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Examining the Variability in the Carbon Factor of Petrol for Road Use

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Executive Summary

Introduction

It is estimated that carbon dioxide emissions associated with the combustion of fuels accounted for circa 80% of the total UK greenhouse gas (GHG) budget in 2015. Given that approximately 40% of those emissions were calculated using carbon emissions factors (CEFs) originating from sources of data from between 1989-1994, ensuring the validity of such data is integral to the accuracy of the UK greenhouse gas emissions inventory (UK GHGI). In 2016, the Department for Business, Energy & Industrial Strategy (BEIS) commissioned a study to assess the current CEFs used for fuels within the UK GHGI and to identify those which required updating.

This report presents the results of a discrete study, designed to examine factors that could affect the variability in the CEF of petrol for road use within the UK. It is the intention that the results of this study can be used to inform what further work, if any, is required to improve confidence in the CEF used for petrol within the UK GHGI.

Study Scope

To investigate the validity of the CEF for petrol within the UK GHGI, a desk-based study was designed to generate a baseline of data relating to:

- The frequency in which petrol blends vary and the key market and environmental drivers
- Typical annual variances in petrol blend composition
- The impact of the addition of single and packages of additives and blending agents on petrol carbon factors
- Realistic and robust amendments that could be made, if applicable, to petrol carbon factors reflective of the operation and constraints of the UK GHGI.

This report makes use of industry and academic sources of information.

Results and Conclusions

The dose rates of the various petrol additives range from a few mg/kg to 1,000 mg/kg for individual additives and can be as much as 2,000 - 3,500 mg/kg for additive packs. Discussions with additive manufacturers suggests that there is no seasonal variability in the use of additives in petrol, and that the CEF of the additive is similar to that of the fuel. Given that the quantities being used are low, it has been concluded that additives will not have a direct effect on the CEF for petrol. No seasonal variation in fuel additive dose rates have been identified.

Seasonal variability in the composition of petrol does occur as a result of the requirements in BS EN228. This standard requires the vapour pressure of the fuel to be maintained between prescribed values that vary between summer and winter. While there is generally a description of 'winter petrol' and 'summer petrol', in reality there are intermediary blends such that there can be a steady transition between different fuel blends across seasons. This variability in fuel composition is managed by the injection of a high volatility hydrocarbon, usually butane, into the fuel. The variability in the CEF of petrol as a direct result of seasonal variations in petrol composition is captured by the UK GHGI.

This study has also identified that the composition of petrol may have changed in response to legislation that has been introduced to limit the emission of pollutants. As refineries have continued to evolve in response to increasingly tight controls on emissions, it is conceivable that the composition of the finished fuel may have changed since the CEF was developed in 1994.

Recommendations

It is recommended that the CEF for petrol should be reviewed.

1 Introduction

It is estimated that carbon dioxide emissions associated with the combustion of fuels accounted for circa 80% of the total UK greenhouse gas (GHG) budget in 2015 (Brown *et*. *al*., 2017a). Given that approximately 40% of those emissions were calculated using carbon emissions factors (CEFs) originating from sources of data from between 1989-1994, ensuring the validity of such data is integral to the accuracy of the UK greenhouse gas emissions inventory (UK GHGI).

In 2016, the Department for Business, Energy & Industrial Strategy (BEIS) commissioned a study to assess the current CEFs used for fuels within the UK GHGI and to identify those which required updating.

The study served to identify (based upon relative contribution to the UK GHG budget and the likely variability in fuel composition - temporally, seasonally and by intended end-use) that the high priority CEFs for fuels that required further investigation were petrol, liquid petroleum gas (LPG), petroleum coke, other industry energy use coal and domestic coal (Brown *et*. *al*. 2017b).

This report presents the results of a discrete study designed to examine factors that could affect the variability in CEFs of petrol for road use within the UK. It is the intention that the results of this study can be used to inform what work, if any, is required to improve confidence in the CEF for petrol that is used in the UK GHGI. The UK GHGI is used to produce annual carbon dioxide emissions data that are submitted to Parliament (under the Climate Change Act of 2008), the European Union and to the United Nations (under the United Nations Framework Convention on Climate Change and the Kyoto Protocol).

