LowCVP Low Carbon Vehicle Partnership

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

Task 3: Costs benefits and likely take-up of selected low carbon technologies

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

June 2014

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

Task 3: Costs, benefits and likely take up of selected low carbon technologies – impact of price on payback survey results

June 2014

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1 INTRODUCTION

1.1 Background

The overall aim of this study is to assist LowCVP, its key members (including central Government) and bus industry stakeholders to identify the most promising technologies from a market perspective, taking into account not only environmental outcomes but a range of barriers and potential related solutions. This will inform recommendations on market support mechanisms, both financial and non-financial.

The purpose of the current activity (Task 3) is to examine costs, benefits and likely take up of selected low carbon technologies. It does this by:
a) identify case study examples of bus industry adoption of low carbon technologies, including costs (£) and benefits; and
b) undertake a survey of bus operators to determine impact of price points on payback

This report contains the results of the second task, the survey, focussed on experience and expectations of operating low carbon emission bus (LCEB) by UK based bus operators. The main objective was to collect quantifiable values on acceptable payback times for a range of specific and generic LCEB technology. It should be noted that Task 1, earlier in the study, already collected qualitative information from bus operators, so should ideally be read in conjunction with the survey results presented in this report if further insight is required as to the reasons behind the quantitative results presented here.

1.2 Report contents

This short report contains Section 2 on Methodology, with the results from the on-line survey presented in Section 3.

Section 4 undertakes analysis based on the survey results on payback times: what this might mean for take up rates of LCEB. Section 5 examines the potential emission savings of take-up rates of LCEB against an all diesel bus fleet, with summary Conclusions set out in Section 6.

2 METHOD

2.1 Approach

An on-line survey was produced with research questions organised under the following categories:
Background to operating organisation and experience of low carbon vehicles
Relative importance of factors in the decision making processes for purchasing low carbon vehicles (including barriers and opportunities)
Financing profile low carbon vehicle technology
What are considered reasonable Payback times, for various LCEB technologies
Other issues

The survey data provided some quantitative values on these central themes and messages, so that conclusions could be drawn.

2.2 Participant recruitment procedure and outcomes

A contact list was generated by collating contacts from successful Green Bus Fund (GBF) applications, supplemented by contacts known to LowCVP, the study Steering Group and TTR. The list consisted of 79 contacts across a range of local bus and coach operators from various organisation sizes and locations.

Participants were recruited through a multiphase approach. Firstly, every contact on the list was invited to take part in the research by LowCVP. Following the initial email invitation, each person on the list was contacted by telephone and encouraged to complete the on-line survey. A further email reminder was sent out by LowCVP. In addition, TTR worked closely with representatives from two of the largest operating groups to ensure the invitation was delivered to around 10-12 key purchasing decision makers.

In total 13 valid survey responses were produced with representatives from most of the large operating groups, plus some other sized operators. This was a much smaller sample than had been hoped for (with a target of 50). However, we are aware that for the large operating groups that responded the survey captured either the views of senior decision makers and in one case the views were expressed after internal consultation and consensus reached on the results to provide. However, a drawback of the sample size is that it not considered statistically representative.

A description of the breakdown of bus operating organisations is provided in the relevant sub-section of Results.

2.3 Survey analysis

The survey is presented as simple presentation of results with brief accompanying analysis. The low sample number does not lend itself to cross-tabulation or statistical tests. The findings on payback times, has however, been combined with an probit curve analysis of take up rates of LCEB and then combined with other data to illustrate the resulting emission benefits should these take up rates be realised.

3 RESULTS

3.1 Introduction

The results for each of the survey questions are presented in this section, organised under the main themes of the survey. While quantitative in nature the sample size means that the results cannot be assumed to be representative of the wider members of bus operators. The results should therefore be used to provide insight and inform understanding, but not taken as the definitive result on a particular topic.

3.2 Organisation type and experience of LCEB

To understand the sample of operators responding to the survey they were asked a series of questions. This resulted in a sample of the following;

- Eleven respondents based in business units or head office locations as part of National Operating Groups;
- 2 respondents represented local commercial bus operators, (not part of a major group);
- No municipal or local authority operators answered the survey (unlike in the Task 1 qualitative interviews).

Respondents were asked to identify whether they were answering the survey from the perspective of a regional/local business unit or from a multi-region (or national) operation. The majority (11) of respondents stated as a Regional/local business unit, with 2 respondents answering as a Multi-region or National operation.

Finally, the geographical location of the sample respondents was determined, in case this affected their views on payback times or technology options. Table 3.1 shows the distribution, which was dominated by England (outside) of London, followed by 3 London based operations, then one from Wales, Scotland and Northern Ireland.

Table 3-1: Sample (operators) experience of LCEB technologies

Location	Response Percent	Response Count
England (outside London)	100.0%	13
London	23.1%	3
Wales	7.7%	1
Scotland	7.7%	1
Northern Ireland	7.7%	1
Total		**13**

Respondents were asked to consider which low carbon technologies they had experience of using in their operations. The results are shown in Table 3-2.

