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Decarbonisation in the Transport Sector of Ghana Using Autogas

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Abstract. Decarbonisation is instrumental in attaining sustainable mobility. To actualize the Ghana Nationally Determined Contribution (NDC) set emission reduction target of 15% relative to Business-As-Usual (BAU) scenario by 2030, sustainable transport actions should be encouraged. Thus, promoting the use of Liquified Petroleum Gas (LPG) and Compressed Natural Gas (CNG) in automobiles is very crucial to ensure efficient and green mobility. Nonetheless, existing policies in Ghana overlook autogas (LPG/CNG) as prospective decarbonizing solution in the transport sector. The study employed survey analysis and analytical modeling approach to elicit the benign effects of autogas in the transport sector using Accra as a case study. The ecological, economic and social dimensions of autogas were expatiated to extrapolate effective measures to facilitate their smooth implementation. Survey was carried out in the central business district of Accra to attain the percentage of autogas and gasoline used by taxis operators for the first time per author's knowledge. A purposive sample of 500 taxi drivers was selected and data analysis was conducted using R statistical package. From the survey, 14% of taxis were powered with LPG whilst 86% were gasoline, however, the LPG-powered taxis were retrofitted gasoline engine vehicles. The analytical model was based on physics principles involving three resistance forces- aerodynamic, rolling resistance and inertia. CO_2 emission savings of 29% and 18.4% were elicited from the use of CNG and LPG relative to gasoline fuel at the end of the simulation using the ambient conditions in Accra. Thus, use of autogas will limit global warming impact and aid the country to fulfill its pledged emission target by 2030. The government is entreated to regulate autogas use in the transport sector and increase its patronage by promoting flexible policies like meager custom duty on imported CNG/LPG vehicles as well as tax credits.

Introduction

Transportation sector is a major contributor to energy consumption and carbon dioxide emissions. It is the principal sector expediting environmental pollution in the current globalized economy [1, 2]. The sector is absolutely dependent on fossil-based fuels with negligible renewable energy share particularly in developed countries. In Ghana, the annual mean growth rate in petroleum products consumption in the transport sector is approximately 5.5% from 2000 -2020, thus the sector is the highest emitter of greenhouse gases within the energy sector [3]. The Intergovernmental Panel on Climate Change (IPCC) calls for a 50-80% reduction in greenhouse gases by 2050 to preclude the adverse impacts of global warming [4]. Consequently, it is imperative to redesign the transport sector to integrate ecologically benign fuels. Several alternative fuels have been identified as environmentally friendly comparative to the conventional gasoline and diesel fuels. Amongst these alternative fuels, LPG and CNG are considered the ideal fuel option for road transportation in respect to its less impact on the environment, economical price and reliant on proven technologies [5].
Autogas is deemed as a *bridging fuel* in the transitioning towards zero-emissions [6]. The global demand of autogas will augment above 50% by 2035 from 2010 levels as proposed by the

International Energy Agency in 2012 [7]. The transport sector is anticipated to be one of the main consumers of the predicted gas demand in the near future [8]. The use of autogas will offer economic and environmental benefits to the country by enhancing cost savings and adhering to environmental standards as compared to other fuel options in Ghana [9]. The study therefore accentuates on autogas (LPG and CNG) inclusion in the transport sector of Ghana emphasizing on the prospective strengths and weakness associated with their implementation. To exemplify their imperative nature in downsizing emissions in the sector, an analytical model was employed based on ambient conditions using Accra- the capital city of Ghana as the case study to help deduce the significance of autogas in Ghana as a whole.

