LowCVP
Low Carbon Vehicle Partnership

A Green Bus For Every Journey

Case studies showing the range of low emission bus technologies in use throughout the UK

Executive Summary

Buses reach into every corner of the UK, moving thousands of people through heavily congested cities and providing essential connections to our rural communities in remote areas of the country. Whilst we can't accurately forecast what the technological future holds for driverless, shared, advanced vehicles, our future green buses will remain the most space and energy efficient method of transport for many journeys.

Our first report, 'The Journey of the Green Bus', explained how manufacturers and policy makers have stimulated a revolution in bus technology by encouraging the development of cleaner buses over the last 20 years.

Here in 'A Green Bus for Every Journey', we show how the latest buses employing a range of fuels from biodiesel and biomethane, through a wide spectrum of hybrid options to full battery electric and hydrogen fuel cells, have been embraced by operators across the UK and are beginning to transform the sector. We aim to demonstrate how the combined and continuing efforts of industry, government and operators can deliver savings in fuel, emissions and money while dramatically reducing the environmental impact of this essential and efficient mode of transport. We are, however, only part way along the journey to fully decarbonising and cleaning the UK's vital bus sector. Successful steps have been taken, as this report shows, but there is a need for continuing financial support from Government to progress with technology advancements, including fiscal incentives such as the influential Bus Service Operators' Grant (BSOG) to continue to help the business case for operating low emission buses.

European engine legislation culminating in the latest Euro VI requirements has seen the air quality impact of new buses dramatically improve but, to date, carbon emissions have not been addressed in bus legislation. Here in Britain, low carbon emission buses have been under development for two decades or more, driven by strong Government policy. Manufacturers, bus operators and fuel suppliers are embracing the change, aware that to maintain their viability, buses must be amongst the cleanest and most carbon-efficient vehicles on the road. Almost 4,000 Low Carbon Emission Buses (LCEB) are now operating across the UK, with 40% of buses sold in 2015 meeting the low carbon requirements. These buses have saved over 55,000 tonnes of greenhouse gas emissions (GHG) per annum compared with the equivalent number of conventional diesel buses.

UK Government funding and policy has been critical in kick-starting this market for low carbon emission buses, to help manufacturers get out of the low production/high cost conundrum, and move through prototype vehicles to demonstrations, trials and, ultimately, full commercial operation. Most recently the Low Emission Bus Grant has provided funding to a number of bus operators for both low emission buses and refuelling/recharging infrastructure.

In supporting policies, Government has identified air quality damage costs to reflect the economic cost to society of different air pollutants related to impacts on human health and the environment. The key pollutants from diesel buses (and all combustion vehicles) are oxides of nitrogen (NOx) and particulate matter (PM). Around £8 million in damage cost savings have been achieved through the low carbon emission buses in operation to date.

Bus operators have invested significant sums of money and committed time and resources in working through the early challenges on the path to successful introduction.

Investment has been made in new bus technologies and refuelling infrastructure, and even routing and scheduling have been reviewed in some cases to allow trials and learning of the most advanced potential solutions. A number of large bus operators have shown clear leadership by embedding low carbon emission buses into their sustainability agenda to drive improvements into the environmental performance of their bus fleet.

There have, of course, been plenty of hurdles along the way; early hybrid and electric buses experienced initial reliability issues like any brand new technology, but through open collaboration the technology has rapidly advanced and is now achieving similar levels of reliability as that employed in gas buses and conventional diesel buses, with warranties extending and new business models developing to further reassure the market. Bus manufacturers will continue to innovate and improve the performance of the full range of low emission bus technologies over the next few years.

There will also be a need for collaboration between a range of stakeholders. With new fuels and technologies moving into the mainstream, manufacturers, operators and government bodies/agencies will need to work with new infrastructure, technology and fuel suppliers. Electric bus operators and manufacturers, for example, now have to work closely with local electricity network operators to manage impacts on the local grid. The web of interactions between stakeholders is, if anything, getting even more complex.

Low emission buses play a key role in reducing GHG emissions that are contributing to climate change and in tackling air quality problems in cities.

Impressive progress is being made but much more will be needed and the support of all parties must be maintained if we are to transform the market and achieve our ambition that every new UK bus in 2020 will be a low emission bus, and show that there really is "a Green Bus for Every Journey".

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Introduction

A wide range of technology solutions are revolutionising the operation of buses across the UK

With almost 4,000 'green', low emission buses currently in operation, no single technology will fit every route and nor will a specific route fit every technology, but with the unrivalled number of clean bus options now available to the UK operators this report shows that there truly is 'A Green Bus for Every Journey'.

This publication provides twenty case studies from across the UK showing how bus operators have introduced a variety of low emission bus technologies; how they are measuring up in terms of cost-effectiveness for operators as well as their contributions towards cutting carbon dioxide emissions and local pollution.

Thousands of low emission buses are already in use in the UK today and the numbers are growing

Reducing greenhouse gas and locally polluting emissions from buses has been the key motivation behind the introduction of new and innovative bus technologies over the last decade. The Department for Transport and Transport Scotland have introduced financial incentives and supporting policies to stimulate the take-up of Low Carbon Emission Buses (LCEB) and, more recently, Low Emission Buses (LEB). These incentives have helped reduce the capital and operational costs of a variety of different technologies including hybrid, plug-in hybrid, electric, electrified ancillaries, hydrogen fuel cell and biomethane buses. The industry, led by the LowCVP, has subsequently developed robust methods to assess the benefits of low emission buses in real operations.

There are currently (September 2016) 3,760 LCEBs in operation across England, Scotland and Wales. There are twenty models produced by eight different manufacturers qualified as LCEBs, with 41% of new buses built now meeting the LCEB criteria. The UK has the largest hybrid and electric bus market in Europe, creating significant opportunities for low emission bus manufacturers.

LCEBs in operation have saved over 55,000 tonnes of greenhouse gas (GHG) emissions per annum compared with the equivalent number of Euro V diesel buses that would have been operating if the LCEB market had not been developed.

The Department for Environment, Food & Rural Affairs (Defra) and the Treasury have introduced air quality damage costs to reflect the economic cost to society of different air pollutants. These costs relate to impacts on human health and the environment.

The key pollutants from diesel buses are oxides of nitrogen (NOx) and particulate matter (PM). If we compare the air pollution emissions savings associated with the LCEBs in operation to conventional Euro V buses, a total damage cost saving of around £8 million has been achieved in 2016.

WHAT IS A

Low Carbon Emission Bus (LCEB)?

In 2008, the LowCVP devised a definition of a Low Carbon Emission Bus as one producing 30% less well-to-wheel greenhouse gas (GHG) emissions than a typical Euro III diesel bus. The greenhouse gas emissions covered were methane, carbon dioxide and nitrous oxide. This served as a performance target for different low carbon bus technologies and fuels and as the bar for qualification for the Government's fiscal incentives. Recognising the need to balance air quality and climate change objectives, the definition of a LCEB has now been superseded by new Low Emission Bus (LEB) criteria.

WHAT IS A

Low Emission Bus (LEB)?

In 2015, on behalf of OLEV and the DfT, the LowCVP revised the definition of a Low Emission Bus (LEB) to take into account the dual goals of cutting greenhouse gas emissions and improving local air quality. A Low Emission Bus is defined as a bus which can achieve a reduction of more than 15% in well-to-wheel greenhouse gas emissions compared with a Euro V diesel bus, and achieve the Euro VI engine standard in terms of other emissions. The LEB accreditation scheme entails a new bus test cycle; the LowCVP UK Bus Test Cycle, measuring both greenhouse gas and air pollution emissions. Another difference from the earlier Low Carbon Emission Bus scheme, is that technologies that can demonstrate zero emission capability – i.e. travel at least 2.5km of a route without releasing any emissions – can benefit from top-up funding.

The Next Generation **of Low Emission Buses**

In 2015 the Office for Low Emission Vehicles (OLEV) announced £30 million of new funding to encourage the take-up of Low Emission Buses (LEBs) and accompanying infrastructure to help reduce GHG emissions from UK bus fleets and improve local air quality.

With the success of Euro VI emission systems in delivering clean engine operation, the overarching objectives for new buses can be defined in three areas:

1. ***Increasing the zero emission operation capabilities***
2. ***Improving the efficiency of engine operation***
3. ***Reducing the carbon impact of fuels used***

The LowCVP developed a revised standard for LEBs to reflect the strengthened objectives. A Low Emission Bus produces 15% less GHG emissions on a well-to-wheel (WTW) basis compared with a Euro V diesel bus of equivalent passenger capacity, and meets the Euro VI certified engine standards, or has equivalent emissions performance.

A new Low Emission Bus Accreditation Scheme has been devised by the LowCVP based on extensive whole vehicle emissions testing.

The winners of the OLEV LEB Grant funding are thirteen bus operator and local authority collaborations, covering 326 Low Emission Buses and associated infrastructure. A range of technology and fuels has been funded, including biomethane, hydrogen fuel cell, battery electric and a variety of diesel hybrids.