Table 3-2: Bus operator sample - experience of LCEB technologies

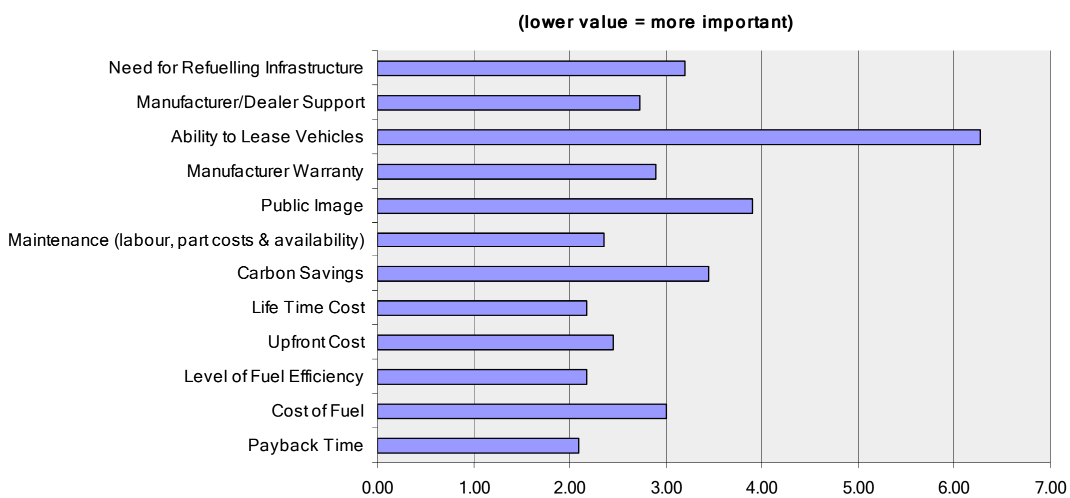
Low carbon or fuel efficient technology	Response Percent	Response Count
Hybrid	100.0%	12
Gas	16.7%	2
Lightweight	25.0%	3
Micro' Hybrid	8.3%	1
Biofuel	16.7%	2
Flywheel	25.0%	3
Battery Electric	8.3%	1
Total		**12**

Within the sample one can see the dominance of diesel-electric hybrids, and other experiences of a range of technologies.

3.3 Decision making and relevant factors for purchasing low carbon bus

The survey respondents were asked what the most and least relevant facts they considered were when buying a low carbon bus. Feedback from earlier tasks highlighted that reliability was considered essential, so we stated this assumption in the survey pre-able to this question and did not include in the list of factors the respondents were asked to rate.

Figure 3.1 Factors and relative importance when considering take up of LCEB



Within the sample, one can see the preference overall for factors such as life time cost, level of fuel efficiency and payback time as having greater value (with lower figures showing their prioritisation). Least important, to this sample, was the ability to lease vehicles, public image or actual carbon savings.

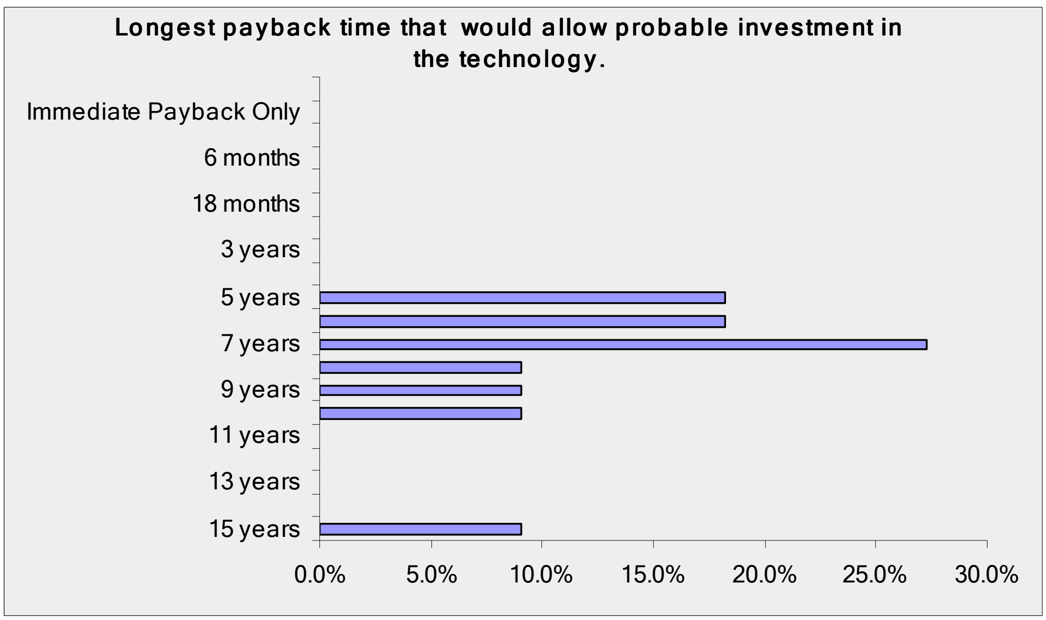
3.4 Payback times and relevance to purchasing LCEB

Bus operators were asked to respond to a generic LCEB technology and then a set of specific technology options. Payback values (years) were provided by operators. This was in response to a question on what would be a reasonable payback time in their view. We did not specify the subsidy environment, so they could base on their current experience and expectations of what would be required for their business to choose low carbon emission buses (of various types).

3.4.1 Generic low carbon emission bus

Survey respondents were asked to consider a generic low carbon technology that reduces emissions and fuel consumption. The technology has a cost to set up, but will pay for itself over time. They were asked to state: *what is the longest payback time that would mean you would probably invest in the technology?* The responses are shown in Figure 3.2 below.

Figure 3.2 Maximum acceptable payback times on (generic) low carbon emission bus technology



From the small sample of survey results we see a preference for 7 years maximum payback, with some weight also attached to 6 or even 5 years. Some respondents were able to respond with much longer payback times, up to 9 years (one respondent) with a further respondent suggesting he would find 15 years payback acceptable.

In a follow-up question the survey asked respondents to assume that a LCEB technology will result in the payback time that you have selected in the question above (through fuel efficiency and/or fuel cost savings) and then consider what kind of cost profiles would be preferable. Respondents were not given £ values, so had to make their own minds about what these might be. The results in Table 3.3 below show the sample more heavily weighted to those thinking that a larger upfront cost (with opportunity for greater savings over time) was preferable to investing in smaller costs and achieving lower returns. This is also representational of the respondents risk profile, which indicated a greater confidence in the returns from LCEB or an acceptance of the risks (should they be present in the respondents view).

