUEL COST RATIO PER KM FOR THE VEHICLES

Year	Truck			Car		
	CNG/ AGO	CNG/ AGO (%)	Saving (%)	CNG /PMS	CNG/ PMS (%)	Saving (%)
1	1.1756	117.56	-17.56	1.1816	118.16	-18.16
2	0.6916	69.16	30.84	0.6908	69.08	30.92
3	0.4251	42.51	57.49	0.5092	50.92	49.08
4	0.4251	42.51	57.49	0.5092	50.92	49.08
5	0.4251	42.51	57.49	0.5092	50.92	49.08
6	0.4251	42.51	57.49	0.5092	50.92	49.08
7	0.4251	42.51	57.49	0.5092	50.92	49.08
8	0.4251	42.51	57.49	0.5092	50.92	49.08
9	0.4251	42.51	57.49	0.5092	50.92	49.08
10	0.4251	42.51	57.49	0.5092	50.92	49.08

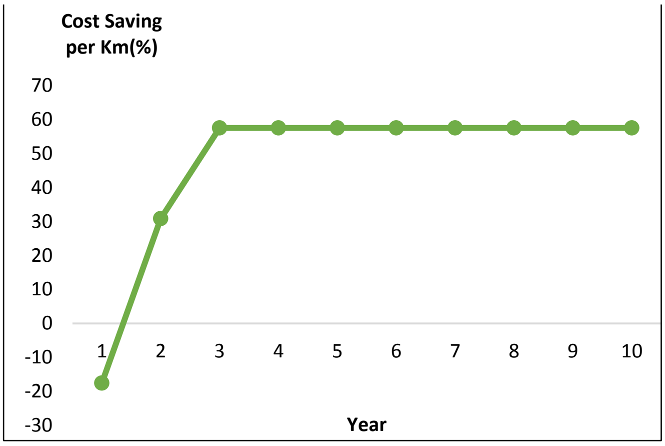

Figure 5. CNG % Cost Saving per km for Truck

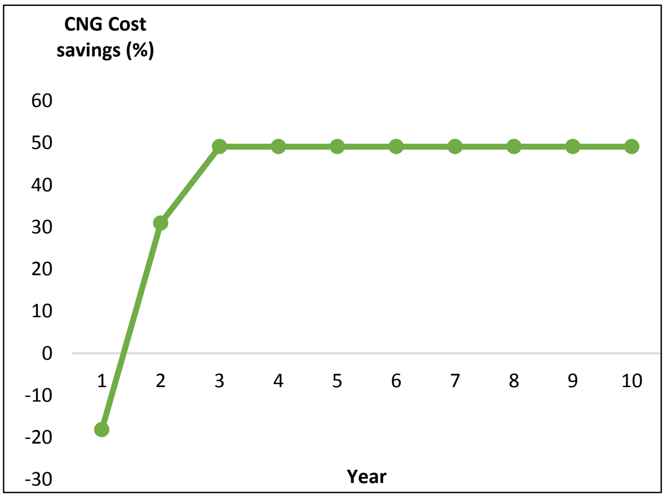

Figure 6. CNG % Cost Saving per km for Car

TABLE X. PAYBACK PERIOD AND BENEFIT COST RATIO OF RETROFITTING

Vehicle Type	Payback Period(Year)	Benefit Cost Ratio
Truck	1.77	5.66
Car	1.37	7.30

CNG-AGO Cost Ratio was 1.17, 0.69, and 0.43 for the first, second, third year and after the payback period respectively. This translates to a saving cost of 31 to 57% cost saving. CNG-PMS cost ratio was 1.18, 0.69, and 0.51 respectively for the first, second, and after the payback period. This also translates to 31 to 49% saving cost.

The result of the statistical hypothesis of the different fuel costs is presented in Table 11 below.

