Comparison and assessment of using Liquefied Petroleum Gas with conventional gasoline and diesel

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الملخــــص

تهدف هذه الدراسة الى استخدام الغاز البترولي المسال (LPG) حول العالم حيث يستخدم في الطهي والتدفئة وفي عمليات توليد الطاقة كما يستخدم كوقود للسيارات وعدة استخدامات اخرى .

يمكن الحصول على (LPG) من عمليات تكرير النفط او من الغاز الطبيعي حيث يحتوي على المركبات الهيدروكربونية الخفيفة نسبياً ويعتبر البروبان والبوتان اهم مكونات غاز(LPG)

يعتبر غاز (LPG) وقود نظيف يستخدم للسيارات مع اقل نسبة ملوثات مقارنة بالوقود الاعتيادي كالبنزين والديزل وايضاً بعض انواع الوقود البديلة مثل الايثانول والغاز الطبيعي وغيرها.

تمت المقارنة في هذا البحث حول استخدام غاز (LPG) كوقود للسيارات بالمقارنة مع الديزل والبنزين ومقارنة الملوثات الناتجة من الغاز مع انواع الوقود الأخرى ومن اهم الملوثات التي تم التركيز عليها هو غاز ثاني اكسيد الكربون (CO2)حيث يعتبر من اهم ملوثات الهواء حاليا والتي يجب التخلص منها ويعتبر غاز(LPG) احد الحلول المستخدمة للتقليل من(CO2) وذلك لأنه يحتوي علي رقم اوكتاني عالي ومركبات هيدروكربونية قليلة .

Abstract :

Liquefied petroleum gas (LPG) is used for cooking, heating, energy generation, and transportation all over the world. Refining crude oil and processing natural gas are the primary sources of it. LPG is made up of variable amounts of light hydrocarbon molecules, primarily propane and butane, depending on the region and source. In its natural condition, LPG is not a greenhouse gas (GHG), and the fumes are not harmful. The low vapor pressure allows it to be stored and transported as a liquid in standard steel containers. It may be carried and kept as a liquid in standard steel containers. Compared to traditional petroleum fuels such as gasoline and diesel, as well as alternative fuels such as ethanol and natural gas, LPG is an attractive transportation fuel. Its superior vaporization properties allow air fuels to mix better than liquid fuels while providing a higher energy density than other alternative fuels. Moreover, compared to regular gasoline, LPG has better octane rating and lower hydrogen-to-carbon ratio, which can improve performance and reduce emissions.

Keywords: Liquid Petroleum Gas, CO2 emissions, greenhouse gas

1. Introduction

Diesel and gasoline are the world's most popular road fuels in a multibillion-dollar fuel market, , but LPG, or automotive gas, is gaining popularity. LPG is a gas that is produced as a by-product of crude oil refining and is used to make gasoline and diesel [B. Stanislav 2001]. In today's transportation industries, diesel and gasoline made from crude petro-oil are widely employed. Biomass can assist to replace these petroleum-based transportation fuels. In gasoline (spark-ignition) engines, ethanol is made from sugarcane and corn, whereas biodiesel is made from vegetable oils like rape seed and utilized in diesel (compression-ignition) engines.

LPG vehicles are rapidly being developed as economical and low-pollution vehicles [H.E. Saleh 2008, D.H. Qi et al 2007]. The potential benefits of using LPG in diesel engines are economic and environmental [Greenhouse Gas Protocol]. Carbon dioxide emissions from road transport are increasing as energy consumption increases, while regulated emissions have been significantly reduced in markets such as the United States, Europe and Japan. However, only industrialized countries can afford modern low-emission transportation technologies, and therefore, increased mobility in developing countries will cause serious environmental problems [Sperling, D et al 2004]. The UK has a legally binding target of reducing greenhouse gas emissions by 12.5% over 1990 levels in 2008-12 as part of the international response following the Kyoto Climate Change Agreement in December 1997, along with a domestic target to reduce UK carbon dioxide emissions to 20% below 1990 levels by 2010. Although transportation is responsible for about 20% of carbon dioxide emissions (the main greenhouse gas), there is no current legislation limiting the amount of carbon dioxide produced by road vehicles. The European Commission's strategy on CO2 from cars aims to reduce CO2 emissions from new cars sold in the European Union to an average of 120 grams per kilometer. This is about a third off from the current average. The strategy, approved by the Cabinet in June 1996, seeks to achieve the goal in large part through a voluntary commitment by European car manufacturers, supplemented by fiscal measures and fuel economy signs to influence consumer demand. In July 1998, the Commission reached a formal agreement with ACEA, the representative of European car manufacturers. To do the following on passenger cars:

- Bring to market individual car models with CO2 emissions of 120 g/km or less by the year 2000;

_ to an indicative median target of 165-170 g/km (mean) in 2003 as a basis for monitoring progress;

_ to reduce CO2 emissions to 140 g/km by 2008 for all its new cars sold in the EU, i.e. a reduction of approximately 25% from current levels;

_ To review the possibility of making additional improvements that year with the goal of moving the average fleet of new cars to 120 g/km by 2012;

_ For ACEA to cooperate with UNHCR in monitoring commitment. Implementation will be jointly monitored by the Commission and ACEA, and the Commission will report to the European Parliament and the Council of Ministers annually. Similar voluntary agreements were agreed (in October 1999) between the commission and Japanese and Korean auto manufacturers that made a commitment to an average passenger vehicle fleet of 140 g/km by 2009 [Sperling, D et al 2004 , Lee, S. Celine et al 2000].