Table 3.3: Bus operator sample - experience of LCEB technologies

View on investment vs. return	Response Percent	Response Count
A technology with a large upfront cost, and high operational savings	45.5%	5
A technology with a low upfront cost, and low operational savings	27.3%	3
No preference between the two	27.3%	3
Total		11

3.4.2 Specific low carbon emission bus technologies

The survey presented some basic information about a variety of LCEB technology, and indicated costs being higher or lower than standard diesel bus where this has commonly found to be the case. Some indicative performance and cost values were provided, these being the ones in use for Task 2 analysis (of incentive mechanisms) at that particular point in the study.

Respondents were told:

> *We will now present you with six vehicles with a variety of Low Carbon technologies, which are described briefly, and ask you to state what payback time would be reasonable for your organisation to use this technology in your bus fleet.*
>
> *Note, the cost and performance data are presented as typical values, but in the real-world there is normally a range of typical values (low to highest). The range for a given technology option can vary by vehicle make, specification, route and vehicle duties. Technology price and performance will also change over time. Your experience may vary from that presented, in which case please respond based on your direct experience.*

Information was not provided on current subsidies, and respondents were not told to factor these in or discount them. In this manner we anticipate the survey registered views based on current support environment, modified by the respondents perception on what is likely to be the case in the near to medium terms (that would affect their investment decision).

A final comment is that the sample only included those with experience of LCEB technologies within their operating fleet. This means is does not apply to those without any experience. If we interpret this response as meaning the 'wider fleet' (e.g. of the national group) then we can see a good proportion of the market for new buses is covered by this experience. If we are more conservative and interpret this response as being 'from my depot' then we may be looking a more skewed response favourable to LCEB (because they have already invested).

3.4.3 Diesel – Electric Hybrid

Respondents were presented with the following statement, which was repeated in a relevant form for each technology:

> *Whilst diesel electric hybrid technology has an increased upfront cost over standard diesel vehicle it will pay for itself in a certain number of years taking into account fuel and other running costs. After that point it becomes cheaper to operate than diesel, and has a lower overall whole life cost. What do you consider is a reasonable payback time for your business, that would mean you would consider investing in this technology?*

Respondents were also provided further information on each technology option, including some illustrative performance figures.

Box 1: Description and example data provided on hybrid bus

Diesel Electric Hybrids (Single Deck)

Diesel Electric Hybrid have a power train that recovers energy that would otherwise be lost in braking to charge a battery, they then use this power from that battery to reduce fuel use. A diesel engine also charges the battery and/or provides extra power. Some hybrid bus can operate purely on electric at low speeds.

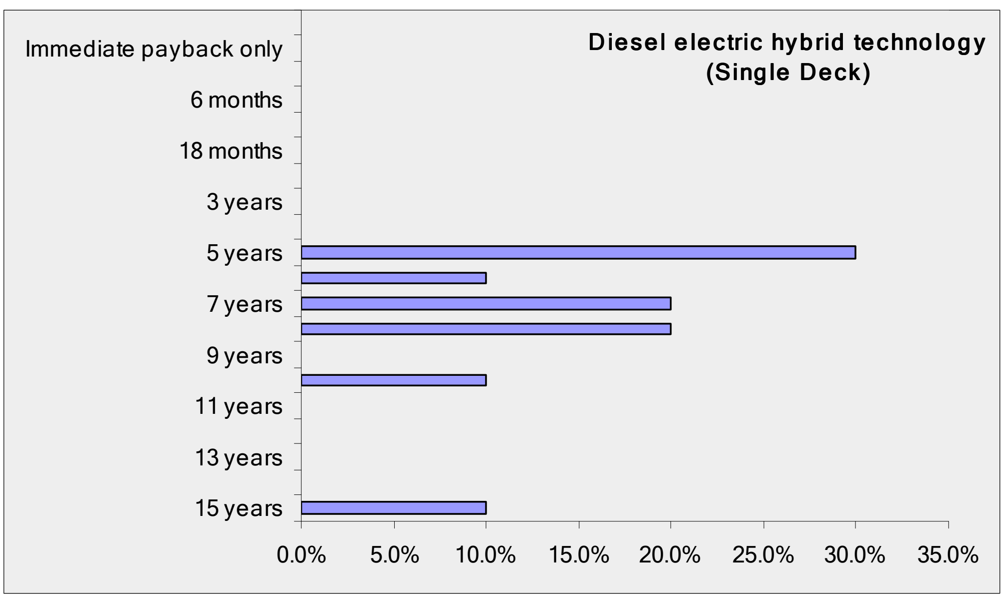
The following figures are within the current performance and cost range for this type of bus in a real-world operation. These figures are provided for people who do not have direct experience of this type of bus.

For a single deck bus, diesel electric eybrid technology costs on average a premium of £90,000 over an equivalent diesel bus. They are not anticipated to cost any more in regular maintenance, but due to the need to potentially replace the battery packs we can factor in an additional £3,270 per year over their lifetime.

Compared to an equivalent standard diesel single deck vehicle, that on a given route has an average mpg of 7.0 mpg, this low carbon emission bus could achieve 9.1 mpg. This is a 23% reduction in fuel consumption (a 30% increase in mpg).

A question on payback rates was asked for each of a number of existing low carbon bus technologies. The results are presented below for diesel electric hybrids.

