LowCVP
Low Carbon Vehicle Partnership

cenex

The Renewable Fuels Guide

Helping fleet operators cut carbon emissions

Acknowledgements

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LowCVP
Low Carbon Vehicle Partnership

The LowCVP, which was established in 2003, is a public-private partnership working to accelerate a sustainable shift to lower carbon vehicles and fuels and create opportunities for UK business. Around 200 organisations are engaged from diverse backgrounds including automotive and fuel supply chains, vehicle users, academics, environment groups and others. LowCVP members have the opportunity to:

- Connect : With privileged access to information, you'll gain insight into low carbon vehicle policy development and into the policy process.
- Collaborate : You'll benefit from many opportunities to work – and network - with key UK and EU government, industry, NGO and other stakeholders.
- Influence : You'll be able to initiate proposals and help to shape future low carbon vehicle policy, programmes and regulations.

cenex

Cenex was established in 2005 as the UK's first Centre of Excellence for Low Carbon and Fuel Cell technologies. Today Cenex operates as an independent not-for-profit consultancy specialising in the delivery of projects, supporting innovation and market development, focused on low carbon vehicles and associated energy infrastructure.

CNG FUELS

CNG Fuels develops, owns, and operates CNG Refuelling infrastructure and sources 100% Renewable Biomethane or Bio-CNG for its stations.

We are rolling out a UK wide network of reliable and convenient refuelling facilities to service customer's vehicle fleets and their off-grid energy needs.

Our Bio-CNG is biomethane 100% sourced from food waste, independently verified and approved by the Department for Transport's Renewable Transport Fuel Obligation (RTFO).

SCANIA

Scania are a major manufacturer of commercial vehicles, specifically heavy trucks and buses. We have a long experience of operating on all of today's major biofuels – bioethanol, biodiesel and biogas.

Scania works in partnership with governments, organisations, universities and other stakeholders to combine our vision and competence in commerce and transport. We take into account the specific transport assignment, flows of goods and people, customer needs, and the local infrastructure.

By supporting this guide we aim to play a definitive role in the growth of renewable fuel use. Along with improved efficiency, sustainably produced renewable fuels are a key part of Scania's approach to Driving the Shift and achieving fossil free transport.

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Introduction

The Renewable Fuels Guide aims to give fleet operators an overview of the range of low carbon and sustainable fuels currently available in the UK, with a focus on high blend biofuels for use in commercial vehicles. The guide demonstrates the business and environmental case for adopting high blend biofuels, and features a series of fleet operator case studies.

The requirement for renewable transport fuels

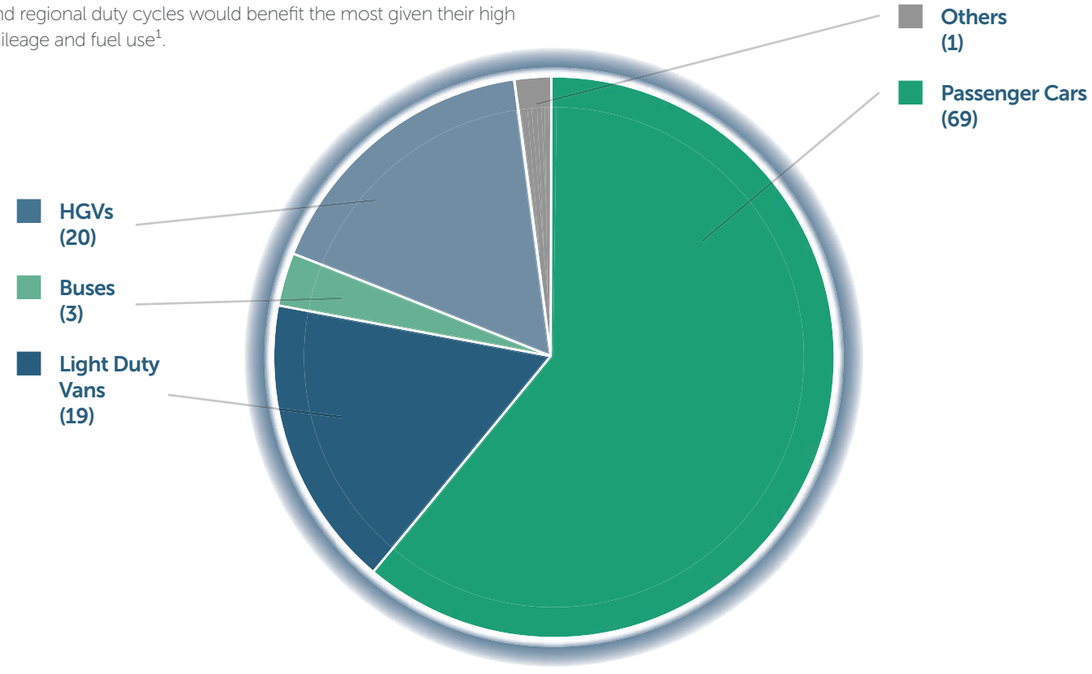
Climate change is the most pressing environmental challenge facing our world today. The burning of fossil fuels for energy and transportation is a key source of greenhouse gas emissions (GHG). This is primarily carbon dioxide (CO_2) but also includes methane(CH_4) and nitrous oxides (N_2O). The growth in greenhouse gas emissions over the last century is causing unprecedented changes to weather patterns through global warming. Scientists have predicted severe long-term impacts on the economy, society and natural ecosystems unless urgent action is taken to limit global warming. The UK Government has set ambitious regulations to achieve a target of net zero carbon emissions by 2050.

In the UK, road transport is responsible for 24% of greenhouse gas emissions, with heavy duty vehicles (HGVs) responsible for 20% of these emissions[1] as shown in the figure below.

Long haul duty cycles account for the largest portion of HGV GHG emissions, even though they make up a relatively small proportion of trucks on the road. The adoption of renewable fuels offers one of the most rapid, and economically viable, routes to lowering GHG emissions for the commercial vehicle sector. Long and regional duty cycles would benefit the most given their high mileage and fuel use[1].

Biofuels are renewable fuels produced from biological raw materials or feedstocks, such as energy crops or organic waste. When biofuels undergo combustion in a vehicle, tail-pipe CO_2 emissions are accepted as zero. This is because CO_2 has already been taken up by plants during its growing process, essentially producing a closed loop in the carbon cycle. A vehicle will still release very small quantities of other greenhouse gases, this will vary depending on the type of vehicle. Producing biofuels gives rise to greenhouse gas emissions influenced by various factors including energy usage during their manufacture and the type of feedstock. Biofuels produced from biogenic waste typically have a much lower carbon intensity than those made from energy crops grown specifically for fuel production. In some cases the manufacture of biofuels can result in net zero or even negative GHG emissions through avoiding methane released to the atmosphere by certain types of organic wastes.

The production of biofuels can offer wider environmental and social benefits. For example, enabling sustainable waste management and the preservation of natural resources, plus helping to stimulate a circular economy through using waste as a resource. The manufacture of biofuels can generate co-products such as animal feed and digestate, a natural fertilizer. Biofuel production can additionally have the potential to create new opportunities for sustainable rural development.