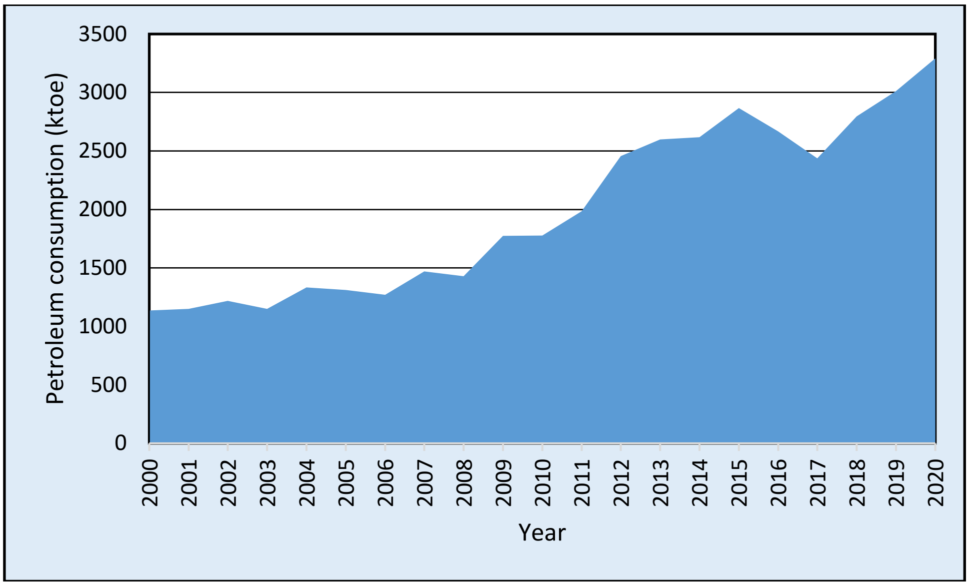

Fig. 1. Fossil fuel consumption in the transport sector [3]

Autogas Market Size

LPG is the only autogas used for mobility in Ghana. The rationale for its use is based solely on economic benefits due to the subsidies provided by the government. According to the survey conducted by [10], taxis drivers using LPG make average daily profit of GH¢100 -150 whilst those with gasoline earn GH¢30-50 engendering massive usage of LPG amongst the drivers. Conversely, utilization of autogas in the developed countries relies on their propensity to limit particularly CO_2 emissions [11]. Thus, usage of CNG and LPG has increased significantly in these regions with their market size anticipated to surge from 2.135 million units' sales in 2021 to 4.389 million units' sales by 2026. Government support in the form of subsidies and tax rebates has facilitated sales with emission reduction as the main target. China, India, South Korea, and Thailand have the largest autogas market primarily because of government initiatives enforcing the use of low emission fuel vehicles and high petroleum tariffs. Vehicle manufactures like Suzuki Motor Corporation (Japan), Honda Motor Company (Japan), Hyundai Motor Group (South Korea), Volkswagen AG (Germany) and Ford Motor Company (US) are the world leading manufacturers in CNG and LPG vehicles [12]. Autogas market size is under-developed in West African regions. Nigeria for instance introduced CNG as an automobile fuel in the 1990s to exploit resources from natural gas with the aim of addressing fuel shortages and gas glaring in the country. Hitherto, autogas market size has not matured due to financial constraints related to higher cost of gaseous vehicles coupling with higher importation duties [7]. As at 2016, Nigeria had a limited number of 6000 autogas vehicles relative to 11.7 million registered cars in the country representing only 0.051% of the total vehicles [4]. In Ghana, autogas market is in the rudimentary stage with 100% of vehicles powered with LPG being switched mechanically. The conventional fuel market is growing exponentially due to the absolute reliance on these fuels with no available plans for gaseous fuel vehicles [13]. Comparative to North Africa, Egypt is the leading country in CNG - powered vehicles after the launch of its Clean Fuel Initiative in 1995 which incorporated autogas as a solution to combat air pollution. Currently, there are 260,000 autogas vehicles in Egypt with additional 61 fueling stations [14].

Composition and characteristics of LPG and CNG

LPG is colorless, odorless and flammable gas which is denser than air [15]. It is derived as a by-product from natural gas production and oil extraction (60%) or to a lesser extent petroleum production and refining. The main constituents are light hydrocarbons - propane, propene and butane with the composition rate varying per country [1]. Its octane number of 106 -110 increase detonation resistance to improve its thermal efficiency [16]. It is usually compressed at 110- 129 psi and stored in carbon steel cylinders [17].

CNG is a natural gas that has been compressed at 3000 psi to 1% of the volume the gas occupies at standard atmospheric pressure [18, 19]. It is primarily methane resulting in higher CH_4 emissions during combustion. It is colorless, tasteless and comparably non-toxic [20]. CNG is lighter than air – a characteristic that causes it to easily disperse hence reducing risk of ignition. Its octane rating ranges from 120 - 130 causing the engine to function at higher compression ratio to enhance thermal efficiency [21]. It has a strong distinctive smell which enables leakage to be easily detected when mixed with Sulphur compounds [22]. Table 1 depicts summary of the characteristics of both LPG and CNG.

