Connect
Collaborate
Influence

Barriers and opportunities to expand the low carbon bus market in the UK

Task 2: Review and role of incentive mechanisms

Prepared for the LowCVP by Transport & Travel Research Ltd, in partnership with TRL.

June 2014

Connect
Collaborate
Influence

Barriers and opportunities to expand the low carbon bus market in the UK

Task 2: Review and role of incentive mechanisms

May 2014

LowCVP Project Manager: Gloria Esposito, Head of Projects

Contractor: Transport and Travel Research Ltd

Bus Working Group Project Steering Group: BAE Systems; David Lemon Consultants; JouleVert Ltd; First Group UK Bus; GSK; Torotrak plc; Alexander Dennis Ltd

Author(s): D Nabarezhnykh (TRL), T Parker (TTR),

Quality Control: T Parker (TTR)

Version: Final 1.0

CONTENTS

1 Introduction 3
2 Current Support and incentives for Low Carbon Buses 5
2.1 Introduction 5
2.2 Bus operators 6
2.2.1 Subsidies and fiscal incentives 6
2.2.2 Regulatory approaches and non-fiscal measures 8
2.3 Bus Manufacturers and Technology Developers 9
2.3.1 Fiscal measures 9
2.3.2 Non-fiscal measures 10
2.4 Public Sector 10
2.4.1 Fiscal policy and funding mechanisms 10
2.4.2 Non-fiscal policy and regulations 11
2.5 Key incentives and mechanisms to support the LCEB UK bus market 13
2.5.1 BSOG (on fuel) 13
2.5.2 Enhanced BSOG (for LCEB) 13
2.5.3 Vehicle purchase grants 14
2.5.4 Funding of refuelling infrastructure 14
2.5.5 R&D funding 14
2.5.6 Non-fiscal (policy) measures 14
2.6 Review of fiscal and non-fiscal support mechanisms in other markets 15
2.6.1 Fiscal (policy) measures 15
2.6.2 Other non fiscal policy options 17

3 Analysis of incentive mechanims 18
3.1 Introduction to research and analysis 18
3.2 Assumptions and input data 18
3.3 Analysis of support mechanism for running costs 20
3.3.1 Introduction 20
3.3.2 Baseline – payback comparisons under no incentives or subsidies 21
3.3.3 BSOG and enhanced LCEB payments 22
3.3.4 Scottish BSOG for LCEB 25
3.3.5 Graduated LCEB 26
3.4 Analysis of support mechanism for capital costs 27
3.4.1 Grants and other support for capital investment in new vehicles 27
3.4.2 Infrastructure grants or first year capital tax allowances 29
3.4.3 Analysis of a feebate approach to support LCEB 30
3.5 Discussion 32

4 Conclusions and recommendations 33
4.1 Introduction 33
4.2 BSOG and LCEB payments – supporting running costs 33
4.2.1 BSOG 33
4.2.2 Enhanced payments for LCEB 33

4.2.3 Other running cost support mechanisms 34
4.3 Vehicle and infrastructure - support on purchase/capital costs 34
4.3.1 Carbon linked vehicle grants 35
4.3.2 Refuelling and charging infrastructure support 35
4.3.3 Use of a feebate 35
4.4 Other support mechanisms 36
4.4.1 R&D support 36
4.4.2 Coordination of available demonstration and trial results 36
4.4.3 Vehicle Excise Duty 36
4.4.4 Linking air quality and carbon reduction 37
4.5 Suggestions for further research 37

Annex 1 Input data 39

Annex 2 Payback analysis under various input assumptions 40

1 INTRODUCTION

The purpose of this task is to review and make recommendations on fiscal and non-fiscal mechanisms that could be used to reduce the payback period of low carbon technology on buses, to what is considered a desirable period of less than 5 years.

A low carbon emission bus (LCEB) is currently defined as a bus that is able to achieve the LCEB target for Greenhouse Gas (GHG) emissions, which is equivalent to a 30% reduction in its GHG emissions compared to the average Euro 3 diesel bus of the same total passenger capacity, the test covers Well-to-Wheel performance. A low carbon emission bus can use any technology or fuel (but cannot be deemed a LCEB by fuel alone, unless it is biomethane in a gas vehicle). In 2013 low carbon emission buses account for 2% of the UK bus market (Low Carbon Vehicle Partnership, 2013).

The technologies focussed on during Task 1 cover a range of fuel efficiency and levels of carbon savings. The exact efficiency does however vary across a range of values, dependant on vehicle manufacturer, its specification, and the duties and type of route it serves.

Table 1.1: Example of technologies in common UK bus fleet use

WTW CO_2 reduction (approx. and indicative)	**LCEB Technology**
<15%	CNG, Packages of smart ancillaries.
15-30%	Flywheel (Mechanical and Electric)
>30% - 50%	Electric (UK grid mix), Diesel Electric Hybrid, Gas. Plus various 'packages' including: light-weighting & smart-ancillaries; smart-ancillaries & flywheels.
> 50%	Compressed Biomethane Gas (in CNG bus)* Electric (using renewable electricity)*

* Note, > 50% WTW savings if supplied or via 'green' electric and gas tariffs or certificates.

Work undertaken earlier in this project, and reported in the Task 1 findings, showed some consensus among the different industry stakeholders on the reasons different LCEB technologies are being adopted and the perceived barriers that remain in place and constrain further market growth.

From Task 1 findings it is apparent that capital costs, uncertainty on battery life (i.e. replacement costs) and costs of refuelling/charging infrastructure are some of the main financial barriers perceived by the industry stakeholders. Other barriers were identified as being a lack of reliable demonstration programmes of new technology complimented by reliable conclusions on efficiency and running costs, lack of information sharing between different stakeholders and need for better partnerships between Operators and Local Transport Authorities (the public sector).

The objectives for Task 2, for which this report is the main output, were to define fiscal and non-fiscal support mechanisms that could be used to expand the low carbon bus market. The task has been carried out using a mixture of desk research, a workshop with stakeholders, inputs from Bus Working Group members and the analysis of cost and payback times.

The contents of this reports is as follows.

- A short review was undertaken of the main incentives available at this time in the UK, with examples from elsewhere also considered. This is presented in Section 2.
- An analysis of current incentives schemes, examining the effect on payback times across a range of relevant low carbon bus technologies. This is presented in Section 3.
- Section 4 draws conclusions and makes recommendations on which support mechanisms are most relevant to addressing the barriers to market uptake. This section also includes suggested topics for further research.

2 CURRENT SUPPORT AND INCENTIVES FOR LOW CARBON BUSES

2.1 Introduction

From the earlier Task 1 research in this study the main 'drivers' in the decision to purchase LCEB suggested by operators, and according to their suppliers, are:

- Fuel savings and efficiencies;
- Availability of funding such as the GBF to assist with purchase price;
- Enhanced BSOG (6 ppkm) for LCEB;
- Opportunity to upgrade vehicle fleet (taking advantage of funding);
- Ease of adopting the new technology (refuelling / maintenance);
- Increased confidence in the technology (reliability being key);
- Meeting environmental targets (both organisational and external);
- The perceived competitive edge from using 'Green technology'; and
- Public image and industry reputation.

For local authority participants the main motivators reported to encourage their support of LCEB were as follows:

- Meeting carbon and air quality targets;
- Availability of subsidies and grants;
- Public image / marketing of the (Local Transport) authority; and
- Reduce congestion by encouraging greater public transport use through new vehicles and services.

However, significant barriers to the uptake of LCEB exist, which bus operators and their vehicle suppliers perceive as being:

- High capital cost of some technologies, including concern and in-life replacement costs (of batteries);
- Infrastructure for CNG and battery electric vehicles requires significant / long-term investment;
- Concern over performance in real-life vs. standard test cycle (used to define LCEB);
- Insufficient steer/guidance on future of the LCEB technologies and longevity of Government support;
- Application process for funding can be complicated and the response time does not always fit existing financial planning.

From the local authority perspective the main barriers to the uptake of LCEB are perceived to be:

- High capital cost of vehicles and / or refuelling infrastructure (if not diesel);
- On-going in-life costs and uncertainty over the 'best' technology;
- Reluctance of operators to adopt available options;
- Some uncertainty regarding actual environmental benefits (including emissions of local air pollutants);

The eventual level of interest in higher cost LCEB technology options is difficult to predict given current uncertainty about a future rounds of GBF, despite positive experiences to date. The impression was gained that operators were not expecting major capital subsidies for LCEB in the near future.

It was clearly stated that for many LCEB in use or already on order for the UK market that GBF and the LCEB 6ppkm element of BSOG had been critical in making the business case. This was particularly the case for diesel-electric hybrid and battery electric options, given their additional cost over other technologies and standard diesel bus.

This section of the report now presents an overview of the fiscal and non-fiscal mechanisms available in the UK at the time of writing relevant to the bus market. Support mechanisms can be generally divided into two categories:

1. Fiscal: These support mechanisms are usually based on some form of financial support financed by Government. They can take form of capital or operating subsidy, grants, tax rebates or duty derogations.
2. Non-Fiscal: These support mechanisms are non-financial but can be used to influence LCEB take up, typically through legislation and regulation, information provision or policy setting.

It is recognised that different stakeholders in the bus sector require different types of incentives and therefore existing mechanisms described below are aggregated by the key stakeholder type as follows:

- Bus Operators – organisations responsible for owning and operating buses to provide a local public transport service.
- Bus manufacturers and technology developers – organisations responsible for developing and manufacturing new or retrofitted LCEB vehicles and technology
- Public Sector – organisations which are part of the local government and are responsible for ensuring that adequate public transport is available in their area. In this case they are termed the Local Transport Authority (LTA).

This section of the report also considers some other fiscal and non-fiscal approaches to stimulated lower emission vehicle markets used in the UK and elsewhere, to complete the review of mechanisms that may be usefully applied to the LCEB market.

2.2 Bus operators

2.2.1 Subsidies and fiscal incentives

Bus service Operator Grant (BSOG)

This government funded subsidy scheme is paid to the operator, and applies to much of England. The amount is based on operator's annual fuel consumption; payment is based on pence per litre, the value is based on annual fuel consumption achieved by entire fleet of public service vehicles (minus exceptions). The rates for diesel, bio diesel and bioethanol is 34.57 pence per litre and the rating of natural gas (or biomethane) as road fuel gas is 18.88 pence per kilogram.

Table 2.1 Impact of BSOG on net fuel price to bus operators

Fuel	Example base price (pence)	Fuel duty	Price delivered (ex VAT)	BSOG rebate	Net fuel price to bus operator
Diesel, bio-diesel, UCO	50.00	57.95	107.95	34.57	73.38
Bioethanol	60.30	24.70	85.00	34.57	50.43
CNG / biomethane (kg)	42.70*	24.70	67.40	18.88	73.38
Electricity (kWh)	8.50	0.00	8.50	0.00	8.50

Note: * = gas supplied from operators own refuelling station infrastructure

The aim of BSOG is to support bus service, including keeping fares affordable and enable operators to run services that might not otherwise be profitable. However, the prevailing view is that this element of BSOG undermines the case for fuel efficiency measures generally as it extends the payback period on low carbon technology compared to if operators were paying the full cost for diesel fuel.

BSOG has a number of related/sub-elements:

- reimburses 6 pence per kilometre in addition to the BSOG rate if the bus is classified as a LCEB; and
- additional payment for bus fleets where AVL and Smart Card equipment are installed.

BSOG predates UK entry into the EU and therefore is not subject to state aid approval. However any major changes may be notifiable to the EU. See section 3.5 for further discussion of this point.

BSOG is undergoing a period of change. In the designated Better Bus Areas of England and also London increasing proportions of the BSOG value is over time being allocated to the local transport authority to spend on their support activities for local bus services (and therefore not directly to the bus operator). Section 2.4.1 provides further information. In Scotland BSOG was radically changed in recent years to create a third system. The variation in BSOG by area of the UK makes it complex for operators (and technology developers) to estimate the operating costs of different LCEB options.

Scotland BSOG

BSOG is applied differently in Scotland where, as of 2011 fuel use is no longer a factor in calculating BSOG payments. Payments are solely based on distance travelled with uplifts for LCEB, and calculated using the equation:

Payment = eligible km x payment rate

From 1 April 2012 the following rates are applied (Transport Scotland, 2013):

- Conventional fuels (i.e. diesel) at 14.4p/km ;
- Biodiesel at 20p/km (for services using 100% biofuel from sustainable sources)
- LCEB at 28.8p/km (including biomethane)[1].

It can be seen from Table 2.2 that Scottish BSOG levels of subsidy are generous, when one considers an annual mileage of 45,000 p.a. The system does provide a subsidy for all bus qualifying bus operations, with additional support for LCEB to incentivise this part of the market.

Table 2.2 Scottish BSOG rates and potential support p.a.

Fuel	BSOG rebate (£pence/km)	Value of rebate p.a. (based on 45,000 miles p.a.) - £
Diesel	14.4	10,285.71

[1] Scotland: A vehicle that produces at least 30% fewer greenhouse gas emissions than a current Euro III equivalent diesel bus of the same total passenger capacity. The greenhouse gas emissions will be expressed in grams of carbon dioxide equivalent measured over a standard test, and will cover 'Well-to-Wheel' performance, thereby taking into account both the production of the fuel and its consumption on board. A vehicle must be certified by the manufacturer that it meets these conditions.

Biodiesel	20	14,285.71
Biomethane (if qualifying as LCEB)	28.8	20,571.43
LCEB (including qualifying hybrid and battery electric vehicles)	28.8	20,571.43

Green Bus Fund

Green Bus Fund (GBF) has been provided by the Department for Transport and was designed to encourage the purchase of hundreds of low carbon emission buses throughout England. It had State Aid clearance from the EC. The GBF has been awarded to bus operators, local authorities in England, Passenger Transport Executives (PTEs), Transport for London (TfL), and companies leasing/renting buses. The organisations requesting funding competed for funds to assist towards the additional cost of low carbon emission buses. GBF has been provided in 4 rounds to date, with more generous grants for additional cost element in first rounds 1 and 2, which were oversubscribed.