1.1 Methodology

To investigate the validity of currently used CEFs for petrol within the UK GHGI, a desk-based study was designed to generate a baseline of data relating to:

- The frequency in which petrol blends vary and the key market and environmental drivers
- Typical annual variances in petrol blend composition
- The impact of the addition of single and packages of additives and blending agents on petrol carbon factors
- Realistic and robust amendments that could be made, if applicable, to petrol carbon factors reflective of the operation and constraints of the UK GHGI

2 Physical and Chemical Properties of Petrol

Petrol is a complex mixture of over 500 hydrocarbons that may have between 5 to 12 carbon atoms. It is usually produced by the fractional distillation of crude oil, which yields approximately 25 – 35% "straight-run gasoline"[1] from each barrel of crude oil but this is often increased by converting higher or lower boiling point fractions into hydrocarbons in the gasoline range (Energy Policy Research Foundation, 2009).

Although the exact formula of petrol varies, it is close to C_8 H_{14} with a molecular weight close to 110 g/mol. Also, because the composition of petrol can be variable, so can its net calorific value (NCV) but it is usually close to 41 - 43 MJ/kg (32 MJ/litre) (https://www.engineeringtoolbox.com). Petrol is hydrophobic and does not absorb moisture from the air, but condensation can occur on the inside of tank surfaces, etc. leading to droplets and globules, of water over which the petrol floats. While petrol is immiscible with water it can form emulsions that cause hazing of the product and requires treatment. Because petrol is a mixture of many different compounds it has no single boiling point. Instead, the lighter fractions start boiling out at about 35°C, with the heaviest fractions boiling off between 250 – 300°C (https://assets.publishing.service.gov.uk) (Table 1).

Table 1 Typical fuel property values for petrol

Fuel Property	Typical Values
Molecular Weight (kg/kmol)	111
Density (kg/l) at 15°C	0.75
Oxygen content (wt-%)	N/A
Net Calorific Value (MJ/kg)	43
Net Calorific Value (MJ/l)	32
Octane number (RON)	97
Boiling temperature (ºC)	30-190
Reid Vapour Pressure (kPa) at 15ºC	75

3 Fuel Additives and Blending Agents

Fuel additives have been developed to overcome operational problems with respect to the production, storage and distribution of fuels, and to enhance their features while helping to reduce the impact of road vehicle emissions on health and the wider environment. Developments in this sector are driven

[1] Straight run gasoline is used for blending into petrol. It is produced straight from the distillation column and comprises a mixture of hydrocarbons, including alkylate, reformate, benzene, toluene, xylene and others.

by the need to improve refinery efficiencies, environmental concerns, original equipment manufacturers' (OEM) requirements and technology advancements in the fuel additive manufacturing industry itself.

Fuel additives for petrol have been used almost as long as people have been driving vehicles. Their addition to petrol enhances the efficiency and performance of engine technology as well as supporting developments in refinery operation. For example, lead alkyl anti-knock compounds were introduced commercially to petrol in 1923 to enhance the octane rating of fuel to the level needed to elevate the compression rating of engines to improve performance, and antioxidants were introduced in the 1930s to counteract the impact of cracking agents on the oxidation of engine components (ATC, 2013). Similarly, the phasing out of lead alkyl compounds in the 1990s led to the development of additives to protect against unwanted exhaust seal wear in older engines. As such, fuel additives are commonly used by the petrochemical industry across the supply chain from the refinery through to the petrol pump. Additives may be used as single stand-alone products, for example antistatic agents in a refinery, or combinations of additives may be used as multifunctional packages as performance enhancers for use in finished fuels. Dosing levels of single additives into fuel are typically low, whilst multifunctional additives may be dosed at concentrations of up to 3500 mg/kg. Typical types of fuel additives commonly found in petrol are presented in Table 2 and are discussed in Appendix 1.

Table 2 - Fuel Additives in Petrol for Road Use

Refinery Product	Storage and Distribution	Automotive Performance
Antioxidant and Stability Improver	Corrosion Inhibitors	Deposit Control
Octane Boosters	Pipeline Drag Reducing Agents	Corrosion Inhibitor
Cold Flow Improvers	Antistatic Agents	Demulsifier Additive
Metal Deactivators		

4 Impact of Fuel Additives and Blending Agents on CEFs for Petrol

The carbon emission factor for the UK GHGI is calculated using data sources dating from 1989-1994 (Brown *et*. *al*., 2017b). However, petrol blends can change, with changes in composition over the past few decades driven by legislative requirements (Table 3), improved refinery efficiencies and OEM developments. Given that petrol fuelled vehicles account for >35% of the UK's transport fleet (DECC 2014), and this is likely to increase in the coming decades as diesel cars are phased out, the accuracy of the CEF for petrol is integral to providing confidence in the UK GHGI with respect to carbon dioxide emissions associated with transportation.