Table 1. Comparison between LPG and CNG

Characteristics	LPG	CNG
Composition	Propane (C_3H_8)	Methane (CH_4)
Octane number	106-110	120-130
Density	0.55 (kg/l)	0.46 (kg/l)
Calorific value	23.3 (MJ/l)	21 (MJ/l)
Storage pressure	110- 129 (psi)	3000 (psi)

Autogas Production and Use in Ghana

The main source of natural gas in the market is via imports and local production with Tema Oil Refinery being the main suppliers [23]. Natural gas production in Ghana commenced in 2014 with production volume of approximately 1.95 bcf. Prior to its commencement, large percentage of natural gas in Ghana was imported from Nigeria through the West African Gas Pipeline [3]. However, importation has declined over the years as local production has gradually augmented from 1.95 bcf in 2014 to 25.76 bcf, 22.93, 32.88, 38.15, 54 and 92.9 bcf in 2015, 2016, 2017, 2018, 2019 and 2020 respectively. The main gas producing fields in Ghana are the Jubilee field, Tweneboa Enyenra (TEN) field and Sankofa fields with the Jubilee field being the largest. The Jubilee together with TEN fields are operated by Tullow Oil whilst Sankofa is a joint project consisting of Eni (44.44%) -main operator; Vitol (35.56%) and Ghana Natural Gas Corporation (GNPC) (20%). Gas production in 2014 commenced at the Jubilee field whilst TEN and Sankofa were 2016 and mid-2018 respectively [24, 25]. The overall gas production by these three predominant fields as at 2021 was approximately 204 bcf making the gas sector a potential area for economic development in Ghana [26].

The domestic and imported gas are primarily used for electricity generation. According to [25], the increase in gas demand is due to rise in electricity production. With an anticipated 45% rise by 2026 gas demand will also augment accordingly. Hitherto, there is no policy encouraging the use of autogas as transportation fuel in Ghana. The available government policies on LPG focus on their consumption as an alternative cooking fuel source for charcoal and firewood. The backbone of this policy was to reduce deforestation and pollution caused by the flaring of LPG at the Tema Oil Refinery [27]. Consequently, LPG use as a transportation fuel in Ghana is unregulated and has resulted in massive competition with domestic consumption leading to frequent shortages that has compelled the population to regress to charcoal and firewood. LPG consumption in the transportation sector accounted for 37% of the total LPG supplied to the market according to the Energy Commission report in 2011 [28]. This has violated the policy action taken to reduce deforestation caused by the predominant use of firewood as cooking fuel [4, 16]. Comparative to USA, Europe and Asia, LPG and CNG consumption are supported by government policies including fuel tax exemptions, tax credits for vehicle conversions etc. which increase the use of autogas [13].

Analysis of Autogas use in Commercial Vehicles

Survey Analysis

Survey was conducted to determine the total number of taxis running on autogas and conventional fuels in Accra. Existing survey studies on LPG use in the transport sector have been conducted in locations like Yilo Krobo [13]; Ho [29]; Tarkwa [30]; Central region [31] and Tema community 1 [32], however to the best of the authors' knowledge no prior study has been carried out within the central business district (CBD) of Accra. The available studies focus solely on household consumption of LPG rather than its use in the transport sector. Therefore, this survey filled the gap by focusing on the use of LPG and gasoline fuels among taxis in Accra's CBD.

The study population focused on commercial taxis drivers operating within the city of Accra. Per Driver and Vehicle Licensing Authority (DVLA) data, there are approximately 10,000 registered commercial drivers in the city including those driving taxis, minibuses (trotro) and other commercial vehicles. A sample size of 500 drivers were selected to ensure a comprehensive representation of the diverse experiences and perspectives of drivers within the population. Purposive sampling was employed, as the survey objective was to elicit specific information regarding the types of fuel used in commercial taxis exclusively. Data were collected through interviews using closed-ended questionnaires. As a rule of thumb in purposive sampling, no new units were sampled once homogeneity in responses was achieved. Data analysis was performed in R Studio, where the percentage distribution of the different fuel types used by the taxi drivers was elicited. From the analysis, 86 % of taxis used gasoline, 14% LPG with none using CNG. Vehicles running on LPG were originally gasoline vehicles that have been converted. Similarly, the study by [30] reported a notably lower percentage of LPG-powered taxis relative to gasoline. In contrast, survey carried out by [10] and [29] in 2016 and 2012 respectively observed higher percentage of LPG vehicles than gasoline. This can be attributed to the disparities in study locations and period (year) of study.