UK Road Transport Emissions Sources (UK Road Transport Emissions Sources[1])
Figures are million tonnes carbon dioxide equivalent ($MtCO_2e$)

The supply of renewable transport fuels in the UK

The Renewable Transport Fuel Obligation Order (RTFO) was introduced by the Department of Transport (DfT) over ten years ago to deliver reductions in greenhouse gas emission from fuels used in road transport and non-road mobile machinery. The legislation requires large UK retail fuel suppliers to ensure that 9.75% (by energy) of the fuel they supply comes from renewable sources by 2020, and 12.4% by 2032. A cap on the use of crop raw materials has been introduced to promote alternative feedstocks such as biogenic wastes.

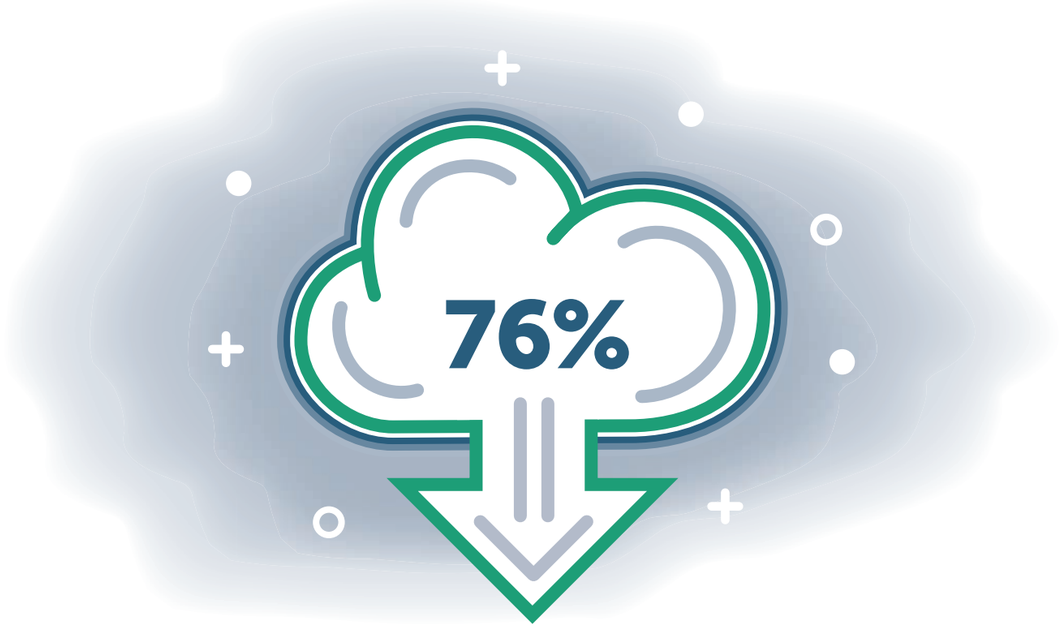
The RTFO requires biofuels to meet GHG emissions and sustainability standards to be eligible under the scheme. Biofuel suppliers are required to meet the following criteria.

- Greenhouse gas emission savings of more than 50% or 60% compared to fossil fuel, depending on the age of the production plant, then rising to 65% in 2021.
  The target is based on lifecycle (well-to-wheel) greenhouse gas emissions. This accounts for growing an energy crop or collecting waste, manufacturing the biofuel, transportation, dispensing at a refuelling station (well-to-tank) and combustion in a vehicle (tank-to-wheel).
- Growing crops for biofuel production should not lead to loss of biodiversity or high carbon value land.
  This ensures protection of sensitive ecosystems such as tropical forests, wetlands and peat land.

Biofuel suppliers can demonstrate their raw materials and supply chain meets these requirements through certification under voluntary sustainability schemes such as the Roundtable on Sustainable Biomaterials (RSB) and International Sustainability and Carbon Certification (ISCC). These schemes include standards related to environmental protection, biodiversity conservation and social issues such as safe working practices and compliance with labour laws. They also require evidence that a chain of custody is in place with regards to waste feedstocks giving assurance of their origin.

Currently 4.9% of total road fuel supplied in the UK comprises of biofuels - biodiesel, bio-ethanol, biomethanol, and biomethane. Biogenic waste is the dominant feedstock for biodiesel and biomethane. For bioethanol the feedstock is predominantly wheat and sugar beet, approximately half of which is grown in the UK. The most recent DfT statistics reveal UK biofuel supply achieves an average greenhouse gas savings of 76% compared to fossil fuels. 98% of biofuel feedstocks meet the sustainability criteria via a voluntary sustainability scheme. For the period 2017-18 biofuels in the UK saved approximately two million tonnes of GHG emissions, equivalent to removing more than one million cars from the road.

If all the UK's long haul and regional HGV operators converted their fleets to running on high blend biofuel over the next decade, this could save an estimated 13.9 million tonnes of CO_2e equivalent. This would be similar to removing over almost of quarter for the UK's car fleet (7.5 million cars).



UK biofuel supply achieves an average greenhouse gas savings of 76% compared to fossil fuels.

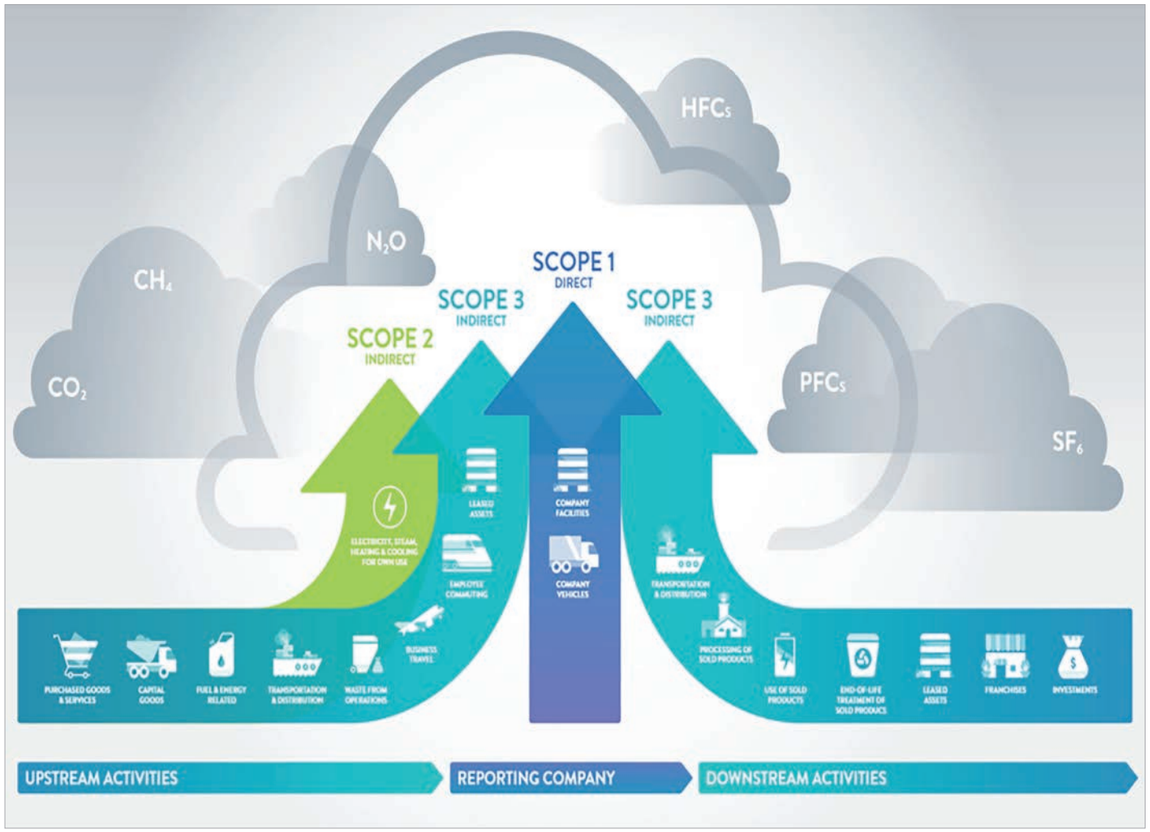
Introduction

Making business sense

Using renewable fuels can reduce fleet operators' running costs as some biofuels are less expensive than fossil fuels and some receive fiscal incentives. Both private and public sector organisations are integrating GHG emission reduction into their business strategies and procurement policies, taking into account their own vehicle fleets and those of their contractors. Many organisations incorporate performance standards for low carbon vehicles and fuels into their contractor tendering process. By operating a renewable fuel vehicle you will be a step ahead of other bidders.