General rules were that: no more than £5 million would be paid to any one bidder; the fund did not include minibus purchases; the funds were only available to new buses; buses operated by hydrogen were not to be funded. Refuelling infrastructure was excluded from this grant so the cost of gas or charging infrastructure could not be supported using this mechanism.

The last round 4 of GBF in May 2013 (with a total potential value of £20m) provide for a reduced grant up to 50% of the maximum difference between the costs of a LCEB compared to its diesel equivalent, with an uplift to 80% of the difference for full electric buses. The last round of GBF was undersubscribed and only around £12m of the funds were taken up, and therefore the balance was used for the Clean Bus Technology Fund (CBTF), see section 2.1.4 below.

Duty differentials

Fuel duty differentials that favour low carbon fuels can support low carbon vehicles (and therefore LCEB). Examples exist, both negative and positive, of how duty differentials can support or undermine LCEB market development.

Firstly, high blends of biodiesel and bioethanol did benefit from duty differentials that heavily incentivised their use, but these were removed in 2010. Secondly, for LPG the differential between the main rate and the liquefied petroleum gas rate will continue to reduce by 1ppl each year to 2024 and this will be reviewed in 2018 budget. There are some LPG bus in operation in the UK.

Finally, the duty differential for gas as a road fuel (i.e. CNG or LNG, and its biomethane equivalents) has been until 2010 operating on a rolling 3 year derogation, which led to uncertainty in the medium term (this was abolished under the Coalition Government at the first budget). However, the early December 2014 'Autumn Statement' it was announced that regards current duty for methane gas as a road fuel will have differential maintained at current levels until March 2024, which provides some degree of certainty.

2.2.2 Regulatory approaches and non-fiscal measures

There is a major difference between bus operations within London and those outside, due to the nature of bus deregulation that took place outside London in 1986. The result has been much greater control of bus services (by Transport for London) compared to the closest equivalent public sector organisations outside of London.

London bus operations

London Buses is the subsidiary of Transport for London (TfL) that manages bus strategy (route, fares and vehicle specifications) within Greater London. All services are then provided by private sector operators against London Buses specifications.

All bus operations are awarded rights to operate under a tendering system in which operators bid for routes in return for a set price per route operated. Bus routes run for 5 to 7 years before being re-tendered. Routes are set up, controlled and tendered out by TfL and they provide day to day assistance via CentreComm which coordinates a large scale network of Network Traffic Controllers to help with any traffic issues that may occur. Operators provide staff to drive the buses, provide the buses to operate and also adhere to set TfL guidelines. Operators paid per mile that each bus runs. Buses are required to carry similar red colour schemes and conform to the same fare scheme.

The set-up and tendering of routes by TfL enables them to specify a significant amount of the characteristics and specifications of vehicles. This has meant, for example, that a strong influence was able to be exerted on bus specifications in London so that all vehicles met the London LEZ standard and subsequent tightening of conditions. The influence continues to support roll-out of LCEB in London. Operators are reimbursed for their costs of running such services, or if they do not feel the terms are favourable can choose to exit the London market.

Bus operation outside London

In comparison, outside of London bus operators can choose to run services completely commercially with little or no interaction with the local transport authority. In practice, there are varying degrees of interaction and co-operation, and this is facilitated through a variety of partnership arrangements, as summarised in section 2.4.2 below.

2.3 Bus Manufacturers and Technology Developers

A number of support measures are considered as having a greater relevance to bus manufacturers, technology developers and major component/module suppliers.

2.3.1 Fiscal measures

Low Carbon Vehicle Innovation Platform

The Transport Strategy Board (TSB) Low Carbon Vehicles Innovation Platform (LCVIP) was established in 2007 and aims to:

- significantly reduce carbon emissions from vehicles;
- accelerate the introduction of low-carbon vehicle technologies; and to
- help the UK automotive sector benefit from the growing demand for low carbon vehicles.

The TSB LCVIP is run by setting competitions to fund collaborative research and development with the criteria set with input from industry and government through the Automotive Council and TSB's Low Carbon Vehicle Steering Group. Project bids are assessed independently by a panel of automotive experts and the funding available depends on the size and complexity of the project. A number of calls are published each year to address specific challenges in the automotive sector, often focusing on developing technologies in the UK that help to reduce CO_2 emissions from transport. Bus manufacturers and technology developers are eligible for this funding which is typically up to 50% of costs. These schemes have received State Aid approval clearance. Examples exist of technology developers and bus operators joining together and testing new approaches to LCEB under TSB competition funding streams.

EU Research Frameworks

The Horizon 2020 European Research Framework follows on from the 7th Research Framework (FP7) and aims to encourage collaboration and provide co-funding for projects that address specific topics within the call for proposals published annually. This year's call for proposals has been recently announced and can be found here: HORIZON 2020. Projects are typically expected to include a number of organisations from different Member States. The participation of industrial partners and SMEs is particularly encouraged. The co-funded projects that result provide opportunities to part-fund R&D activities for development of vehicles and technologies and also to support pilot and demonstration programmes. Past projects have funded demonstration and pilots of low emission bus in various forms, including hydrogen bus in London, gas bus in Merseyside and battery electric (mini)bus in Bristol.

2.3.2 Non-fiscal measures

It appears that in terms of standards and regulations the EC direction is towards mandatory reporting of fuel consumption (and by implication CO_2 emissions) using a simulation method, however this is not in place yet.

2.4 Public Sector

Given the pivotal role of the public sector in organising, influencing and funding large parts of the UK bus operating market it is relevant to set out the main fiscal policy approaches public sector can take and funding mechanisms they can access. This would normally be the local transport authority or passenger transport authority, whether that now be a City or County Council or an Integrated Transport Authority, and can be termed the Local Transport Authority (LTA).

2.4.1 Fiscal policy and funding mechanisms

Better Bus Areas (BBA)

The Government launched the Better Bus Area (BBA) application process in February 2013, the BBA is a new way of supporting the bus market by using funding currently channelled through the Bus Service Operators Grant (BSOG). In the BBA, the BSOG currently paid to the bus operators for commercial services will be gradually reduced. Instead the Local Transport Authority will receive a yearly grant equivalent to commercial BSOG which has been devolved plus a top up grant which is proposed as an equivalent to 20% of the total commercial BSOG that would otherwise be paid to the operators within the designated BBA.

The BBA grant is designed to enable the Local Transport Authority to carry out projects identified in its BBA application to improve bus services. The relevance of BBA is that it will gradually (over 5 years) funnel all BSOG payments to the LTA, rather than direct to the operator, and hence expose the bus companies wishing to operate services within this area to the full diesel fuel price. This process began on 1 October 2013 and currently covers 5 areas, centred on Nottingham, Merseyside, York, West of England (Bristol and Bath) and Sheffield BB. It is not known if further LTA will apply to be BBA.

A similar process for BSOG is taking place in London with TfL being incrementally paid the BSOG equivalent. However in London, given the contractual nature of the relationship between TfL and bus operators it is envisaged that the value of the BSOG will be returned to the operator, in the short term at least.

Better Bus Area Fund

This additional fund aimed to promote passenger growth through collaboration between bus companies and local authorities. The policy aims it supports are those to improve patronage, create economic growth and cut carbon emissions. The fund was available to any English LTA outside London, and in total £50m was available to fund bus projects worth up to £5m each. This was allocated in the financial year 2012-13 and is currently being implemented on a range of projects.

The funding could not be used to purchase buses; however, it can be used to retrofit existing buses with technologies that improve their performance and customer experience, including environmental performance. Example projects which were funded under this fund are bus priority schemes, marketing and information schemes, development of smart and/or multi operator ticketing schemes, enhancement of bus infrastructure and elimination of pinch points that affects bus punctuality[2].

Ensuring that bus services work more efficiently, and drive up patronage, may enable the operators to justify investing in LCEB.

Clean Bus Technology Fund (CBTF)

This government funding programme (announced in 2013) focused on reducing emissions of nitrogen dioxides (NOx). The programme aims to explore what can realistically be achieved at local scale and establish technologies for upgrading older buses. A total of £5 million was available for 2013-2014 and maximum fund available for a single project was £1m. Eleven local authorities were been awarded grants. The funding will allow almost 400 buses to be upgraded, reducing pollution in towns and cities across England. An additional £1.4m was subsequently made available for some projects that were initially unsuccessful in attracting funding. Bids have been led by a local authority (generally in partnership with bus operators) to adopt technologies that will reduce nitrogen dioxide emissions. Some of the technology options that could be considered include: retrofitting SCR (selective catalytic reduction), engine replacement, engine retuning, alternative fuels and hybrid conversion. The majority of grants were provided for SCR fitment, but also was reported as supporting some flywheel retrofit and conversion to electric[3] and gas buses[4], where there is a clear carbon reduction opportunity due to fuel efficiency gains likely to follow.

2.4.2 Non-fiscal policy and regulations

There are a range of regulatory and partnership options available to LTA to influence the local bus service provision and engage with bus operators on improved services. Generally the focus is on overall service provision, with vehicles forming part of the overall objectives, and in many cases there is a financial aspect to the priority setting. Further information (and short case studies) are available in the LowCVP Low Emission Carbon Bus LTA toolkit[5], which is summarised here.

Subsidised Service Procurement

The LTA can specify services that operators do not currently run commercially, inviting them to bid competitively and run them to the standards set by the LTA. Examples include city centre loop services, Park & Ride etc. In this case, the LTA has full power to specify the bus service. The LTA can specify a LCEB, but generally will prefer the operator to own vehicles so avoiding ownership of the vehicle at the end of the contract. The cost of specifying LCEB (to the LTA) is normally greater that

[2] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/3228/summary.pdf
[3] http://www.york.gov.uk/news/article/163/york_is_first_city_in_the_uk_to_get_electric_bus_makeover
4 http://www.airqualitynews.com/2013/10/21/biomethane-buses-to-help-cut-sheffield-transport-emissions/
[5] http://www.lowcvp.org.uk/lceb/_docs/LTA_ToolKit_For_Low_Carbon_Buses.pdf

allowing operators to offer lower priced alternatives as the operator will tend to price in the additional costs of LCEB, including risk over residual values.

Voluntary Partnership Agreement (VPA)

The foundation for a VPA can be the LTA improving local highway and passenger infrastructure to help commercial performance on the route. This can be in exchange for some level of commitment to improve quality service from the bus operator(s). The partnership could in theory be extended to LCEB by local authorities providing road-side support, capital grants and improving route infrastructure to encourage operators to purchase LCEB (perhaps supported by Better Bus Area Fund projects, see 3.4.1 below). The suitability of vehicles will also be determined by the operator's commercial requirement. VPA are the most common of 'formal' relationship setting, but are not legally binding in any way. VPA have been one of the relationship building blocks that work between LTA and bus operators and have enabled bids under GBF to be supported by both types of organisations.

Quality Partnership Scheme (QPS)

QPS have as their basis an LTA designing a scheme with minimum service standards that local bus operators must meet in order to use the enhanced facilities provided by the LTA. The scheme may include traffic priorities, improved facilities for bus passengers or in theory setting suitable fare structures to support the investment required for LCEB. Service improvements can include the quality of vehicles used. A QPS could set high standards for buses to reduce pollution levels in return for facilities that improve travel times, increase in punctuality, improve reliability etc. Once in a QPS the partners are legally required to deliver their commitments. The arrangements are determined by the LTA, and even if the all operators object to the scheme, it could still go ahead as the local Traffic Commissioner is the ultimate arbiter. However, because it is voluntary on the part of the Operator to participate they could decide to withdraw from running services in this area rather than participate in the QPS. Examples of QPS reviewed by TTR to date do not include ambitious vehicle specifications; they are focussed primarily on service provision in its other forms. However, a QPS could in principal set vehicle specification standards requiring the use of low carbon buses. Grant funding from Government might be used by the LTA or the operator(s) to bridge the gap in investment capital required to utilise LCEB.

Quality Contract Scheme (QCS)

In a QCS the LTA uses significant and wide-ranging powers to specify the bus services operating in an area, and sets up an 'off the road' competition to let one or more franchises to an operator or operators. No QCS are currently in operation, although some PTE are in advanced stages of forming one or more.

It is possible that long contracts of 5 years and upwards may justify investment in a new or largely new fleet of buses. Length of contract has been noted a supporting factor for increasing LCEB take-up in London. The additional capital costs of LCEB may be justified by the lower fuel costs over the life of the QCS, depending upon the view taken about future fuel costs and BSOG benefits. Thus, in some scenarios, selecting an LCEB may be a lower lifetime cost option than using conventional vehicles, as well as delivering significant environmental and passenger benefits. LTAs considering this option would be well advised to include discussions with manufacturers early in their deliberations as a large-scale commitment to LCEB may warrant investment in local support and maintenance facilities.

Examples of QCS being developed to date do not appear to include ambitious vehicle specifications, instead they are focussed primarily on service provision in its other forms. However, a QCS could in principal set vehicle specification standards requiring the use of LCEB and provide one part of the longer-term certainty bus operators would find useful to justify additional investment in vehicles as required for LCEB.

Traffic Regulation Condition (TRC)

Where local air quality is poor the Traffic Commissioner has powers to place a Traffic Regulation Condition (TRC) on bus operator registrations to improve the situation. This has been used in one known instance (Bath) to focus on local tour buses, where there were concerns over pollution. A TRC was prepared to ensure only tour bus operators with lower emission vehicles were allowed to operate in the city centre, and their numbers reduced, in an effort to reduce their contribution to pollutant emissions.

Hence using a TRC, in appropriate circumstances, can either directly influence operators or raise the promise of action and bring operators into a discussion. Care should be taken to avoid operators choosing to withdraw service rather than taking the option of replacing polluting vehicles with lower emission options.