Figure 3.2 Required payback times on hybrid bus (single deck)

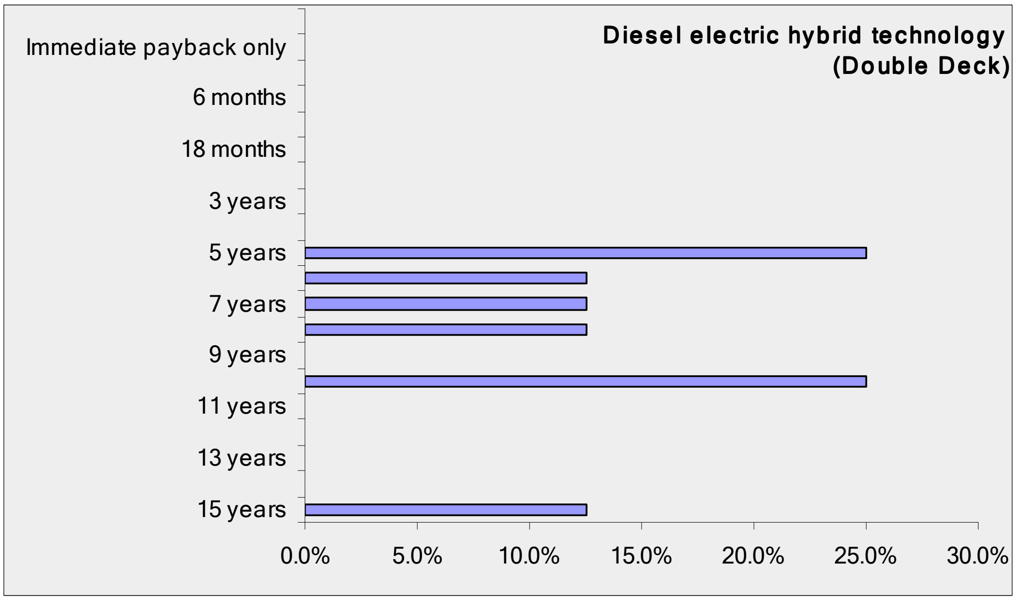


When asked to explain the over-riding reason(s) for choosing this time period and any technology specific considerations 5 respondents replied, as follows, which provides insight into bus operator considerations and working practices:

- Financial business case: Battery life and replacement cost remain a concern and risk to whole life costs.
- Our normal pay back period is 5-6 years, though some projects can be given longer.

- Running and maintenance cost will increase with vehicle age after 5 years battery/engine/electric motor replacement with it being new technology its also the unknown.
- We only have one route with a five year tender.
- Time period longer than 6 years is likely to mean that technology will have moved on and better alternatives will be available. Also lifespan of batteries in service not yet known.
- This is the maximum acceptable ROI.

Figure 3.3 Required payback times on hybrid bus (double deck)

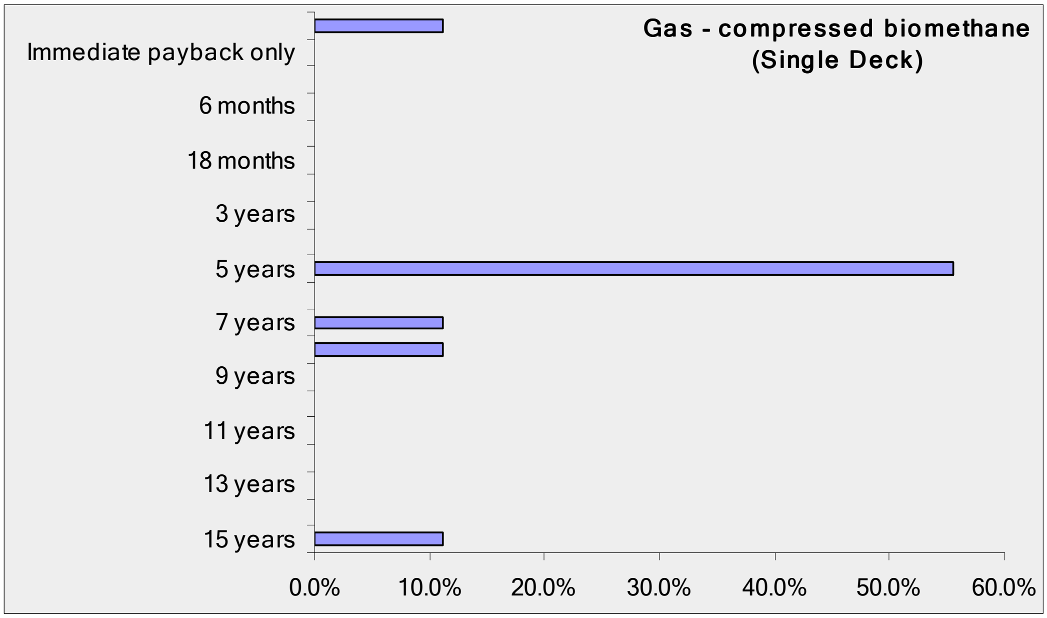


It appears that on average a slightly longer payback time is considered acceptable for a Double Deck hybrid, perhaps because of the greater upfront cost but also higher fuel efficiency providing more certainty. In terms of supporting and explanatory comments these were the same as for single deck but with one additional comment: *"Currently operating 10+ vehicles, that are proving to be reliable, but still the fear is what will be the running cost over 15 years".* These are similar findings from the qualitative responses in Task 1.

3.4.4 Gas

For the gas bus option (and subsequent options) there were slightly fewer responses, as perhaps some survey fatigue started to set in with the respondents. The results were quite differently distributed from diesel-electric hybrids however, with a more 'polarised' distribution, including one respondent who would not invest at any payback rate. This is as expected for a technology that also requires refuelling infrastructure, and is clearly seen in the take up rates in the UK wide.

Figure 3.4 Required payback times on gas bus



The values for gas bus do seem to cluster around the 5-8 years payback time period. Five of the respondents also provided reasons and the thoughts behind their choice of payback rate for gas bus, stating:

- Our trials and test results question the benefit of CNG against class leading fuel efficient diesels, impacting on cost benefit and carbon footprint. This, combined with the c£35k premium of gas buses, means that a robust return on investment is required.
- Our normal pay back period is 5-6 years, though some projects can be given longer.
- Currently Gas bus are being trialled in another of our operating units.
- Uncertainty over future gas prices. Payback period would need to include fuelling infrastructure build costs.
- Payback stated (15 years) is linked to lease of fuelling station.