TABLE XI. RESULT OF THE T-TEST FOR COST OF FUEL PER KILOMETRE FOR THE VEHICLES

Parameter	Truck	Car
Difference	10.036	7.997
t (Observed value)	6.161	5.991
|t| (Critical value)	2.101	2.101
DF	18	18
p-value (Two-tailed)	<0.0001	<0.0001
Alpha	0.050	0.050

Statistical hypothesis test results for the saving cost were t (18) =2.101, p=<0.0001 at $\alpha = 0.05$. Since the *p-value* is lower than the significance level alpha we reject the null hypothesis H_0, and accept the alternative hypothesis H_1.

Net Present Values (NPV) calculated indicated that CNG investing in retrofitting and switching from AGO, PMS technology fired vehicles to CNG technology fired vehicle is a good investment based on the NPV calculated. The NPV for Truck retrofitting investment was ₦680,022.21 and for Car retrofitting investment was ₦802,499.70. Based on the positive NPV from both retrofitting investments, switching to CNG vehicles is the best choice based on the concept of cost minimization and positive NPV.

Comparative Greenhouse gasses emission computations have shown a 21.13% CO_2 Emission reduction per year and 18.85% NO_2 Emission reduction per year for switching from AGO to CNG. 20.09% CO_2 and 7.45% NO_2 reduction per year will be achieve for switching from PMS to CNG. This will translate to an improvement of local air quality and reduction in lung and respiratory illnesses. However, for CH_4 Emission CNG has higher emission as compared to the two automotive fuels (AGO and PMS).

TABLE XII. NET PRESENT VALUE OF THE TRUCK RETROFITTING

NPV For Truck Retrofitting		
Year	Cash Flow(₦)	PV(₦)
0	(-)300000	-300000
1	169913.5171	152388.8
2	169913.5171	136671.57
3	169913.5171	122575.4
4	169913.5171	109933.1
5	169913.5171	98594.705
6	169913.5171	88425.745
7	169913.5171	79305.6
8	169913.5171	71126.099
9	169913.5171	63790.223
10	169913.5171	57210.963
Total(NPV)		680,022.21

TABLE XIII. NET PRESENT VALUE OF THE CAR RETROFITTING

NPV For Car Retrofitting		
Year	Cash Flow(₦)	PV(₦)
0	-250000	-250000
1	182479.5	163658.71
2	182479.5	146779.11
3	182479.5	131640.46
4	182479.5	118063.19
5	182479.5	105886.27
6	182479.5	94965.266
7	182479.5	85170.642
8	182479.5	76386.226
9	182479.5	68507.826
10	182479.5	61441.996
Total(NPV)		802,499.70

It was discovered that the payback period of CNG Retrofitting cost and Benefit Cost Ratio were 1.77 Years and 5.66 for the Truck; 1.37 Years and 7.30 for the Car respectively. A comparative cost of fuel per kilometer were for Truck on AGO was ₦21.21, CNG ₦9.01 and for the car on PMS ₦19.73 and on CNG ₦10.05 after the payback period. This gives a cost saving of ₦12.19 (57%) for the Truck and ₦9.68 (49%) for the Car. A Total cost saving achieved for the entire service life of the vehicles were ₦1,927,877.22 for Truck and ₦1,507,274.09 for the car. The results of the confirmatory data analysis carried out indicated that for Truck t (18) =2.101, p =<0.0001 while for Car were t (18) =2.101, p=<0.0001 respectively. Investment in retrofitting returned positive NPV for both vehicles. 20.13% and 20.09% of CO_2 Emission reductions were achieved per year for Truck and the Car. 18.85% and 7.45% NO_2 Emission reduction per year were achieved for the Truck and the Car. Based on the results obtained, economic benefit of 31 to 57% and 31 to 41% cost savings will be achieved by switching from AGO, PMS to CNG. Also, a CO_2 Emission reduction per year of 21.13% and 18.85% NO_2 will be achieved for Truck. While CO_2 Emission reduction per year of 20.09% and 7.45% NO_2 will be achieved for Car.