Local Air Quality Management

There are clear links in the policy and practice of many Local Authority/Local Transport Authorities between carbon reduction potential of LCEB and the reduction of pollutant emissions relevant to local air quality management (LAQM)

Diesel buses are an important source of NO_x and PM_{10} emissions and efforts to improve air quality through low emission strategies and LEZ can play an important role in increasing the demand for LCEB. Examples include the London LEZ and Nottingham Clear Zone. Current infraction proceedings by the EU over NO_2 levels may bring this subject into sharper focus. Measures to reduce NO_x emissions from buses and other road transport sources appear to be necessary to meet national air quality standards in many areas of poor air quality. LCEB, notably hybrid, electric and biomethane, can address air pollution and greenhouse gas emissions simultaneously. It was noted during the Task 1 of this study that better information on air pollutant emissions from LCEB was particularly important for LTA decision making, and they have an important role in air quality management and a track-record in supporting innovation in the UK bus market.

2.5 Key incentives and mechanisms to support the LCEB UK bus market

The review of current fiscal and non-fiscal measures (by stakeholder type) together with a comparison of barriers identified in Task 1 has highlighted a some key points regarding current incentives available to support the UK bus market for LCEB.

2.5.1 BSOG (on fuel)

The potentially unintentional impact of the BSOG has been that it reduces the cost saving potential of technologies which can offer the highest reductions in CO_2 (such as hybrid and battery electric buses) due to the subsidised cost of diesel fuel. The removal of this subsidy could highlight the potential for cost savings using those technologies. However, it should be noted that this could also be potentially damaging to bus operators as their costs would increase due to higher diesel prices and they may become even less able to make investments into LCEB. A more sustainable approach would be for DfT or LTA where/if BSOG is devolved to move to technonolgy subsidy, to remove the link with fuel consumption and tie it more closely to a relevant service provision.

2.5.2 Enhanced BSOG (for LCEB)

The reimbursement of 6p per mile for LCEB does send a strong and encouraging signal to support the adoption of LCEB technologies. However, in order for this incentive to be more effective it may need to be guaranteed for the lifetime of the buses that meet the LCEB criteria. There are also arguments for adopting a more discriminating approach that uses a graduated payment scale to encourage technologies that can go well beyond the current 30% qualifying threshold.

2.5.3 Vehicle purchase grants

LCEB and other low carbon vehicles can often carry a higher capital cost than conventional petrol and diesel vehicles. As a result, fewer operators are able or willing to purchase the vehicles, even if longer term running costs are lower. In order to bridge this gap and bring the capital costs of technology more in line with conventional vehicles, sometimes a vehicle purchase grant can be introduced by the government. One intended purpose is to increase demand to the point where volume sales reduces the on cost to parity.

Green Bus Fund has played an important role in stimulating take-up of LCEB to date. A number of lessons have been learned, including that the price of LCEB does not appear to have reduced significantly. There is however now a stronger appetite for fuel efficiency in the bus industry and willingness to invest in enhancements to diesel bus and LCEB technologies which may well be linked to the promotion and positive experience of LCEB, as well as the continued rise in fuel cost as a proportion of operating costs.

2.5.4 Funding of refuelling infrastructure

Most of the fiscal measures aimed at reducing the impact of the high capital costs of LCEB currently available to the Operators and the Public Sector in the UK are based on subsidising the capital costs of the bus itself or its running costs. However, funding refuelling infrastructure is also important as the costs can be extremely high in the early stages of deployment. This is particularly true for more novel refuelling infrastructure, such as hydrogen infrastructure for fuel cell buses or inductive charging infrastructure for electric buses.

2.5.5 R&D funding

For bus manufacturers and technology developers, R&D and implementation of LCEB technology can require substantial amount of investment. Take up of this technology to date has been slow due to the high capital costs typically associated with it, often resulting in long pay-back periods which are unattractive to the operators. This ends up being a cycle where initial R&D into new technology development drives up the prices of LCEBs initially. The high purchase price can make them unattractive for operators and LTA and so they cannot be sold in large volumes, which then drives those prices higher still.

Technology developers and bus manufacturers should look to utilise the available R&D grants and subsidies as much as possible in order to break this cycle. UK based companies can subsidies their R&D work through TSB, Horizon 2020 or EPRSC funding streams. EPSRC is focused more on primary research and may be less appropriate for near market technologies, however, 100% funding can be available. European Research Framework Horizon 2020 and TSB funding is typically restricted to 50% of eligible costs but can be a good way to part fund development activities.

2.5.6 Non-fiscal (policy) measures

Partnerships

The Local Transport Act 2008 went some way to introducing new measures and giving LAs more powers to encourage LCEB take up through the introduction and update of abilities such as Voluntary Partnership Agreements and Quality Partnership Schemes. This has provided a basis for some partnership working, seen in the number of supportive positions taken in GBF bids by either LTA or local bus operator. However, outside of London, LTA have relatively limited powers to encourage use of LCEB (unless they are willing to bring funding) and budget constraints mean sustained investment is difficult, instead relying on the competition for discrete funding pots.

Link with air quality

The significant level of interest in addressing local air pollutant ants is linked to a higher level of interest in LCEB from LTA and other local authorities. This has been particular obvious in London, but also expressed by other major UK city authorities and LTA.

There is a high degree of complementarity between carbon and air pollutant emission policy that could be better addressed in future incentive regimes for LCEB. A complementary action would be for DfT to commit sharing findings and results of demonstrator programmes and trials (such as GBF and CBTF). There may be role for organisations, such as LowCVP, to act as an information channel to support DfT.

2.6 Review of fiscal and non-fiscal support mechanisms in other markets

In addition to the existing schemes and incentives currently available in the UK bus market, the project team reviewed other possible fiscal and non-fiscal measures used in the wider transport sector and other countries. Some potentially relevant measures are summarised below.

2.6.1 Fiscal (policy) measures

Purchase tax and VAT are already applied in the UK at varying rates to a range of different goods and services and the same mechanism might apply to different types of vehicles. This section raises the evidence of this approach being applied elsewhere in the EU to support low carbon vehicles of varying types. The thinking is that as well as UK specific mechanisms aimed at the bus market (e.g. grants, LCEB 6ppkm) there are various purchase and VAT taxes that might be used to support the financial case for LCEB if that were desired.

Purchase tax

Purchase tax is a tax on the purchase of a vehicle, normally in addition to VAT. It is aimed at encouraging consumers to make a choice in whether to own a car and what car to buy. The policy also encourages the car manufacturers to develop vehicles that the consumers can purchase. Many European countries have a purchase tax and incentives on low carbon vehicles are applied to promote low CO2 emission vehicles; for example the Netherlands has introduced a series of reductions to its original 42 per cent car purchase tax for most fuel-efficient vehicles. The purchase tax in Spain varies from 0%- 14.75% depending on CO2 emissions.

Variable Rate of VAT

This is varying the rate of VAT depending on engine size or CO2 emissions. The tax is targeted at consumers to encourage the purchase of smaller sized engines or low emission vehicles. Italians pay two rates of VAT on car purchases; a standard 19 per cent on cars with an engine capacity of less than 2,000cc (2,500cc for diesels), and 38 per cent above this threshold.

Vehicle Excise Duty

Vehicle Excise Duty (VED) is the annual tax to license the use of a vehicle on public roads. The VED varies by the engine power but some EU Member States, including the UK, have adapted the tax to address fuel efficiency or environmental aspects. The tax is aimed at consumers and vehicle manufacturers and it aims to encourage the use and production of low carbon vehicles. The circulation tax directly affects the consumer’s choice of vehicle. In the 2007 budget, (HM Treasury 2007a) estimated that vehicle excise duty would help to deliver a 0.1-0.17 MtC (0.37-0.62 Mt CO2) annual reduction by 2020. VED in the UK has less impact on the type of vehicle purchased than a purchase tax. The combination of purchase and circulation tax in Denmark and Italy have helped to achieve 20% better fuel economy compared to UK.

For buses in the UK, vehicle tax is based on seating capacity with a separate rate applied if the bus is classified as a reduced pollution bus (which means having a Diesel Particulate Filter fitted to an older vehicle, to reduce PM). The range of 12 month tax rates are shown in Table 2.3 below. All Euro IV buses and newer achieve TC38 status.

Table 2.3: Bus vehicle tax, 12 month rates, Source (Directgov, 2013):

Seating capacity	Bus (TC34)	Reduced emission bus (TC38)
10-17	£165	£165
16-36	£220	£165
37-61	£330	£165
62 and over	£500	£165

It can be seen that VED rates are relatively low as a proportion of the vehicle cost, compared to light duty vehicles (car/van). This weakens the potential effectiveness and leverage of graduated VED, although given the long life of a bus this may still become a component of incentivisation.

A focus on oldest vehicles (through changes in VED) may be useful for the bus market evolution as no legislative drive to remove oldest vehicles once Equality Act compliance complete.

Feebate

A feebate is a combination of a rebate for a vehicle that exceeds a certain environmental benchmark, combined with an additional fee for those vehicles which under-perform. In essence, a fee is levied on the purchase of high carbon vehicles, and the revenue raised is then used to provide a rebate for the lowest carbon purchases. The measure also aims to encourage vehicle manufacturers to develop their business plans on carbon reduction according to the customer demand shaped by taxes/subsidies. There exists an example in France, where under the 'Bonus-malus' scheme the purchaser of a new car with CO2 emission of less than 130 gCO2/km benefits from a subsidy whereas cars emitting greater than 160 gCO2/km has to pay an additional purchase tax.

Feebate schemes can have the following advantages over other more conventional tax schemes (Campaign for Better Transport, 2012):

- In contrast to emissions standards, feebate schemes offer incentives for continuous improvement in CO2 emissions for all new vehicle models / technologies anywhere along the spectrum;
- They incentivise risk averse customers to factor fuel economy more fully into their purchase decisions by amplifying the price signal upfront, rather than relying upon them to make rational and accurate forecasts of future fuel cost savings, when these are in their nature uncertain and heavily discounted; and
- They develop a stronger and undistorted market for fuel economy to which all manufacturers can cater, but in addition, they establish for manufacturers a known price for CO2 reductions, which can then be factored into their model design and marketing strategies.

The pivot point for a feebate scheme can be set at the level at which the total income from fees broadly balances the total rebate given out, thereby creating a revenue-neutral scheme. However, this is unlikely to be practical in the UK bus market which exists in its current form and level of service provision via public support through a range of subsidies.

It should be noted that as with most other tax schemes, consistency and guarantee of long term political support are key to a feebate scheme's success.

2.6.2 Other non-fiscal policy options

Transport policy and regulations
Policies establishing Clear Zones and Low Emission Zones (LEZ) can be used, by an LTA, to encourage take-up of low emission vehicles. Examples in the UK include the London LEZ and the Nottingham Clear Zone, both of which have been used as part of a co-ordinated approach to introduce lower emission vehicles, focussed primarily on local air quality pollutants.

Regulations and Standards
European mandatory emissions standards have been set for vehicle manufacturers which means that each vehicle manufacturer's weighted fleet average emissions need to be below the threshold value by a given target year. Failure to comply results in financial penalties for the vehicle manufacturer. Similar regulation exists for commercial vehicles.

Technology demonstrators
In order for new vehicles and technologies to succeed, it is important that these can be tested by customers before adoption in a way that shares the risks associated with new technologies between all key stakeholders, namely the technology developers, vehicle manufacturers and vehicle operators. This can be effectively done through small scale demonstrator programmes that help to build understanding of the new technologies and their positive benefits. Another alternative is to set up part funded demonstrators through part funded research frameworks such as those developed by TSB or the EU through the Horizon 2020 programme.

3 ANALYSIS OF INCENTIVE MECHANIMS

3.1 Introduction to research and analysis

There are a number of routes to achieving the same goal, and the 'best' incentive mechanism is not the same for all stakeholders. These conclusions do not suggest one incentive mechanism, but rather set out a range of options, with some firmer recommendations on ways to improve the current approaches to LCEB. These vary in scale of ambition and speed of change. An important consideration is what effect a policy has on the operation of the extensive standard diesel bus fleet, which could be damaged by an insensitive LCEB policy.

Conclusions on how best to support the growth of the LCEB market now follow. Each is accompanied by an analysis of payback times under illustrative costs of vehicle operation under the range of incentive regimes and support mechanisms.

The support mechanisms have been presented, firstly those mechanisms that encourage purchase of LCEB by reducing running costs and secondly those incentives that can support capital expenditure on LCEB. Existing mechanisms are examined and impacts explained and potentially new variations and options added, including graduated incentives based on level of carbon reduction. Finally, through the feebate mechanism an approach that combines incentives and penalties is raised for discussion. It may be appropriate to combine both running cost incentives and capital cost support.

Illustrative analysis of incentive mechanisms (at different levels) on payback times has been prepared and will follow in the fuller reporting from this study. This study has used a typical bus life of 15 years, and also a '5 years or less' benchmark to illustrate the effect of changing incentive mechanisms (including their removal, addition and combination). Decisions about the exact levels of subsidy are for decision makers to consider, based on these illustrations.

3.2 Assumptions and input data

This study was designed to build on cost input data from earlier work by LowCVP in preparing the LowCVP Low Carbon Bus Technology Roadmap [6]. It was possible to revisit some of the cost data with input from stakeholders and Bus Working Group members.

The costs analysis takes a similar approach taken for the LowCVP Low Carbon Bus Technology Roadmap, with some updating of cost data (where available within study time frame). The cost elements are: the vehicle investment and any (refuelling) infrastructure costs plus the ongoing running costs (based on fuel and maintenance). These are quantified based on a comparison with a standard diesel bus. In this analysis the majority of reference vehicles are single deck (12m) vehicles, with the addition of a double deck diesel and double deck hybrid comparison. Assumptions are stated in the section above, with input data summarised in Annex 1 of this report.

[6] http://www.lowcvp.org.uk/assets/reports/LowCVP-Ricardo%20Bus%20Roadmap%20FINAL.pdf

It has been necessary to simplify the wide range of input data on vehicle performance and costs in order to carry out analysis on the impact of incentive mechanisms. The assumptions and key input data are included in Annex 1. A sensitivity test, with varied input data is presented in Annex 2.