Table 3 Example of changes in the quality of petrol at UK pumps

Higher RON requirements results in loss of 2-Star petrol from the market in 1989-1990
Ban on lead additives in 1998
Progressive increase in the use of very volatile components in the fuel blend
Increase in the use of ethanol in petrol: initially at 5% volume, but with the expectation that 10% volume will soon be readily available (and possibly higher levels in the blend in the future.
Amendments to Directive 98/70/EC requiring member states to move to sulphur-free petrol and diesel (10ppm or less) by 2009.

4.1 Seasonality Considerations

The UK has a moderate climate and temperature variations between summer and winter are relatively small when compared with continental Europe. As a result, the need for additives to counteract the effects of changes in the physical environment on the properties of petrol is low, with changes in the Reid Vapour Pressure (RVP) to meet the requirements of BS EN 228 being the primary driver of seasonal differences in fuel composition.

While winter and summer minimum and maximum values for RVP are specified within BS EN 228:2012, the range of values is sufficiently broad such that the transition from 'summer petrol' to 'winter petrol' can be managed using intermediate blends. The triggers that signal the transition from one blend to another have not been clearly identified and in some cases are driven by customer requirements. However, the following provides a simplification for the transition dates:

- Summer: 1st June – 31st August;
- Winter: 16th October – 15th April
- Intermediate: 16th April – 31st May and 1st September – 15th October.

When considering carbon emission factors for fuel combustion only, butane has a lower emission factor than petrol and, depending on its use in the petrol blend, could influence the total quantity of carbon emitted from the use of petrol. While the seasonality of petrol blends is accounted for in the UK GHGI, with the seasonal effects averaged across a year for reporting purposes, improvements in refinery efficiency over the last few decades for 'better use of the barrel' has produced a more refined product with improved RVP. As a direct result of this, together with improvements in engine technology, there is potential for the effect of seasonality to be overestimated as the volume of butane added during the cooler months to enhance the RVP of the fuel may not be as great as assumed in order to comply with the fuel standard. Furthermore, while outside of the scope of this work, warmer ambient winter temperatures as a direct result of climate change should also be a consideration for future scenarios.

4.2 Fuel Blends

Fuel refineries have faced significant challenges in recent years to produce a petrol blend that is compliant with the everchanging legislation. The switch from leaded to unleaded petrol, the reduction of sulphur levels in diesel and petrol, and more recently, the increased use of biofuels in petrol and diesel have all required considerable investment in new plant for refineries and upgrades to existing refinery units. Such changes in the fuel manufacturing landscape have necessitated novel approaches to improve efficiency, and as fuels continue to evolve in response to increasingly tight environmental legislation, this is resulting in a reduction in the variability of component chemicals used within the final blend. Given that there is potential for some significant changes in fuel composition since the CEF for petrol was derived, the CEF should be reviewed regardless of the impact of additives.

In considering the effect that ethanol has on vehicle performance it is important to consider the energy content of the two components. Petrol has a typical net calorific value (NCV) of 43 MJ/kg, whilst the NCV of ethanol is 26 MJ/kg (>60% lower). Because ethanol yields less energy than petrol, more fuel is required for ethanol-petrol blends to do an equivalent amount of work compared to using petrol alone. Furthermore, the change in fuel chemistry and physical properties means that ethanol blends can negatively affect fuel management systems and, because ethanol is hygroscopic, it will readily absorb water and lead to higher rates of corrosion if incorrectly managed and will likely require greater quantities or more efficient moisture control additives and demulsifiers. On the plus side, ethanol has a much greater octane number than petrol (109 RON compared to 95 RON) and the need for additives to boost the fuel octane number is reduced in petrol-ethanol blends. Furthermore, when considering vehicle emissions, there is a complex interaction between fuel ethanol content and pollutant concentration at the exhaust, with researchers generally reporting a decrease in the emission of CO_2 and regulated pollutants for ethanol-petrol blends (e.g. Srinivasan and Saravanan, 2013), while others have reported an increase in pollutant emissions under specific conditions (Masum et al., 2013).