The introduction of the Euro VI engine emission standard for trucks and buses in 2014 resulted in a step change in NOx (oxides of nitrogen) and PM (particulate) emissions reduction compared to Euro V: a Euro VI bus saves a massive 95% in terms of NOx emissions compared with a typical Euro V bus. All new Low Emission Buses are required to meet this standard to drive improvements in air quality.

The LowCVP has stated as a target that by 2020 every new bus sold in the UK should meet the definition of a Low Emission Bus. Using this ambitious target it is possible to illustrate the potential greenhouse gas and pollutant emissions savings associated with LEBs in 2020. In that year it is forecast that a total of 11,710 new buses will be on the roads in the UK, based on a projection of existing bus sales. If we assume that bus operators replace their old Euro III buses with new LEBs, then impressive emissions benefits are possible.

By 2020 air quality damage cost savings of £248.5 million could be achieved from the reduction in particulate matter and NOx emissions due to the introduction of new LEBs, in addition to WTW GHG emissions savings of 432,000 tonnes, achieved by replacing Euro III buses with new LEBs.

Paving the way to zero emission-capable buses

Electric *Buses*

There are currently 175 electric buses operating across the UK, predominantly in cities that have experienced poor air quality. They include London, Nottingham, York and Milton Keynes in England, and Inverness in Scotland.

The electric bus market is dominated by the British automotive manufacturer Optare which produces a range of single-deck electric buses. Other electric bus manufacturers include Wrightbus, Volvo and Irizar. BYD has recently entered into a partnership with Alexander Dennis Ltd to build single decker electric buses in the UK.

Current electric buses operate using a lithium battery for propulsion. Electricity from the grid is used to charge the battery once depleted, or at points along the route. Various strategies exist for charging electric buses such as simple plug-in charging, using a cable connected to the local electricity network, to more innovative wireless (inductive) charging at bus stops.

One of the biggest drivers of the introduction of electric buses is the fact that they produce zero tailpipe air pollution emissions. They are also much quieter than a conventional diesel bus. The well-to-wheel greenhouse gas emissions of an electric bus when charged using the UK electricity grid are more than 60% lower than a typical diesel bus, and the increasing use of renewable electricity will further reduce the carbon footprint of electric buses.

Location of electric buses in the UK

"The move to electric buses is exciting."

THE VIEW FROM ARRIVA ELECTRIC BUSES, CROYDON

Transport for London (TfL) currently operates 31 electric buses and by the end of 2016 will be running Europe's largest electric bus fleet of 73 vehicles.

Included in TfL's fleet are five of the UK's first double decker electric buses, built by BYD. TfL's electric buses are run by several operators - Arriva, Metroline and Go-Ahead Group. The electric buses, and accompanying infrastructure, have been funded by Transport for London, the Green Bus Fund and the recent Low Emission Bus Grant.

The Mayor of London has introduced ambitious targets for transforming the capital's bus fleet over the next few years with a particular focus on introducing low emission buses to meet air quality objectives. The introduction of the Ultra Low Emission Zone in 2020 has already encouraged the commitment to deploy 300 zero-emission single decker buses in central London.

Arriva operates nine Optare electric buses from its depot in Croydon, South London, on behalf of TfL. This is Arriva London's first venture into electric buses, which were introduced in 2015. The buses run in Croydon's Air Quality Management Area. Chris Bateson, Arriva's Depot Manager, says that he's excited about the introduction of electric buses to his fleet.

Arriva's electric buses are used on the '312' ten mile route, five times per day, in Croydon's Air Quality Management Area. They operate wholly on electricity; the 50 mile total distance is comfortably within the 80 mile range of the bus.

The Optare electric bus incorporates brake regeneration technology, which captures energy that would otherwise be lost when braking, and recycles it back into the battery. Although the '312' route is mostly flat, the buses have been trialled on routes with more hills and the regenerative braking can be optimised for such conditions. The electric buses outperform diesel in terms of engine torque, giving instant response. The vehicles have proved to be very reliable.

A lot of background work was required before the buses were purchased, along with subsequent support with batteries, charging technology, and the optimisation of the regeneration system and therefore the driving range.

Arriva's Croydon depot until recently only had two operational fast chargers – many of the buses had to rely on slow charging (taking three hours to deliver a full charge, compared to one and a half hours for a fast charger). To ensure more fast charging for all the electric fleet, a major consideration was to ensure that the capacity of the electricity supply was sufficient. An upgrade of the existing supply substation facilities was required, a process which was carried out by EDF, taking around six months from start to finish.

Chris Bateson was keen to ensure that other operators looking at adopting electric buses should be aware of the timescales and significant costs associated with upgrading the electricity infrastructure.

The Go-Ahead Group depot in Waterloo will be the first to switch to all-electric buses

TfL and contractor Go-Ahead Group launched Europe's first all-electric bus depot in Waterloo, London on 9th September 2016.

Go Ahead acquired its first two BYD electric buses in January 2015 and trialled these vehicles over the subsequent twelve months. The vehicles proved to be reliable and performed well on their central London bus route. Following this initial success, Go-Ahead has purchased 46 BYD-ADL Enviro200 (as part of a fleet of 51), the first nine entering into service in September with the remaining fleet to be introduced by the end of November 2016. Go-Ahead's electric bus fleet will run throughout the day on central London routes 507 and 521 and only require charging at night. In order to accommodate the large number of electric buses being charged at the Waterloo bus garage the capacity of the local electricity network required large-scale upgrading. This entailed the installation of two new electricity sub-stations at a cost of over £1 million. The upgrading work took almost one year to complete and was funded by TfL.

Electric buses are the target that we're heading for

"Electric buses are the target that we're heading for – the biggest challenges are with charging, the grid supply and infrastructure. Thought needs to be given in advance to the charging infrastructure for electric buses, as substantial upgrading work on the local electricity network is typically needed – such as for the 51 electric buses that need charging overnight at Waterloo. Therefore greater collaboration is required between TfL, OEMs and energy companies."

MIKE WESTON, DIRECTOR OF BUSES, TRANSPORT FOR LONDON

NOTTINGHAM:

Electric bus pioneer

Nottingham operates one of the largest electric bus fleets in the UK. Unusually, the buses are owned by Nottingham City Council. Out of the council's 45 electric buses, 41 are operated by the charity Nottingham Community Transport.

The buses are used on routes such as Medilink, a free service which links the Park & Ride to local hospitals and the tram network. The all-electric Medilink bus service carries 30,000 passengers each week.

Nottingham took delivery of its first four electric buses – Optare Solos – in 2012, then acquired another 41 over the next three years. The Green Bus Fund – which provided a subsidy on vehicle purchase – was critical in Nottingham's decision to invest in electric buses as it helped cover the premium cost of these vehicles. Plugged-in Places Midlands funding was used to support the purchase of 25 slow and fast charging points. These are located at the council's electric bus depots and at two park and ride locations.

The Optare electric buses have a maximum range of 95 miles, with drivers achieving up to 80 miles in real-life driving. Brake regeneration is key to achieving maximum range. The running costs are significantly cheaper - around one-third of the cost of a diesel bus - and servicing costs are also lower. The electric buses have reduced carbon dioxide emissions by over 1,000 tonnes compared to the previous diesel buses.

Nottingham is also unusual in choosing to carry out the maintenance of the electric buses itself, rather than rely on the bus manufacturer. Steve Cornes, Principal Project Officer, says that this gives them the ability to be independent and deal with any issues quickly.

Being an early adopter, Nottingham experienced a variety of challenges over the first two years, particularly with reliability, but also with charging. Working closely with the supplier, things have improved significantly over the past two years, with technology and reliability getting better, but one big issue remains: the capacity of the local electricity network to power fast chargers. Nottingham City Council paid for upgrading work to be carried out by its Electricity Distribution Network Operator that included the installation of new electricity substations. The electric charging infrastructure and local network upgrading work has cost over £300,000.

I would recommend electric buses to everybody

"Since driving electric buses I've had lots of compliments. The passengers do notice that the buses are quieter and smoother, and they don't smell of diesel. Electric buses are much better to drive around town, I would recommend them to everybody."

COLIN GODBER, DRIVER, NOTTINGHAM COMMUNITY TRANSPORT

"In terms of the future, Nottingham can see only electric buses as the way forward, as increasing awareness of air quality issues will lead to the creation of low emission zones, eliminating the use of fossil fuels by vehicles in city centres."

STEVE CORNES, PRINCIPAL PROJECT OFFICER, PUBLIC TRANSPORT, NOTTINGHAM CITY COUNCIL

MILTON KEYNES:

Wirelessly charged electric buses

Arriva operates eight Wrightbus StreetLite electric buses as part of a multi-stakeholder project to demonstrate the UK's first all-electric route and this was the first UK application of inductive charging.

The management of the project is the responsibility of the Mitsui-Arup joint venture – MBK Arup Sustainable Projects (MASP). The collaborators are: eFIS, Mitsui & Co, Arup, Milton Keynes Borough Council, Arriva, University of Cambridge, SSE, Wrightbus, IPT-Technology, Western Power Distribution and Chargemaster plc.