Simplification has meant, for example, picking one fuel consumption rate (e.g. mpg) for each technology being used in the illustrations. We acknowledge and appreciate that fuel consumption varies widely and the range in variation can be related to, among other factors, the: vehicle technology; the manufacturer of that type of technology; the specification of the vehicle; the route and duty cycle; the topography of the route; the fluctuating price of competing fuels etc. Similarly cost data can vary widely, based on readiness to market of a technology, the volume of orders and the purchasing power of the customer. We believe the values chosen fall within an acceptable and achievable range of performance and cost; however a clear caveat is that these should be considered to be indicative and not be used as a basis for choosing a particular technology or choosing between technologies.

One key simplification, required to isolate the effect of incentive mechanisms from other variables, has been to assume fixed prices over time. For example, fuel costs are fixed for all, which is not realistic unless it is a fuel that enables fixed price contracts over a number of years. As well as fuel, costs and performance of technology will change over time, both new and standard diesel technology. For example, it is argued that costs for diesel vehicles and maintenance may rise with Euro VI, and may not for other vehicles (e.g. electric and gas).

All vehicles are assumed to undertake 45,000 miles per annum. Averages from London and non-London locations appear to range between 35,000 and 45,000. Mileage will affect payback times with higher mileages favouring fuel/cost efficient running to offset additional upfront capital costs.

Table 3.1: Assumed vehicle cost and performance – compared to single and double deck diesel

Cost/performance item	**Diesel Bus**	**Diesel Bus**	**Hybrid (SD)**	**Battery Electric (SD)**	**CNG (CBG) (SD)**	**Flywheel**	**Hybrid (DD)**
	Single Deck (SD)	Double Deck (DD)	SD	SD	SD	SD	DD
Bus / Tech cost - difference	£ -	£ -	£75,000	£97,500	£35,000	£15,000	£90,000
Maintenance/replace - cost difference	£ -	£ -	£3,273	£4,940	£500	£60	£4,610
Infrastructure - cost difference	£ -	£ -	£ -	£30,000	£40,000	£ -	£ -
MPG (kWh/mile) (kg/mile)	7.20	5.20	8.90	2.10	0.57	8.47	7.20
Mileage p.a.	45,000	45,000	45,000	45,000	45,000	45,000	45,000
LCEB @ 6ppkm?	N	N	Y	Y	Y	N	Y
Fuel (litres/kg/kWh) consumption per km	0.40	0.55	0.32	1.30	0.34	0.34	0.40

*

There are a number of assumptions to note:

- To better compare vehicle technologies we have focussed largely on single deck (SD) vehicles as a common platform available for all;
- We have also added a double deck (DD) hybrid given the difference in costs and performance, plus the prominence of double deck vehicles within the hybrid technology type;

- The hybrid illustration was formed from an amalgamation of different actual vehicles, including a both parallel and series types. The performance data supports this approach;
- The flywheel technology is based on one technology option, others exist and costs and performance vary. Other technologies are available in this price/performance category that also work in parallel with a diesel engine. The option illustrated here does not currently quality for LCEB status (and therefore the 6ppkm BSOG enhancement);
- Flywheel costs are those forecast and assumed reasonable after realistic production-scale volumes, to better compare with the other technology options which have achieved maturity on the market;
- CNG buses are assumed, for low carbon status, to be powered by biomethane fuel (available via the grid using green gas certificates) and termed Compressed Biomethane Gas (CBG);
- For CBG buses it is assumed the location of the refuelling station is close to the high or medium pressure gas grid to ensure reasonable costs;
- The assumption for battery electric buses and full hybrids are for battery packs to be replace around every 7 years (with the cost spread over each year of operation to even out);
- Battery electric buses are specified with fast charging stations, and the cost included, as this is a more realistic way of recharging over-night or between peak periods. Alternatives are slow charging (at approximately half the infrastructure costs), purchase more buses or invest in inductive charging; and
- A range of battery electric bus designs exist, with varying sizes of battery and passenger capacity. We have taken some typical characteristics, but note that a range exists.

There are different ways to treat any infrastructure costs. For battery electric and compressed biomethane gas (CBG) we have assumed an additional cost for paying back the refuelling/charging station over 10 years. A second option for gas (CBG) is 'wet-leasing', where the refuelling station is installed and operated by a 3rd party. The infrastructure costs are then paid back via the price of the fuel in order to change the cost from being an upfront capital investment to be part of longer term running costs. It may be possible to fix fuel prices in such circumstances.

It should be noted that costs may vary from one vehicle model or manufacturer to another (e.g. vehicles to TfL specification will cost more than those for use outside London). Also, performance will vary by vehicle type, operator and route. We do not attempt to model all the possible variations. The technologies selected are those where we had higher confidence or confirmation of cost inputs, from previous LowCVP projects and verification by BWG members. They are also selected to illustrate the impact of different support mechanisms on a range of technologies that have varying characteristics. This is to illustrate better the impact of a given support mechanism and support the recommendations on how to best apply a range of policy options.

LCEB technologies should be assessed in terms of how well they fit with the duties required of them, and availability or access to infrastructure, support, etc. So, for instance, battery electric vehicles may have narrower set of applications than hybrids (but innovative approaches may widen their scope) or in another example the cost of installing sufficient gas refuelling will be heavily influenced by proximity and type of gas grid to the desired refuelling station (e.g. the depot). This type of information is available from a number of sources, but is not within the scope of this study.

The values utilised here are therefore a snapshot view, to illustrate the impact of a given incentive mechanism and also combinations of incentives. Analysis and recommendations on improvements to existing incentives as well as potential changes or new options now follow.

3.3 Analysis of support mechanism for running costs

3.3.1 Introduction

Figure 3.1 below, and all subsequent charts in this section, should be read as follows:

- The diesel vehicle comparator always forms the x–axis, against which LCEB options are compared under the specific incentive mechanism being presented;
- Generally one incentive mechanism is illustrated at a time (unless it is stated they are combined), in order to isolate the effects of the particular subsidy;
- While the payback time-period extends to 15 years in these illustrations the other costs (fuel etc.) are fixed, as stated in the assumptions (see Section 3.2 above);
- Each of the LCEB options starts below the x-axis, with a negative £ value, because the LCEB considered all cost more to purchase than the comparable diesel bus (either in terms of vehicle or fuelling infrastructure or both).
- As each year of operation is completed the lower running cost of the LCEB options reduce the differential between it and the diesel comparator (on the x-axis), until the LCEB payback trajectory crosses the X-axis and achieved parity with the diesel bus. The point the line is crossed is the payback time in years.
- For subsequent years, with the LCEB having crossed the x-axis (diesel comparator) line, the assumption is the operator is saving money against the equivalent diesel bus. The gap between the LCEB line and the X-axis (diesel) represents the cumulative financial benefit for that year of operation since Year 0.
- The payback relationship between LCEB and diesel bus have been estimated for each technology and incentive scenario up to 15 years. In some cases the payback takes longer, sometimes much less.

It should be noted that increasing the subsidy rates will affect the payback times, and therefore this strongly influences how effective a support mechanism appears to be. The main objective is to compare a range of subsidies to illustrate how they change the relative attractiveness of technologies and provide insight for further policy investigation and development.

Initially the payback rates of the illustrative LCEB options (compared to diesel) are presented without any support mechanisms in place, other than existing duty differentials between diesel fuel and gas as a road fuel. Then existing incentives are examined to illustrate the impact they have on various LCEB options and their payback rates. New proposals on incentive mechanism are tested through further analysis, including a graduated LCEB payment (per km and per vehicle purchase) and a feebate mechanism.

3.3.2 Baseline – payback comparisons under no incentives or subsidies

This is an illustrative scenario, which assumes that no current incentives (such as current BSOG on fuel) are in place. It provides the baseline from which we can more clearly see the effect of a range of incentives on payback times, using illustrative technologies (with varying costs and performance). See Figure 3.1.

By removing all incentives the current BSOG regime that subsidises diesel consumption is removed, and this impacts heavily on diesel using vehicles (extending payback) and on non-diesel vehicles (shortening payback) compared to a standard diesel vehicle. It can be seen that when no incentives are taken into account, different technology pay-back periods vary widely compared with diesel (the horizontal comparison line at zero £). Most notably, battery electric pays back in the 5th year and results in the highest cumulative payback of over £80,000 per bus in 10 years. The speed of payback is vs. a standard diesel vehicle and is short because the diesel vehicle has become comparatively more expensive to run without BSOG at 34.57 pence per litre. CBG and flywheel technologies also achieve payback within a 4 to 6 year timeframe. In this analysis hybrid technology takes longest to payback and the double deck variant does so in 13 years and the single deck requiring over 15 years (due to and assumed lower fuel efficiency).

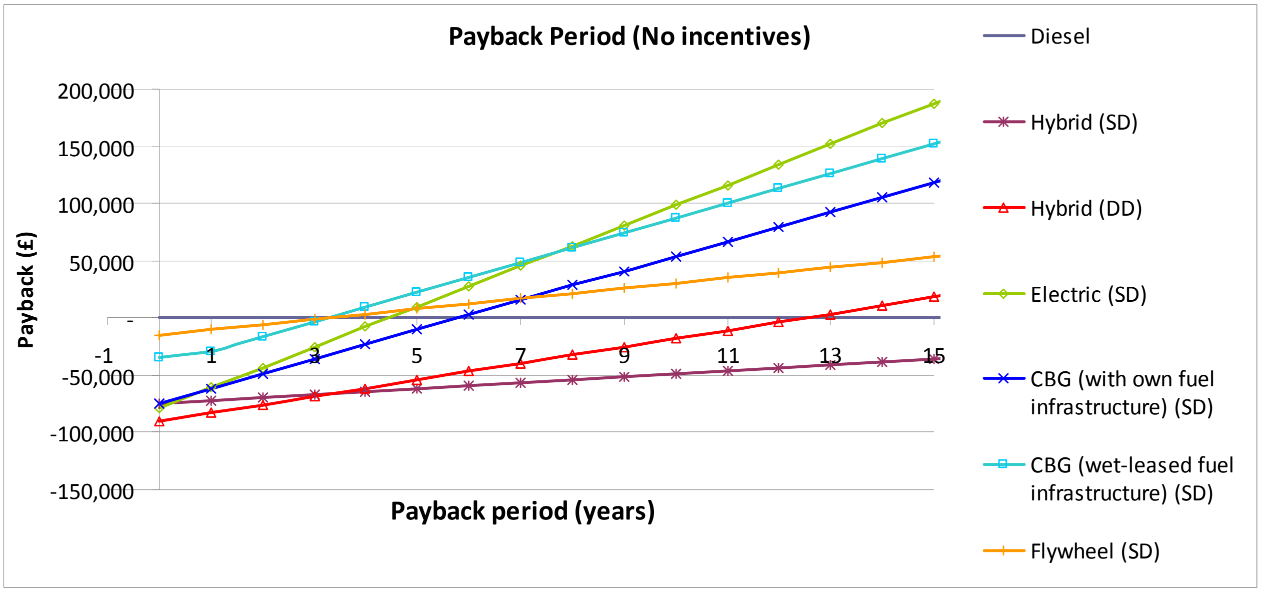

Figure 3.1: Payback comparison without any incentives

It should be noted that this is a payback period compared to a standard diesel bus: costs for the LCEB technologies are not reduced in any way, rather the standard diesel bus costs (specifically running costs) have risen so the alternative technologies (with additional investments costs) can pay-back over a shorter length of time in comparison.

3.3.3 BSOG and enhanced LCEB payments

Currently in the UK many bus operators are able to benefit from the BSOG, which is made up of three parts;

- a fuel subsidy component;
- a LCEB component that provides a further subsidy for buses that meet the current LCEB requirements (currently at 6 pence per km); and
- a component related to on-bus equipment (AVL, ticketing).

The addition of the fuel subsidy component of BSOG only, which subsidises fuel used (including gas and bioethanol), has nevertheless the strongest impact on diesel-based technologies and therefore lengthens the potential (comparable) payback period for all LCEB technologies due to diesel buses being comparatively cheaper to operate. With BSOG only, the technology that can achieve a positive payback in under 10 years is flywheel, see Figure 3.2. Compressed Biomethane Gas (own-infrastructure) appears to payback in around 10 years (compared to 4 years with no incentives, in Figure 3.1).

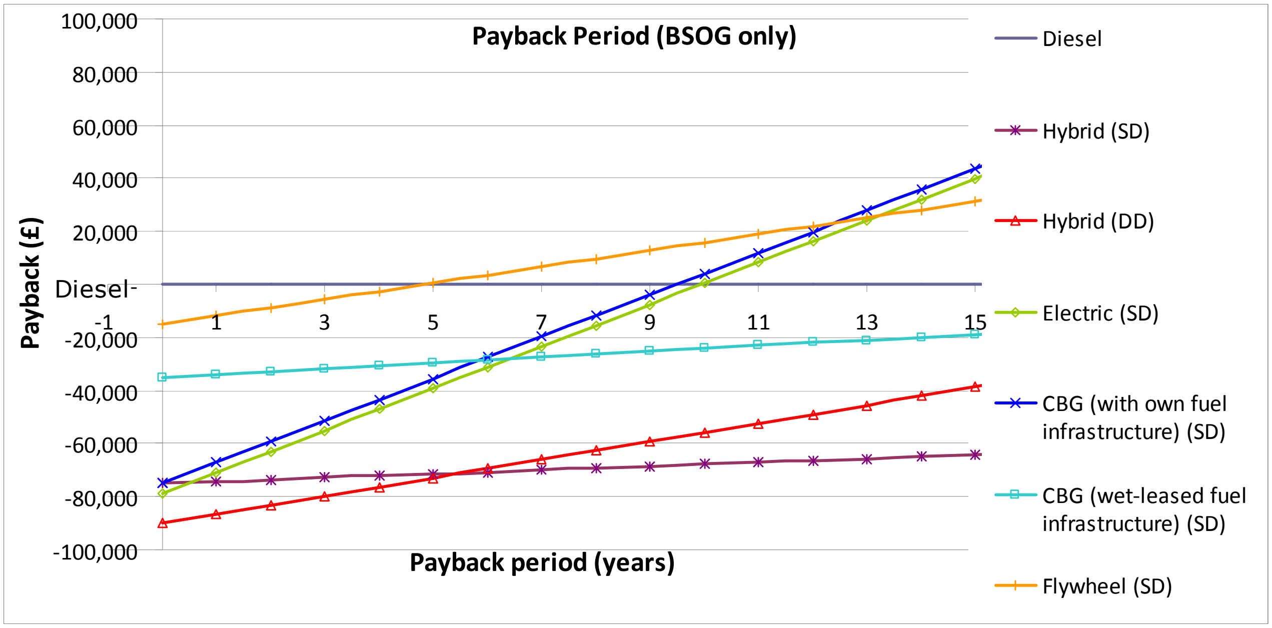

Figure 3.2: Comparison of payback periods with BSOG only (per litre) [no LCEB component]

If the LCEB component of BSOG is also taken into account (at 6ppkm), to represent the current situation in terms of available subsidies in most of England, then the payback period for all LCEB technologies that meet the LCEB bus requirement is reduced, see Figure 3.3. More of the LCEB technologies are able to achieve payback within the 10 year timeframe, with hybrids estimated at 12 and 15 years respectively for double and single deck vehicles. This scenario does not include any Green Bus Fund grants to offset the technology costs, as BSOG and LCEB only impact on running costs once the vehicle has been purchased.