However, many of these studies are short-term and do not consider the increased corrosivity of ethanol fuel blends, which unmanaged can damage fuel delivery components (Jafari et al., 2010) and reduce fuel efficiency. Such arguments regarding the corrosivity of ethanol fuel blends in petrol engines are being addressed by additive manufacturers and packages specific to the use of ethanol blends are undergoing continuous development to ensure that the additives have no adverse impacts on engine performance. How these new additives will affect the CEF is currently unclear.

4.3 Fuel Additives

Fuel additives have been used in petrol vehicles for nearly as long as vehicles have been used. The benefits that modern additives impart are wide ranging, but regardless of the problem being targeted, the net effect is one of improved fuel efficiency and enhanced engine functionality and performance, resulting in improved mechanical reliability and lower carbon emissions per kilometre travelled. When considering an additive being used from the start of a vehicle's life, the effect on efficiency is one of loss avoided and benefits may be difficult to establish without direct comparison with a vehicle that has not been treated with the additive. Alternatively, tests treating in-service vehicles with specific packages of additives can be used to measure the benefits accrued when using performance enhancing additives by measuring the improvement in the vehicle's performance. However, the measured benefits will also be a function of the test vehicle's history and results of tests may range from insignificant to measurable.

For a full suite of additives such as those described in Table 4, the highest dosing rates would result in the addition of approximately 2500 mg/kg of fuel (or 0.25%). When considering such small additions, the carbon factor for these additives would need to be significantly greater than that of the fuel in order that a measurable difference outside of the inherent uncertainty in the original value of the CEF could be stated. Nevertheless, what seems like small imperceptible changes may become significant on a national level. This argument is also true for any changes that may occur in the composition of petrol. The CEF for petrol that is used in the National Atmospheric Emissions Inventory has been calculated using data sources from 1989-1994. Since then there have been numerous changes in OEM requirements and improvements in refinery efficiencies. These changes have been driven primarily by changes in environmental legislation and may have altered what was once a standard blend of chemicals to produce petrol. Given that petrol is a blend of many different hydrocarbons, it is unclear if the pressures on the refinery to produce a cleaner petrol and to get better returns per barrel could have altered the ‘basic’ petrol blend. Furthermore, updating the CEF for petrol to take account of the effect that fuel additives may have on emissions of CO_2, could lead to double-counting impacts without first understanding what additives were being used historically in the basic petrol blend.

Table 4 Typical additive treat rates in petrol (ATC, 2013)

Class of Additive	Typical Treat Rates (mg/kg)
Deposit Control Additives	100-1000*
Fluidiser/Carrier Oils	
Friction Modifiers	50-300
Corrosion Inhibitors	5-100
Antioxidants	8-100
Conductivity Improvers	1-40
Metal Deactivators	4-12
Markers & Dyes	2-50
Demulsifiers/Dehazers/Emulsion Preventatives	10-500
Copper/Silver Corrosion	2-20
Octane Boosters	8-150
Anti-Valve Seat Recession	100-200
Total	**290-2472**

5 Recommendations

There have been significant changes in the regulation of pollutants over the past three decades that have resulted in the development of cleaner fuels. We recommend further dialogue with fuel refineries to understand if the blend of chemicals that makes up petrol has changed since the development of the CEF.

Given that the CEF for petrol was derived before BS EN 228 was published, we recommend a sampling strategy across all UK refineries to confirm the CEF for 100% mineral petrol. The sampling strategy should also confirm the effect of 5% and 10% ethanol on the CEF and should be carried out across all seasons to confirm the applicability of the current methodology for quantifying the effect of seasonal management of fuel vapour pressure. While our discussions with additive manufacturers suggests that the CEF of the fuel additives is similar to that of carrier petrol or slightly heavier fuels, we would recommend that this is verified using empirical data.

6 Acknowledgements

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Appendix 1 Fuel Additives

A1 Fuel Additives

A1.1 Octane Boosters

Octane requirements for petrol engines vary with engine type. If the fuel octane is too low for a given compression ratio, the fuel may prematurely and spontaneously ignite early and result in incomplete combustion. The net effect is a loss in power, increased engine wear/damage and an audible 'knock'. The octane number of petrol is a measure of its resistance to engine knock.