The number of cars produced worldwide in 2008 was expected to reach 71 million. With increasing recognition of climate change issues and the contribution of the transportation industry, improving vehicle fuel economy and emissions are the biggest challenges facing the industry. To help reduce greenhouse gas emissions and achieve the goals of the Kyoto Protocol (the international treaty on global warming, the most notable feature of which is the agreement to reduce carbon dioxide emissions from new passenger cars to 140 grams of carbon dioxide per kilometer by 2008 mainly through vehicle technology), countries that ratify the Protocol are committed to reducing their emissions of carbon dioxide and other greenhouse gases associated with global warming [J. Stans et al 2007, A. Fukuda et al 2007]. In 2007, the European Union adapted a new strategy to reduce CO2 emissions from new cars and trucks sold in the European Union, to not exceed 120 grams of CO2 per kilometer by 2012 for new cars [L. Schipper 2008, Wang M.Q et al 1999].

2. Fuel properties

LPG consists mostly of propane, but depending on the region in which it is produced or destined for sale, as well as the fuel specifications to which it is adhered, its composition and composition can vary. For example, the United States (USA) HD-5 standard for LPG consists of a minimum of 90 percent by volume of propane, a maximum of 2.5 percent by volume of butane and heavy hydrocarbons, and a maximum of 5 percent by volume of propylene [ASTM International, "D1835]. Other regions of the world use higher formulations of butane, for example the butane content of certain countries in Europe ranges from 20 to 30 percent butane depending on the season [M. Farrugia et al 2014], while Korea uses more than 85 percent of butane in LPG in the summer months [Y. Lim and H. J. Kim 2013]. The ratios in which these components are present can have significant effects on the fuel properties of LPG such as energy content, vapor pressure, and octane number.

The composition of LPG also determines its carbon density which is often measured by the hydrogen to carbon (H:C) ratio of the fuel. Propane, the main component of natural gas, contains eight hydrogen atoms and three carbon atoms equivalent to a H:C ratio of about 2.67. The H:C ratio increases for lower order alkanes such as methane (4) and ethane (3) and decreases for higher order alkanes such as butane (2.5). On the other hand, conventional transportation fuels, i.e., gasoline and diesel, usually show an H:C ratio ranging from 1.7 to 1.9 [J. Heywood 1988]. In theory, this results in higher carbon dioxide (CO2) and soot production during combustion.

2.1. Energy content

The energy content of a fuel can be expressed on the basis of mass or on the basis of volume and can be measured through various methods. Table 1 provides the energy content via the low heating value method and the density of several common transportation fuels. Note that on a mass basis, LPG shows one of the highest energy contents (MJ/kg), slightly lower than LNG. However, on a volume basis, LPG has a lower energy content than conventional fuels such as gasoline and diesel. As shown in Table 1, this correlates with lower density of LPG versus these conventional fuels. This requires more fuel on a volume basis to achieve the same production as conventional fuel. LPG shows a small advantage in this regard compared to other alternative fuels, such as LNG and ethanol.

Table 1: Energy Content (Lower Heating Value) and Density of Select Fuels [U.S.A Department of Energy 2015]

Fuel	Density (kg/liter)	Lower Heating value (MJ/liter)	Lower Heating value (MJ/kg)
LPG	0.58	23.7	46.6
Low-Sulfur Gasoline	0.748	31.7	42.4
Low-Sulfur Diesel	0.847	36.1	42.6
Liquefied Natural Gas	0.428	20.8	48.6
Ethanol	0.789	21.3	27.0

2.2. Octane number

Compared to gasoline available at the pump, LPG has a relatively high octane number. Although the octane rating of LPG can vary based on its composition, the HD-5 has an octane rating, a mean search octane number (RON) and an engine octane number (MON), around 105. In the United States, 93 octane (Average gasoline (RON and MON) is the highest octane rating available at gas stations while 87 octane is the most common [U.S.A Department of Energy2017]. Similarly, in the European Union (EU), the most commonly used gasoline is rated at 95 RON, which is approximately 91 octane (average RON and MON) [G. Mellios and C. Kouridis 2015]. In general, as the percentage of higher-order hydrocarbons than propane (eg butane) increases the octane number decreases and vice versa for lower-order hydrocarbons, eg methane and ethane. The higher octane number of LPG compared to gasoline can provide advantages in performance and efficiency. More advanced ignition timing and a higher compression ratio can be used with less pre-ignition or knocking when compared to the gasoline found at most petrol stations.

3. LPG fueling system technology:

There are an assortment of advances to meter LPG for interior ignition motors. These advances range in cost and intricacy, just as effectiveness and emanations execution. By and large, LPG energizing advances have firmly followed those of gas fueled motors. Concerning sparkle lighted motors, port fuel infusion (PFI) and direct infusion (DI) are the most important LPG energizing innovations at the present time.