Note that flywheel technologies are not affected by the addition of the LCEB component as they do not meet the 30% CO2 reduction criteria for LCEB and therefore do not benefit from this particular incentive. However, flywheel technology (under the assumptions in this study) has already been shown to payback in the 5th year in this incentives regime.

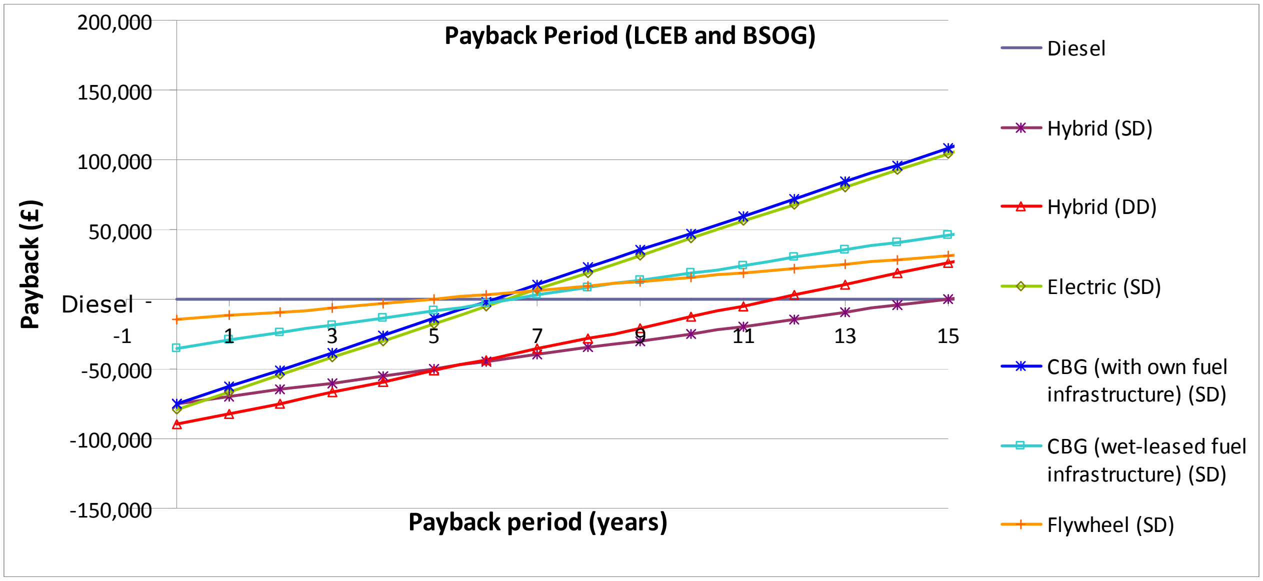

Figure 3.3: Comparison of payback periods with BSOG, including LCEB component

A key objective of this project is on identifying which support and incentive mechanisms can help to bring the payback periods of the LCEB technologies to within five years. Therefore, Figure 3.4 shows an expanded view of the first 5 years shown in Figure 3.3.

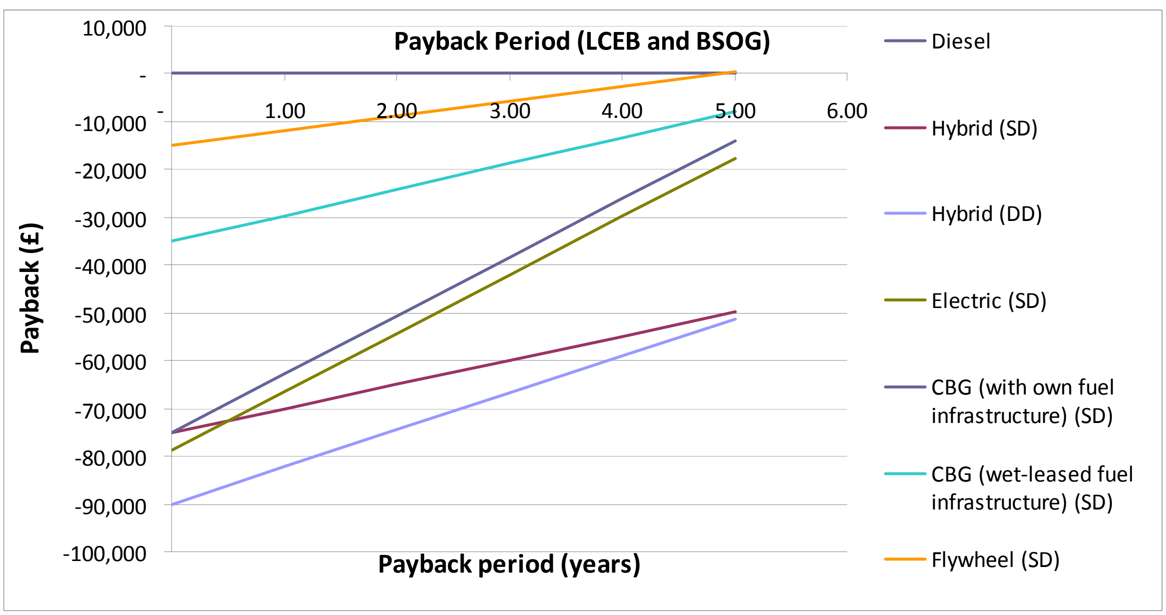

Figure 3.4: Comparison of payback periods with BSOG, including LCEB component (5 year timescale)

The simple illustration of payback periods above highlights the importance of the incentive mechanisms on running costs and the impacts that they can have on different technologies. It also highlights that the current BSOG mechanism (including the

LCEB component) is not optimally configured to encourage the adoption of a variety of LCEB technologies. The LCEB component specifically does appear to work well to reduce the payback periods compared to diesel as it only applies to technologies that can meet the 30% CO2 reduction target, but then offers a much lesser incentive to go further.

3.3.4 Scottish BSOG for LCEB

An alternative approach to BSOG is the one now adopted in Scotland. This approach aims to decouple the incentive provided to bus operators from fuel use while encouraging the adoption of LCEB technologies. As of 2011 fuel use is no longer a factor in calculating BSOG payments. Payments are solely based on distance travelled and calculated using the equation:
Payment = eligible km x payment rate. From 1 April 2013 the following rates are applied (Transport Scotland, 2013):

- Conventional fuels: 14.4p/km
- Biodiesel: 20p/km (for services using 100% biofuel from sustainable sources)
- LCEBs: 28.8p/km (including biomethane bus that qualify as LCEB)

The impact of Scottish BSOG setup on the adoption of different LCEB technologies is shown in Figure 3.5 below. The results show that this type of incentive mechanism is very effective in encouraging the adoption of LCEB technologies while continuing to provide some subsidy for diesel bus operation. Almost all LCEB technologies can achieve payback within a five year timeframe, with hybrids taking around 6 years.

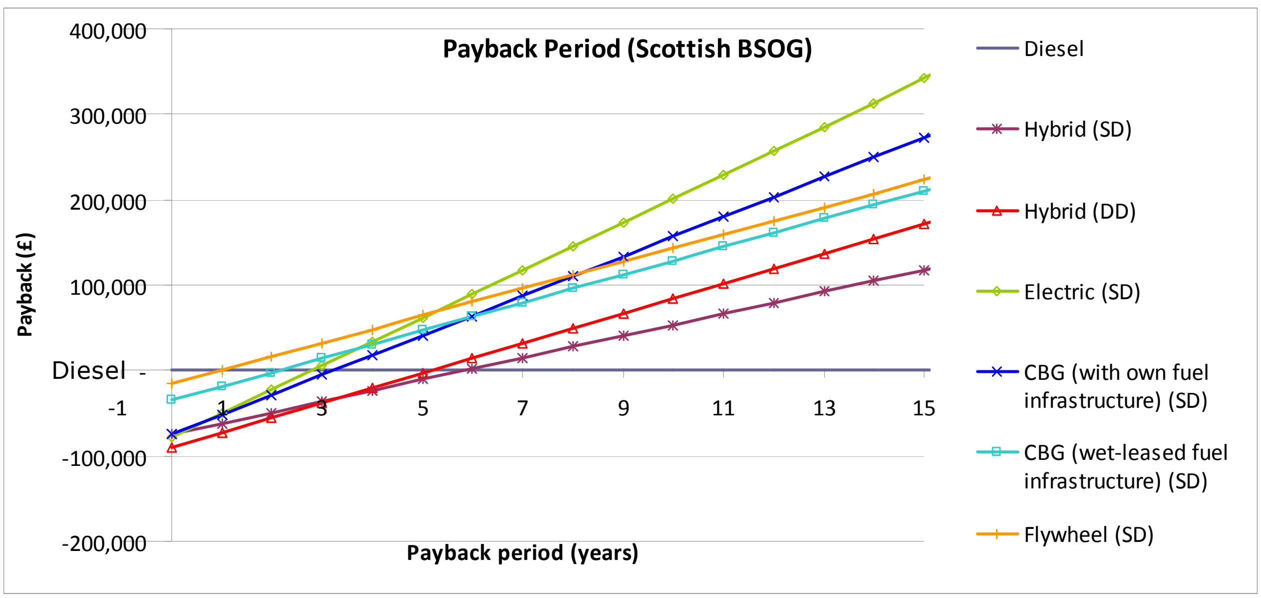

Figure 3.5: Comparison of payback periods for Scottish BSOG (15 years)

It should be noted that Scottish BSOG has higher value of rebate on per km basis than the hypothetical graduated LCEB mechanism considered in section 3.3.5 below, and is therefore likely to cost more to implement. The Scottish BSOG discriminates between technologies based on fuel type used as well as whether the technology is able to meet the 30% CO2 reduction. The analysis suggests that Scottish BSOG will result in the fastest payback rates from all the actual and theoretical mechanisms considered.

3.3.5 Graduated LCEB

As noted in the section above, the LCEB component is fixed as 6ppkm for all technologies that are able to achieve 30% CO2 reduction or more, and it does not differentiate between other LCEB technologies that can achieve higher or lower savings and still contribute to the overall CO2 reduction. The current scheme does not therefore incentivise over achievement beyond 30%. The project team therefore assumed a hypothetical graduated (sliding scale) LCEB incentive to test the impact of this approach, given its support by stakeholders. In this test 5-15% CO2 reduction results in 3ppkm subsidy, 15-40% CO2 reduction results in 6ppkm subsidy and any technologies able to achieve over 40% CO2 reduction can benefit from 9ppkm subsidy. This approach encourages the adoption of all LCEB technologies while providing the largest incentives to those which can achieve the largest reductions. For the purpose of this assessment, flywheel technologies were assumed to fall in 3ppkm category, hybrids (parallel and series) in the 6ppkm category and CBG and battery electric in the 9ppkm category. The results are shown in Figure 3.6.

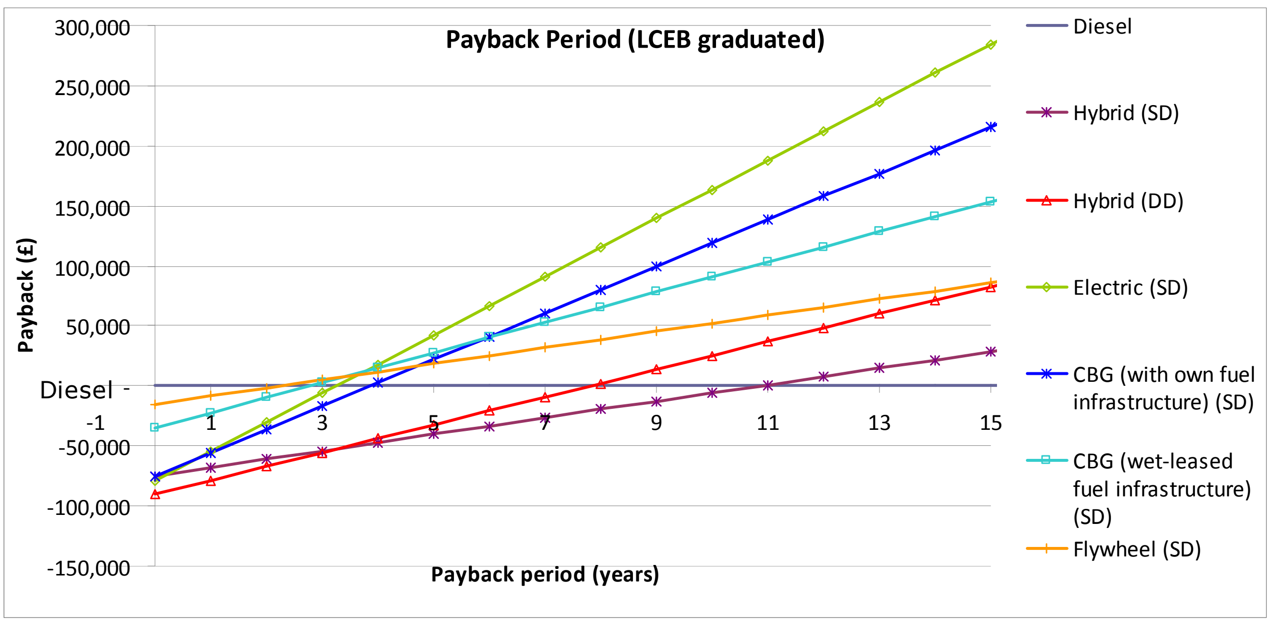

Figure 3.6: Comparison of payback periods with graduated LCEB (15 years)

A stepped approach has been used in this study to simplify the estimation process (due to the a limited range of technologies and fixed performance rates) but we recommend any actual implementation should use a graduated (sliding scale) approach, to avoid the problems of threshold effects similar to those asserted to occur in the current 6ppkm approach.