As more petrol engines were produced for automotive use in the 1920s, it rapidly became apparent that the low octane rating of straight run light distillate for use with spark-ignition engines presented a significant barrier to technology development. To help overcome the issue of engine knock, octane boosters were added to fuels to promote greater engine efficiencies and reduce damage. Anti-knock additives tend to be organometallic compounds such as tetraethyl lead (no longer used in road fuel in the UK due to public health concerns), ferrocene and methylcyclopentadienyl manganese tricarbonyl (MMT).

Straight-run gasoline has a Research Octane Number (RON) of approximately 70, too low for modern vehicles. Cracking, isomerization, and other refining processes are used to improve the octane rating of the raw fuel, and anti-knock additives are used to further increase the octane rating. The typical RON for petrol use in modern spark ignition engines is in the range of 90 to 98 RON. In Europe, the minimum requirement is 95 RON and, in the UK, petrol is typically sold at the pump as 95 RON (minimum permissible rating) and 97 RON. While there is a minimum RON defined in the relevant fuel standards, enhancements beyond this are driven by OEM requirements and by a fuel storage depot's customer's requirement for speciality forecourt blends. Octane boosters are typically used at concentrations up to 150 mg/l of active metal and there is no seasonality in their use.

In recent years, the reconfiguration of modern refineries and improvements in their efficiencies have resulted in the production of naturally high-octane components within modern gasoline. This has inevitably resulted in a reduction in the quantity of octane booster being added to petrol. This trend may continue as the chemistry of petrol evolves to keep pace with increasingly tight legislation (for example sulphur reduction) while commercial drivers will continue to encourage refinery efficiencies to make better use of the raw materials.

A1.2 Reid Vapour Pressure

The volatility of petrol must be high enough to ensure efficient engine operation across a range of environmental conditions (during start-up, warm-up and acceleration, while providing the correct throttle response under normal conditions). Conversely, if the volatility is too high, this can result in vapour lock, excessive evaporation losses, adverse impacts on local air quality and safety issues during storage and handling.

CSN EN 228:2012 defines 10 volatility classes to meet hot and cold vehicle driveability requirements under European seasonal and geographical conditions. Each country is expected to specify which of these volatility classes apply during different periods of the year for defined regions of the country. This requirement has been transposed into BS EN 228:2012 which specifies a summer minimum and maximum RVP of 45 - 70 kPa and winter minimum and maximum RVP of 70 - 100 kPa. This is normally managed at the refinery by the addition of butane to the refinery stock blend. Butane is typically used to manage the RVP within the requirements of BS EN 228 as it has a high vapour pressure, is readily available, is cost effective and meets OEM requirements for "no harmful in-service effects".

A1.3 Deposit Control Additives and Fluidisers

Deposit Control Additives, often referred to as detergents, are designed to reduce the formation and accumulation of deposits in the entire engine fuel system. They limit the formation of deposits that may develop on fuel injection components, in the fuel intake system, and on combustion chamber components. These deposits can limit the flow of fuel and air and alter the way fuel is introduced to the combustion chamber. The resulting reduction in performance and engine efficiency ultimately increases carbon emissions and can increase the concentration of other pollutants (Xin Yue *et al.*, 2011).

Deposit Control Additives are usually combined with other fuel additives to form a package of treatments. Fluidisers are typically used in combination with Deposit Control Additives to reduce the formation of sticky deposits around engine valves that can compromise engine start-up, particularly in cold weather. Deposit Control Additives and Fluidisers are one of the largest contributors to the fuel additive package and usually have a combined additive contribution of 100 - 1000 mg/kg. The precise treat rate for the combined deposit control package is subject to the fuel storage depot's customer requirements. However, continuous advances in fuel additive technology has meant that over recent years treat rates have been reducing by as much as 60% (*Pers*. *Comm*. Innospec, 2018). There is no seasonality in the use of Deposit Control Additives.

A1.4 Friction Modifiers

Friction Modifiers typically have a water-soluble polar head and hydrophobic tail. The water-soluble end of the molecule attaches to metal surfaces and provides a sacrificial liquid to minimize friction between the cylinder wall and piston rings. The interface between the piston ring and the cylinder wall represents the greatest parasitic load for an engine. By reducing wear, Friction Modifiers can improve the efficiency of the engine, which improves power and fuel economy and helps to promote a longer engine life (Bennett, 2017). Although Friction Modifiers are key additive components, they are only present in small quantities. Typical Friction Modifier treat rates are in the range of 50 - 300 mg/kg. There is no seasonality in the use of Friction Modifiers.