The first three StreetLite electric buses arrived in January 2014 with numbers rising to eight by May 2014. Rather than being solely charged overnight at a depot, the buses are topped up wirelessly when they stop over a charging plate at bus stops at each end of their route. This enables the entire route to be electric with the buses operating all day. The buses cover a maximum range of 190 miles in one day, and around 17,000 passenger journeys are completed each week.

To wirelessly charge the vehicle, the driver positions the bus over the plate at the bus stop, lowers a charging plate that sits underneath the bus and the bus battery is charged inductively. The plate on the bus and the plate on the road don't actually come into contact; energy is instead transferred magnetically across the small gap. The principle is based on the fact that magnetic fields can be used to create a current in a wire and magnetic fields can be transferred through air.

The bus is at the 'rest stop' for 13 minutes, with the induction charging lasting 10 minutes before passengers board. During this time the 120 kW induction plate provides up to two-thirds of the energy consumed on the 15 mile bus route, which runs from the north to south of Milton Keynes, via the town centre.

The buses leave the depot just after 6am in the morning fully charged and can stay out all day, returning at 11.30pm. They never come back with less than 40% of battery charge remaining, which helps to maintain battery efficiency.

The buses are then 'trickle-charged' overnight for five and a half hours at 20 kW (the minimum charge). This balances out the batteries, which again prolongs battery life. The 20 kW minimum charge means that a new substation wasn't required to provide electricity for the depot, something that is usually needed when a number of electric buses need to be charged at one location.

Induction charging on the bus route means that the vehicle battery can be smaller and lighter than it would have to be if it had to complete 190 miles without any opportunity charging.

Kieran Lawson, General Manager, Arriva Milton Keynes, says that the project has been successful: "It has proved that the technology works and there are huge savings in fuel costs and CO_2 emissions compared with diesel-powered buses. We were expecting the vehicle batteries - one of the main costs of the vehicle - to last five years, so allowed for three battery packs over the 15 year bus lifecycle. However, they appear to be lasting longer. We have been keen to share the learning from the project, including with a number of representatives from EU countries that have visited us."

Milton Keynes Borough Council has recently been successful in bidding for funding from the Office for Low Emission Vehicles (OLEV) Low Emission Bus scheme, receiving funding of £1.6 million for 11 new electric buses, plus £127,500 for infrastructure.

The energy infrastructure for electric buses:

The view from the electricity Distribution Network Operator

Electric buses need a significant quantity of electricity to charge their batteries, and significant upgrades to the local electricity network – along with the associated time and cost – are often required to cope with charging a depot of electric buses.

Having three inductive chargers (two at either end of the bus route, plus a third plate at Milton Keynes railway station) enabled the local electricity Distribution Network Operator (DNO), Western Power Distribution (WPD), to test different connection methods. Two connections cost £40-£50,000, but a third connection was into the existing low voltage (LV) supply, and it only cost £3-£4,000.

Ben Godfrey, Innovation and Low Carbon Networks Engineer, WPD, has advice for bus operators considering electric vehicles: "Securing sufficient capacity on an electricity network can be a major obstacle. Early consultation with the DNO is essential – this doesn't cost anything and a feasibility study can be undertaken. We can advise on the best, and cheapest, places for charging."

"To put the charging required for electric buses into context, one three-phase fast bus charger (30 kW) is equivalent to the power demand of 15 houses. Inductive chargers are equivalent to the power demand of 70 houses. If all the buses in Milton Keynes were electric, there would be a load of 80 MW – this would need significant reinforcement of the high voltage supply infrastructure. If all buses in the UK went electric, 850 MW of power would be needed – the same as one large nuclear reactor or two coal-fired turbines."

However, the overall message is that charging for electric buses throughout the UK can be provided, but it does require early consultation with the DNOs who really need clear oversight of where large changes in power demand are going to occur.

The driver's view of electric buses in Milton Keynes

The drivers at Arriva Milton Keynes say that the electric buses are quieter and smoother, and that the ride comfort is better, than their diesel counterparts. All drivers receive training for the electric buses, particularly in how to position the bus directly over the induction charging plate. The drivers are pleased to be identified as being of a sufficiently high standard to drive the electric buses. They're also interested in how they perform, with drivers commenting that, thanks to their regenerative braking, the buses haven't had to have their brake pads replaced since they were introduced at the depot over two and a half years ago.

YORK:

Electric buses serve York's park and ride routes

First York has had 12 Optare Versa electric buses in operation since 2014. These were part-funded by First Bus, with the extra cost of the electric buses covered by the Green Bus Fund.

The buses travel along an eight-mile route serving the park and ride sites at Poppleton and Monks Cross; they cover 112 miles a day. The electric buses are charged overnight at the First Bus depot at James Street, which takes about eight hours.

York City Council has funded the installation of a 50 Kw rapid charger at each park and ride site. This essentially allows the electric buses to top up their batteries during the daily operation and takes about 40 minutes when the battery is completely depleted. The local electricity network at both locations required upgrading to enable sufficient power to be made available for the rapid chargers, and allow for extra power if additional chargers are installed in the future.

First York commented that it was important to integrate its electric bus fleet into the whole organisation – this was a key element in the success of running the fleet. It was a new technology that required a variety of changes across the organisation, so joined-up working and awareness-raising was important. First York sees the adoption of electric buses as a planned and managed transport 'system' with the need for a programme of management and systems integration.

The buses have proved to be very reliable although there were some initial teething problems. These included incidences of electric bus breakdowns and various technical issues with the first set of electric chargers, causing delays in charging time. York City Council has invested much time and effort into resolving the technical problems associated with the electric charging infrastructure. First York has worked closely with Optare and York City Council to resolve these issues resulting in improved performance of both the electric buses and charging infrastructure.

The operators have found that various factors affect electric range including cold weather and the level of loading on the buses. First York Managing Director Marc Bichtemann highlights that driving style also has a big impact, so driver training is important to optimise electric range. First York has fitted its electric buses with on-board monitoring software that tracks electricity consumption and range. This helps the company engage with its drivers to encourage ongoing improvements in driver behaviour.

The City of York Council's aspiration is to increase the numbers of electric vehicles across the city to improve air quality. The council undertook an electric vehicle feasibility study which identified that 80% of York's bus routes could go electric, which would reduce road transport NOx emissions by 70%.

The driver's view of electric buses in York

First York's drivers say that it took a while for some of them to get used to driving an electric bus, especially for drivers who had many years of experience of driving diesel buses, but they now enjoy the experience, especially the quick acceleration. They say that customers also find the electric buses more pleasant, they offer a smooth ride and are quieter than diesel buses.

THE BUS MANUFACTURER:

Optare

Optare has 93 electric buses in operation in the UK. One of Optare's electric buses has been in service at Stranraer for over five years and has completed over 100,000km. Despite this time in service and the distance it has covered, the battery pack is still almost 100% effective. Graham Belgum, Optare's President, says this is because the charging of the battery has been managed correctly.

Optare works with ViriCity to remotely monitor each of the 52 battery cells in the overall bus battery pack. If an issue is identified with one of the cells then it is replaced; otherwise it can stop other cells charging. Out of 93 vehicles in service, each with 52 cells, only five cells have ever been replaced.

Optare is now able to offer bus operators the opportunity to buy the bus and lease the batteries separately. Just as a bus operator doesn't pay for years of diesel fuel when it buys the bus, it can now spread the cost of the battery over the long-term.

Graham says that the biggest challenge for the widespread adoption of electric buses is infrastructure. A common charging regime would make life much easier, and it would be ideal if all local authorities had a strategic approach to expand the number of charge points, which could also serve council vehicles. This would also encourage the adoption of electric vehicles in city centres, so helping with the key issue of local air quality.

In future, Optare is keen to keep the weight of its electric buses as low as possible in the interests of efficiency and to maximise capacity for passengers.

Graham concludes by saying that there is a lot of smart investment worldwide going into electric vehicle projects at companies such as Tesla, Apple and Google – the UK should learn from these developments and take more of a collaborative approach to ensure we move quickly to sustainable low emission transport solutions.

Plug-in Hybrid Buses

There are five plug-in hybrid buses operating in the UK, located in London and Bristol. These plug-in hybrid buses are in the early stages of commercialisation and are presently involved in demonstration trials.

Plug-in hybrid technology offers a stepping-stone to the full electrification of public bus fleets and zero emission operation in key areas while retaining wide route capabilities beyond those of a fully electric bus. Provided that sufficient battery charge is available, a plug-in hybrid can provide emissions-free operation over significant parts of a bus route. This can give the zero-emission benefits of an electric bus in the city centre combined with the range and flexibility of a diesel hybrid bus for sections of the route that are less emissions-sensitive or beyond the reach of electric vehicles.

The use of plug-in, inductive or conductive pantograph charging systems on the route further reduces overall dependence on the diesel engine. The ADL Enviro 400 Virtual Electric is the only plug-in hybrid bus model currently operating in the UK. It can travel up to 24 miles in fully electric operation.

Volvo has recently introduced the V900 PHEV in the UK. The vehicle has an electric range of five miles. The company has matched its plug-in hybrid buses with on-route 'opportunity charging' using pantograph conductive charging infrastructure.