Increased desire for sustainable products and services is driving consumers to align their purchase behaviour with companies who are addressing climate change and ensuring their supply chains are sustainable. Corporate social responsibility is more important than ever, while businesses' reputations have never been under greater scrutiny by their customers. Adopting a low carbon fuel will demonstrate your commitment to mitigating climate change, whilst reducing the carbon footprint of your vehicle fleet.

Disclosure of an organisation's sustainability performance including GHG emissions reporting is becoming increasingly common. The Companies Act 2006 requires all UK quoted companies to measure and report their greenhouse gas emissions as part of their annual Directors' Report. This relates to Scope 1 emissions, those that your company is directly responsible, for example emissions from your vehicle fleet. Scope 2 indirect emissions from electricity use, and Scope 3 indirect emissions that are outside of your direct control, for example your suppliers' vehicles. Scope 1 and 2 are mandatory for reporting purposes. A switch to using renewable fuels for your transport operations can greatly reduce Scope 1 GHG emissions. Measuring and reporting GHG emissions from your suppliers' vehicles can offer greater opportunities for improvements. Setting procurement standards for suppliers to use low carbon fuels, and educating your contractors about options available, can help cut GHG emissions from your supply chain. Further information is given at the end of this guide about measuring and reporting your company GHG emissions.



Company GHG reporting emission sources

LowCVP Low Carbon Fuel Assurance Scheme

The LowCVP hopes to be launching a new low carbon fuel assurance scheme in 2020. This aims to give fuel consumers (fleet operators) confidence that high blend biofuels achieve the RTFO's GHG emission and sustainability standards. The scheme will require renewable fuel suppliers to submit evidence to LowCVP that the volumes of renewable fuel sold to their customers throughout the year are both low carbon and sustainable. This will include evidence of RTFO approval. As part of the scheme, LowCVP hopes to issue a certificate to fuel suppliers as independent verification of a biofuels' blend, greenhouse gas emission savings, feedstock and voluntary sustainability scheme certification.

Factors to Consider

The following factors should be considered when assessing the suitability of renewable fuels for your fleet. These have been addressed in each renewable fuel chapter.

- **Operational:** vehicles and fuel storage must be compatible with the high blend biofuels, engine warranty may need to be checked with the manufacturer for certain blends, vehicle maintenance and storage of biofuels may require minor modifications. Availability of public refuelling infrastructure should be considered where back to base infrastructure is not possible. Installation of new fuelling infrastructure may be required for some fuels
- **Financial:** renewable fuels should be assessed on a whole life cost basis, in some instances fiscal incentives are available which reduce operational costs. Annual mileage will have an important influence on potential fuel cost savings, with high mileage fleets achieving the largest financial benefits.
- **Environmental:** The production of renewable fuels is highly complex and environmental performance varies significantly with feedstock. It is important that biofuels are produced from sustainable feedstocks and achieve genuine greenhouse gas savings over fossil fuels across their supply chain. Fleet operators are encouraged to confirm the GHG savings and sustainability performance of renewable fuels from their supplier.

Topic Sheet 1 - Biodiesel

Fuel overview

In the UK biodiesel is predominantly made from waste based raw materials. It has similar properties to fossil fuel diesel and is already present, as a small percentage, in regular diesel purchased at public forecourts. High blend biodiesel usually contains at least 20% biodiesel. Common blend strengths are B20 (20% biodiesel), B30 (30% biodiesel) and B100 (100% biodiesel).

Biodiesel, as known as FAME (Fatty Acid Methyl Esters), is produced via the transesterification of waste oil with methanol. One of the by-products of biodiesel production is glycerine. FAME is required to meet specific European fuel specifications. For example, B100 must comply with European Biodiesel Standard EN14214 and B20/30 with EN16709.

UK biodiesel suppliers currently include Argent Energy, Greenergy and Olleco. Each supplies FAME at a variety of blends.

GHG Emissions Performance

The table below shows the GHG emissions performance of the primary feedstocks used for producing biodiesel supplied in the UK. Data has been sourced from Government's renewable transport fuel statistics[2]. The GHG emission savings of biodiesel varies depending on the type of feedstock and final blend. Crop-based biodiesel typically give lower GHG savings while waste based, as produced in the UK, achieves much higher savings. .

	Biodiesel Range
WTW GHG emission intensity	8 - 13 gCO_2e/MJ
WTW GHG emission savings	87% - 92%
Average GHG emission savings	B100: 89% B20:17%
Primary sustainable feedstocks	Brown grease, tallow, used cooking oil (UCO)

Current Deployment

High blend biodiesel ranging from B20 to B100 is currently deployed in approximately 8000 buses across the UK. In Scotland bus operators have benefitted from the BSOG incentive for biodiesel. Demand for high blend biodiesel is increasing in commercial vehicle market with companies such as McGregor Logistics and McDonalds using this biodiesel to reduce their GHG emissions. It is estimated that 300 to 600 hundred trucks are running on some form of high blend biodiesel in the UK. Based on current HDV figures it is estimated that approximately 170,000-400,000 tonnes of GHG emission have been saved over the last year[3].

Refueling Infrastructure

Blends <B30

High-blend biodiesel is not available at retail fuel forecourts but is typically delivered to fleet depots with standard diesel storage and refuelling equipment. Depending on operators' tank cleaning policy, it can be advisable to clean a tank before switching to high blends in order to remove the inevitable sludge formed from storing fossil diesel.

B100

B100 biodiesel storage requires additional equipment and management compared to standard diesel. All diesel has a temperature point at which it begins to gel in colder weather. Pure waste-based biodiesel (B100) starts to be affected if cooled down to between zero and 10 degrees depending on the base raw material and must be kept above that temperature (Cold Filter Plugging Point, CFPP). Suppliers of B100 are able to provide information and infrastructure such as heated tanks, heated lines and dispensing pumps.

Biodiesel is more hygroscopic than diesel and the presence of water in diesel should be avoided as it can contribute to microbial growth in the fuel storage tank. Although rare, if left unchecked high microbial growth can lead to fuel filter blockages. Anti-microbial products can easily be added to stop microbial growth in both storage and fuel tanks.