A1.5 Anti-Corrosion Additives

A1.5.1 Moisture control

Moisture can become associated with petrol from a variety of sources and when it enters the extreme engine environment it can generate a corrosive atmosphere that has serious implications for complex instruments used in the fuel management system, as well as degrading the surfaces of ferrous and non-ferrous engine components. Furthermore, moisture in the fuel storage system can lead to rust, which can block filters and reduce the efficiency of the fuel transfer system. Minimising the effects of moisture is therefore extremely important to ensure the efficient running of an engine and helps to promote a longer engine life.

Anti-corrosion additives can be blended in the fuel at any point between the refinery and the fuel storage depot and can also be added as part of a package of additives. Typical treat rates for anti-corrosion additives is between a few milligrams to 100 mg/kg.

A1.5.2 Non-Ferrous Metal Corrosion Inhibitors

Non-ferrous Metal Corrosion Inhibitors are usually added at the refinery at dose rates of a few milligrams to 20 mg/kg but can be used as part of a package of additives. They are used to minimise the corrosive effect of even low levels of contaminants in the fuel that can have a harmful effect on electronic sensors. There is no seasonality in the use of Anti-Corrosion Additives

A1.6 Antioxidants and Metal Deactivators

Antioxidants are used to stabilise the chemistry of petrol and increase the length of time it can be stored. As petrol oxidises it can produce gums and sediments that interfere with the efficient operation of an engine.

Metal salts naturally present in petrol can catalyse the formation of gums and other deposits and promote instability, even at very low concentrations. The metal deactivators inhibit the action of the metal salts and help to maintain the fuel's stability.

Antioxidants are typically used at treat rates of few milligrams to 100 mg/kg, whereas Metal Deactivators are typically dosed at 4 - 12 mg/kg. There is no seasonality in the use of Antioxidants or Metal Deactivators.

A1.7 Anti-Static Additives

As fuel is moved through pipelines a static charge may develop, bringing with it obvious safety implications. To minimise static electricity charges as fuel is moved between the refinery and the vehicle fuel tank, Antistatic Additives are dosed at very low quantities from a few milligrams to 40 mg/kg. There is no seasonality in the use of Anti-Static Additives.

A1.8 Demulsifiers and Emulsion Preventatives

Demulsifiers and Emulsion Preventatives are used at any point between the refinery and fuel storage depot and can be added as part of a package of additives to meet the fuel storage depot's client's specifications. When petrol is contaminated with moisture, emulsions can form that can lead to blocked fuel lines and filters and promote excessive corrosion. This class of additive works at the fuel-water interface and prevents the formation of emulsions. They can also be added to break down emulsions and hazes. Demulsifiers and Emulsion Preventatives are usually added as part of a package of additives at a dose rate of a few milligrams but can be added as stand-alone additives at dose rates approaching 500 mg/kg to manage existing water contamination. There is no seasonality in the use of Demulsifiers and Emulsion Preventatives.

A2 Blending Agents

A2.1 Petrol-Ethanol Fuel Blends

The Fuel Quality Directive (FQD) (2009/30/EC) sets standards for transport fuels and requires that fuel suppliers meet a 6% reduction in greenhouse gas emissions by 2020, relative to 2010 baseline levels, across all fuel categories. According to the FQD, ethanol can be blended into petrol up to a limit of 10% by volume. BS EN 228 initially permitted blending ethanol up to a limit of 5% v/v. At this level there is no issue with compatibility with car fuel systems. However, the level of ethanol permitted has increased to 10%, and at these higher concentrations there are potential compatibility issues with the fuel system components of older engine technologies. This has necessitated the clear labelling of the fuel type at the pump for fuel blends with greater than 5% ethanol. Fuel additives therefore need to be validated or optimised for these variations in fuel composition. Furthermore, for engines that have been modified or designed for use with higher biofuel blends, a different additive package chemistry may be required.

A2.2 Other Fuel Blends

As well as butane, other hydrocarbon-based blending agents, namely alcohols, ethers and alkanes, are used by the refinery to enable petrol to meet the required quality specification. Refinery blending agents are typically used at levels between 1% and 15% and are blended when manufacturing in-spec petrol from straight run fuel. Further work is required to understand how the composition of petrol varies.

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