It should be noted that this graduated LCEB is applied with no other subsidies, which means no general pp litre BSOG. Therefore the comparison should be made with a LCEB only approach, as seen in Figure 3.7 below.

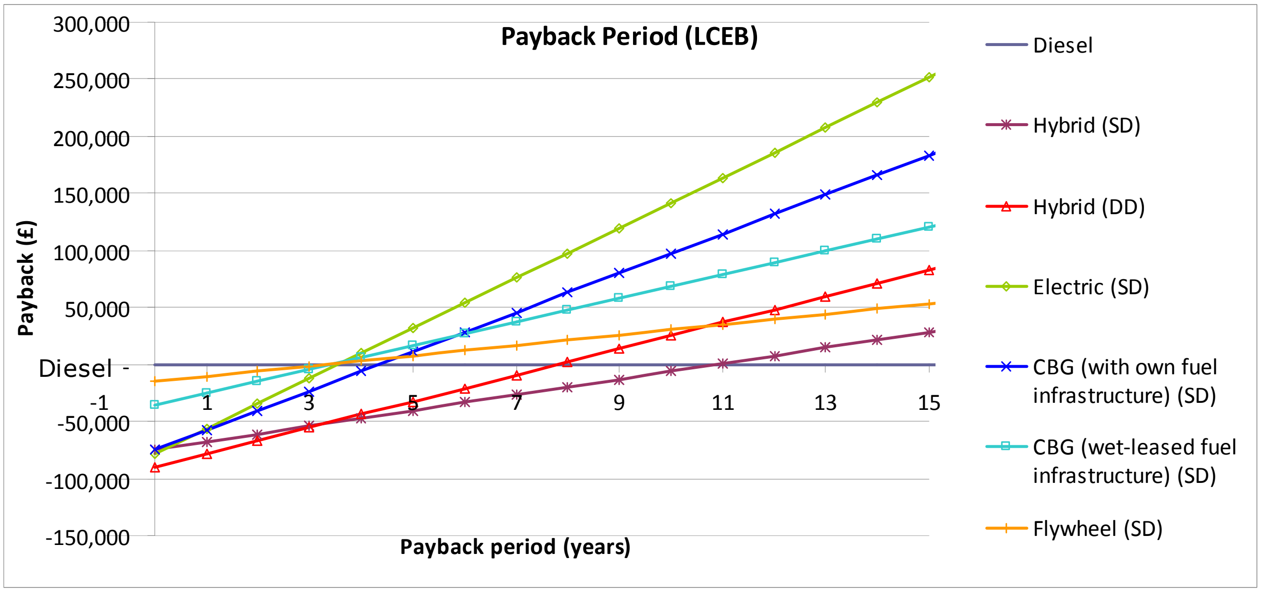

Figure 3.7: Comparison of payback periods with current 6ppkm LCEB (15 years)

Under such a hypothetical incentive scheme, CBG, battery electric and flywheel technologies (at the cost rates assumed in this analysis) can achieve faster payback than under current LCEB because they are incentivised to a greater value. Hybrids pay back at the same rate as under current 6ppkm flat LCEB BSOG because the way in which the tiers have been drawn keeps them in the same 6ppkm rate.

This illustrates that the CO2 reduction boundaries in this scenario are still relatively wide and therefore technologies at either end of the same tier will benefit differently. This is likely to be the case with any scheme that aims to define boundaries and could cause problems with agreeing on how to set the boundaries in the first place. This is the reason for recommending a fairer approach that assigns a value per 1g of CO2 per km saved compared with diesel. This would be more difficult to implement and may require accurate testing methodologies but would also allow to provide incentives for each technology based on its ability to reduce CO2 and remain technology agnostic.

3.4 Analysis of support mechanism for capital costs

Capital grants are very helpful for complex low carbon technologies, particular with energy storage requirements or requiring new fuel delivery systems (such as refuelling stations or charging points). Grants can be considered as important to assist a developing set of technologies that have generated momentum in the bus industry towards low carbon options. Ensuring that vehicles with a high energy efficiency are incentivised through capital grants is important now that a wider range of LCEB are available and are gaining market share against standard diesel vehicles.

This section presents analysis on proposed methods of supporting either or both vehicles and refuelling infrastructure.

3.4.1 Grants and other support for capital investment in new vehicles

It was noted in the Task 1 phase of this study – engagement with stakeholders – that the competition element for GBF and timing/window of opportunity did not always sit well with bus operators financial planning and calendar for new vehicle procurement decisions.

The study has therefore examined an option of a vehicle grant, linked to carbon reduction that would apply to any LCEB purchase. The greater the carbon saving the larger the grant that could be claimed.

In this analysis a linear value of £26 per each gCO2/km was used and a reference point for grant payment of 1100gCO2/km was set for a single desk and 1600gCO2/km for a double deck. These values are slightly more efficient than the baseline diesel vehicle values used in the remainder of the analysis. It should be noted that the values are selected for illustration purposes only and in order to determine a series of appropriate values, they would need to be investigated in detail.

The approach would be to provide a grant to offset purchase price based solely on the carbon performance against the benchmark levels. Based on the fuel consumption values used in this analysis the values of grant provided to each illustrative technology are in Table 3.2 below.

Table 3.2: Carbon linked grant – example £values per technology

Type	CO2 (g/km) WTW - examples	Grant £
Diesel (SD)	1194	£0
Diesel (DD)	1654	£0
Hybrid (SD)	966	£3,558
Hybrid (DD)	1194	£8,659
Electric (SD)	579	£26,000
CBG (SD)	292	£14,903
Flywheel (SD)	292	£2,420

The effect of grant funding part of the purchase price can be seen on the chart of payback times, in Figure 3.8 below. The vehicles with the largest grants are battery electric followed by compressed (biomethane) gas, given their carbon performance values. The impact of these grants has quite a powerful effect even with no other subsidies or incentives in place.

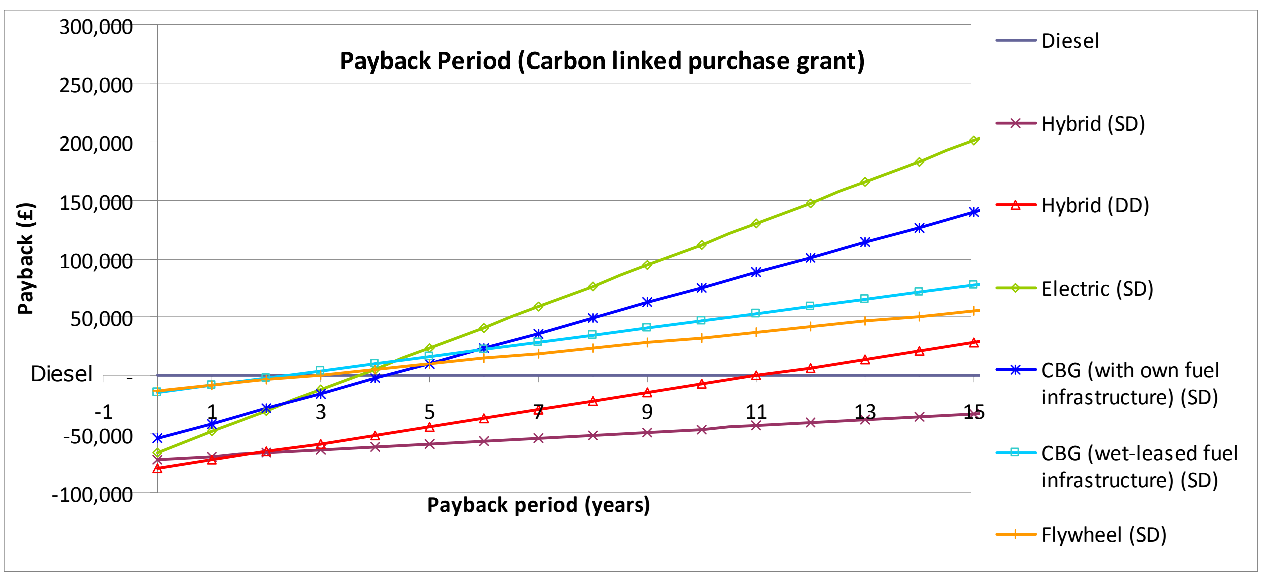

Figure 3.8: Comparison of payback periods with carbon linked purchase grant (graduated)

It should be noted that this scenario does not include other subsidies, so a truer reflection of implementing such a capital grant on the current (English) system in place in most areas would be to combine the carbon linked purchase grant with BSOG and LCEB (of 6ppkm). This is shown in Figure 3.9 below. As might be expected the payback times on all technologies are shortened over the BSOG & LCEB illustration in earlier analysis, with all technologies paying back with the 5 to 15 period. Again, this shows that such a grant could have a quite powerful effect on a range of technologies, in terms of shortening payback times.

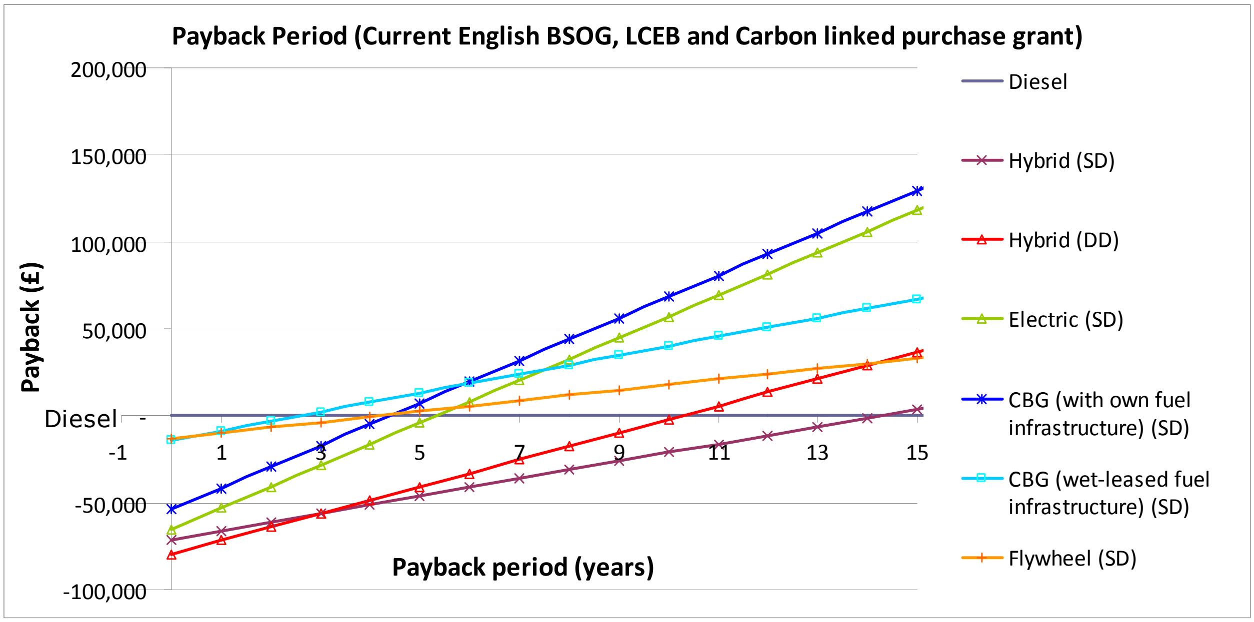

Figure 3.9: Comparison of payback periods with carbon linked purchase grant (graduated) combined with BSOG and LCEB

3.4.2 Infrastructure grants or first year capital tax allowances

The assessment for the carbon linked purchase grant on its own (no other incentives or subsidies) in the section above showed that CBG buses refuelled at a bus operators own station would repay the additional within 5 years and Battery Electric Buses in 3 years. An alternative, or complementary, approach would be to reduce capital costs through the introduction of an infrastructure subsidy or grant, as is currently done with charging points for EVs in the car and van sectors.

Assuming a 50% reduction in infrastructure capital costs, the payback period for CBG (with an operator's own infrastructure) falls to 4 years (see Figure 3.10). Therefore, although useful in reducing a high initial capital cost, and maybe helping to remove this as an entry barrier for some operators, the impact of even significant (50%) infrastructure subsidy over 5 years is fairly small (a 1 to 2 year shortening of payback) under current incentive conditions. However, if the importance placed on the infrastructure capital investment by bus operators is deemed to be a barrier then a grant system could be implemented to help overcome the constraint.