Topic Sheet 1 - Biodiesel

Vehicle Compatibility and Availability

UK truck manufacturers have been contacted regarding the use of high blend biofuels in Euro VI vehicles still under warranty. The majority of OEMs warranty new vehicles for blends of B20 and B30, predicated on the biofuel complying with EN16709. These include Renault, Mercedes Benz, DAF, MAN and Scania. OEMs can fit certain parts whilst building the vehicles to enable them to run on high blend biofuel, or retrofit them. Fleet operators should therefore enquire with manufacturers which biofuel blends new vehicle products are warrantied for. Scania, Mercedes Benz, MAN and Renault warranty some vehicle products to run on B100. Iveco does not currently warranty any vehicles on blends higher than B7.

If fleet operators wish to run on B100 biofuel suppliers can fit upgrade packages to certain engine types which include heated fuel tanks. B100 used should meet EN14214.

Costs

Vehicle Costs: For high biodiesel blend use, standard diesel vehicles may be used, although some manufactures require a biodiesel upgrade package to be installed, typically costing a few hundred pounds. For B100 use, the vehicles require a conversion to include a simple system for warming the fuel. Various conversions are available either at factory or retrofitted. These typically cost from £6,500 - £8,000 per vehicle. Converted buses in the UK have been running successfully on B100 for over 5 years.

Fuel Costs: Depending on the supply chain, use of high blends can offer fuel cost savings over fossil fuel. Typically, the higher the blend level the lower the price.

Maintenance Costs: High blends are a drop-in replacement. While many operators of high blends have not found any need to change maintenance regimes, some vehicle manufacturers suggest modified routines such as increased fuel filter changes. Biodiesel is an effective surfactant and more frequent filter inspections after switching fuel types may be useful if small particles of dirt are removed from fuel pipes. The fuel quality standard for biodiesel requires anti-oxidation treatment to be used to provide protection against oxidation issues occurring. However, some engine manufacturers recommend more frequent oil changes as a further precaution

Infrastructure Costs: Biodiesel blends up to B30 can be stored in and dispensed from existing infrastructure for diesel vehicles at no extra cost. B100 however needs to be kept at an appropriate temperature to ensure it remains liquid in the colder months. Fuel suppliers test for the Cold Filter Plugging Point (CFPP) and can advise on the optimal minimum temperature for the fuel. This will result in some heating costs.

Case Study: **McGregor Logistics**

McGregor Logistics Ltd is a haulage, warehousing and distribution firm based in Doncaster, South Yorkshire, with depots in Tilbury and Cardiff. It sought the most cost effective and environmentally beneficial way of fuelling its fleet of vans, rigid and articulated trucks. Following a review of the market, McGregor selected Argent Energy to supply high blend (B30) biodiesel to power its fleet. The biofuel is now deployed in over 80 trucks and vans.

McGregor sources B30 from Argent Energy for use in its bunkered fuelling system delivering significant savings against conventional diesel. It was a smooth transition and after using it for over a year it has not presented any issues with its engines or operations. Apart from deciding to have their tank cleaned to remove the residual sludge that had accumulated over time, there was nothing else to do to support the introduction of this fuel.

Argent Energy's RTFO-approved biodiesel is all made from waste to avoid using crops that would normally go to the food or feed chain. Argent guarantee that no fuel supplied and used by McGregor will be made from food or feed crops. Their feedstocks include waste animal fats, fats oils and greases recovered from grease traps and water treatment facilities, used cooking oils and food waste oils. The technology includes intensive pre-treatment to clean up the waste oils and full distillation of all product to ensure maximum purity of the biodiesel. Argent Energy achieves greenhouse gas emission savings of between 87% and 92% compared to conventional diesel. They are certified under the voluntary sustainability scheme ISCC.

Using UK government data, McGregor calculates that using this fuel has reduced their emissions by 1,197 tonnes of CO_2 in the last 12 months. As a result, they plan to expand their use of high blend biodiesel, aiming to reduce emissions by around 2,350 tonnes CO_2 per year. In addition to the competitive purchase price, McGregor sees a commercial advantage in operating biodiesel. The business reports that many existing and potential customers are now interested in what steps it is taking to reduce its carbon footprint (and therefore their carbon footprint) as part of the contract process. There is a substantial capital cost involved in setting up on-site refuelling, but McGregor is confident that the savings they make on fuel will cover this within two years.

Argent supplies nine fleets across the UK operating over 3,000 vehicles, with a further 850 vehicles expected to add to these numbers in the near future. They promote the use of their biodiesel blends as a here-and-now solution to decarbonisation of trucks, coaches and buses currently running on fossil diesel.

Topic Sheet 1 - Biodiesel

Case Study: **McDonald's**

Olleco and McDonald's UK have worked together to create a mutually beneficial circular economy, using waste resources from restaurants to fuel the McDonald's logistics fleet. And help it meet its commitment to reducing emissions right along its value chain.

Olleco is the UK's leading supplier of premium cooking oils and fats and collector of used cooking oil and food waste, serving over 50,000 catering establishments including McDonalds. It operates five used cooking oil processing plants, a biodiesel plant, a bulk liquid storage facility and three anaerobic digestion plants. Olleco's biodiesel supply, produced from 100% UCO, achieves greenhouse gas savings of 89% compared to diesel. Their supply chain is approved under the RTFO scheme and has been certificated under the voluntary sustainable scheme ISCC.

Using its on-site anaerobic digestion plant, Olleco generate renewable heat and power from the food waste collected and use it to power the production of renewable biodiesel from used cooking oil. The biodiesel is then used as a B100 in McDonald's delivery trucks, operated by Martin Brower. It operates specialised heated and insulated tanks (available as a retrofit option for around £8,000) to ensure that the fuel can be used safely in colder temperatures. Likewise, bunkered storage tanks need to be heated to keep the fuel above zero degrees Celsius.

B100 has a lower energy density than mineral diesel and as a result may reduce fuel efficiency. Olleco has not observed any whole life cost savings from using this fuel. However, it does deliver very cost-effective carbon emissions reductions.

Topic Sheet 2 - Hydrotreated Vegetable Oil

Fuel overview

Hydrotreated vegetable oil (HVO) is a paraffinic fuel that is chemically similar to conventional fossil fuel diesel. It is classed as a 'drop-in' fuel, which means it can be substituted for conventional fossil fuel diesel with no impact on operational requirements. HVO can be produced from virgin vegetable oil, typically crude palm oil, and waste feedstock such as UCO and waste vegetable oils.

HVO is produced by hydrotreating vegetable oils and fats. In this process, hydrogen is used to remove oxygen from the vegetable oil molecules and to split the molecules into separate hydrocarbon chains equivalent to those found in conventional fossil fuel diesels. HVO must conform with European Standard EN1590.

UK suppliers of HVO include Green Biofuels and Prema Energy. These companies import HVO produced in continental Europe by Neste.

GHG Emissions Performance

The table below shows the GHG emissions performance and of the primary feedstocks for producing HVO supplied in the UK. Data has been sourced from Government's renewable fuel statistics[2]. The GHG emission savings of HVO varies depending on the type of feedstock. Efforts are being made to increase the volume of HVO produced from waste based raw materials.

	HVO
WTW GHG emission intensity	7gCO_2e/MJ
WTW GHG emission savings	91%
Primary sustainable feedstock	Waste pressings from vegetable oil production.

Current Deployment

The UK market for HVO is very small, its use is more prevalent in Europe. Organisations using this fuel include The London Borough of Hackney, Lucketts and Red Funnel. It is estimated that between 50 to 200 HDVs use HVO giving a GHG savings of approximately 3,800 tonnes over the last year over the last year[3].