3.4.5 Electric

For the electric bus option there were again fewer responses, perhaps as a result of survey fatigue or reflecting the lower interest in this technology (as demonstrated by numbers in commercial operation). The results were again differently distributed to diesel-electric hybrids however, with a more 'polarised' distribution, including one respondent who would not invest at any payback rate. This is as expected for a technology that also requires recharging infrastructure, and is appropriate for a selected proportion of vehicle duties and range, and reflected in the take up rates UK wide.

Box 2: Description and example data provided on electric bus

Electric only vehicles fuel by plugging in to a recharging facility. Electric vehicles have the advantage that their tailpipe emissions are zero, as any emissions happen where the electricity is generated. The level of carbon savings depend on the source of the electricity used, which can include low carbon renewables.

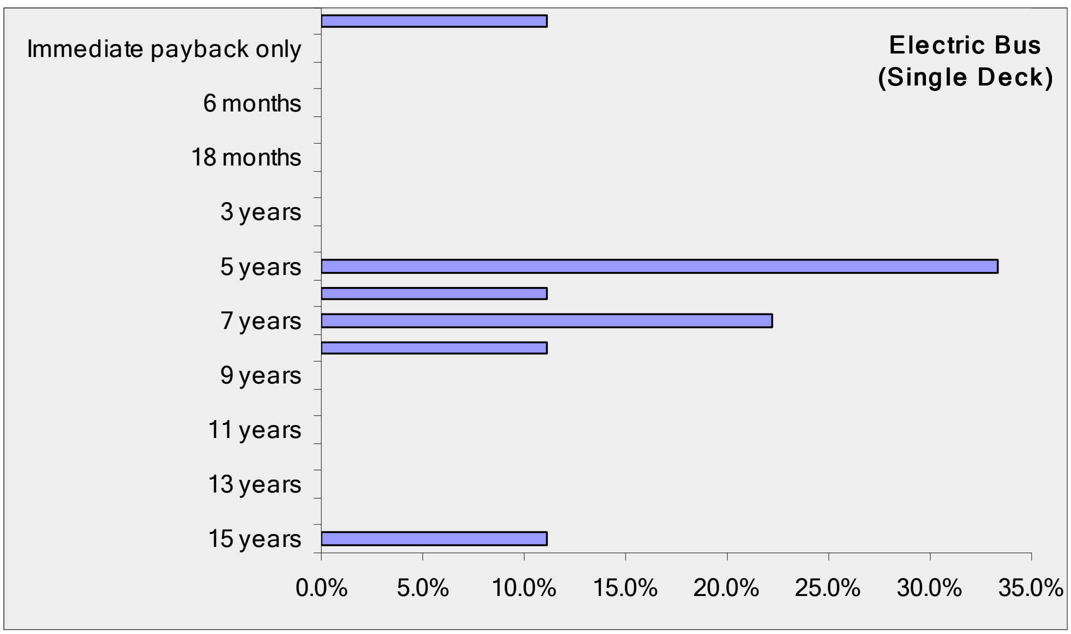
The following figures are within the current performance and cost range for this type of bus in a real-world operation. These figures are provided for people who do not have direct experience of this type of bus.

For a Single Deck electric bus the additional cost of the vehicle over an equivalent diesel bus is up to £97,000. A typical cost for a recharging facility would be up to £30,000 per bus. Normal maintenance is expected to be very much lower than a typical diesel bus, but battery replacement costs mid-life means factoring in £4,940 p.a. However, fuel costs are very low.

Compared to an equivalent standard diesel single deck vehicle, that on a given route has an average mpg of 7.0 mpg, this low carbon emission bus could achieve approximately 0.45 miles per kWh of electricity. A typical price for electricity is 8.5 pence per kWh. (i.e. a fuel cost of 18.8 pence per mile)

The distribution of payback times for electric bus are shown below.

Figure 3.5 Required payback times on electric bus



The values for electric bus do seem to cluster around the 5-8 years payback time period. Five of the respondents also provided reasons and the thinking behind their choice of payback rate for electric bus, stating:

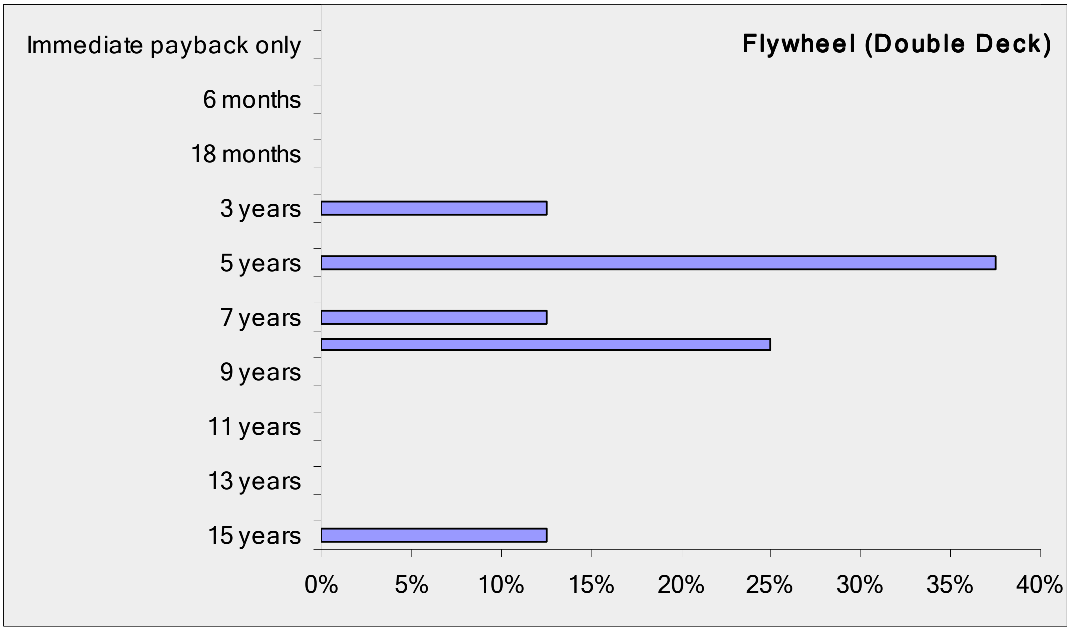
- Concerns over battery life and replacement costs.
- Our normal pay back period is 5-6 years, though some projects can be given longer.
- Currently Electrical vehicles do not have the range to cover operated miles.
- Further development in battery technology will be likely to improve financial performance in the future, however some degree of uncertainty exists over lifespan of batteries etc.
- Concern over market volatility of technology.