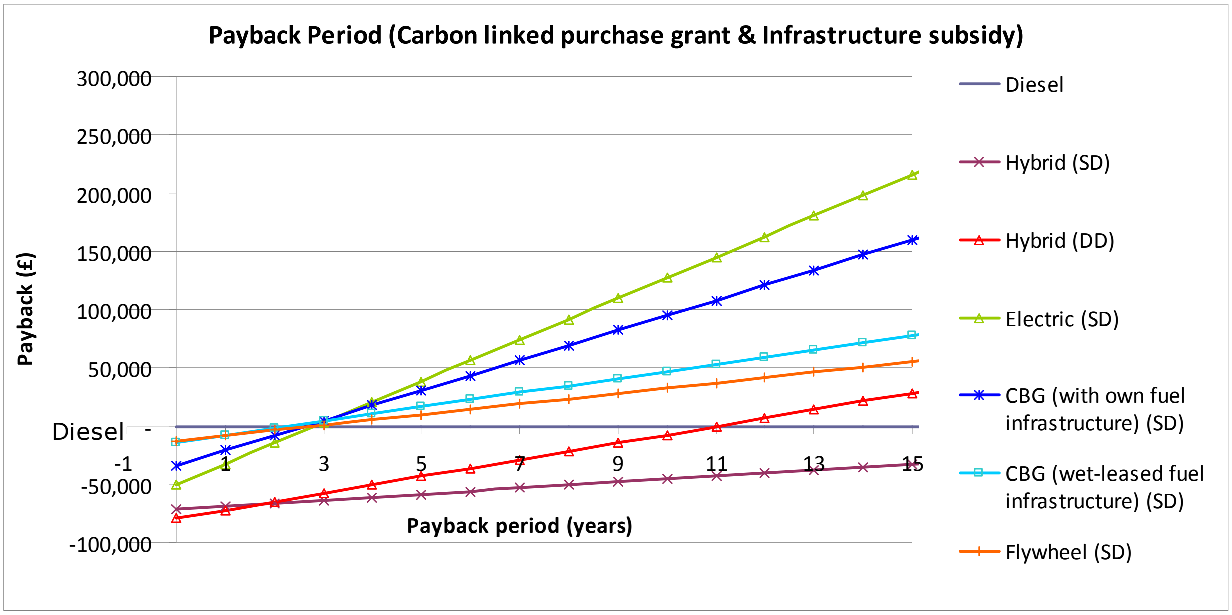

Figure 3.10: Comparison of payback periods for infrastructure subsidy & vehicle purchase grant

An alternative to direct grants, which may raise issues over State Aid, could be Enhanced Capital Allowance (ECA), similar to that which enables businesses to invest in energy or water efficient technologies[7]. Both existing 'efficiency' schemes offer a 100 per cent First-Year Allowance (FYA) for investments by industry and other commercial companies in specified energy/water saving plant and machinery i.e. if you buy equipment that qualifies, you can write off 100 per cent of the cost against that year's taxable profits[8]. A similar allowance should be set up for energy (carbon) efficient transport related equipment, including refuelling infrastructure and vehicles. If it were applied to vehicles then other types of LCEB (such as hybrid electric vehicles) may be in scope.

It is expected that standard Euro VI vehicle will cost more than Euro V vehicles, meaning that the next two years could be critical and very effective for supporting alternative fuelled technologies that already meet Euro VI emission standards, in order to rapidly grow this market.

3.4.3 Analysis of a feebate approach to support LCEB

It may be possible to consider a complete overhaul of the various incentive mechanisms with a holistic view on what incentives and disincentives are in place and will operate in future years. One option would be to utilise a feebate scheme to deliver the required changes and set the support framework for a significant time period, to give certainty for investors in new technology options.

[7] http://www.hmrc.gov.uk/capital-allowances/fya/
[8] http://www.hmrc.gov.uk/capital-allowances/fya/energy.htm

As outlined in section 2.6.1 above a feebate scheme is a combination of a rebate for a vehicle that exceeds a certain benchmark, combined with an additional fee (i.e. penalty) for those vehicles which under-perform. In essence, a fee is levied on the purchase of high carbon vehicles, and the revenue raised is then used to provide a rebate for the lowest carbon purchases. The scheme does not have to be designed as cost neutral, although that may be possible in some markets.

The illustrative analysis carried out in this study shows how a feebate scheme could be used to bring more LCEB technologies under the 5 year payback period, including value attached to carbon savings/excess over a particular pivot point (in grams per km). A high level illustration of the possible impact of a feebate mechanism on the payback of LCEB technologies is shown in **Error! Reference source not found.**.

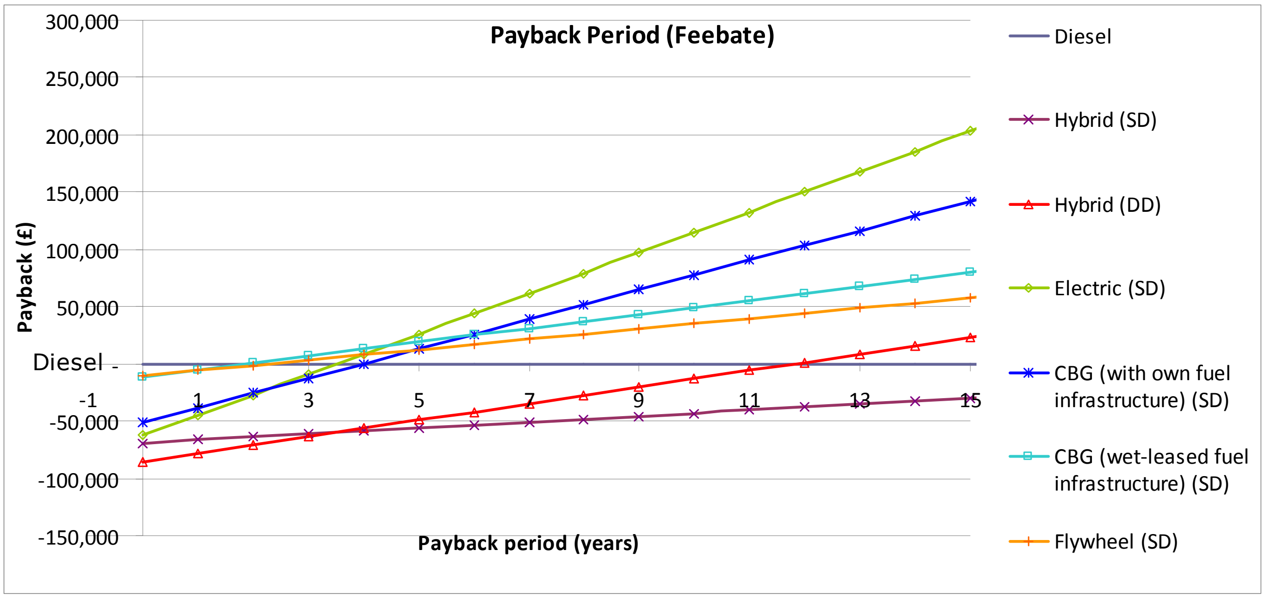

Figure 3.11: Comparison of payback periods for a Feebate mechanism (15 years)

In this particular example, a linear feebate value of £26 per each gCO2/km was used (the same value as was adopted on average for cars in the French feebate scheme) and a pivot point for fee rebate of 1100g CO2/km was set for single deck and 1600 CO2/km for double deck buses. This is believed to be attainable by the most efficient single deck diesel bus technologies but will result in an additional fee (e.g. a purchase tax for an average diesel bus (assumed to be 1066gCO2/km in this analysis for a SD vehicle). It should be noted that the values are selected for illustration purposes only and in order to determine a series of appropriate values, they would need to be investigated in detail.

For reference, the values generated for this analysis are as follows (in Table 3.3).

Table 3.3: Carbon linked feebate values (rebate & penalty)

Type	CO2 (g/km) - WTW	Penalty or Grant £
Diesel (SD)	1194.4	- 2453.8

Diesel (DD)	1653.8	- 1397.5
Hybrid (SD)	966.2	3477.9
Hybrid (DD)	1194.4	10546.3
Electric (SD)	578.5	13559.0
CBG (SD)	291.9	21011.4
Flywheel (SD)	1015.2	2204.3

The values are initial figures used solely to illustrate the feebate method and impact within this study. Section 4 includes further discussion and recommendations on a number of high-level steps required as part of developing a robust feebate system for the UK bus market.

3.5 Discussion

The choice, or blend of support mechanisms, may be made based on whether it is more desired to support a reduction in capital expenditure or running costs.

It is considered that supporting a reduction in capital expenditure provides more direct and immediate control over what technologies are supported and to what extent (and is likely to have a faster impact in the market due to upfront funding). However, it might also means that market prices may take longer to reduce and removal of support would need to be carefully planned. Supporting running costs could provide less flexibility (for funding agencies/departments to withdraw support) and less immediate impact but allow the market to compete to reduce the capital costs to access demand for lower carbon technologies (driven by customer demand for lower running costs).

What appears vital is certainty on support mechanisms, to enable long term planning, and a fair and technology neutral approach wherever possible that incentivises the greatest carbon savings (via graduated mechanisms). This could be applied to either or both of the purchase costs (via carbon reduction linked grants) and running costs (as per a graduated LCEB payment). Further, linking the incentive linked to the whole (or defined portion) of life of the vehicle is very attractive and thought necessary to give confidence in any financial and investment planning.

A major consideration for policy makers is how best to support carbon reduction in the various transport sectors. One might conclude that the UK and its Government needs to focus its efforts and resources on those technologies that truly take it towards a long term goals of 100% zero emissions operations in cities. Supporting the up-take of lower cost, lower benefit solutions that do not meet the long term vision and only incrementally decrease fuel bills may not be the best approach. That is why the study has highlighted the use of graduated (sliding scale) incentives to better value the highest carbon reductions. This might be achieved by packaging up various technology options, or adding lower cost technologies onto a base LCEB to further improve efficiency. The ideal is to maintain incentives for a range of technology options and encourage the best vehicle (specification) to be available for the duties required of it.

A caveat needs flagging here on the restrictions on State Aid to private industry. This has been suggested (by stakeholders) as the reason DfT are moving very carefully with any reform to BSOG, in order to avoid losing it completely if there is an EC review. It should be noted that the Scottish Government is thought (by some stakeholders) to have decided changes to Scottish BSOG do not require declaration to EC, and no EU State Aid approval is required. This position may not be followed by DfT for England. Therefore incentives that require only the mandate of UK Government i.e. Fuel Duty, VED and Capital Allowances, may be more attractive although these may provide less room for manoeuvre and design of the optimal policy support mechanisms.

4 CONCLUSIONS AND RECOMMENDATIONS

4.1 Introduction

Primarily, the research has identified a number of support mechanisms, working either on their own on in combination, that can reduce the payback time for a number of LCEB technology options to 5 years or less (indicating a desirable return on investment). The analysis has also highlighted how existing support mechanisms influence the payback times, and tested how changes to the various existing mechanisms might help them better achieve equitable support to a wider range of relevant technology options (and packages of technologies).

A number of conclusions can be drawn from the Task 1 stakeholder input and Task 2 analysis of support mechanisms and a number of recommendations now follow. Because the decision on scope and speed of change is with decision makers the study has made are recommendations made on mechanisms that potentially overlap or could be used in place of another.

Finally, while the focus of this study is on carbon reduction it would be advantageous for policy makers to consider, and then fully integrate, the opportunities LCEB provide for reducing local air pollutants to varying degrees in any future incentive regimes. Promoting an integrated view point on LCEB and their environmental performance is to the benefit of operators, local authorities and the public.

4.2 BSOG and LCEB payments – supporting running costs

4.2.1 BSOG

BSOG on diesel fuel use (per litre) undermines a key part of the business case for investing in fuel efficient and non-diesel technologies, by lengthening payback times compared to standard diesel vehicles (and standard fuel efficiency rates). Whether BSOG is administered by DfT or devolved to the LTA it should be delivered in a technology neutral manner that does not stifle opportunities and interest in fuel efficiency.

4.2.2 Enhanced payments for LCEB

The BSOG element (currently supporting LCEB at 6ppkm) has been extremely helpful and continues to justify investment and deployment of LCEB. However, the 30% threshold seems to provide a constraint on going further in terms of fuel economy and also discourages lower cost technologies (that may be ideal for packaging up or vitally to improving fuel efficiency of older vehicles via a retrofit solution). Enhanced LCEB BSOG should therefore be modified, so that:

- The payment per km should continue to assist LCEB, but on graduated (i.e. sliding) scale to ensure a fair and technology neutral approach that rewards both mild and major carbon reduction with appropriately scaled incentives.
- This element of BSOG should be paid directly to the operator to ensure maximum effect (even in BBAs).
- This subsidy should be attached to the specific vehicle that qualifies, so it applies for the lifetime (or part thereof) of a specific qualifying vehicle, from the date of registration.

The recommendation on a 'lifetime' incentive is to enable sound financial planning by bus operators and remove the risk associated with suddenly higher fuel bills if the subsidy is unexpectedly removed.

An incentive targeted at running costs is particularly important for the justification of retrofitting older vehicles with LCEB technologies. These vehicles are unlikely to benefit from measures aimed at reducing capital costs so the business case for spending money on retrofitting them will be largely based on benefit achieved through reducing running costs throughout the vehicles life cycle.

Careful thought is needed on what is the benchmark vehicle (or level of energy efficiency), and how this might change over time. Thought will need to be given to how the scheme handles more modern vehicles that might incorporate significant light weighting which makes them more fuel efficient as standard. Currently these are compared to the LCEB benchmark as per any other low carbon technology

Overall, a dual approach where graduated LCEB support (per km) is matched with the per km BSOG payment for general bus support would appear to provide the most attractive mix of (running cost) support to the bus industry

In areas where fuel element of BSOG is being paid incrementally to the Local Transport Authority (e.g. TfL for London and other non-London authorities in Better Bus Areas), then the LCEB element of BSOG should be considered separately and necessarily paid to the bus operator to have the intended effect.

Were LCEB payments to be based on a sliding scale of (graduated) carbon savings this suggests the need for a more detailed testing and certification processes than the current LCEB (30%) threshold, and open up discussion around test cycles (MLTB vs. other areas). This is not insurmountable, but should be noted. It is recommended that DfT develop a better real life test cycle for non-London users for accurate carbon ratings and certification. Ideally the test specification would enable this the carbon certification to be combined with use of on-board equipment to understand real life pollutant emissions from various LCEB options.

There may be a barrier to making changes to support mechanisms under the terms of State Aid (approval from the EC).

4.2.3 Other running cost support mechanisms

The study has briefly considered other running cost support mechanisms:

Fuel duty

Fuel duty changes have the advantage of being within the UK Government's sole discretion, so there are no issues over State Aid. There is already a duty derogation in place for CNG and biomethane as road fuels and also, although on a reducing trajectory, for LPG. There have been calls for a reworking of duty based on carbon content. However, it seems difficult to design a technology/fuel neutral approach that can also incentivise efficient diesel vehicles.