Refueling Infrastructure

HVO is not currently available at retail fuel forecourts, although HVO suppliers can provide and install refuelling infrastructure at depots. HVO can be stored in the same way and has the same storage life as regular diesel. There is no need for any specialist equipment.

Vehicle Compatibility and Availability

As HVO is a drop-in fuel its use has no impact on maintenance or warranty. All major truck OEMs approve 100% HVO for use in their vehicles as long as the fuel meets European Standard EN15940[4].

Costs

Vehicle Costs: No impact on vehicle cost.

Fuel Costs: Cost of fuel per litre is typically higher than diesel.

Maintenance Costs: Maintenance costs are identical to that of diesel vehicles.

Infrastructure Costs: No specialist equipment is needed to store HVO.

Topic Sheet 2 - Hydrotreated Vegetable Oil

Case Study: **London Borough of Hackney**

At just over 470 vehicles, London Borough of Hackney (LBH) operates one of the largest local authority fleets in London of which approximately 270 are light commercial vehicles supplied by a range of manufacturers. It also operates a fleet of HDVs including Dennis Eagle refuse collection vehicles.

LBH aims for all of its commercial vehicles to be ultra low emission vehicles (ULEVs) by 2028. Ideally this will be achieved by using electric vehicles which have zero tailpipe emissions. However, current vehicle technology does not currently support this vision, particularly for the heavier vehicles, so LBH is using renewable fuels to minimise its emissions.

LBH used FAME biodiesel in blends of up to 100% for several years, saving significant quantities of CO_2. More recently, it has trialled and deployed HVO across its commercial vehicle fleet.

Green Biofuels Ltd supplied HVO produced by Neste in Finland and the Netherlands, the company is RTFO approved. Neste's fuel is produced from waste and residue fat fractions from food, fish and slaughterhouse industries, and from non-food grade vegetable oil fractions. Their HVO supply chain is ISCC certified.

LBH uses an on-site fuel management system to monitor and analyse fuel consumption and mileage data. This means they can calculate their carbon footprint on an individual basis. Analysis undertaken by LBH has found that this fuel offers well-to-wheel CO_2 emissions savings of 80% compared to conventional diesel.

The fuel has performed well from an operational point of view. HVO requires no additional maintenance or changes to operational procedure as it is used as a direct replacement for conventional diesel so there is no price differential for the vehicles themselves. The fuel costs more per litre than mineral diesel so there is no whole life cost saving however, it represents a cost-effective option for reducing fleet carbon emissions.

LBH sources its suppliers through the public sector tendering process and can use this to encourage use of low emission vehicles, though it currently does not mandate use of HVO or other specific fuels or technologies.

The organisation is currently re-tendering its bulk fuels contract to make HVO its primary road fuel for all vehicles above 3.5t GVW. LBH is considered a leader among public sector fleets and encourages other local authorities and organisations in London to follow its lead and deploy renewable fuels to cut transport emissions.

Case Study: **Luckett's Travel**

HVO was trialled from June to September 2018 by Luckett's Travel National Express operations. Two routes were chosen: Portsmouth to London and Portsmouth to Brighton. The routes routinely use 14 vehicles; these were split with seven of the vehicles running on HVO and seven on regular diesel so that a direct comparison could be drawn between the two. Temporary refuelling infrastructure was located at Luckett's Travel Fareham depot.

The trial had a number of aims, including decarbonising coaches by using a renewable and sustainable fuel option, educating the industry and the wider audience of the existence of HVO and its benefits, and using the findings to work with government so the fuel can receive support to encourage its use within this segment.

HVO was deployed in Scania K410 EB coaches which can carry 56 seated passengers. The fuel was supplied by Green Biofuels. The HVO used in the Luckett's Travel National Express trial was produced from used cooking oil. The fuel cost is around 5-10% more expensive than conventional diesel per litre, but the fleet benefitted from other savings such as reduced GHG emissions and reduced maintenance and operational costs.

Alongside the on-road trial, whole vehicle testing was undertaken at Millbrook Proving Ground using the LowCVP UK Coach cycle. The testing showed that each coach achieves savings equating to 180 tonnes CO_2e per annum, based on annual consumption of 62,500 litres of fuel. This represents a reduction of over 90% compared to conventional diesel.

Scania is confident that all its engines from Euro IV onwards can run on HVO straight away with no modifications or maintenance changes. Scania approves HVO EN 15940 as a fuel in its Euro IV, Euro V and Euro VI diesel engines for trucks and buses. Scania now hope that the results of the trial will lead to government and policy support to encourage HVO use within the coach sector.

Topic Sheet 3 - Biomethane

Fuel overview

Biomethane is the renewable equivalent of natural gas. It can be used as a drop in fuel for natural gas vehicles both CNG and LNG. When used as renewable vehicle fuel in the UK, biomethane is made from a variety of organic waste materials via the process of anaerobic digestion. It requires upgrading to a quality suitable for use in gas vehicles then typically injected into the National Gas Grid for distribution. The RTFO scheme allows biomethane producers to inject biomethane into the grid and an equivalent mass of methane to be extracted from the grid at a refuelling station. This process is known as mass-balancing. Biomethane can be dispensed as compressed biomethane gas (CBG) or liquid biomethane (LBM).

UK suppliers of biomethane include CNG Fuels, Air Liquide, Gas Alliance, BOC, Gasrec and Bennaman Ltd.

GHG Emissions Performance

The table below shows the GHG emissions performance of the primary feedstocks used for producing biomethane supplied in the UK[2]. Data has been sourced from Government's RTFO statistics and interviews with biofuel suppliers. When a high proportion of biomethane is produced from manure it can achieve a negative GHG emission intensity. This is because methane is released to the atmosphere when manure is stored in the open environment. Methane is twenty five times (by mass) more powerful as a greenhouse gas than carbon dioxide. By using manure as feedstock, methane and nitrous oxide can be captured giving rise to a carbon neutral or negative biofuel. Currently the RTFO does not report negative renewable fuels, however this is likely to materialise over the next twelve months.

	Biomethane Range
WTW GHG emission intensity	5 - 15 gCO_2e/MJ
WTW GHG emission savings	82% - 94%
Average GHG emission savings	88%
Primary sustainable feedstocks	Food waste, manure, agricultural residues

Current Deployment

Biomethane is relatively widely used in the UK with increasing take up by the freight sector. As the accompanying case studies highlight, it is used by John Lewis Partnership, London Borough of Camden, Cornwall Council and Kuehne + Nagel. Other fleets include Asda, Howard Tenens, DHL, Ocado, Hermes, DPD, London Borough of Islington, Veolia, and Lawsons building merchants. It is estimated that approximately 400 HDVs operate on biomethane in the UK. Biomethane has been popular in the bus sector due to specific incentives via BSOG requirements to mandate the use of biomethane in gas buses. There are 363 biomethane buses in operation in cities such as Nottingham, Bristol and Reading. Based on current gas vehicles running biomethane, it is estimated that approximately 15,000 tonnes of GHG emissions have been saved over the last 12 months[3].

Refueling Infrastructure

Both public access and depot-based refuelling are available for CBG and LBM. For more information refer to the next chapter on biomethane infrastructure.

Vehicle Compatibility and Availability

Gas heavy duty vehicles can run interchangeably on natural gas and biomethane with no impact on fuel consumption or warranty considerations. The engines are either dedicated spark ignition (LNG or CNG) or High-Pressure Direct Injection dual fuel (Volvo – LNG only).