3.4.6 Flywheel

For flywheel technology the survey presented double deck and single deck options, with the explanation that this technology (while available in a range of devices) would provide an approximate 15% increase in mpg.

The response on payback rates for double and single deck were the same, and presented in the Figure below.

Figure 3.6 Required payback times on flywheel bus



The values for electric seem to be somewhat lower, starting at 3 years, and extend in the main to the 8 years payback time period. Five of the respondents also provided reasons and their thoughts behind their choice of payback rate for flywheel fitted bus, stating:

- Relatively low risk technology, although may be additional maintenance cost.
- Return on investment needs to be the same as any other technology for new bus procurement.
- Our normal pay back period is 5-6 years, though some projects can be given longer.
- Lower risk than hybrid or electric vehicles. If flywheel fails vehicle can still operate, plus replacement cost likely to be lower & less likely to be necessary than with hybrids.
- Fairly instant short term solution for existing vehicles.

The comments clearly recognise and reflect the potentially lower upfront costs, and potential for retrofitting existing vehicles. These are likely to have explained the shorter desired payback rates for flywheel technologies (and the expectation that this would be the case).

3.4.7 Conclusions from survey respondents

A number of the survey respondents provided a series of final thoughts and comments on low carbon bus via the survey, with the most relevant observations being as follows:

- Enhanced BSOG is an important part of de-risking investment in emerging technology.
- It is recommended that BSOG incentive funding is scaled so that the most efficient vehicles gain the greatest reward/funding to encourage continuous efficiency improvements of new buses.
- A longer term view that the current annual cycle needs to be taken in order to be effective at driving technology in the most effective manner. This is needed to de-risk technology and give operators and OEMs confidence before committing large amounts of capital.
- There is a need to incentivise and better understand the true Total Cost of Ownership as well as the true fuel efficiency and emissions. Funding should be based on better understanding of these factors.

4 ANALYSIS OF PAYBACK TIMES & TAKE-UP RATES

4.1 Introduction

To meet this requirement of the brief (using an appropriate statistical method) we have generated probit curves for a selection of technologies, both for new vehicle and for retrofit. Previous work has shown that operators may be more influenced by the break even time than in the whole life cost for a given option, and strongly favour shorter payback times than total cost of ownership indicates is economically rational, particularly when faced either uncertainty or intense market competition.

Box 4.1: Description of probit curve technique

Probabilistic Modelling of Take up for Low Carbon Technologies (Probit Curves)

A probit curve assumes a normal distribution of responses – in this case around an average payback time which would cause 50% of bus operators to be interested in a given technology.

The cumulative frequency of uptake based on this normal distribution is taken as a curve that demonstrates the likely interest of the market at any level of payback time.

The input to the analysis was the stated payback times from the survey of bus operators. This task has generated a series of probit curves to represent the stated interest in uptake of green bus technology against the break even time for that technology. With greater numbers of respondents in the sample there would be greater certainty of the results. However, the senior decision makers and influencers responding to the survey means we may wish to attach more weight to the results than the sample size would suggest.

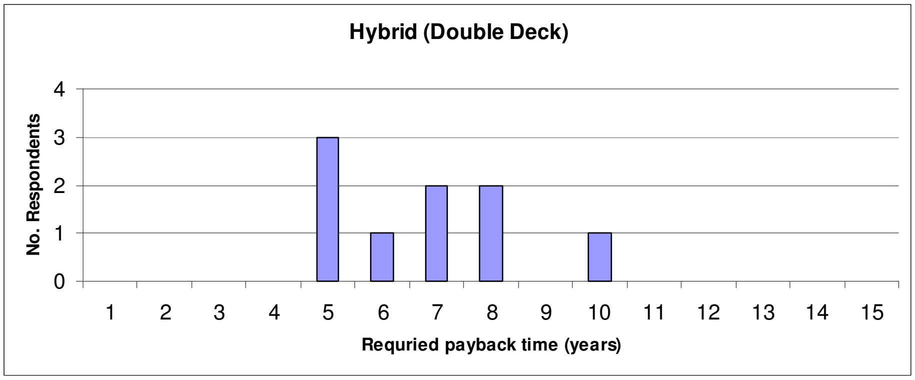
4.2 Results from take-up rate analysis

Bus operator representatives were asked:
Whilst (this particular LCEB) technology has an increased upfront cost over standard diesel vehicle it will pay for itself in a certain number of years taking into account fuel and other running costs. After that point it becomes cheaper to operate than diesel, and has a lower overall whole life cost. What do you considered is a reasonable payback time for your business, that would mean you would consider investing in this technology?