According to the drivers, the rate of conversion into LPG has decreased recently due to the rampant gas shortages in the country which has deterred them from relying absolutely on LPG as transportation fuel. This is consistent with the survey by [13] where drivers lamented on the intermittent LPG shortage as the main challenge resisting their use. According to [33] drivers using LPG usually experience shortages which persist for more than 4 weeks in every year. Few of the drivers also lamented on the current exorbitant price of LPG as the main hindrance in using the fuel. Study was limited by focusing solely on the proportion of vehicles using autogas whilst excluding other relevant areas like quantity of gas used per trip, maintenance procedures etc. Therefore, survey results are only applicable to the different fuels used by taxis drivers in the CBD of Accra.

Fig. 2. Taxis at a gas filling station Source: (Photo by authors, 2023)

Modelling Approach
After the survey, comparative analysis was conducted to deduce fuel consumption and emission rate of gasoline and LPG/CNG in three spark - ignited engine vehicles – Daewoo Matiz, Toyota Matrix and Toyota Yaris. An analytical model adopted from [35] was modified and used in the analysis as depicted in equation 1. This model is based on the principle of physics expressed through the use of mathematical formulas.

$$Q = bsf * 10^{-2} \left[\frac{F_{roll} * F_{inertia} * F_{drag} * (v)^3}{\eta T * \rho f * vh}\right] \qquad \textbf{Eq. (1)} \ [34].$$

Q = fuel consumption (l/100 km), bsf = brake specific fuel consumption (gkW/h), F_{roll} = rolling resistance force, $F_{inertia}$ = force of inertia acceleration , F_{drag} = force to overcome aerodynamic drag, ηT = transmission efficiency, ρf = fuel density (kg/l), v= velocity in (m/s) vh = velocity in (km/hr).

The three resistance forces were ascertained using the vehicle specifications depicted in table 2 and ambient environmental conditions (temperature 27.7°C) at an average speed of 44.2 km/h. CO_2 emissions were deduced from the amount of fuel attained after mathematical simulation and the default emission factors from the IPCC 2006 guidelines. Model was validated by conducting a field experiment with LPG and gasoline powered Daewoo-matiz vehicle. The percentage difference between the actual and predicted fuel consumption values was determined using equation 3. Fuel consumption of the real value determined on-field was 0.6% higher than the predicted value from the model.

$$CO_2 = F_f \times E_{CO2,f}. \qquad \textbf{Eq. (2)} \ [36].$$

Where CO_2 is carbon dioxide emissions (kg); F_f = fuel consumed (TJ); $E_{CO2,f}$ = carbon dioxide emission factor (kg/TJ); f = fuel type (gasoline, LPG and CNG)

$$\% \, change = \frac{\text{actual value} - \text{predicted value}}{\text{predicted value}} * 100. \qquad \textbf{Eq. (3)} \ [37].$$

Table 2. Vehicle specifications

Model	Engine capacity (cc)	Mass (kg)	Area (m^2)	Vehicle drag	Maximum power (kW)	Acceleration (m/s^2)
Matiz	796	775	1.91	0.342	38	1.63
Toyota Yaris	1298	1000	2.09	0.29	64	2.12
Toyota Matrix	1798	1300	2.24	0.33	99	2.79

Simulation Results
All vehicles exhibited similar patterns in gasoline, LPG and CNG fuel consumption and CO_2 emissions. Fuel consumption was higher in the gaseous fuels but their CO_2 emissions were relatively lower than gasoline. From figure 3, CNG recorded the highest fuel consumption and lowest CO_2 emissions in all vehicles. Fuel consumption and CO_2 emissions were notably higher in Toyota Matrix followed by Toyota Yaris and Daewoo Matiz respectively. This is basically because of the larger size and engine capacity of Matrix that reduce its fuel efficiency relative to Yaris and Matiz [38].