Both CBG and LBM vehicles are available as rigid and artic HGVs up to 44t GVW. Example vehicles include the Iveco Stralis NP, Iveco Eurocargo, Scania's two, three and four axle rigids, Mercedes Benz Econic, Volvo FH and Volvo FM.

Topic Sheet 3 - Biomethane

Costs

Vehicle Costs: Gas HGVs can cost around 25% more than a conventional diesel equivalent when purchased outright. A number of companies offer gas vehicles on a lease contract.

Fuel Costs: Biomethane is cheaper than diesel on a pence per mile basis, partly driven by the fuel duty. Treasury has committed to maintaining the fuel duty differential between natural gas and diesel through to 2032. This rate difference is 50% lower than conventional diesel. Fleets which have high annual mileages, such a long haul logistics companies, achieve the greatest cost and carbon savings.

Maintenance Costs: Maintenance costs of gas vehicles are 20%-25% more diesel vehicles.

Infrastructure Costs: Costs vary depending on whether fleets use public access or depot refuelling. The capital costs of depot refuelling station can be recovered through lower fuel operating costs. Alternatively, some providers will provide infrastructure and recover costs through the fuel price directly (wet lease).

Case Study: **John Lewis Partnership**

Sustainability is at the core of John Lewis Partnership's (JLP) operation. It has implemented ambitious measures to reduce their carbon emissions, with a target of a zero carbon fleet by 2045.

The commercial vehicle fleet consists of 1,600 vans, 400 light trucks, and 600 heavy duty trucks. JLP is reducing road transport carbon emissions by driving fewer miles, improving fuel efficiency and switching to alternative fuels.

In 2010 JLP and Imperial College London reviewed 30 alternative fuels and technologies. Using criteria covering sustainability, availability and the long-term business case, JLP concluded that biomethane was the best option for its heavy fleet. The process of introducing biomethane began with a trial of one demonstration vehicle. JLP rolled the fuel out gradually over the past eight years and now uses it in 85 Scania P 340 trucks. It has committed to changing the whole fleet of 600 trucks to dedicated gas HDVs fuelled by biomethane by 2028.

The gas trucks cost around 25% more than diesel vehicles to purchase. This is offset by fuel savings, as they are paying around 30-40% less for biomethane than diesel on a pence per mile basis. This means they recover the investment in no more than two years. Over the lifetime of a vehicle the total cost is about 24% lower than an equivalent diesel truck, though payback depends on factors such as fuel price and miles driven.

Vehicles are refuelled with RTFO-approved, and ISCC-certified, methane at the CNG Fuels stations at Leyland and Northampton. The biomethane sourced, which is produced from feedstocks including food waste and manure, can reduce well-to-wheel greenhouse gas emissions by 84%, compared to mineral diesel.

Other fleets using Leyland include Hermes, Argos and HPH Group. CNG Fuels also operate a refuelling station at Crewe and Northampton, and will be opening new sites at Warrington, Erdington, Knowsley, Larkhall and Bellshill between late 2019 and summer 2020.

In total CNG Fuels supplies an annualised amount of more than 10 million kilograms of biomethane. This figure is growing rapidly as existing customers order additional gas trucks and new customers order their first gas trucks. CNG Fuels expects annual growth rates of dispensed volume of biomethane of up to 150%, powering up to 300 vehicles by early 2020.

The carbon intensity of biomethane varies depending on where on the gas grid the stations are connected, with the lowest intensity for stations connected to the high pressure grid. All existing CNG Fuels stations and the majority of their planned stations are on high pressure grid.

The vehicles and refuelling infrastructure have been extremely reliable, helping JLP gas trucks cover over 10 million miles. The organisation now works to encourage other businesses to switch to biomethane by participating in programmes such as TfL's LoCITY to disseminate the benefits to other freight and logistics operators.

Topic Sheet 3 - Biomethane

Case Study: **London Borough of Camden**

London Borough of Camden (LBC) uses biomethane to help achieve its ambitious carbon reduction target of 40% by 2020 across its estates and operations. LBC's fuel hierarchy has plug-in electric vehicles at the top as they have zero tailpipe emissions. Biomethane is next on the list as it offers significant well-to-wheel carbon savings.

LBC has used biomethane in its fleet since 2012. Currently it uses biomethane in 18 VW Caddy vans and two 5.5t Iveco Daily trucks. The vehicles mostly operate within the borough, so their daily working mileage is low. However, the vans are also used for employees' commutes, from as far away as Southend. Pure battery electric vehicles do not currently offer the required range, while biomethane offers the best combination of long range and low emissions.

LBC pay around £1 per kg of gas, which on a pence per mile basis delivers cost parity with diesel. There are no whole life cost savings due to their low vehicle mileage however, the council receives substantial carbon emissions savings. Vehicles are refuelled from a compressed biomethane refuelling station installed at the LBC fleet depot. Other fleets which use this station include London Borough of Islington (for a street sweeper and minibuses) and Lawsons building merchants (for their 18-tonne loader crane) and several small local businesses.

Gas Alliance manage the station and supply the biomethane using the Green Gas Trading Scheme. The feedstock for the biomethane is organic waste saving 84% GHG emissions compared to diesel. Gas Alliance supplies over 4 million kilograms of biomethane annually for passenger transport and freight vehicles. It operates seven sites across the UK with a further three planned.

LBC is improving sustainability within its supply chain by asking suppliers to show how they will reduce road transport emissions over the duration of the contract. They don't specify a particular technology but encourage the use of biomethane and other alternative fuels to reduce greenhouse gas emissions as cost effectively as possible.

LBC plans to increase the capacity of the refuelling station to support a larger fleet of gas vehicles to coincide with the expansion of the Ultra Low Emission Zone from October 2021. LBC is keen to continue using biomethane in the HDV fleet and may deploy it within its bus fleet as well. Overall biomethane plays a vital role in helping LBC cut emissions from HDVs and acts as a stepping-stone to zero tailpipe emissions within the van fleet.

Case Study: **Cornwall Council**

Cornwall Council's fleet service provider, Cormac, are sourcing biomethane for their HDV fleet from the county's dairy farmers in an innovative local production model based on Bennamann Ltd.'s processing technology. The company's decision to transition from diesel to biomethane has been driven by environmental considerations in particular reducing their carbon footprint. Furthermore, the Council's Climate Emergency Declaration and 'zero carbon Cornwall by 2030' aspiration has influenced the company's decision to switch to using renewable vehicle fuel.

Bennamann's technology captures biogas that would otherwise escape to atmosphere as methane and nitrous oxide from manure slurry lagoons. This results in significant reductions in greenhouse gas emissions. The biogas is then upgraded to CBG and LBM. The process additionally captures CO_2 for merchant sale (for example in the food and drink sector) and produces digestate as a fertilizer replacement. The biomethane production helps improve the sustainability of farmland management and demonstrates a local circular economy using agricultural waste to produce a range of bio-products. Bennamann have commissioned the University of Exeter to undertake a life cycle analysis exercise to accurately determine the carbon intensity of their biomethane supply chain.

Bennamann's innovations include patented equipment to process, liquify and store biomethane on the farm and proprietary engineering for lagoon enclosure and biogas off-take. Distribution models include using biomethane as a low carbon fuel for tractors; hyper-local off-farm supply; aggregation for local fleet use, such as in the case of Cormac; and wider market participation in and out of county.