Plug-in hybrid buses offer exciting opportunities in cities that experience poor air quality and which have designated low emission zones. Manufacturers can control and force the electric mode of a plug-in hybrid bus using GPS, known as 'geofencing', in defined geographical zones where the bus automatically switches to full EV mode on entry. In some cases geofencing can also take into account time of day, so a route connecting a residential area to a city centre could deploy EV mode in the city during the day, or during the night to reduce both noise and emissions.

While plug-in hybrid buses offer zero tailpipe air pollution and CO_2 emissions when operating in electric mode, like full EVs the carbon footprint of the electricity to charge the bus needs to be taken into consideration. When a plug-in hybrid bus operates as a conventional hybrid, CO_2 emission savings will be achieved. The latest plug-in hybrid buses meet Euro VI standards ensuring low emissions even when the engine is operating.

↑ *Location of plug-in hybrid buses in the UK*

BRISTOL:

Virtual Electric buses in Bristol

First West of England operates two ADL Virtual Electric plug-in buses amongst a range of low carbon emission bus technologies.

The Virtual Electric plug-in buses are very expensive as they are prototype vehicles, designed to be charged using inductive charging infrastructure. The Virtual Electric buses, and accompanying infrastructure, were funded by the Department for Transport which wanted a location to trial plug-in hybrids outside of London.

The buses went into service in December 2015 and are used on the '72' route which runs through Bristol's air quality management area. The plug-in hybrid buses incorporate geofencing, switching the powertrain to pure electric mode automatically as soon as the bus enters an air quality management area. In total, the buses produce zero tailpipe emissions around 80% of the time.

The buses are charged at an inductive charging plate at the University of the West of England where the bus route terminates. The underground plate gives 20 miles of range from seven minutes of charging. The buses can also be fully charged in 45 minutes via a fast charging system.

First West of England also has three Nissan LEAF pure electric cars at its depot in Bristol to transport drivers at shift changes from the hospital back to the depot, one mile away. The electric cars have replaced travel by bus, resulting in savings in fuel and emissions.

Virtual Electric buses – the view from the driver

Drivers say that the Virtual Electric buses are excellent to drive; lots of torque means that they have good acceleration when needed, and they are very smooth and comfortable from the passengers' point of view. Drivers receive much positive reaction to the buses from the public.

LONDON:

'Virtual Electric' buses in London

ADL Virtual Electric plug-in hybrid buses are also being trialled by Transport for London (TfL). This is part of a large European demonstration project called ZeEUS - the Zero Emission Urban Bus System.

ZeEUS is testing innovative electric bus technologies with different charging infrastructure in ten demonstration sites across Europe. The ZeEUS project aims to validate the economic, environmental and societal viability of these electric bus fleets.

The Virtual Electric plug-in buses went into service in 2016 and are run by TfL's contractor, Tower Transit. The batteries of the plug-in hybrid buses get a quick 'top up' charge at bus stands at either end of route 69 at Canning Town Bus Station and Walthamstow Bus Station, using inductive charging, enabling them to operate in EV mode about 80% of the time. The buses run for 12 hours per day and the 'top up' charge takes about eight minutes. It is hoped the wireless charging technology will help reduce running costs and extend the range of the plug-in hybrid buses without impacting on route timing.

THE BUS MANUFACTURER:

Alexander Dennis Limited (ADL)

Alexander Dennis Limited (ADL), the largest supplier of buses into the UK market, manufactures the plug-in hybrid Enviro400 Virtual Electric bus, but the company also offers a full range of low emission buses including series hybrids, full electric and CNG – in single decker and double decker guises.

Over 1,000 series hybrid double deckers are in service, many in London, which have been jointly developed with powertrain partner BAE, supplier of hybrid driveline components such as batteries and motors. ADL is also currently working with BYD to produce full electric buses.

ADL says that the best bus solution depends on the individual requirements of the duty cycle (route). In areas with challenging air quality conditions such as London, fully electric vehicles are ideally suited to making the maximum improvement. However, combustion powertrains are still the most effective for longer routes/extended speeds.

Stuart Cottrell, Advanced Engineering Manager at Alexander Dennis, admits that there has been a disconnect between the supply of plug-in buses and the electricity infrastructure that they require. He says that experience is being gained rapidly in this area with each new project and there is fast progress.

Hydrogen Fuel Cell Buses

There are currently 18 hydrogen fuel cell buses running in London and Aberdeen, supplied by WrightBus and Belgian coach and bus manufacturer Van Hool.

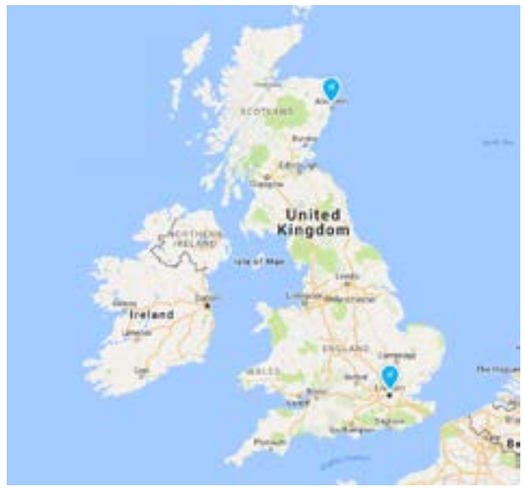
Hydrogen buses offer zero tailpipe emissions and longer range than electric models, though costs are higher. They use a hydrogen fuel cell to power an electric motor which provides propulsion. The fuel cell converts chemical energy from hydrogen into electrical energy, producing only water vapour. Like full electric vehicles, hydrogen buses offer benefits in terms of improving air quality in cities and the potential for cutting CO_2 emissions.

The latest hydrogen fuel cell buses are equipped with hybrid technology, which improves the fuel efficiency and electric range of the vehicle. Hydrogen is stored in cylinders in a compressed state, typically on the roof of the bus.

Hydrogen can be produced by several methods that vary significantly in carbon intensity. In the UK it is mainly produced industrially, through steam reforming of natural gas, compressed and transported by road to a fleet operator's refuelling station. Steam reforming of natural gas is associated with a high carbon footprint as the process is energy-intensive.

A lower carbon method of generating hydrogen is via the electrolysis of water using renewable electricity. This involves running an electrical current through water in an electrolyser to split the water into hydrogen and oxygen. By using electricity from renewable sources in this process, the hydrogen can be produced with very low carbon emissions.

The hydrogen transport sector is in the early stages of commercialisation with only a small number of vehicles currently on the roads in the UK. The opportunities for hydrogen fuel cell buses in cities have been given particular attention through several large demonstration projects - running for nearly a decade in Europe - to explore the practical, economic and environmental case for operating hydrogen buses.



↑ *Location of hydrogen fuel cell buses in the UK*

LONDON:

London's hydrogen fuel cell buses

Tower Transit, on behalf of TfL, runs eight Wrightbus hydrogen fuel cell buses on the RV1 route in central London which links Tower Gateway Station and Covent Garden. Each bus is in operation between 16 and 18 hours per day, and covers a daily distance of 200km.

This is the first time a whole route has been fully operated by hydrogen-powered buses in the UK. The hydrogen buses play an important role in helping meet TfL's commitments to improving air quality in London.

The first three hydrogen fuel cell buses went into service in 2009 as part of the Cleaner Urban Transport for Europe (CUTE) European-funded project. A further five hydrogen hybrid fuel cell buses, which are more efficient and have a longer range, went into service in 2011 via the CHIC (Clean Hydrogen in European Cities) project.

The buses take approximately ten minutes to refuel; each bus has total storage capacity of 30kg on the bus and, typically, uses 15kg per day. The buses are refuelled at Tower Transit's Lea Interchange bus garage in East London at a facility supplied by Air Products, which also supplies hydrogen gas produced by steam methane reformation. The station has a total permanent storage capacity of 320kg of hydrogen.

Tower Transit has seen the performance and reliability of its hydrogen buses improve over time, evidenced by fewer breakdowns and longer range. This has been achieved by ongoing technological improvements made by hydrogen bus manufacturers and stronger familiarity with fuel cell buses by operators.

Two more hydrogen hybrid fuel cell buses, supplied by Van Hool, will come into service in central London early in 2017 as part of the CHIC project.

TfL and Birmingham City Council have recently been awarded £3.8 million through an OLEV LEB grant for 42 hydrogen fuel cell buses and hydrogen refuelling infrastructure.

ABERDEEN:

Europe's largest fleet of hydrogen fuel cell buses

The oil and gas industry is central to Aberdeen's history. This means that there is significant local experience in the high-tech handling of gases. Project leaders in Aberdeen have a clear vision for a future beyond oil and gas, which involves moving to sustainable energy. Aberdeen has a fleet of ten Van Hool vehicles, six operated by Stagecoach and four by First.

The hydrogen buses, owned by Aberdeen City Council and leased to the bus companies, started operation in March 2015 as part of a four-year EU demonstration project to make hydrogen buses more commercially viable. In total there has been a £21m investment, comprised of £19m funding (half from the EU and half from Innovate UK), and £2m from BOC for the hydrogen refuelling station.