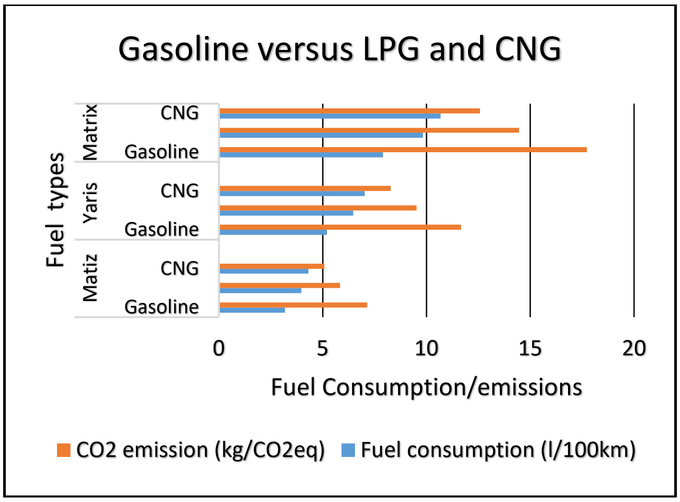

Fig. 3. Fuel consumption and CO_2 emissions based on fuel types

Potential of Autogas as a Decarbonisation Technique in Ghana

The analytical model output was used to exemplify the potential of CNG and LPG as decarbonizing fuels based on ambient conditions in Accra which is the most populous city in Ghana. Fuel consumption and emission savings were the metrics used to extrapolate the rate of decarbonization using these gaseous fuels.

Autogas Consumption

Fuel consumption depends on the energy content of the specific fuel. The higher the energy content/calorific value, the lesser the rate of fuel consumed. Gasoline has a net calorific value of 32.4 MJ/l with LPG and CNG as 23.3 MJ/l and 21 MJ/l respectively [21, 38]. Per obtained simulation results, LPG and CNG resulted in 24.4 % and 26 % increment in fuel consumption relative to gasoline. [39] observed 22% fuel consumption increment in LPG - powered vehicle relative gasoline. Empirical results of [40] also depicted higher fuel consumption in LPG and CNG compared to gasoline. The lower energy content per volumetric basis of LPG and CNG accounted for the notable higher rate of fuel consumption. According to [41, 42], LPG and CNG have lower volumetric efficiencies which influence higher consumption of their fuels. Nevertheless, in countries with resounding policies, the affordability of autogas compensates for the higher rate of fuel consumption. The affordable prices of gaseous fuels due to subsidies and tax rebates especially in Europe, USA and Asia make LPG and CNG more desirable to use with their lower energy content notwithstanding. According to [12], CNG vehicle can consume 4.8 kg/100 km whilst diesel and petrol averagely use 5.9 l/100km and 6.7 l/100 km respectively. Thus, gas fuels are capable of covering long mileages at a lower cost of fuel which maximize profit provided the availability of efficient government regulations.

In Ghana, the price of LPG has increased gradually after the subsidy was removed in 2013 [33]. However, the nation has experienced a sudden upsurge in price within the last four years. Prices rose from GH¢ 5.8 ($ 0.37) per kg in 2020 to GH¢ 16 ($1) per kg in 2024 which is slightly higher than the price of petrol GH¢ 15.10 ($ 0.96) as at 2024. The exorbitant hike in prices is anticipated to surge exponentially in the coming years unless government intervene to stabilize the price [43]. The exorbitant LPG price coupled with high consumption are few of the underlying factors causing reduction in LPG use in recent times as observed from the field survey.

Autogas CO_2 Emission Savings

CO_2 is the principal greenhouse gas. Its emissions are proportional to the amount of fuel consumed per distance [44]. Albeit, fuel consumption of gaseous fuels is relatively higher, their CO_2 emissions are lower than gasoline. Using the simulation results as benchmark, the emission savings from CNG and LPG were 29 % and 18.4% respectively using gasoline as the base fuel. Carbon to hydrogen (C:H) ratio in LPG - 0.37 and CNG - 0.25 are lower than gasoline -0.54 and thus, influence the higher rate of CO_2 emissions in the later. Aside the C:H ratio, the carbon content in gasoline is 85% relative to 75% in CNG and 82% in LPG [45, 46]. Comparison between the two gaseous fuels depicts CNG to be more environmentally friendly than LPG. This is due to the higher H:C (hydrogen to carbon) ratio in CNG- 4.1 compared to LPG - 2.67 resulting in further decrease in CO_2 emissions. The study observed 13 % emission savings from the use of CNG relative to LPG. The experimental results by [11] which ascertain the effects of gasoline, CNG and LPG on CO_2 emissions observed 10% and 25% lower CO_2 in LPG and CNG relative to gasoline under the NEDC cycle. [40] compared the tailpipe CO_2 emission of gasoline to LPG and CNG and observed lower percentage differences due to the lesser CO_2 emissions of the gaseous fuels. The percentage difference was extremely lower for CNG due to the additional reduction in CO_2 caused by its higher H:C ratio. The analysis has explicitly depicted the low- carbon benefits of gaseous fuel irrespective of consumption rate and prices in the context of Ghana. Therefore, integrating CNG and LPG can highly downsize CO_2 emissions in the transport sector.