Initially CBG is being provided to Cormac for use in road maintenance equipment ('hot-box' tar burner trailers). LBM will be used in gas trucks that tow them by Spring 2020. One highly novel aspect of this biomethane application is that Cornwall Council could be both an end-user, through Cormac, and the source of waste feedstock. Six out of fifty-eight tenant dairy farms with slurry lagoons on the Council Farm Estate are currently being studied for conversion to facilitate the biomethane production technology offered by Bennamann.

Topic Sheet 3 - Biomethane

Case Study: **Kuehne+Nagel**

Kuehne+Nagel (K+N) provide third party logistics services for Virgin Media and Whitbread using LBM trucks run on 100% biomethane. The company installed an LBM refuelling station from Air Liquide at its depot to support the vehicles deployed on its Whitbread contract, making the decision to switch to gas vehicles for Virgin Media relatively straightforward. Currently, biomethane is used in four Iveco trucks for Virgin Media, and at the time of writing K+N has just ordered Volvo HPDIs for the Whitbread contract to extend and confirm its environmental commitments.

The biomethane trucks are cheaper to run than equivalent diesel models: K+N has achieved savings of up to 30% in fuel cost on a pence per mile basis. The vehicles and infrastructure were easy to fit into daily operations, with no significant challenges reported during the early acquisition and deployment phases. Based on the financial and economic success already achieved, K+N plans to invest in additional LBM HGVs in the near future powered by biomethane.

Virgin Media is committed to reducing the impact that its supply chain has on the environment and is working in partnership with K+N to help achieve this. Both organisations actively communicate the benefits of their biomethane vehicle fleet to a wide range of stakeholders.

The LNG refuelling station was installed and is operated by Air Liquide, which additionally supplies biomethane approved under the RTFO scheme. Average GHG emissions are in the order of 80% lower compared to diesel.

Air Liquide is in a unique position in the UK of both producing biomethane and supplying it to its own network of filling stations. All of Air Liquide's biomethane is produced from organic waste sources, and re-utilisation of these resources rather than discarding to landfill will be something that is expected to evolve over the coming years. Indeed, Air Liquide is at the start of an increase in biomethane production, loading of filling stations, and expansion of station network, that will follow in further announcements.

Topic Sheet 4 - Biomethane Infrastructure

Introduction

Biomethane refuelling stations can be categorised into three types, depending on the product(s) they provide.

- CBG stations can be grid connected or have gas delivered by a gas cylinder tanker.
- LBM stations consist of a cryogenic tank and a fuel dispenser. They deliver liquid fuel at 2 to 8 bar pressure.
- Liquefied to Compressed Biogas (LCBG) stations supply both CBG and LBM. LBM is vaporised and compressed into storage tanks to add CBG functionality to the station. A sophisticated Liquefied to Compressed Biogas (LCBG) station may also utilise any 'boil off' from the LBM tank to compress into CBG.

Fleet operators can install refuelling infrastructure at their depot or choose to refuel at a public access refuelling station. Refuelling with biomethane is straightforward and usually takes no longer than filling up a diesel vehicle.

Depot-Based Stations

Depot-based refuelling stations are ideal for fleets which operate a return to base duty cycle. Smaller fleets can be refuelled using trailer-based or skid-mounted stations. Larger fleets, or fleets which need to refuel vehicles quickly, may need a gas grid connection. The depot will need to have sufficient space to install the equipment and enough electrical power supply as well as access to a gas main. Timing for ordering new gas vehicles and installing a refuelling station is important and appropriately planned.

Depot refuelling station costs vary significantly and as such we are unable to provide specific figures in this guide. Factors which influence costs include:

- Capacity: The amount of gas the station will be required to provide, which in return is driven by the number of vehicles to be refuelled, daily mileage, and forecast future demand.
- Gas Grid Connection: If the station will be connected to the grid the distance to the mains supply and the pressure of the local gas grid will impact the cost.
- Electricity Grid: Power availability and distance to the three phase mains.
- Refuelling: Number of refuelling nozzles required for the fleet size.
- Footprint: How large is the station and how much space is available at the depot.

How maintenance costs will be managed?

Typical payback periods for depot-based stations are between two and six years, depending on the factors listed above. Gas refuelling stations can have a direct national grid connection or have gas delivered by tanker (a so-called Mother and Daughter arrangement).

Rather than purchasing a gas refuelling station outright, a fleet operator can adopt a wet leasing contract with a gas infrastructure supplier. This is the approach has been taken by London Borough of Camden and the majority of biomethane bus operators. This model entails a company supplying biomethane and CNG or LNG refuelling infrastructure, overseeing the station installation, operation and maintenance. The station will be provided and installed at no cost to the end user but with a marginally higher price per unit of biomethane to reflect the cost and risk undertaken by the supplier. Full repair and maintenance are offered over different contract periods, service contracts are typically ten years. Wet leasing has the added advantage of reducing the capital outlay required by truck operators to introduce gas vehicles and the assurance that the infrastructure required is operated by experts in the gas supply industry.

Grid Connected

Gas from grid-connected stations is compressed on-site for dispensing into vehicles. It is therefore important to understand the specification of the local gas main; it must have enough pressure and capacity to supply the required demand.

- Connecting to a relatively high-pressure part of the gas network reduces the amount of compression needed and therefore lowers running costs and reduces the GHG emissions of the biomethane. However, installation costs increase with increasing distance from the gas main network to the compressor unit.
- A lower pressure connection will require additional compression and potentially supply fewer vehicles or required additional gas cylinder storage. However, it may be suitable if vehicles are stationary for several hours, allowing gas to be compressed into tanks gradually.

A fast fill grid-connected station maintains sufficient site storage to allow vehicles to be filled in minutes. Where vehicle use is less intensive slow fill stations can be utilised. Here gas is compressed directly into vehicle tanks over several hours, saving the cost of site pressurised gas storage (this approach is not used in the UK but has been applied in Spain and Sweden).

Topic Sheet 4 - Biomethane Infrastructure

Tanker Delivered

Daughter stations refuelled by tanker can be used if a grid connection is not feasible. These stations offer flexibility as the location and capacity can easily be adapted. Mother and Daughter station arrangements can also be used where a Mother-grid connected station supplies a local Daughter station via a tube trailer.

Public Access Stations

Fleets which do not operate a back to base duty cycle can still operate gas vehicles by using the UK's growing network of public access refuelling stations. At the time of writing there are 21 depot or private stations in the UK and 12 public filling stations, with up to 10 new public stations planned over the next 12 months. In addition, some depot and private stations can be accessed by prior arrangement with the depot owner.

For an up to date map and details of refuelling infrastructure in the UK visit the Gas Vehicle Hub website: https://gasvehiclehub.org.

Topic Sheet 5 - Biopropane

Fuel overview

Biopropane is a renewable fuel that is chemically identical to conventional fossil fuel LPG. It is a 'drop-in' fuel, which means it can be substituted for conventional LPG with no impact on operational requirements.

Biopropane is mainly produced as a co-product of the HVO production process and is separated during the HVO refining process. 50kg of bio-propane is generated for every tonne of HVO produced. Feedstocks include energy crops and waste materials.

The only UK suppliers are Calor Gas and Avanti. Calor imports bio-propane produced in continental Europe by Neste. Calor Gas' product is RTFO-approved, certified under the ISCC voluntary sustainability scheme. Biopropane is a relatively new product and only small volumes (around 40,000 tonnes) are currently produced.