The buses are used across the city's park and ride routes. They have the same range as diesel buses (up to 250 miles) and are refuelled just once per day. The local hydrogen refuelling station produces hydrogen through the electrolysis of water with renewable electricity, sourced via a green electricity tariff, being used to power the equipment. In future Aberdeen has plans to produce its own sustainable supply of hydrogen with the help of renewable energy from an offshore windfarm. There is also an intention to expand the number of other hydrogen vehicles in the city, including cars and vans.

Councillor Barney Crockett, Aberdeen's Lead Councillor for Hydrogen, says: "Aberdeen Council has a strategy and action plan to create a hydrogen economy. However, there is a need for an international approach – with the EU and beyond – to share best practice in the area of sustainable transport. This will also help to make technology such as hydrogen fuel cell buses more cost-effective."

THE BUS MANUFACTURER:

Van Hool

Van Hool currently has ten fuel cell buses operated in Aberdeen by First and Stagecoach, and two other fuel cell buses for London are in production. The ten fuel cell buses in Aberdeen are travelling around 30,000 miles per year per bus and they save around 145,000 litres of diesel annually.

In 2018 Van Hool will have 30 diesel hybrid articulated Bus Rapid Transit (BRT) vehicles operating with Translink in Belfast. The diesel hybrid vehicles consume 20-25% less fuel compared to standard diesel vehicles.

Van Hool offers a multi-propulsion platform, ranging from hybrid to 100% electric. High-end public transport solutions provided by Van Hool, such as the Exqui.City Trambus (BRT), are diesel-electric hybrid or gas-electric hybrid. The company also supplies vehicles that are fully electric, with inductive or conductive charging, as well as fuel cell vehicles.

Innovation in technologies to improve fuel consumption in buses

Hybrid Buses

Hybrids are the most popular low emission bus technology in the UK. There are 2,367 hybrids operating across 32 regions throughout the country.

The first hybrid buses came into service in London in 2006, driven by the need to improve air quality whilst also saving fuel. Bus operators running the largest hybrid bus fleets include Transport for London, Stagecoach, Go-Ahead, First and Arriva. London, Scotland, Manchester and the West Midlands are the regions operating the highest numbers of hybrid buses.

A hybrid-electric bus combines an internal combustion engine with an electric propulsion system. On a conventional bus, when the driver brakes the kinetic energy of the moving bus is dissipated as heat in the brakes or retarder. The bus slows down but the energy is lost. On a hybrid bus, when the driver brakes the hybrid system captures kinetic energy and stores it for use later, when it is required for propulsion. The next time the bus accelerates, the stored energy is fed back to the driving wheels reducing the load on the engine, saving fuel and reducing CO_2. Hybrid buses can save 30% or more in fuel consumption compared to a conventional diesel vehicle.

Hybrids are classified as either 'series' or 'parallel'. A series hybrid bus is exclusively propelled by the electric motor. The ADL Enviro 400 and the Wrightbus New Routemaster are examples of series hybrids. In a parallel hybrid bus, the combustion engine and the electric motor are connected to the transmission independently. The electric motor is designed to provide power during stop and start traffic, while at highway speeds the vehicle is powered solely by the internal combustion engine. The Volvo 7900H and B5HL are examples of parallel hybrids.

Some hybrids can travel up to 1 km in all-electric mode. The latest Euro VI hybrid buses can achieve very low levels of emissions, offering benefits in cities with poor air quality whilst also helping to cut CO_2 emissions significantly.

↑ *Location of hybrid buses in the UK*

MANCHESTER:

The largest hybrid bus fleet in the UK outside of London

Stagecoach has a range of low carbon initiatives and sets targets each year as part of its sustainability agenda. Stagecoach has heavily invested in hybrid buses to reduce the carbon footprint of its bus fleet and they help to reduce fuel costs. Stagecoach operates a total of 263 hybrid buses across the UK.

Government funding including the Green Bus Fund, Scottish Green Bus Fund and the BSOG incentive have played a key role in supporting the business case for these hybrid buses.

Transport for Greater Manchester (TfGM) has the largest hybrid bus fleet in the UK outside London. Stagecoach in Manchester and Wigan operates 132 hybrid buses out of a total fleet of 800. The ADL TB08 was the first hybrid, introduced in 2010. This was followed by the second generation, full hybrid TB100 double-decker. This vehicle has a smaller diesel engine than normal, but it is supplemented by a lithium-ion battery powering an electric motor. The engine drives the wheels directly 80% of the time, and the bus is able to pull away from bus stops in electric mode. The latest hybrids have stop/start technology. The buses are used on routes in Manchester city centre, with Stagecoach working closely with the Greater Manchester Combined Authority.

The company anticipated a 35% improvement in mpg, compared with equivalent diesel-engine buses, and this was achieved in the first year of operation. This has subsequently fallen to around 26-27%. The hybrids cover approximately 4,250 miles per week (over 200,000 miles per year) representing significant savings in fuel costs and emissions.

Reduced performance of the hybrid bus batteries has been suggested as the cause of the drop in fuel efficiency. Manufacturers have made technical improvements to hybrid buses leading to enhanced performance over recent years. Furthermore, bus operators are understanding more about how to optimise the performance of hybrid buses both in terms of routes and driver behaviour.

Overall the hybrids have become more reliable than when the technology was first introduced. Stagecoach is expecting to replace the vehicle batteries at some stage but an extended warranty is in place to support this.

Sam Greer, Engineering Director, Stagecoach UK Bus says: "Hybrid technology has evolved over the last six years. Our close relationship with the OEMs has ironed out maintenance issues and thereby improved reliability."

Lothian Buses has saved £1.4 million in fuel costs since 2011 thanks to use of hybrid buses

Lothian Buses, based in Edinburgh, has aligned the operation of its bus fleet with local air quality targets and carbon reduction through the use of hybrids. The company operates 85 hybrids, single and double deckers, with the first buses having come into operation in 2011.

The routes are a mix of urban and suburban, running west to east and north to south in Edinburgh, all passing through the city centre. All hybrids run on routes that enter six air quality management areas.

In order to help cover the cost premium of the hybrid buses, Lothian won funding from the Scottish Green Bus Fund. The company has also been supported through the BSOG LCEB incentive for its hybrid bus fleet.

Lothian has purchased both series and parallel hybrids, supplied by ADL and Volvo, over the last five years. The organisation has a good working relationship with both OEMs, resulting in successful maintenance of its hybrid fleet.

Battery changes have been required on some of the older hybrid buses. Lothian is expecting the latest batteries to last another five years and has extended the warranty period for its hybrid buses. Lothian has observed no difference in breakdowns of newer and older vehicles, but Euro VI powertrains have been performing better in terms of fuel savings.

Lothian has said that the performance of its hybrid fleet, based on 600,000 miles per year, has been very good, and it has achieved between 30-36% fuel savings from the operation of its Euro V hybrid buses compared to equivalent Euro V diesel buses. This has been achieved on a mixture of routes.

Euro VI hybrid buses have shown greater fuel savings, for example the Volvo DD B5HL has achieved 40% fuel savings. The company says that it has saved £1.4 million in fuel costs since 2011 thanks to its adoption of hybrid bus technology. Hybrids are only operated on high-mileage routes, enabling the company to more quickly recoup the increased capital cost of the hybrid buses due to fuel cost savings.

BIRMINGHAM:

Birmingham's hybrid buses offer cost savings

National Express Bus, Birmingham, operates 18 Volvo B5LH parallel hybrid double decker buses. The motivation to buy hybrid buses was the potential cost saving through improved fuel economy.

The hybrid buses have been in operation for around five years, and there is now two years of fuel economy data. This shows that a Euro V bus returns around 7mpg, but the hybrids return 8.5mpg; over the lifetime of a bus, an extra 1.5mpg in fuel economy can deliver significant savings in cost and CO_2 emissions.

The battery life of the buses was expected to be five years, but as they approach this timescale they don't appear to be in need of replacement.

John Parker, Engineering Manager at National Express Bus in Birmingham says that the hybrid buses are a success: "They've gone down well with the public and the drivers, they're more fuel efficient and they do offer cost savings. They're now reliable and there are even benefits in the area of maintenance, as there's little wear of the braking systems thanks to the hybrid brake regeneration."

National Express Bus has had feedback from local residents who prefer the hybrids driving past their house early in the morning rather than conventional diesel buses, as there is less noise and vibration. Passengers have occasionally complained if a conventional Euro V bus turns up at a stop rather than a hybrid. Thanks to the unique livery, the hybrids stand out from the conventional buses and appear to have been embraced by the travelling public.

THE BUS MANUFACTURER:

Volvo

Volvo manufactures conventional hybrids, as well as plug-in hybrids and fully electric buses. The company has also produced gas buses for use in the UK and Europe, and has trialled alternative fuels.

Volvo brought conventional hybrids to market in 2009 with Transport for London (TfL) in order to evaluate their emissions savings. Hybrids have now become the mainstay of public transport in London. There are 950 Volvo hybrids in the capital and around a further 300 in other cities, including Manchester, Liverpool and Birmingham.

The manufacturer is now bringing plug-in hybrids to market with larger energy storage systems; the battery allows the bus to run over four miles on electric power.