Conditions for Autogas Implementation in Ghana

According to the updated and enhanced nationally determined contribution (NDC) under the Paris Agreement, the country has pledged absolute reduction of 64 $MtCO_{2e}$ in GHGs by 2030. In addition to the NDC's, the Ghana energy transition plan has targeted a net zero energy related emissions by 2060 through deploying low-carbon solutions across key economic sectors especially the transportation sector. [47]. Therefore, in employing CNG and LPG as one of the suitable technologies to facilitate the attainment of the decarbonization target set in the country, requisite factors have to be considered.

Enlisted below are some laid down conditions to observe when implementing autogas as alternative fuels. These multi-faceted conditions encompass economic, technical, regulatory and environmental dimensions in the provision of sustainable actions for autogas technology implementation.

- Legalization of Autogas: Government regulations to legalize autogas as a transportation fuel in the country. Establishment of strong coordination between autogas vehicle owners and operators of refueling stations in connection to the policies set by the government on autogas usage.
- Public Awareness: The environmental benefits of autogas should be publicized to increase attraction to the fuel. Concerted efforts by stakeholders- government (policy makers), gaseous vehicle manufacturers and owners, autogas supply industries are required to enlighten the general public about the benign effects of autogas over conventional fuels to increase the market size [6].
- Gas Reserves: Availability of adequate gas reserves to reduce gas shortage. There should be clear policies to guide the supply of gas as both cooking fuel and transportation fuel.
- Pilot Study: Feasibility study to determine the economic and infrastructure potential of implementing autogas [26]. Financial constraints associated with switching permanently to CNG and LPG vehicles should be thoroughly evaluated as gaseous vehicles require high initial investment costs [12].
- Autogas Vehicles Assessment: Strategic implementation plans in relation to gas storage and targeted autogas car fleet in terms of vehicle performance, durability and drivability.
- Training of installers: Autogas industry under the regulation of the government should encourage and enhance the training and certification of autogas kit installers to improve the conversion quality.
- International co-operation: Collaborate internationally to ensure alignment with global standards and regulations related to autogas use. Creation of formidable alliances with nations with more experience and expertise in autogas adoption [48]. Relative to countries like Bangladesh, Armenia, Pakistan and Argentina with more than 20% share of autogas vehicles as well as Brazil with 10%, Ghana can draw motivation from such countries to design optimum and cost-effective plans for autogas implementation in the country. In Egypt for instance, there is governmental support for drivers who use CNG which can also be adopted in Ghana [14].

Merits and Challenges of Autogas as Transportation Fuel in Ghana

Merits

Autogas integration in the transport sector can positively influence the socio-economic and environmental aspects of the sector which is the major polluting sector in Ghana based on the [3] report. Beside the reduction in CO_2 emissions, CNG and LPG are also associated with lower NOx and particulate matter (PM) emissions [49]. Reduction in NOx and PM will ameliorate air quality in larger cities like Accra and Kumasi where auto emissions are the highest indices for pollution [50]. This improves human health and boost social welfare benefits due to health cost savings [6]. Conversion of conventional fuel vehicles to autogas automatically creates job opportunities which enhance the livelihood of people. Currently, Ghana boasts of substantial domestic supply of gas, hence autogas can possibly augment foreign exchange reserves unlike the prevalent use of conventional fuels that necessitate high rate of importation [26]. Moreover, integration of CNG and LPG as alternative fuels will reduce the over-dependence on gasoline and diesel. This will suppress the adverse impacts emanating from the excessive use of conventional fuels in the country.