3.1. Emissions from Petrol Vehicles.

Emissions from petrol cars have been dramatically reduced by the introduction of catalytic converters, which oxidize pollutants such as CO to less harmful gases such as CO_2. When compared to petrol cars without catalysts, catalyst cars have much lower CO, HC and NOx emissions, at the expense of CO_2 emissions, which increase due to the oxidation of carbon monoxide to CO_2. As a consequence of this, a catalyst car will also use slightly more fuel and become less efficient. However, despite these improvements, petrol cars with catalysts still produce more CO and HC than diesel cars, although exhaust emissions of NOx and particulates are much lower than diesel cars. In fact particulate emissions from petrol cars are so low that they are not routinely measured.

3.2 Emissions from Diesel Vehicles

Diesel fuel contains more energy per liter than petrol and coupled with the fact that diesel engines are more efficient than petrol engines, diesel cars are more efficient to run. Diesel fuel contains no lead and emissions of the regulated pollutants (carbon monoxide, hydrocarbons and nitrogen oxides) are lower than those from petrol cars without a catalyst. However, when compared to petrol cars with a catalyst, diesels have higher emissions of NOx and much higher emissions of particulate matter .

While GDI motors can offer more prominent eco-friendliness contrasted with PFI motors, they do have specific downsides. Commonly, GDI motors utilize numerous infusion occasions to stifle motor thump and take into consideration higher pressure proportions. This methodology can bring about a more delineated air and fuel blend contrasted with PFI motors which give a more extended chance to the air and fuel to blend and consequently a more homogeneous combination. This delineated blend comprises of locally rich areas in the ignition chamber which builds the arrangement of particulate matter (PM) and CO. While a TWC can productively oxidize CO, expanded PM emanations stay an issue for GDI motors. The latest EU PM and molecule number (PN) guidelines have brought about specific producers presenting particulate channels for GDI motors. These without a doubt increment the expense and intricacy of vehicles notwithstanding likely decreases in eco-friendliness because of pressed the motor. It is expected that more makers will go with the same pattern, and different districts of the world will take on comparable guidelines making particulate channels for GDI motors ordinary. On the other hand, LPG enjoys an inborn benefit concerning PM arrangement contrasted with fuel in SI DI motors. The higher unpredictability of LPG advances blending inside the burning chamber giving a less separated air and fuel combination decreasing locally rich areas that are related with residue creation. The lower carbon force of LPG contrasted with gas lessens its inclination to deliver ash and cutoff points CO2 creation. Besides, DI of LPG in fluid state keeps up with and can surpass the effectiveness benefits of GDI motors. .

3.3. Dual-Fuel Compression-Ignition

Pressure start (CI) motors, normally alluded to as diesel motors, generally offer preferable efficiency over SI motors. This can be ascribed to higher pressure proportions and the absence of a choke which decreases siphoning misfortunes. Besides, these motors commonly work at a general lean A:F proportion. Nonetheless, this lean A:F proportion requires the utilization of considerably more progressed fumes after treatment frameworks to decrease NOX emanations contrasted with SI motors and TWCs. A common present day diesel motor uses a particular synergist decrease (SCR) framework to lessen NOX which additionally requires diesel fumes liquid (DEF), a urea and water based arrangement, to be continued board the vehicle. Diesel fuel likewise has a lower H:C proportion contrasted with LPG and the DI framework utilized on by far most of current diesel motors brings about locally rich areas that produce essentially more significant levels of PM than SI motors. This expanded PM creation requires the utilization of diesel particulate channels (DPF) to fulfill administrative guidelines for PM. A diesel oxidation impetus (DOC) is for the most part likewise needed to diminish tailpipe emanations of HC and CO to administrative norms and give legitimate fumes conditions to the DPF and SCR framework. In certain occurrences. The utilization of ordinarily SI powers, like fuel and LPG, in flawless structure in CI motors requires trend setting innovation and control, and has not been financially taken on. Be that as it may, high power powers, for example, LPG can be utilized in CI motors by subbing a piece of the diesel fuel with LPG. This innovation is called double fuel. Normally, the LPG or other high power fuel is infused through the admission port and a decreased amount of diesel fuel is infused straightforwardly into the chamber to touch off the LPG. Such a framework takes into consideration the utilization of LPG while holding the eco-friendliness related with traditional diesel motors. The lower carbon force of LPG can likewise assist with diminishing ash from these motors. Lamentably, these motors actually work at a general lean A:F proportion and require the utilization of perplexing present day diesel after treatment frameworks. Moreover, double fuel motors require the vehicle to convey two separate powers which can be dangerous on more modest vehicles where space is at a higher cost than expected and accordingly normally consigns this innovation to substantial vehicles[G. Mellios and C. Kouridis, USA Department of Energy 2009].

4. Transportation Fuels

When examining different fuels used for transportation it is important not only to consider the exhaust emissions produced from combustion of a fuel, but also the production, processing/refining, transportation/delivery, and other sources of emissions in the supply chain.