Vehicle Excise Duty

Vehicle Excise Duty – VED – ('road tax') is relatively low for bus in comparison to their new purchase price so that a variation in VED (i.e. reduced) for lower carbon models is likely to provide a lesser incentive (than in the case of cars). However, VED can be varied by UK Government, and higher levels of VED on high-emission vehicles might be considered as part of an overall strategy to maximise the impact of a feebate payment (or subsidy) on low carbon vehicles.

4.3 Vehicle and infrastructure - support on purchase/capital costs

Capital grants can be helpful for supporting purchase of complex low carbon technologies, particular those with energy storage requirements in the form of batteries. Grants can be considered as important to assist a developing set of technologies that have generated momentum in the bus industry towards low carbon options. Ensuring that vehicles with a high energy efficiency are incentivised through capital grants is important now that a wider range of low carbon bus are available and are gaining market share against standard diesel vehicles.

4.3.1 Carbon linked vehicle grants

It is recommended that if a 'Green Bus Fund' or other grant to support purchase cost of LCEB is to operate in the future it should:

- Operate on a graduated (sliding scale) basis, so that vehicles with highest carbon savings qualify for greater levels of support as a proportion of the additional cost; but
- Enable lower cost technologies that nevertheless make recognisable carbon reductions to benefit from some support.

As noted in the recommendation on graduate LCEB (with the change to a sliding scale) a scheme where LCEB capital grants are based on a graduated (sliding scale) of carbon savings suggests the need for a more detailed testing and certification processes than the current LCEB (30%) threshold.

4.3.2 Refuelling and charging infrastructure support

Battery electric and CBG technologies can require a significant capital investment upfront for refuelling infrastructure. These costs can vary widely depending on the exact type of refuelling station and availability and proximity to the necessary distribution infrastructure for gas or electricity. We have assumed gas and electric charging infrastructure can add significant costs to operators' overall investment in CNG/biomethane or battery electric buses, in the range of £20,000 to £40,000 per vehicle. It may be necessary to consider a large fleet of vehicles (if gas) and to keep the infrastructure operating for ~10 years in order to achieve payback on the infrastructure.

The capital cost is only one barrier to accessing infrastructure because duration/timing, uncertainty over grid connection (and variability of its cost) are also significant. These can be constraints, and compared unfavourably to the ease of using diesel fuelled LCEB options. No grants are in place for bus refuelling infrastructure, while they do exist for cars and have in the past for HGV (via TSB's Low Carbon Truck competition).

Enhanced capital allowances may provide method of supporting investment in new infrastructure, as an alternative to direct grants, and a template may be provided by the current approach to incentivising energy and water efficiency measures.

4.3.3 Use of a feebate

A feebate scheme was investigated by analysing the impact of combining a rebate for a vehicle that exceeds a carbon benchmark, combined with an additional fee (i.e. penalty) for those vehicles which under-perform. In essence, a fee is levied on the purchase of high carbon vehicles, and the revenue raised is then channelled to provide a rebate for the lowest carbon purchases. A feebate scheme can in theory be designed as cost neutral, but this is thought unlikely to be possible in the UK bus market which requires public support to provide services in their current form.

As the purpose of a feebate scheme is to reduce the initial capital costs associated with the vehicle purchase, and make high carbon emission vehicles more expensive to purchase, it does not on its own mean a longer term commitment to subsidise vehicle operation. Therefore, if a feebate scheme is the only incentive scheme operated then it might be possible to allocate more funding to it (without penalising standard diesel vehicle directly) and create a bigger differential.

While the feebate scheme illustrated here would apply to new vehicle purchases the idea of a feebate might be used, in a careful manner, to affect a change in the existing vehicle fleet through changes in VED paid per vehicle, while noting the limits of the current value of VED. This has not been investigated further at this point, but would be useful further work given the need to influence the existing vehicle fleet to ensure fuel efficiency is not simply driven by new vehicle purchase. Evidence from other countries has shown that combining the introduction of a feebate scheme with a scrappage scheme can have benefits by encouraging the removal of the oldest, most polluting vehicles from use and at the same time encouraging the take up of new LCEBs.

It should be noted that as with most other tax schemes, consistency and guarantee of long term political support will be key to a feebate scheme's success. Any further design of a feebate scheme requires considerable scrutiny and a detailed examination with supporting research to:

- Account for different size/weight of comparable vehicles;
- Consider where to set the pivot point, steepness of lines and length of threshold;
- Conduct an extensive survey of carbon emissions from the existing bus fleet;
- Particular attention would be required to not unduly penalise in-service vehicles, while providing some incentive to purchase/retrofit low carbon technologies;
- Decide if it were a revenue neutral scheme (where fees paid for rebates) or whether additional funds were being created to support low carbon bus and not risk otherwise commercially viable vehicles.

Compared to the alternative carbon linked grant mechanism examined in this study the feebate adds an additional encouragement (through the penalty) on the higher carbon emission diesel bus. The method of levying the fee has not been determined by this study, but a purchase tax or first year VED hike of some type might be added (by whatever route is most convenient to Government) if a feebate scheme was thought of interest.

4.4 Other support mechanisms

4.4.1 R&D support

There are examples of vehicles (in the current bus market) that demonstrate how R&D funding for collaborative projects has led to new low carbon technologies being developed ready for market adoption. It is therefore recommended that:

- R&D support for collaborative projects (between OEM, technology suppliers and Operators) to be maintained or increased.

A number of possible sources for R&D co-funding were identified in Section 2.5.4. However, the multitude of research call topics and funding streams can be confusing and sometimes it is not clear which of these are applicable to LCEBs. It is suggested that a coordination activity could be set-up, most likely through an existing industry body, which would digest and disseminate opportunities for R&D and demonstration co-funding activities in the UK and Europe.

4.4.2 Coordination of available demonstration and trial results

A number of bus operators are undertaking independent trials and testing of low carbon bus technologies, including use of non-London test cycles. There may be appetite for and advantage to more openly sharing and disseminating results of pilots, testing and on-going in-service trials. This data and information sharing arrangements to keep it current might be managed by DfT, one of its agencies or another independent organisation (such as LowCVP).

4.4.3 Vehicle Excise Duty

For the UK bus market the VED rates are relatively low as a proportion of the vehicle cost, compared to light duty vehicles (car/van). This weakens the potential effectiveness and leverage of graduated VED. However, given the long life of a bus this may still be a useful a component of an over-arching incentivisation strategy. A focus on oldest vehicles (through changes in

VED) may be useful for the future bus market evolution as no legislation is otherwise in place to remove the oldest vehicles once Equality Act compliance is complete (turning all buses to low floor models). The alternative to a national approach on older vehicles would be to strengthen local policies to then implement schemes that prioritise low emission vehicles (including LCEB) over less fuel efficient and more polluting buses.

4.4.4 Linking air quality and carbon reduction

There are clear links in the policy and practice of many Local Authority/Local Transport Authorities between carbon reduction potential of LCEB and the reduction of pollutant emissions relevant to local air quality management (LAQM). Measures to reduce NO_x emissions from buses and other road transport sources appear to be necessary to meet national air quality standards in many areas of poor air quality. Low carbon buses, notably hybrid, electric and biomethane can address air pollution and greenhouse gas emissions simultaneously. Therefore it is important that:

- Cross-Government support for low emission strategies and low emission zones be made a priority in order to support local authorities take positive, long-term action towards reducing road traffic emissions from urban areas;
- Better information on air pollutant emissions from LCEB be made available, and such data collection be allowed for (and positively encouraged) in any future LCEB certification procedure.

4.5 Suggestions for further research

A range of future activities and project ideas arise from the research to date:

- Review and potentially revise the LCEB definition and certification process to ensure it is fit for the purpose and requirements of graduated support schemes. As part of this examine case for a new low carbon bus test cycle suitable to a more representative location, duty and route and propose the appropriate benchmark bus (be it Euro or energy efficiency standard).
- Design a revised BSOG payment for LCEB (currently 6ppkm) with a graduated (i.e. sliding scale) rate to support a greater range of LCEB performance and which that applies fairly to all technology options.
- Investigate a revised GBF (vehicle grant) scheme that rebates a proportion of a vehicle purchase cost based on carbon reduction, and is potentially open to all new vehicle purchases for an extended time window.
- Undertake further research into a feebate scheme for LCEB, leading to outline design of a scheme for the UK bus market (with lessons for other commercial vehicles), that includes analysis and recommendations on how to influence existing fleet (through operating costs).
- Run workshops \ regional meetings with operators and local authorities, to share experience of trials, pilots and in-service experience.
- Investigate LowCVP setting up a brokerage service for bus operators to share (anonymous) detailed test and operational data on in-service and test track results from various LCEB bus in various configurations, routes and duties. Investigate and propose incentives that will encourage operators to collect and share existing test data they already commission.
- Produce a revised, shorter version of the LowCVP Low Carbon Bus Technology Roadmap that is accessible for bus operators, including up to date information on performance and financial costs, case studies of different LCEB fleets

in and out of London plus information on trials. To be updated annually and may also draw together information from mainland European experience.

Annex 1: Input data

Table A.1: Assumed vehicle cost and performance – compared to Single and Double deck diesel

Cost/performance item	Diesel Bus	Diesel Bus	Hybrid (SD)	Battery Electric (SD)	CNG (CBG) (SD)	Fly-wheel	Hybrid (DD)
	Single Deck (SD)	Double Deck (DD)	SD	SD	SD	SD	DD
Bus / Tech cost - difference	£ -	£ -	£75,000	£97,500	£35,000	£15,000	£90,000
Maintenance/replace - cost difference	£ -	£ -	£3,273	£4,940	£500	£60	£4,610
Infrastructure - cost difference	£ -	£ -	£ -	£30,000	£40,000	£ -	£ -
MPG (kWh/mile) (kg/mile)	7.20	5.20	8.90	2.10	0.57	8.47	7.20
Mileage p.a.	45,000	45,000	45,000	45,000	45,000	45,000	45,000
LCEB @6ppkm?	N	N	Y	Y	Y	N	Y
Fuel (litres/kg/kWh) consumption per km	0.40	0.55	0.32	1.30	0.34	0.34	0.40

Table A.2: Impact of BSOG on net fuel price to bus operators

Fuel	Assumed base price (pence)	Fuel duty	Price delivered (ex VAT)	BSOG rebate	Net fuel price to bus operator
Diesel, bio-diesel, UCO	50.00	57.95	107.95	34.57	73.38
CNG (kg) (own station)	42.70	24.70	67.40	34.57	73.38
Electricity (kWh)	8.50	0.00	8.50	0.00	8.50

Table A.3: Scottish BSOG rates and potential support p.a.

Fuel	BSOG rebate (£pence/km)	Value of rebate p.a. (based on 45,000 miles p.a.) - £
Diesel	14.4	10,285.71
Biodiesel	20	14,285.71
LCEB (inc. biomethane)	28.8	20,571.43

Annex 2: Payback analysis under various input assumptions

As noted in section 3.2 various assumptions and input data were considered during the course of the study. This Annex provides a summary of the payback time values from the core analysis and also a sensitivity test with some alternate inputs assumptions. As anticipated, and flagged in section 3.2, varying the input assumptions of vehicle cost, fuel consumption, fuel prices etc. is normal (as costs and performance will change over time) and will impact on payback rates, independently of the incentive mechanisms. Such a variation is normal, and still enables clear recommendations on incentive mechanisms and their application to reduce relative payback times for different types of LCEB. The following tables illustrate the effect of varying input assumptions on LCEB cost and performance.

Table A4: Summary of payback rates (base analysis)

The following payback rates summarise the data presented as charts in Section 3 of this report, with assumptions described in section 3.2 and the input values presented in Annex 1 (as Tables A1 – A3).

	Illustrative payback times for LCEB under different incentive mechanisms					
Incentive mechanism	**Hybrid (SD)**	**Hybrid (DD)**	**Electric**	**CBG (own station)**	**CBG (wet-leased)**	**Flywheel**
No incentives	29	13	5	6	4	4
BSOG (fuel) only	30+	27	10	10	30+	5
LCEB (6ppkm) only	11	8	4	5	4	4
BSOG and LCEB (*most of England*)	15	12	7	7	7	5
LCEB (graduated) only	11	8	4	4	3	3
Scottish BSOG	6	6	3	5	4	1
Feebate (inc. penalty for diesel bus)	27	12	4	4	2	3
Carbon linked vehicle grant	28	12	4	5	3	3

Table A5 Summary of payback rates (sensitivity test)

If the assumptions are varied the payback times change, representing a different range of costs/performance that could apply to a set of technology options. Table A5 represents payback times when the input data is changed with:

- Electricity cost *increase* from 8.5p kWh to 11p kWh
- Gas fuel consumption *increase* from 0.34 to 0.42 kg per km
- Flywheel technology cost *increase* from £15,000 to £25,0000 per unit
- Hybrid technology costs are not varied over the base assumptions.

Any increase in payback rates is flagged with a change in text colour in the table below.

	Illustrative payback times for LCEB under different incentive mechanisms					
Incentive mechanism	**Hybrid (SD)**	**Hybrid (DD)**	**Electric**	**CBG (own station)**	**CBG (wet-leased)**	**Flywheel**
No incentives	29	13	5	**9**	**6**	**6**
BSOG (fuel) only	30+	27	**15**	**16**	30+	**9**
LCEB (6ppkm) only	11	8	4	**6**	**8**	**6**
BSOG and LCEB (*most of England*)	15	12	**8**	**9**	**9**	**9**
LCEB (graduated) only	11	8	4	**5**	**6**	**4**
Scottish BSOG	6	6	**4**	4	4	**2**
Feebate (inc. penalty for diesel bus)	27	12	4	**7**	**6**	**5**
Carbon linked vehicle grant	28	12	4	**7**	3	**6**

As can be anticipated the higher input values on cost for electric and flywheel bus, and fuel consumption for gas bus, impact on the payback rates. It is interesting to note how the variation against the base changes under different incentive regimes, with the Scottish BGOG doing most to insulate against the variation in cost/performance.

Report Contact Details

Project Manager: Tom Parker
Transport & Travel Research Ltd

Tel: 0117 917 5037
Email: Tom.Parker@ttr-ltd.com
Web: *www.ttr-ltd.com*

Transport & Travel Research Ltd.