4.2.1 Hybrid

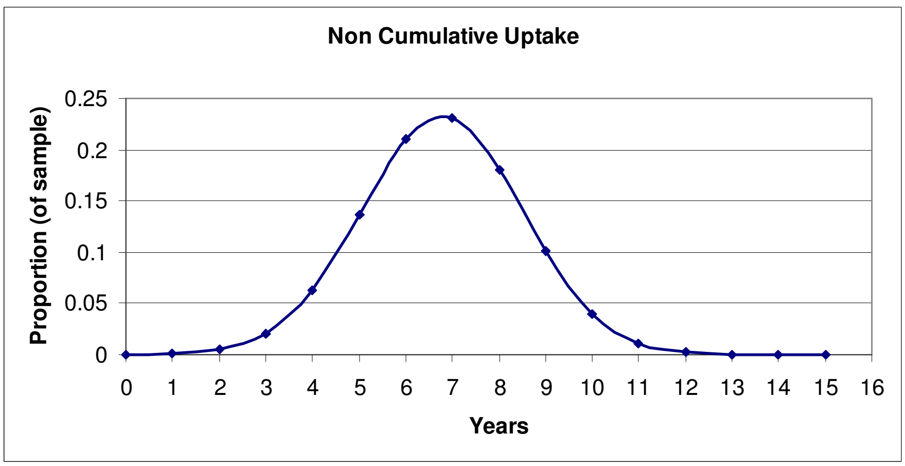
The results of the payback time question, presented previously in Section 3, were cleaned up to remove the 15 year payback response as this was considered an outlier. The distribution of responses are shown in the following three figures, for diesel-electric hybrid bus (double deck).

Figure 4.1 Required payback times on hybrid bus



This distribution of payback values produced a mean of 6.7 with a Standard Deviation of 1.7. Using the mean and SD figure a curve is generated to represent the wider market and intermediate points.

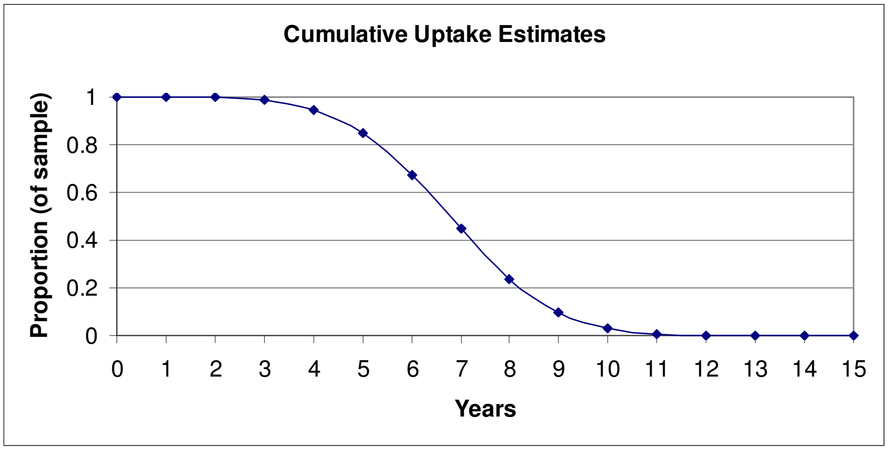
Figure 4.2 Non-cumulative take-up rates on hybrid bus



The same data is then presented as a cumulative curve, to represent the total proportion of respondents (i.e. the take-up rate) at each potential payback time along the x axis.

This chart is interpreted as representing the bus operator market appetite for this technology option, based on its payback time (i.e. time to break even). For example, if the break even time is 8 years then 23% of the market should be interested to consider purchasing this vehicle. However, if the payback time is reduced to 5 years (perhaps using subsidies, or because technology cost reduces) then 86% of the market thinks this is a reasonable payback time for their business and *they would consider investing in this technology.*

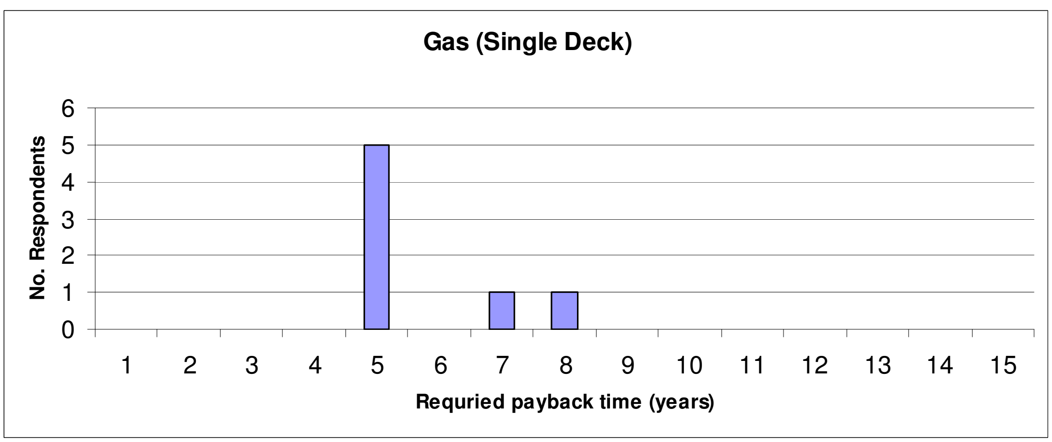
Figure 4.3 Cumulative (probit curve) take-up rates on hybrid bus