GHG Emissions Performance

The table shows the GHG emissions performance for primary feedstocks used to produce bio-propane supplied in the UK. Data has been sourced from Government's renewable fuels statistics[2]. Similar to HVO and biodiesel, the feed-stocks for bio-propane can vary, subsequently influencing carbon intensity of the final product. Crop-based feed-stocks, such as palm oil distillate, give rise to lower GHG savings than waste based.

	Biopropane Range
WTW GHG emission intensity	8 - 31 gCO_2e/MJ
WTW GHG emission savings	63% - 90 %
Average GHG emission savings	76 %
Primary Sustainable Feedstocks	Palm fatty acid distillate and UCO

Current Deployment

At the time of writing bio-propane is not used in any HGVs in the UK. Its primary use is in heating and to power non-road vehicles (forklift trucks) in the UK. It is estimated that approximately 200 forklifts run on bio-propane saving <12 tonnes of GHG emissions.

Infrastructure & Vehicle Compatibility and Availability

There are currently around 1,500 LPG refuelling stations in the UK, most of which are on conventional retail fuel forecourts. Bunkered LPG can also be supplied to fleet depots as HGVs cannot fit under many forecourt canopies. bio-propane is not available at public forecourts yet. Depot-based refuelling can be supplied on request. As bio-propane is chemically identical to LPG it can be blended with conventional LPG, enabling a phased and secure transition to 100% bio-propane.

LPG vehicles are only available in the UK as retrofit conversions and therefore performance and maturity varies between systems and suppliers. Suppliers such as Mercury Fuels convert HDVs to dual-fuel which typically allows around 25% of diesel consumption to be replaced by LPG. An additional third-party warranty will be needed for an LPG vehicle as the conversion process may invalidate the OEM warranty. The vehicle converter takes responsibility for the retrofit warranty and the certified tailpipe emissions to the relevant standard. Check with the LPG conversion company to see what warranty they offer. LPGUK (the LPG trade association) maintains a list of approved suppliers.

There are developments of Range Extended Electric Trucks that use an on board LPG engine as a generator to provide on board recharging coming to market soon. These can use depot based bio-propane refuelling to provide a very low CO_2 footprint to the truck without range anxiety.

Costs

Vehicle Costs: Converting a conventional diesel HDV to run on LPG or bio-propane costs around £4,000 to £8,000. Range Extended Trucks could cost around £90,000 more than a diesel but will payback inside 5 years of a typical 7-8 year life. The additional capital cost of the LPG conversion can be repaid through lower fuel costs if annual mileage is high enough.

Fuel Costs: Biopropane is considerably cheaper than diesel at the pump due to a preferential rate of fuel duty. This makes it cheaper than diesel on a per mile basis.

Maintenance Costs: Costs increase by a few hundred pounds per year due to the need to service the LPG refuelling system.

Infrastructure Costs: HGV fleets typically have depot based bunkered fuel with the infrastructure provided and maintained as part of the fuel supply contract.

Summary Matrix

	Biodiesel	Hydrotreated Vegetable Oil	Biomethane	Biopropane
WTW GHG Emission Savings Range*	87% - 92%	92%	82% - 94%	63% - 90 %
Whole Life Costs	Cost improvement for some high blend supply chains	Increase	Cost improvements dependant on annual mileage and ownership period	
Financial Incentives	Bus Service Operators' Grant (England and Scotland)	None	Reduced fuel duty rate Bus Service Operators' Grant (England and Scotland)	Reduced fuel duty rate
Vehicle Availability & Compatibility	Manufacturers can warranty up to B20/ B30. Some warranty B100 dependent upon approved vehicle conversion	Drop-in fuel, warrantied by all manufacturers	CNG and LNG vehicles available	LPG conversion warranties need to be applied for after conversion - no warranty implication for using Bio LPG
Fuel Availability	A number of suppliers UK wide	Limited availability in the UK	A number of suppliers	Limited availability in the UK
Refuelling Infrastructure	Depot-based only		Public refuelling stations (via certification) and depot-based refuelling available	

*** WTW GHG emission ranges based on UK Government renewable fuel statistics data for 2018**

Further Information

General Advice and Calculator Tools	
The free-to-use LoCITY Fleet Advice Tool provides guidance on the economic and environmental performance of low emission technologies.	**https://fleetadvicetool.cenex.co.uk**
Official UK Government factors for converting your fuel use into carbon emissions.	**https://www.ukconversionfactorscarbonsmart.co.uk**
The Gas Vehicle Hub provides impartial information about the costs and benefits of operating gas vehicles and hosts an up-to-date map of the UK's gas refuelling infrastructure.	**https://www.gasvehiclehub.org**
UK trade association for the LPG industry.	**https://www.uklpg.org/**
Drive LPG provides advice and information about converting to LPG including a list of approved installers.	**https://www.drivelpg.co.uk**
The Freight Portal has resources to help fleets become more sustainable, and signposts fleet support schemes.	**https://thefreightportal.org**
The LowCVP find out more about renewable fuels and low carbon vehicles	**https://www.lowcvp.org.uk/**

References

[1] BEIS UK GHG emissions national statistics 2009-2017

[2] Renewable Transport Fuel Obligation statistics: Period 10 (2017/2018), report 6 [DfT 2019]

[3] Estimates of the number of vehicles, volume of fuel sold and estimated GHG savings have been derived by Cenex from assessments of the market, interviews with fuel suppliers, average UK annual mileages of freight and duty cycles.

[4] Focus on: Paraffinic Fuels [Transport Engineer, August 2018]

Glossary

BSOG	**Bus Service Operators Grant**
CBM	**Compressed Biomethane**
CH_4	**Methane**
CO_2	**Carbon Dioxide**
CO_2e	**Carbon Dioxide Equivalent**
FAME	**Fatty Acid Methyl Ester**
GHG	**Greenhouse Gas**
HDV	**Heavy Duty Vehicle**
HVO	**Hydrotreated Vegetable Oil**
ISCC	**International Sustainability and Carbon Certification**
LBM	**Liquid Biomethane**
LCBG	**Liquefied to Compressed Biogas**
LowCVP	**Low Carbon Vehicle Partnership**
LPG	**Liquefied Petroleum Gas**
N_2O	**Nitrous Oxide**
OEM	**Original Equipment Manufacturer**
RTFO	**Renewable Transport Fuel Obligation**
TTW	**Tank-to-Wheel**
UCO	**Used Cooking Oil**
WTT	**Well-to-Tank**
WTW	**Well-to-Wheel**

Low Carbon Vehicle Partnership
3 Birdcage Walk,
London,
SW1H 9JJ
Tel: +44 (0)20 7304 6880
https://www.lowcvp.org.uk

Cenex
Holywell Building, Holywell Park,
Ashby Road, Loughborough,
Leicestershire, LE11 3UZ
Tel: +44 (0)1509 635750
https://www.cenex.co.uk

CNG Fuels
56 Warwick Rd,
Olton,
Solihull,
B92 7HX
Tel: +44 07971 541 000
Email: info@cngfuels.com

Scania Great Britain Ltd
Delaware Drive, Tongwell,
Milton Keynes,
Buckinghamshire,
MK15 8HB
Tel: +44 (0)1908 210210
Email: drivingtheshiftuk@scania.com