4.1. Production and Refining of Transportation Fuels

Most of LPG is created from two sources; raw petroleum handling (roughly 40% around the world) and flammable gas creation and preparing (roughly 60% around the world) [World LPG Association 2017]. Every strategy for creation has various rules toxin and ozone depleting substance (GHG) discharges levels which can differ altogether. The portion of LPG created from each source fluctuates all through the world and even among various districts of a solitary nation or mainland. For instance, in the Marcellus Shale area of the U.S.A., LPG is delivered from flammable gas creation and preparing, while in the Inlet of Mexico locale critical amounts of LPG is created from unrefined petroleum refining tasks. The emanations from these exercises can likewise shift dependent on the underlying feedstock and the hardware used to concentrate and deal with gaseous petrol or raw petroleum. Discharges from these exercises are viewed as a piece of the "upstream outflows" concerning the general emanations from the utilization of LPG as a transportation fuel. Likewise remembered for the upstream outflows are those related with the pressure, transportation, and last conveyance of LPG. The blend of this load of upstream outflows is regularly alluded to as the well-to-tank (WTT) discharges. The variety underway techniques, transportation strategies and distance make evaluating WTT emanations troublesome. In any case, there are models that have been fostered that utilization industry information and suppositions to evaluate these emanations for both upstream and downstream exercises related with the transportation area; the Ozone depleting substances, Managed Outflows, and Energy use in Transportation (Welcome) model is one such instrument that has been used by concentrates on referred to in this report [Argonne National Laboratory 2017].

4.2. Crude oil: Gasoline and Diesel

Diesel and gasoline are the two most predominantly utilized transportation fuels in the world. Fossil fuel derived forms of these fuels are produced from crude oil extracted from the earth. Similar to other sources of energy such as natural gas, LPG, and coal, the emissions from crude oil extraction and transportation to the refinery can vary significantly depending on the region and equipment used. For example, some regions in the world import all of their oil from other regions and thus emissions associated with marine tankers, pipelines, railway, or trucking must be considered for an accurate well-to-wheels (WTW) assessment. The refining process for diesel and gasoline is also a major source of WTW energy consumption and emissions production.

4.3. Natural gas: LNG &CNG

The creation and use of petroleum gas has expanded drastically throughout the last decade, especially identified with eccentric recuperation methods like even boring and cracking. The emanations related with these exercises shift with the broadness and extent of their utilization. Like other energy sources, emanations from the conveyance and transportation of petroleum gas can differ essentially dependent on the area and the strategies utilized. Moreover, the essential part of flammable gas, methane (CH_4) is a powerful ozone harming substance itself. With an unnatural weather change potential (GWP) of 28 to 36 over a long term premise (CO_2 is given a GWP of 1), CH_4 outflows from the extraction, preparing, and transportation of flammable gas should likewise be considered for WTT and WTW GHG investigations of gaseous petrol emanations [U.S.A Environmental Protection Agency 2017]. Concerning WTW, and all the more explicitly end use or tank-to-wheels (TTW) emanations in the transportation area, the strategy for capacity and related energy required should likewise be thought of. To accomplish adequate energy thickness for transportation utilize petroleum gas should be packed to high 11 pressures (CNG: roughly 200 to 250 bar) or cryogenically stuck to fluid structure (LNG: around - 160 °C) [U.S.A Department of Energy 2017]. Both of these cycles are energy serious and add to the by and large WTT and WTW outflows .

4.4. Ethanol

As a transportation fuel, ethanol is for the most part blended in with gas for execution and security purposes. In the EU 72.4 percent of all gas sold in 2014 contained up to 5 percent ethanol (E5), while 10% contained up to 10 percent ethanol (E10) [G. Mellios and C. Kouridis2015]. In the U.S.A. E10 is the most well-known mix and is sold for use in all vehicles. E15 (fuel with up to 15 percent ethanol) is additionally accessible in specific spaces of the U.S.A., yet it is just ensured for use in model year 2001 and more current vehicles [Renewable

Fuels Association2017]. Higher centralizations of ethanol for example E85 (gas containing up to 85 percent ethanol) must be utilized in vehicles with reason fabricated fuel frameworks and motor regulators. Ethanol can be created from various substances including sugar stick and corn through refining. WTT or WTW discharges from ethanol got from these inexhaustible plant sources should likewise think about the creation, refining, and transportation of the fuel. Nonetheless, ethanol from plant sources has a huge GHG advantage from photosynthesis that can counterbalance its GHG outflows from cultivating, creation, transportation, and end use.

5.Fuel-cycle emissions from petroleum-based fuels and alternative fuels

As mentioned above, alternative fuels are somewhat “cleaner” than petroleum-based fuels. However, in addition to the direct GHG emissions resulting from the combustion of fuels by vehicles, there are GHG emissions associated with the production and transport of the fuel prior to combustion. Consideration of all GHG emissions in evaluating the attractiveness of different fuels is commonly referred

to as a "full fuel cycle" analysis, which include emission from almost all related process: energy feedstock (or primary energy) production, feedstock transportation and storage, fuel production, fuel transportation, storage and distribution, and vehicle operation that involves fuel combustion or other chemical conversions .There can be major differences between the full fuel cycle emissions associated with two different fuels that produce nearly equivalent emissions based on vehicle fuel consumption. For example, biomass-derived fuels will consume some amount of CO2 during the plant growth, which will to some degree offset GHG emissions resulting from fuel production and use . Another example, having been discussed above, is electric vehicle whose fuel-cycle emission depends on how the electricity is generated Table (2) summarizes the “fuel-cycle” emission from both petroleum-based fuels and alternative fuels. In order to compare and contrast the results of multiple studies with various units, a percent differencing method was used to obtain a percent increase or decrease of emissions from a particular fuel with regards to LPG. This allowed for the data to be normalized for almost all of the studies, however, discrepancies can arise by the percent differencing method used, particularly the denominator used. For all but one of the studies, raw emissions data was extracted and the following equation was used to calculate the percent difference.