Challenges

Autogas usage by drivers are in two forms- originally manufactured gaseous fuel vehicles or locally retrofitted gaseous vehicles. Retrofitting is usually done in spark-ignited engines due to the easy conversion of SI engine powertrains from liquid to gaseous fuels [11]. In Ghana, all LPG powered vehicles were initially spark-ignited gasoline engine vehicles converted by technicians. Vehicle conversion by retrofitting requires technical know-how and precise engineering [51]. According to [29], there are few formally trained LPG conversion technicians in Ghana. The available informally trained mechanics apply their mechanical experience which is insufficient for efficient conversion. Based on their survey an average cost of conversion was 450 cedis ($300) which is cost effective comparable to purchasing originally manufactured gaseous vehicles which are priced higher than regular conventional vehicles due to extra components added to them during manufacturing [12]. Nevertheless, the lack of expertise in the conversion process in Ghana lead to frequent break downs of the conversion system increasing susceptibility to fire outbreaks in vehicles [29]. This has increased the misconception surrounding the safety and reliance of LPG in the country. Aside the technical know-how, most technicians lack standard diagnostic tools and conversion kits to enable effective conversion which eventually lead to frequent breakdown of the system and affect the engine performance. From the study of [52], 62.5% of LPG mechanics utilize already-used spare parts as kits with less than 10% using brand new ones. The inappropriate conversion affects air/fuel ratio which ultimately increase exhaust emissions [53].

Moreover, the predominant use of retrofitted engines reduces efficiency of autogas during combustion. The retrofit engines are not designed to run on gas but outdated engine technologies (due to the old imported vehicles) resulting in higher tailpipe emissions [54]. According to [55], the higher-octane ratings of CNG and LPG enhances their engines to function at higher compression ratio which improve thermal efficiency. Conversely, the retrofitted gasoline engine cannot operate at such optimum thermal efficiency because its compression ratio is already set at the level required for gasoline fuels. Thus, the beneficial thermal efficiency can be attained only with the requisite fuel engine. These factors marginally contribute to higher fuel consumption in retrofitted engines comparative to originally manufactured engines.

Infrastructure and fiscal issues can also hamper the growth of autogas in Ghana considering improvement in the conversion process, importation of originally-manufactured CNG and LPG vehicles, provision of gas storage facilities and re-fueling stations.

Solutions to these challenges are available at the enlisted conditions and policy recommendations.

Policy Recommendations

Government policies create critical role in switching from conventional fuels to autogas. [6]. Policies in the form of taxation, carbon tax system, fueling infrastructure will determine the demand of autogas among automobile users. Therefore, integration of fiscal incentives like tax incentive - tax credits, vehicle and fuel tax rebates on autogas-powered vehicles can increase gaseous fuel market in Ghana. The price of autogas should be 50-60% lower than the conventional fuels. According to [7], the best incentive policies are those that increase autogas competitiveness with conventional fuels by giving substantial financial motivation for consumers to shift to autogas. Policies to exempt or collect meager custom duty on imported autogas vehicles compared to conventional vehicles in order to augment originally manufactured CNG and LPG cars in the country whilst minimizing use of retrofit kits [5]. Development of carbon tax policies to increase conventional fuel cost and decrease the price of autogas. This will compel vehicle owners to use CNG and LPG in order to minimize excessive cost [4]. Policies to increase the availability and access to autogas re-fueling stations through the provision of loans to autogas fuel station investors to attract more investors and investment by the government in order to increase the percentage of stations.

Conclusion

CNG and LPG can optimally supersede conventional gasoline and diesel fuels in Ghana. Based on the study results, they can effectively reduce CO_2 emissions which is the main contributor of global warming. Thus, use of gaseous fuel vehicles are prospective solutions to air pollution, oil shortages and climate change. Incidentally, the transport sector in Ghana has not incorporated CNG as a transport fuel, the only autogas used is LPG with its usage being unregulated. Therefore, as means to decarbonize the transport sector in order to attain the net-zero energy related emission target under the Ghana Transition Plan by 2060, gaseous vehicles should not be downplayed. Study entreat government to reshuffle vehicle stocks imported into the country to include gas vehicles as well as increasing local production of gas to boost the provision of more fueling stations to enhance rapid access to gaseous fuels. Primarily, gas produced is mainly for electricity generation, hence proportionate amount should be diverted into the transport sector to be utilize as clean fuels to reduce CO_2 emissions. Furthermore, government plans and policies on green mobility should incorporate LPG and CNG alongside electricity and biofuels which are more pronounced. Further studies should focus on hydrogen addition to CNG and liquified natural gas (LNG) to determine their rate of fuel consumption and emissions. The feasibility of such technologies as suitable fuels in the transport sector in Ghana should also be assessed.

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