IV. CONCLUSIONS

Economic and environmental benefits of compressed natural gas have been highlighted in this study. A cost reduction benefit in the range of 31 to 57% in cost savings could be achieved by switching from AGO to CNG, while 31 to 49% cost savings could be achieved by switching from PMS to CNG. In the same manner, it has been shown that cost saving of ₦12.19 or ₦9.68 per kilometer travelled could be achieved by using CNG instead of AGO or for using CNG instead of PMS respectively. Cost savings achieved for both vehicles have been shown to be statistically significant at 5% confidence interval, Truck t (18) =2.101, p=<0.0001 while for Car were t (18) =2.101, p=<0.0001. Emission reductions per year of CO_2 21.13% and NO_2 18.85% could be achieved by switching from AGO to CNG, while the corresponding reduction values are 20.09% CO_2 and 7.45% NO_2 for switching from PMS to CNG. Public enlightenment campaign on CNG, its economic and environmental benefits is therefore of pertinent importance, while carrying out further research to find the effect of other greenhouse gasses.

REFERENCES

[1] DPR. (2019). 2018 Nigerian Oil and Gas Industry Annual Report. Retrieved February 14, 2021, from https://www.dpr.gov.ng/wp-content/uploads/2020/01/2018-NOGIAR-1.pdf

[2] NNPC. (2019). 2018 Annual Statistical Bulletin. Retrieved February 14, 2021, from https://www.nnpcgroup.com/NNPCDocuments/Annual%20Statistics%20Bulletin%E2%80%8B/ASB%202018%201st%20Edition.pdf

[3] James, H. G., & Glenn, E. H. (2001). *Petroleum Refining Technology and Economics* (4th ed.). New Yourk: Marcel Dekker Inc.

[4] Chikezie, N., & Iyoke, J. (2013, May). A review on natural gas utilization and cutting carbon emissions: how viable is compressed natural Gas for road vehicle fuel? Retrieved February 15, 2021, from https://www.researchgate.net/publication/281528690_Areview_on_natural_gas_utilization_and_cutting_carbon_emissions_how_viable_is_compressed_natural_Gas_for_road_vehicle_fuel

[5] Ram, P. (2010). *Petroleum Refining Technology* (6th Reprint,1st ed.). Delhi, India: Khanna Publishers.

[6] NNPC. (2020). 2019 Annual Statistical Bulletin. Retrieved February 15, 2021, from https://www.nnpcgroup.com/NNPCDocuments/Annual%20Statistics%20Bulletin%E2%80%8B/2019%20ASB.pdf

[7] NGV Global. (2021). International Natural Gas Vehicle Statistics. Retrieved February 10, 2021, from https://www.ngvglobal.org/ngv-statistics/#

[8] NGV Global. (2021a). Ntural Gas Vehicle Safety. Retrieved February 14, 2021, from http://www.iangv.org/natural-gas-vehicles/naturally-safe/

[9] NGV Global. (2021b). Emission. Retrieved February 14, 2021, from NGV Global: http://www.iangv.org/natural-gas-vehicles/emissions/

[10] EIA. (2020, June 25). Nigeria. Retrieved Febuary 10, 2021, from https://www.eia.gov/international/analysis/country/NGA

[11] U.S. Energy Information Administration. (2021). *January 2021 Monthly Energy Review*. Retrieved February 6, 2021, from https://www.eia.gov/totalenergy/data/monthly/pdf/mer.pdf

[12] IPCC. (2006). 2006 IPCC Gudelines for National Greenhouse Gas Inventories:Mobile Combustion. Retrieved February 06, 2021, from https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_3_Ch3_Mobile_Combustion.pdf

[13] U.S. Department of Energy. (2021). *Fuel Conversion Factors to Gasoline Gallon Equivalents*. Retrieved February 6, 2021, from https://epact.energy.gov/fuel-conversion-factors

[14] NIPCO PLC. (2021, February 10). CNG Price and Retrofitting Cost Price.

[15] NNPC Retail Station. (2021, February 3). Price of AGO and PMS.

How to Cite this Article:

Abdullahi, I. A. & Oduola, M. K. (2021). Comparative Techno-Economic Analysis of Compressed Natural Gas as Automotive Fuel With Diesel and Petrol. International Journal of Science and Engineering Investigations (IJSEI), 10(110), 35-41. http://www.ijsei.com/papers/ijsei-1011021-05.pdf