$$\text{Percent Difference} = \frac{\text{Emissions}_{\text{lpg}} - \text{Emissions}_{\text{fuel x}}}{(\text{Emissions}_{\text{lpg}} + \text{Emissions}_{\text{fuel x}})/2}$$

Where the difference in emissions from LPG to the fuel being compared to (Fuel X), is normalized by the average of the emissions from both fuels. From this approach a negative percent difference indicates that LPG produced less of that emissions constituent and vice versa. This approach results in a maximum or minimum of 200 and -200 percent difference[Gattikon, 2014].

Environmental Protection Agency (EPA) emissions certification database for cars and engines [U.S.A E P 2017a,b,]. These assets further to the others indexed in Table 2 protected records on diesel, fuel, E10, E85 and CNG fueled vehicles and engines compared to LPG. The records sources originated from multiple areas at some point of the arena and the model years taken into consideration ranged from 2000 to 2017, despite the fact that the general public of the records came from publish 2010 version yr vehicles bought inside the European and U.S.A. Markets. Consequently, the engine, gasoline injection gadget, and exhaust after treatment era was wide ranging many of the facts. Data become extracted from those sources for similarly evaluation and was only blanketed whilst exceedingly direct comparisons can be made for a selected fuel and LPG. For SI fuels consisting of fuel, E10, E85, and CNG, comparisons were made to LPG with the identical or pretty similar displacement engine and similar if no longer the equal automobiles based totally on gross vehicle weight rating and cut back weight. Comparing diesel to LPG is really more complex given that diesel engines utilize CI. For those comparisons, a vehicle that supplied a diesel engine, and LPG engine become used. Even with these constraints on comparisons there had been still several elements that can have an impact on or bias the character comparisons. These are discussed in addition for character fuels [U.S.A E P A 2017].

Table 2: Sources for Regulated Pollutant Data

	from	From alternative fuels, relative to gasoline					
Emissions	gasoli ne	MTB E	Ethan ol	LPG	CNG	M85	Elctronic
GREEN HOUSE GASSES							
Water vabor	Yes	more	more	more	more	more	less
CO2	Yes	less	less	less	less	less	4()

CH4	Yes	Equal	Equal	more	more	Equal	less
N2O	Yes	()[5]	()[5]	()[5]	()[5]	()[5]	()[5]
CO	Yes	less	Equal less	less	less	Equal	less
NOX	Yes	Equal	More Equal	Equal	Equal	Equal	()[5]
None-methane organic compounds							
Methanol	No	more	No	No	No	more	No
Ethanol	No	No	more	No	No	No	No
Formaldehyde	Yes	more	more	Equal	Equal	more	less
Acetaldehyde	Yes	less	Equal	less	Equal	Equal	less
Ethane	Yes	Equal	Equal	Equal	Equal	Equal	less
Total ozone	less	less	less more	less	less	less	less
SO2	Yes	less	less	No	No	less	more
PM	Yes	less	less	less	No	No	more

1-Consumed with the gasoline in which it is blended (e.g., oxygenated gasoline and reformulated gasoline).

2-Includes ethanol in oxygenated gasoline, reformulated gasoline and gasohol, and ethanol as E85.

3-Life-cycle emission from electric vehicles depend on the utility boiler feedstock; these projections assume that feedstock is coal.

4-CO2 emissions vary widely. In some cases, emissions could be either higher or lower than gasoline, depending on the feedstock and method of production.

5-Results are not provided because emissions vary widely, depending on the engine compression, temperature, and fuel/oxygen mix.

6-More for splash-blended gasohol with higher Reid vapor pressure; equal for gasohol with controlled Reid vapor pressure (not splash-blended) and for E85/E100.

7-Methane and ethane are just two of hundreds of volatile organic compounds. Others, such as hydrocarbons from unburned fuel or partial combustion, are not reported here.

8-Ozone precursors include NOx, CO2, and non-methane organic compounds.

9-More if splash-blended gasohol, but less if specially formulated gasohol or E85/E100.

Where the distinction in emissions from LPG to the gas being in comparison to (Fuel X), is normalized with the aid of the average of the emissions from each fuels. From this method a bad percent difference suggests that LPG produced much less of that emissions constituent and vice versa. This method effects in a most or minimum of 200 and -200 percentage distinction, respectively. The handiest facts that changed into now not available in uncooked shape became from the take a look at name “Direct Injection LPG - Opportunity and Threat in Europe” [Atlantic Consulting 2017] in Table 2. Only a percent increase or decrease of gas emissions in comparison to LPG changed into furnished (emissions from a single fuel within the denominator). Additionally, a few resources used zero whilst an emissions constituent changed into no longer mentioned. In instances where a zero became present, a percentage distinction was now not calculated for the emissions constituent and the information become not blanketed within the analysis. From the USA. EPA certification database, there had been now and again a couple of consequences for LPG for a specific automobile or engine. In this example the producer or converter that had OEM guide (e.G. Roush® for Ford® cars, and Power Solutions Inc.® for General Motors® automobiles) become selected because the base to compare to. When this selection wasn’t to be had the best acting LPG car or engine with admire to emissions become selected because the comparator. These elements, as well as the vast variety of automobile model years and technologies created a records set that had a extensive range of percent variations for the general public of the emissions parts. This huge variety can be located in Figure 1.