Volvo says it does not want to be seen just as a bus manufacturer, but instead as a solutions-based provider of city mobility systems. The company is implementing a strategy to bring public transport with the greatest emissions reductions to market without government subsidies. To achieve this Volvo is working with bus operators, local authorities, government bodies, energy companies and other partners to look at solutions that would work over longer timescales; typically 15 years.

Volvo sees progressive electrification as the only long-term sustainable way forward at this time. Electrification includes conventional hybrids, as well as plug-in hybrids, and fully electric buses – with opportunity charging where possible.

A number of obstacles to the electrification of public transport are generally cited by stakeholders, the primary one being cost. To mitigate this concern, Volvo says it will pay for the necessary infrastructure over the period of a contract, whether this is 10, 15 or 20 years.

Such infrastructure may include conductive pantograph charging, using overhead connectors at bus stops that have a physical contact with the bus. Such 'opportunity' charging means that the bus can have a lighter battery, freeing up more capacity for passengers, and this has less impact on the local electricity grid than if all buses needed a full recharge at one site at the same time.

Mike Weston,
Director of Buses at TfL, says:

"The hybrid buses have performed very well, which is why their numbers are rising; if they weren't sustainable we wouldn't have grown the fleet."

London leads by example by spearheading the roll out of hybrid buses

TfL has a bus fleet of 9,200 vehicles which serve 6.5 million people each day. Within this total there are already 1,750 diesel hybrids, the largest hybrid fleet in the UK.

From 2006 to 2010 TfL conducted trials of single and double-decker diesel hybrid buses including 56 vehicles across eight major operators, and four manufacturers: ADL, Volvo, Wrightbus and Optare. Hybrids were chosen as they offered the most cost-effective means of CO_2 reduction. A 30% CO_2 saving was demonstrated over the Millbrook London Transport Bus (MLTB) test cycle (derived from Route 159), and 40% for the New Routemaster. The success of these trials and the increasing need to improve air quality led TfL to purchase a significantly larger number of hybrid buses.

London's Ultra Low Emission Zone (ULEZ) requires diesel buses to meet the Euro VI emission standard by 2020. With this target in mind, all double-decker TfL buses operating in central London will be hybrid, a total of 3,100 buses. The Mayor of London recently announced that double-decker buses will comply with the ULEZ a year earlier by 2019.

GO-AHEAD LONDON:

The fleet with the largest proportion of hybrid buses

Go-Ahead Group runs one of the largest hybrid bus fleets in London on behalf of TfL. By the end of 2016 this will have increased to around 600 vehicles; 25% of Go-Ahead's entire fleet. The company operates ADL, Volvo and Wrightbus hybrids, both series and parallel.

The first hybrids were introduced in 2009 and there has since been seven years of development and experience. The hybrids are generally now considered to be as reliable as standard diesel buses; there are fewer breakdowns compared with the early days following their introduction. Go-Ahead Group had replaced several batteries under warranty and the first hybrids underwent a complete refit at seven years. The company has extended the warranty of its hybrid buses: although expensive this is seen as an important means of ensuring the effective operation of the buses. All hybrid models have achieved fuel savings but this does vary – the operational terrain and speed profile is a large factor in this.

Since 2007/8 Go Ahead Group has reduced its emissions by around 16% on a like-for-like basis and the target is to reduce this figure by a further 10% by 2018. To achieve this, a major part of Go-Ahead's strategy is to continually invest in new, low emission buses.

Electrified Ancillaries

Efficient diesel buses fitted with electrified ancillaries.

Several manufacturers have improved the fuel efficiency of conventional Euro V and Euro VI diesel buses through exploiting electrified ancillaries, thereby aiding CO_2 emissions reduction. Improvements can be achieved through the adoption of ancillaries such as the alternator, air compressors and electrical systems.

Different approaches have been adopted by manufacturers. For the ADL 'Smart Accessories' range, the electrical system and the compressed air system are controlled to enable charging when the vehicle is coasting/decelerating. In order to gain further reductions in fuel consumption, ADL has designed the E400 with lightweighting, e-cooling and stop-start technology.

'Micro-hybrid' is the terminology Wrightbus uses to describe the intelligent control of engine ancillaries to deliver energy and fuel savings. Wrightbus offers a range of micro-hybrid models, such as the StreetLite and StreetDeck, which have been designed with a variety of measures to improve fuel efficiency. The features include improved opportunity charging for electrical systems, optimising the electric radiator fan and electric power steering plus lightweighting of the vehicle bodywork.

There are currently 1,091 diesel buses equipped with electrified ancillaries operating across twenty regions of the UK. First Bus has spearheaded the adoption of this technology and operates the largest fleet in the country. The regions operating the highest number of electrified ancillary buses are Glasgow, Bristol and Hampshire.

↑ *Location of electrified ancillaries in the UK*

Buses battle it out on the test track

First Bus holds a competition at Millbrook Proving Ground every year to test new buses for fuel efficiency and a range of other criteria.

Vehicles are tested on a course that is designed to reflect a variety of rural, urban and inter-urban bus routes. The buses are fitted with sophisticated equipment to monitor many aspects of performance.

The results of the competition play a major part in the First Bus vehicle procurement strategy. In 2016 First Bus is investing £70 million in 305 new vehicles, and since the event was implemented in 2012 the company has invested around £300 million in almost 1,600 new buses.

The latest innovations in bus manufacturing from vehicle manufacturers such as Wrightbus, ADL and Optare were most recently trialled in August 2016, leading to hopes that a further 10% fuel efficiency improvement could be achieved in 2017.

Smart Accessories

Buses with 'smart accessories' offer one of the more cost-effective ways to reduce emissions. Rather than have the diesel engine power all engine accessories (such as alternators and air conditioning) all the time, it just powers such ancillary items when the engine isn't being used for acceleration. These buses also often feature a stop-start system to reduce emissions further.

On top of the smart accessories, there are also low cost hybridisation options – for a much lower cost than full series hybrids, plug-in hybrids or full electric vehicles.

Electrified ancillary buses deliver payback within two years for the Go-Ahead Oxford Bus Company

The Oxford Bus Company is part of the Go-Ahead Group plc. It operates 120 buses in total, of which 18 hybrids are supplied by Volvo and ADL, plus 11 Wrightbus micro-hybrids.

The City of Oxford has an Air Quality Management Area (AQMA) and, in 2014, it declared a Low Emission Zone for buses, which currently has the strictest emissions standard in the UK, requiring compliance with Euro V.

The Oxford Bus Company has a close relationship with the local authority air quality team and says that it is focused on meeting local environmental objectives. It deploys the 'best buses in its fleet' in the AQMA. The company's Euro V hybrids have been judged to be a success in terms of environmental performance as they have contributed to an improvement in air quality in the AQMA since the vehicles were introduced.

The Oxford Bus Company purchased 11 Wrightbus StreetDecks (Euro VI) in 2015. Phil Southall, the company's Managing Director, says that this has been a good option for a double decker, offering very good performance and reliability. The Wrightbus StreetDeck achieves 9mpg, outperforming other diesel buses in the fleet and delivering a fuel saving of over 20% compared to conventional Euro VI buses at a price that produces a payback within two years. The company receives 6p/km BSOG LCEB incentive for operating the Wrightbus micro-hybrids – although Phil says that they would still purchase the vehicles without this.

Electrified ancillaries at First Bus

Across the UK, First Bus operates 869 electrified ancillary buses, split between Euro V and VI, across its fleet comprised of Wrightbus StreetLites and StreetDecks, and ADL E200 and E400 Smart Accessories. When assessing the whole-life costs of different technologies, First Bus was attracted to electrified ancillary buses as they provided reasonable fuel cost benefits at a relatively small increase in vehicle capital cost.

Both the Wrightbus and ADL electrified ancillary buses have proved very reliable and are tolerant of a wide range of route characteristics. The vehicles are performing well in terms of fuel economy, although the actual percentage improvement is highly dependent on the bus route and comparator vehicle. Compared to the older vehicles in the fleet, or the buses being replaced, the electrified ancillary buses have achieved fuel savings up to and in some cases beyond 30%. They are simple to maintain, with all maintenance carried out in-house. Given the success of First Bus's current fleet of electrified ancillary buses, the company has placed orders for another 131 buses this year.

Reducing the carbon footprint of buses using renewable fuels

Biomethane Gas Buses

The use of biomethane in gas buses.

Biogas is produced when organic matter is decomposed by micro-organisms in the absence of air. This occurs through the process of anaerobic digestion. Raw biogas is a mixture of methane, carbon dioxide and other chemicals. It requires cleaning to around 95-98% methane to allow it be compressed and injected into the national gas grid. Gas can then be extracted from the local grid and used as renewable vehicle fuel to power gas buses.

In the UK there are over 100 anaerobic digestion (AD) facilities injecting biomethane into the national gas grid. Organic waste feedstocks used in these plants include agricultural wastes such as farm slurry and crop residues. AD operators can sell biomethane as a physical gas, along with its low carbon properties, through green gas certificates. This allows the AD industry to certify the 'green' credentials of biomethane and allow end users, such as bus operators, to claim the 'bio' benefit of the methane gas.

Biomethane is associated with significant greenhouse gas savings compared to natural gas due to the fact that its production reduces both methane (a potent greenhouse gas) and carbon dioxide emissions. Biomethane can, for example when produced from farm slurry, reduce greenhouse gas emissions by over 80% compared to diesel. Biomethane is considered a sustainable biofuel as the feedstocks used to produce the fuel are derived from organic waste materials indigenous to the UK. The AD process also produces environmentally friendly by-products such as a biofertiliser and renewable CO_2, which can be used in the drinks industry and as a refrigerant.

To run on gas, buses are equipped with a spark ignition engine and produce inherently low air pollution emissions. Gas is stored on-board the bus, compressed in cylinders. The range of a gas bus is typically 250 miles (similar to a conventional diesel). Gas buses can run on natural gas or biomethane. However, only a gas bus running on biomethane is entitled to the Government tax incentives for low carbon operation.

Manufacturers offering gas buses in the UK are Scania ADL and MAN. Vehicles on the market have historically been single deckers, but this year saw the introduction of the world's first double decker Euro VI gas bus by Scania – the Scania/ADL E400. Several bus operators in the UK are introducing the Scania double decker into their fleets over the next year.

Gas buses are refuelled using a compressed natural gas (CNG) refuelling station located at a bus depot. While the refuelling station will extract grid gas, the operator will be using biomethane purchased through the green gas certificate scheme.

Bus operators have the choice of either purchasing, installing and maintaining a CNG refuelling station independently or 'wet leasing' the CNG station. The latter involves a company supplying biomethane and taking responsibility for installation and maintenance of the station.

Gas vehicles are a mature vehicle technology and there are over 17 million gas vehicles operating globally. The UK currently has a small gas vehicle market, mainly associated with trucks and bus fleets. The market for biomethane buses has grown rapidly over the last three years, with the first buses coming into service in 2013. There are presently 112 biomethane buses operating across six regions of the UK. The largest fleets are operated by Reading Buses, Arriva and Stagecoach.

The numbers of biomethane buses are set to grow. For example, Nottingham County Council has been awarded the OLEV Low Emission Bus Grant to purchase 55 biomethane buses and associated CNG refuelling infrastructure.

↑ *Location of biomethane gas buses in the UK*

92% of Stagecoach North East passengers prefer gas buses

Stagecoach launched its fleet of 40 gas buses that run on biomethane in Sunderland in 2013. The Scania ADL E300S single decker gas buses have proved to be extremely reliable. The initial investment of £4 million was part-funded by the Department for Transport's Green Bus Fund. Stagecoach invested £2.5 million in new buses and over £1 million on changing the infrastructure of its Sunderland depot. Reducing air pollution and CO_2 emissions were, it says, the key drivers for adopting biomethane.

Stagecoach owns and operates its own CNG refuelling station. This decision was taken due to the suitability of the depot layout and proximity to National Grid gas mains and electricity supply. The gas refuelling infrastructure was supplied and installed by Roadgas. The grid gas is condensed and stored on-site and a bus can be filled in 3-5 minutes, which is similar to diesel refuelling. Biomethane is purchased via green gas certificates enabling Stagecoach's fleet to be carbon neutral.

The buses cover approximately 33,700 miles per week and achieve around 2.3 km per kg of natural gas. A customer survey run by Stagecoach revealed that 92% of passengers preferred gas buses; 93% said they were smoother with a more comfortable ride; and 94% said they were quieter with less engine noise.

READING:

Reading's biomethane buses achieve 30% savings in fuel costs

Reading Buses has operated 34 Scania ADL E300S single decker gas buses running on biomethane since 2013 across six routes, urban and inter-urban. These buses have been part-funded through the Green Bus Fund. Reading is one of the pioneers of biomethane buses in the UK. Reading's gas buses have a distinct livery to stand out from the rest of its diesel fleet. The company has recently invested in five Scania/ADL E400 double decker gas buses.

Reading Buses refuels its gas buses via a CNG refuelling station located at its depot. Reading invested over £1m to purchase and install the station. The company has a gas supply contract with the Gas Bus Alliance that provides biomethane via a green gas certification scheme. This allows Reading to effectively run its buses on biomethane even though it is drawing the gas directly from the national gas grid. Reading Buses benefits from the BSOG Low Carbon Emission Bus incentive using its green gas certificates.

The refuelling times of biomethane buses are comparable to those of a diesel bus. The vehicles travel between 1,000 and 4,000 miles each week and Reading has reported excellent performance of its biomethane buses. The company says it has a very good relationship with Scania; the company has provided Reading with much support over the last three years. The buses have performed very well on all routes, experiencing fewer breakdowns than diesel buses. The gas buses are also easier and cheaper to maintain primarily due to the fact that they are equipped with less complicated exhaust gas after-treatment systems than diesel buses. The company has achieved 30% savings in fuel costs, which will help offset the cost of the CNG refuelling station over time.

Reading Buses has had very positive feedback from passengers and it has seen a growth of 7-15% over the last two years on the gas bus routes. Gas buses are visibly different with distinct liveries.

John Bickerton, Chief Engineer, organises tours of Reading Buses' CNG refuelling station and its biomethane bus fleet. He is keen to show other bus operators how to set up stations (it could be done in just six weeks!), which is important for people to see and understand. John advocates 'wet leasing' for CNG refuelling stations as this reduces the risk for the bus operator and makes installing and managing the station much easier. He says: "Wet leasing is simple - it takes the headache away from the operator." John also adds that the biomethane buses are the most reliable vehicles in his fleet, and they save 10% of costs for every mile running on gas with wet leasing.

Reading Buses has been successful in gaining a £1.7 million OLEV LEB grant for a further 16 Scania double decker gas buses and for the expansion of the CNG refuelling station.

Arriva Runcorn biomethane buses are 24% more cost-effective compared to similar diesel buses

In 2013 Arriva launched 10 MAN EcoCity gas buses in Runcorn following a successful trial of the technology in Merseyside in 2012. The buses were part-funded through the Green Bus Fund.

Arriva wanted to be at the forefront of new technology in Runcorn and to trial gas buses alongside hybrids. Helping to improve local air quality was an important driver of the decision to use biomethane buses. MAN was the first manufacturer to bring Euro V gas buses to market in the UK. Arriva has found its gas buses to be very reliable, with less maintenance required than diesel buses. The maintenance of the gas buses was originally carried out by MAN staff; Arriva's depot engineers were trained on the job and soon took over maintenance work.

Phil Cummins, Area Managing Director, Arriva North West & Regional Engineering Director, Arriva North West & Wales, says: "The gas buses have worked well from day one, with positive feedback from drivers and passengers. They have proved to be 24% more cost-effective compared to similar to diesel vehicles."

Arriva contracted for the installation of a CNG refuelling station at its depot in Runcorn. The bus operator has a 'wet lease' contract for the CNG refuelling station with the Gas Bus Alliance, which supplies Arriva with biomethane via green gas certificates. The Gas Bus Alliance was responsible for installing the CNG refuelling station and training staff in health and safety procedures, and continues to provide maintenance for the station. Wet leasing made the installation and ongoing maintenance of the CNG refuelling station much simpler for Arriva.

Arriva's gas bus fleet is soon to expand. The company was awarded LEB grant funding to purchase an additional ten MAN EcoCity gas buses that run on biomethane.

Bus Hound – the fastest bus in the world

A Reading Buses gas bus running on biomethane (produced from 'cow poo') set a new land speed record for a service bus at Millbrook Proving Ground on 19 May 2015. The single decker vehicle achieved a top speed of 80.7mph and an average speed over a full lap of 76.78mph, setting a new record in the process. It didn't quite match the 1000mph land speed record hoped for from the Bloodhound supersonic car project, but it's not bad for a vehicle that had no major modifications and which was back in service in Reading the following morning!

GAS BUS ALLIANCE:

Providing bus companies with a biomethane solution

The Gas Bus Alliance was formed in 2009 with the aim of providing bus companies with a complete compressed biomethane solution. Biomethane offers the benefits of emissions that are CO2-neutral together with low operating costs.

Biomethane - a renewable, sustainable fuel - is produced from farm waste which is cleaned and injected into the UK gas grid. So although most bus operators can't guarantee they are using biomethane rather than natural gas in their buses, if they have bought biomethane they are able to claim the renewable benefits of displacing the equivalent amount of natural gas.

The Gas Bus Alliance has installed five biomethane refuelling stations to date, resulting in 14 million kg of CO2 being removed in 2015 compared to natural gas. The refuelling process for compressed gas is as close as possible to a diesel refuelling operation.

THE BUS MANUFACTURER:

Scania

Globally, Scania has a broad portfolio of hybrids and alternative fuel buses and combinations of the two in operation on all continents of the world. For the UK, Scania specifically focuses on gas and biogas, which it sees as the most commercially viable options for cost-efficient CO_2 reduction. Scania has 40 gas buses in operation across the UK.

A key challenge in terms of the introduction of alternative fuel technologies is the new infrastructure required. To overcome this challenge in the context of biogas, Scania has developed a partnership with Roadgas that can put refuelling infrastructure in place for all types of operations and requirements - as well as developing different financing packages suited to both large and small operators.