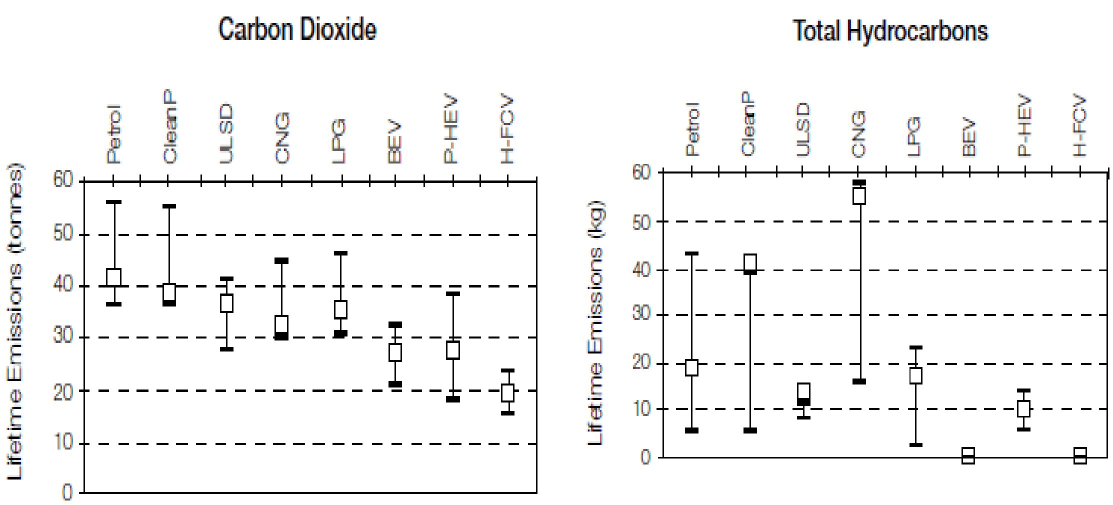

Figure 1: Fuel-cycle emissions from gasoline and and from alternative fuels

The wide ranging variation in the data make it difficult to draw accurate overarching conclusions about the data. For example, the average percent difference of NOX emissions from LPG versus all other fuels was approximately -14 percent, i.e. LPG exhibited lower NOX emissions on average than the average of all other fuels considered. However, the large span of the box and whiskers in Figure 1 demonstrates that there are instances where LPG produces significantly less and more NOX emissions than other fuels. Thus the data should be examined on a fuel-by-fuel basis while considering the level of fuel injection and after treatment technology, as well as the region from which the technology was utilized and the emissions regulations that pertain to it.

6. Greenhouse Gas Emissions

In many regions of the world regulations exist limiting the GHG emissions of engines and vehicles. These GHGs typically include CO2, CH4, and nitrous oxide (N2O). For analysis, GHGs are typically examined on a WTT, TTW, and WTW basis. Additionally, results are commonly presented on a CO2 equivalent basis (CO2e) that includes CH4 and N2O with their respective GWPs.

6.1. Well-to-Tank

Four of the studies reviewed contained citable data regarding the upstream or WTT GHG emissions of LPG as compared to different fuels. Two of the studies, [Propane Education and Research Council, 2009 and 2014], utilized the GREET version to estimate upstream GHG emissions elements for more than one fuels. The consequences from the first study used the GREET model model 1.8c and are displayed by table 3 [Propane Education and Research Council, 2009]. The authors referred to that the default values for the enter parameters of the model have been used apart from uncompressed natural gas. Uncompressed herbal gas was modeled via placing the compression performance to one hundred percent basically getting rid of emissions from compression. However, as it pertains to transportation uncompressed or un-liquefied herbal gas isn't viable as a gasoline because of its very low energy density. It ought to also be stated that the feedstock ratio of LPG became a required enter to the model and the default values of 60 percentage from natural gas processing and forty percentage from crude refining have been used. With the exception of E85, the authors demonstrated that propane (i.E. LPG) produced the lowest WTT GHG emissions of all transportation fuels on a CO2e basis. As discussed in phase 4.4 the WTT CO2 emissions of E85 are offset by means of photosynthesis from the growth of plants used to produce ethanol. On the other hand, the N2O WTT emissions are substantially extra than any other gas.