Scania says that there is no single technology or solution that can tackle growing CO_2 emissions from transport, and that there needs to be work on three levels:

1. ***Saving energy - including more efficient powertrains and driver training***
2. ***Smarter transport - efficient logistics, from cars to public transport***
3. ***Replacing the fossil energy in the system, regardless of energy form (electricity, gas or liquid fuels) with renewables.***

All the above need to be achieved in a way that doesn't cost more per mile for the operator than diesel. So Scania focuses on solutions that provide the maximum CO_2 and emissions reductions for the money spent. For the UK, biomethane is one of the best options, delivering up to 90% WTW CO_2 reductions, and with running costs that are cheaper than diesel.

Scania points to the success of long-term low carbon transport policies and technology solutions in Sweden, and elsewhere in Scandinavia. A CO_2 tax has been imposed on all forms of energy, leading to a phase-out of fossil fuel energy sources in transport and all other sectors. As a result, more than 70% of the bus network is now operating on renewable fuels.

Biodiesel *Buses*

Biodiesel is a renewable alternative to standard diesel.

Biodiesel is a renewable alternative to standard diesel. It can be produced from vegetable oil and waste materials such as used cooking fat and tallow from animal rendering processes, and grease from waste water systems. In the UK, standard diesel is sold with a 7% blend of biodiesel, driven by the UK's Renewable Transport Fuel Obligation (RTFO).

The adoption of road transport biofuels is one of a package of measures the UK Government has introduced to reduce road transport CO_2 emissions. Used cooking oil is currently the most abundant feedstock for manufacturing UK biofuels, with a continuing trend away from crop-based biofuels due to concerns over sustainability and conflict with food crops.

Fleet operators can purchase biodiesel either as a blend of biodiesel and standard diesel, sold as B20 and B30, or as 100% biodiesel, sold as B100. For the UK bus market, biodiesel is produced from waste oils and fats sourced from animal rendering plants in Scotland and North East England, while in London used cooking oil is the main feedstock.

Producing biodiesel from waste oils is sustainable and results in much greater greenhouse gas savings than producing biodiesel from crop-based oil. Biodiesel produced from tallow oil can achieve up to 90% reduction in GHG emissions. Further emission reductions are possible through the use of locally-sourced waste materials by avoiding CO_2 emissions associated with the road distribution of feedstocks.

There are a total of 9,186 buses running on biodiesel across the UK, with higher than RTFO-mandated blends, mainly using B20 and B30. The first buses running on biodiesel were introduced in 2012. Stagecoach and Transport for London are leading the adoption of biodiesel. The largest fleets operate in Scotland.

↑ *Location of biodiesel buses in the UK*

Stagecoach operates over 4,500 buses on biodiesel

Stagecoach operates 4,581 buses on biodiesel; 15 buses are run on 100% biodiesel in Kilmarnock and Canterbury, and 4,566 buses fuelled using biodiesel blend B30 are operating in Scotland, Lancashire, Manchester, Merseyside, Yorkshire, Midlands and Oxfordshire.

Argent Energy has been the biodiesel supplier for Stagecoach for the last four years. The company produces biodiesel from waste oil derived from animal rendering plants. Stagecoach says that the adoption of biodiesel has cut its overall bus fleet CO_2 emissions by around 25%.

The company plans to increase the number of buses running on biodiesel to nearly 6,200 by the end of 2016.

In Dundee a B30 blend has been used in conventional diesel buses in one of Stagecoach's largest biodiesel fleets, including the latest Euro VI vehicles, as well as hybrids supplied by Scania, Volvo, ADL and Optare. Stagecoach sought and gained permission from these OEMs to use biodiesel to ensure they would continue to be covered under warranties when using this fuel.

The company has benefited from the BSOG biodiesel incentive offered in Scotland. The buses running on B30 have been reliable and have performed as well as standard diesel buses; they have experienced no reduction in fuel consumption.

LONDON:

Transport for London's 2020 target is to have the entire fleet of 9,000 buses utilising B20

Transport for London currently operates a third of its buses, 3,000 vehicles, on B20 biodiesel. By 2020 the target is to have the entire fleet of 9,000 buses utilising B20. The drive for the adoption of biodiesel has come from the Mayor's Biodiesel Programme. The aim is to produce biodiesel from organic waste feedstock from London and to use it within the city itself. TfL undertook a trial of B20 with two bus operators in 2015 and, following the successful adoption of B20 made from used cooking oil, decided on a widescale adoption of biodiesel. On average B20 currently achieves a 15% CO_2 emissions reduction compared to conventional diesel.

ARGENT ENERGY:

Supplying biodiesel to bus operators

Argent Energy supplies biodiesel to bus operators throughout the UK, including to Stagecoach in Dundee. Across the UK, 7,000 vehicles run on Argent's biodiesel. The company supplies B20 and B30 biodiesel as well as B100. Argent's fuel conforms to national fuel quality standards for biodiesel.

Argent started by collecting used cooking oil brought in by members of the public in Kilmarnock, which was then converted to 100% biodiesel; in other words the passengers provided the fuel that the bus ran on. In return they were given a special deal on tickets. This still happens in Kilmarnock. Today, Argent's main business is manufactured biodiesel which uses waste feedstocks such as animal and vegetable waste oils and fats.

Low emission buses – a vision for the future

There has been escalating action to reduce greenhouse gas emissions over the years and, more recently, greater attention to improving local air quality. As a consequence, there is greater political action at both local and national level. This is manifesting itself in the introduction of low and ultra-low emission zones in urban areas and progressively greater emphasis on the introduction of low emission vehicles.

Like all forms of transport, bus technology will only be going one way: towards lower levels of CO2, NOx and particulate emissions. This path is already clearly evident in many UK cities from London to Oxford, York to Manchester. The challenge is to deliver ultra-low emission public transport cost-effectively.

Overall the bus industry provides good news for every operator. We are at a point where a step change is being made with new technology, resulting in buses becoming dramatically cleaner and more efficient. There are now a wide range of low emission bus technologies available and these can be combined in many cases to meet the diverse range of bus operating environments in the UK, so there will always be a technology that will be best suited to individual operators. The examples given in this report show how manufacturers and technology providers have embraced this challenge and now provide a portfolio of solutions to improve vehicle efficiency, limit tailpipe emissions and decarbonise the energy and fuel used.

UK Government funding and policy has been critical in kick-starting this market for low carbon emission buses, to help manufacturers get out of the low production/ high cost conundrum, and move through prototype vehicles to demonstrations, trials and, ultimately, full commercial operation. Most recently the Low Emission Bus Grant has provided funding to a number of bus operators for both low emission buses and refuelling/ recharging infrastructure.

There is real potential for collaboration between bus manufacturers, operators, technology providers and other stakeholders such as Government, local authorities and users. We are, however, only part way along the journey to fully decarbonising and cleaning the UK's vital bus sector. Successful steps have been taken, as this report shows, but there is a need for continuing financial support from Government, to encourage technology advancements, including fiscal incentives such as the influential Bus Service Operators' Grant (BSOG) to continue to help the business case for operating low emission buses.

Bus operators have invested significant sums of money and committed time and resources in working through the early challenges on the path to successful introduction. Investment has been made in new bus technologies and refuelling infrastructure, and even routing and scheduling have been reviewed in some cases to allow trials and learning of the most advanced potential solutions. A number of large bus operators have shown clear leadership by embedding low carbon emission buses into their sustainability agenda to drive improvements into the environmental performance of their bus fleets.

There have, of course, been plenty of hurdles along the way; early hybrid and electric buses experienced initial reliability issues like any brand new technology, but through open collaboration the technology has rapidly advanced and is now achieving similar levels of reliability as conventional diesel buses, with warranties extending and new business models developing to further reassure the market. Bus manufacturers will continue to innovate and improve the performance of the full range of low emission bus technologies over the next few years.

There will also be a need for collaboration between a range of stakeholders. With new fuels and technologies moving into the mainstream, manufacturers, operators and government bodies and agencies will need to work with new infrastructure, technology and fuel suppliers. Electric bus operators and manufacturers, for example, now have to work closely with local electricity network operators to manage impacts on the local grid. The web of interactions between stakeholders is, if anything, getting even more complex.

Low emission buses play a key role in reducing GHG emissions that are contributing to climate change and tackling air quality problems in cities.

Impressive progress is being made but much more will be needed and the support of all parties must be maintained if we are to transform the market and achieve our ambition that every new UK bus in 2020 will be a low emission bus, and show that there really is "a Green Bus for Every Journey".

REPORT PRODUCED BY THE LOW CARBON VEHICLE PARTNERSHIP FOR GREENER JOURNEYS

Greener Journeys is a campaign dedicated to encouraging people to make more sustainable travel choices. It is a coalition of the UK's leading public transport organisations, user groups and supporters. It aims to reduce CO_2 emissions from transport by encouraging people to switch some of their car journeys to bus or coach instead. Switching from car to bus for just one journey a month would mean one billion fewer car journeys on our roads and would save two million tonnes of CO_2 every year. For more information visit ***www.greenerjourneys.com***

greener journeys

The LowCVP was established in 2003 as 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, environmental groups and others.

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