Table 3: Upstream Emissions Factors (grams per million BTU) Note: LPG is labeled as Propane [Propane Education and Research Council, 2009]

	CO2	CH4	N2O	TOTAL CO2 EQUIVALENT
PROPANE	9,195	115	0.16	12,124
NATURAL GAS*	5,480	239	0.09	11,471
COMPRESSED NATURAL GAS	11,468	247	0.17	17,684
ELECTRICITY	213,067	287	2.81	221,083
GASOLINE	16,812	109	1.14	19,871
DIESEL	15,488	105	0.25	18,175
E85	-10,464	109	30.64	1,385

A comparable study turned into conducted several years later making use of a more modern version of the GREET model (2013) [Propane Education and Research Council, 2014]. Again, default values have been used for the calculation of WTT GHG emissions apart from the compression efficiency of un-compressed herbal gas become set to one hundred percent. The feedstock ratio of LPG changed into additionally adjusted to 70 percent from herbal fuel processing and 30 percent from crude oil refining to reflect the maximum current marketplace proportion data to be had. Although absolutely the figures for WTT CO2e usually extended for all fuels examined, the identical fashion held actual, most of the fuels that can be used for transportation.

Table 4:Upstream Emissions Factors (Grams per million BTU) Note: LPG is labeled as Propane [Propane Education and Research Council, 2014]

	CO2	CH4	N2O	TOTAL CO2 EQUIVALENT
ETHANOL	-14,409	113	41.0	-387
NATURAL	6,995	317	1.34	16,228

GAS				
PROPANE	**12.,867**	**188**	**0.26**	**18,204**
GASOLINE	**16,010**	**118**	**3.95**	**20,368**
COMPRESSED NATURAL GAS	**10,985**	**324**	**1.4**	**20,429**
DIESEL	**18,727**	**118**	**0.31**	**22,104**
FUEL OIL	**18,727**	**118**	**0.31**	**22,104**
ELECTRICITY	**182,897**	**317**	**2.84**	**192,523**

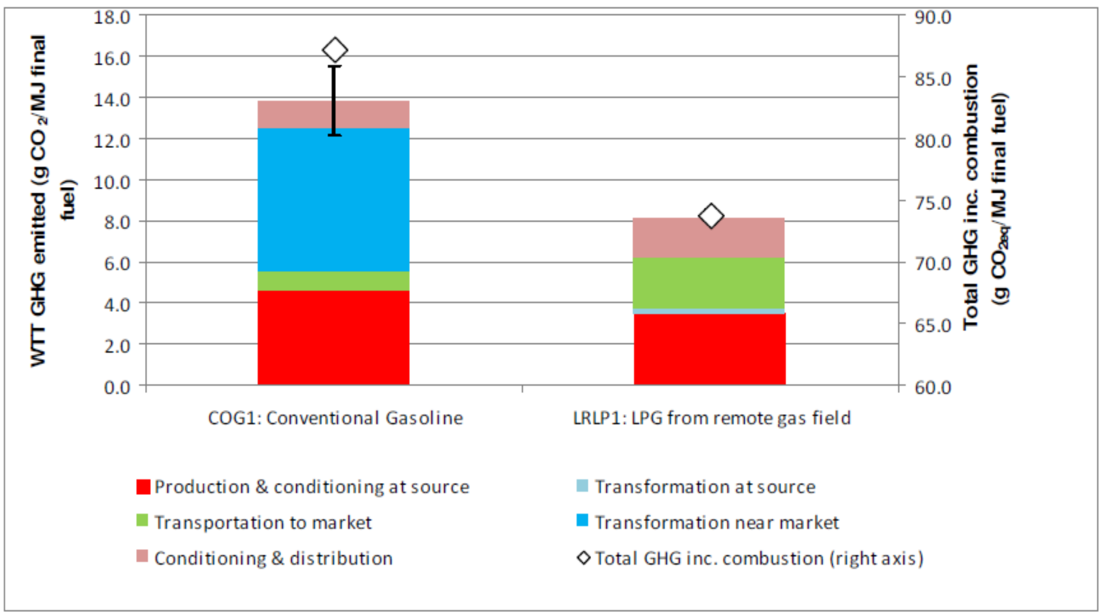

Figure 2: WTT GHG Balance of LPG Pathway [R. Edwards et al 2013]

Another examine commissioned by means of the European Commission, evaluated rules 443/2009 and 510/2011 on CO2 emissions from light-responsibility automobile [G. Gibson et al 2015]. The authors extracted information from

the previously referred to file [R. Edwards et al 2013] to provide a evaluation amongst fuel, diesel, CNG (indexed as natural fuel) produced in the EU, and LPG imported to the EU displayed through Table five. These results agree with others provided, LPG produces much less WTT CO2e emissions than the alternative fuels considered.

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Table 5: WTT Emission Factors [G. Gibson et al 2015]

Fuel	Well-to-tank emission factor (g co2e/MJ)
Petrol	13.8
Diesel	15.4
Natural gas	13.0
LPG	8.0

7. Big savings with low emissions.

Some test results indicate that CO2 emission from LPG vehicles is 13 to 15 percent lower than comparable gasoline vehicles due to the lower carbon-energy ration]. Others have estimated that CO2 emissions are 19or 20 percent lower for LPG vehicles.CO2 and other greenhouse gas emissions from the production and distribution of LPG are among the lowest of all conventional and alternative transportation. By switching to Auto gas you can make a reduced impact on the environment and a big difference to your fuel costs. And because it's cleaner you'll find there are financial benefits to be gained elsewhere) [U.S.A E P A 2017].

- Lower emissions – compared to petrol and diesel, Auto gas produces far less emissions and has less of an impact on the environment, (Environmental benefits) .

Compared to petrol

75% less Carbon monoxide.

85% less Hydrocarbons.

40% less Oxides of nitrogen.

87% less Ozone

10% less Carbon dioxide.

Compared to diesel

90% less Carbon monoxide.

90% less particulates, hydrocarbons

50% less Oxides of nitrogen

60% less Ozone.

- Compared with petrol and diesel, LPG is the best environmental alternative
- Reduction in fuel costs - Auto gas is approximately half the cost of petrol and diesel resulting in annual savings of around 40%
- Vehicles running on LPG have quieter engines. engine noise is low.
- There are further benefits such as lower road tax.
- Engine wear is reduced when running on LPG.
- Service intervals for LPG cars are increased due to lack of carbon buildup.
- Due to LPG car's reduced running cost, LPG cars sell at a premium. also due to our warranty being transferable selling your LPG vehicle will be easier.

7.1. LPG saving money, saving the environment.

Environmental initiatives are often costly or time consuming. One of the main problems that the environment is facing is over use of cars, and the carbon dioxide that they produce, not to mention the other chemicals that are released into the atmosphere when burning petrol or diesel. What is needed is a fuel that is not only better for the environment than these other fuels, but also is not expensive to use, Such as LPG. We all know that cars are not good for the environment, but we still need to go places. This is why LPG is such a great option, not only does is it better for the earth, but it is better for the pocket . LPG vehicle users can save around 40% on fuel costs compared with petrol, and over 20% compared with the equivalent diesel. A typical example of a popular car is the 2005 Vauxhall Vectra for which the table is:

Table (6) Fuel comparative Analysis [Brussels2017]

Fuel Type	Model details	Euro Emission Level	MPG	Fuel Price	Cost per 1000 miles
LPG	122ps 1.8i 5 speed saloon	IV	29.4	£2.64 per gal 58.1p per liter	£89.79
Diesel	120ps	IV	49.5	£5.95 per	£120.20

	1.9cdti 6 speed saloon			gal 131.0p per liter	
Petrol	122ps 1.8i 5 speed saloon	IV	38.6	£5.34 per gal 117.5 p per liter	£138.34

Another way of looking at the massive savings by running on LPG auto gas is by comparing the number of miles travelled for £10 for each fuel . The table (6) for the above example show:

8. Conclusions :

The results presented in this document highlight the benefits of LPG compared to conventional and other alternative transportation fuels. The emissions benefits of LPG advocate for its utilization and its advantageous application to modern technologies such as DI further that case. Compared to gasoline powered vehicles, LPG has demonstrated an ability to produce similar NOX, CO, and THC emissions with lower levels of PM, PN, and CO2 emissions. With respect to GHGs, the utilization of LPG compared to gasoline produces significantly lower CO2e emissions on a WTW basis. Evidence also suggests that the application of LPG to modern DI technology can improve the shortcomings of GDI such as increased PM and PN while delivering improved BTE. While LPG prices are rising as a result of the overall increase in the cost of crude oil, it continues to be a popular alternative fuel choice. For fleet owners, the ability to operate their own filling stations removes one of the primary barriers to LPG adoption. With respect to consumers, the proliferation of bi-fuel vehicles ensures that it is unlikely they will be left stranded in the event that they cannot find a propane filling station. These factors contribute to a strong trend towards LPG adoption, and in some parts of the world, such as Europe and Australia, up to 30% of vehicles have already converted to LPG . The most common motivation for vehicle operators introducing LPG are, in order of importance; costs, local air quality, PM10, NOx, noise and CO2. Costs are the main decision factor for all commercial, fleet operators and local authorities. Although these groups have an objective to reduce the environmental impacts of transport, the solutions must be ‘green’ at the lowest cost in preference to diesel and petrol. The LPGA estimate that the market for LP Gas powered vehicles could grow from 7,000 at the start of 1999 to over 250,000 vehicles in 5 years time. In consumption terms, this will relate to increasing from around 3,000 tonnes to 300,000 tonnes of LP Gas over the same period. To start significant growth in this new market, the LPGV fleet must be increased by around 1,000 vehicles within the next year. This requires considerable commitment from all parties involved in developing LPG as a viable clean fuel. The most significant growth sector for LPG vehicles is predicted to be car and LGV in urban areas with fleet users being predominant over private users. The LPGA does not see a significant increase in the bus market until fiscal measures make this a more economical option .

There are estimated to be over a billion vehicles in the world today. Over nine million of these use LPG as of 2005 (see table below) and the number is growing at a rate of 12-15% per year. Globally, 8.1% of LPG produced is used as fuel for transport. 90% of Japans taxis run on LPG, 20-30% of all Armenian vehicles use the fuel. Many countries throughout Europe have a significant number of LPG drivers. The world's largest user of LPG is South Korea which has 1.7 million LPG cars on the road . Examining the global market is the best way to answer the critic who queries whether LPG will really ever take off - it has already spectacularly done so

Considering not only the tailpipe emissions of LPG, but also the WTW GHG emissions, the argument for LPG as a transportation fuel is strong. LPG offers a viable pathway to reduce regulated and GHG emissions compared to conventional fuels, while offering a less costly option and lower environmental impact compared to other popular alternative fuels.

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