4.2.2 Gas

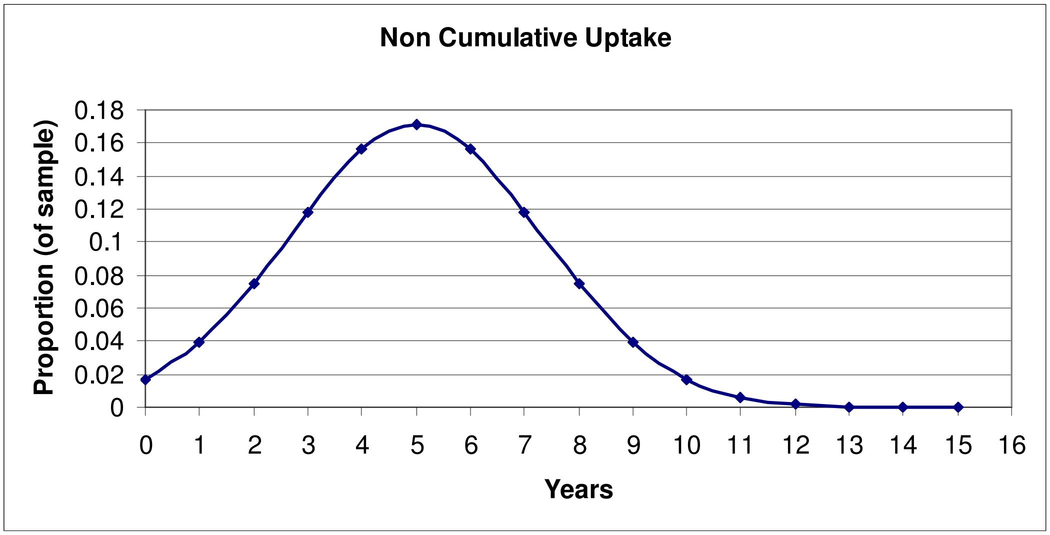
The distribution of responses are shown in the following three figures, for gas bus (single deck), operating with biomethane. There were slightly fewer responses and the curve was skewed to slightly lower payback times, compared to hybrid as can be seen from the Figures below. Again, the 15 year outlier response was removed. This produced a mean of 5 with a Standard Deviation of 2.22.

Figure 4.4 Required payback times on gas bus



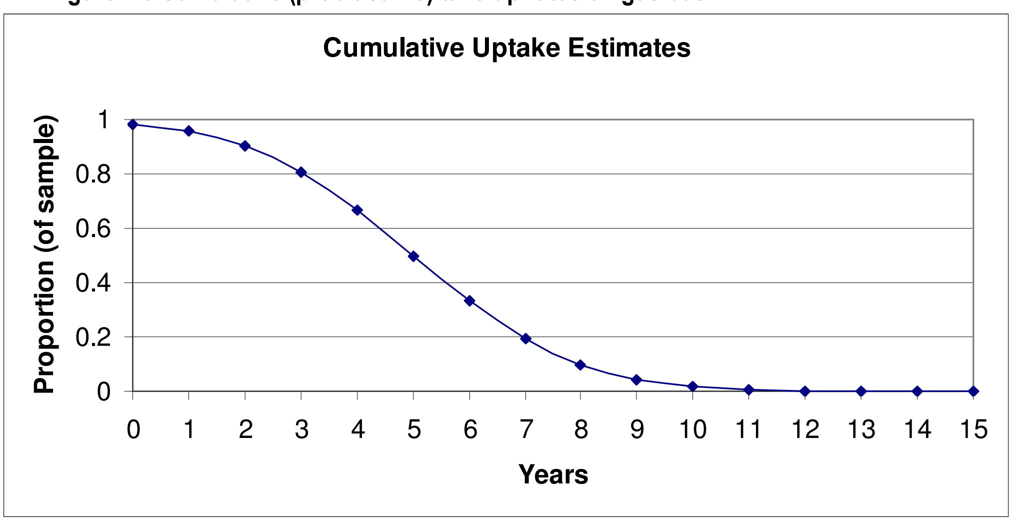
To generate the probit curve a decision was made to include the one response in the sample of *'no investment at any payback rate'* as a zero value, because without this value the curve appeared too optimistic. As can be appreciated from these adjustments, arriving at the probit curve is not an exact science. Using the mean and SD figure a curve is generated to represent the wider market and intermediate points.

Figure 4.5 Non-cumulative take-up rates on gas bus



The cumulative chart is interpreted as representing the bus operator market appetite for this technology option, based on its payback time (i.e time to break even). For example, for gas bus, if the break even time is 8 years then around 10% of the market should be interested to purchase this vehicle. However, if the payback time is reduced to 5 years (perhaps using subsidies, or because technology costs radically reduce) then around 50% of the market thinks this is a reasonable payback time for their business and *they would consider investing in this technology.*

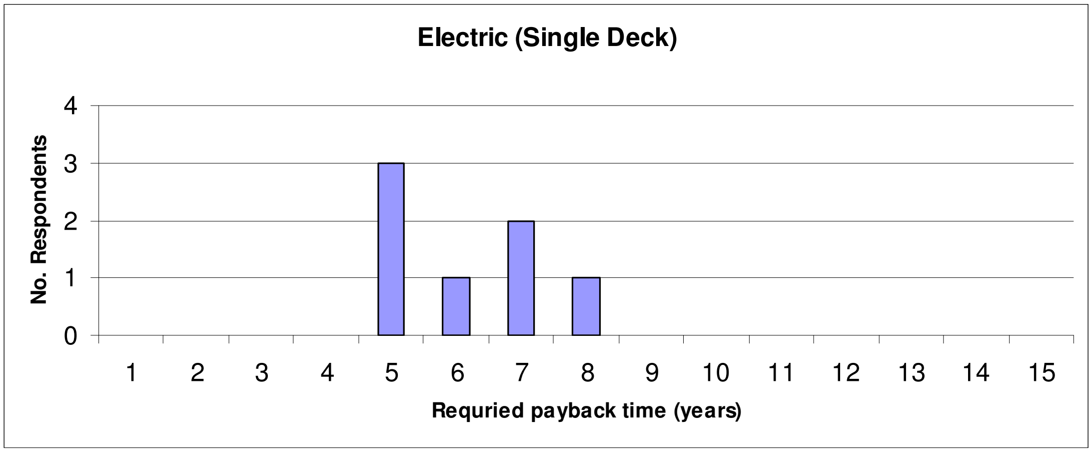
Figure 4.6 Cumulative (probit curve) take-up rates on gas bus



4.2.3 Electric

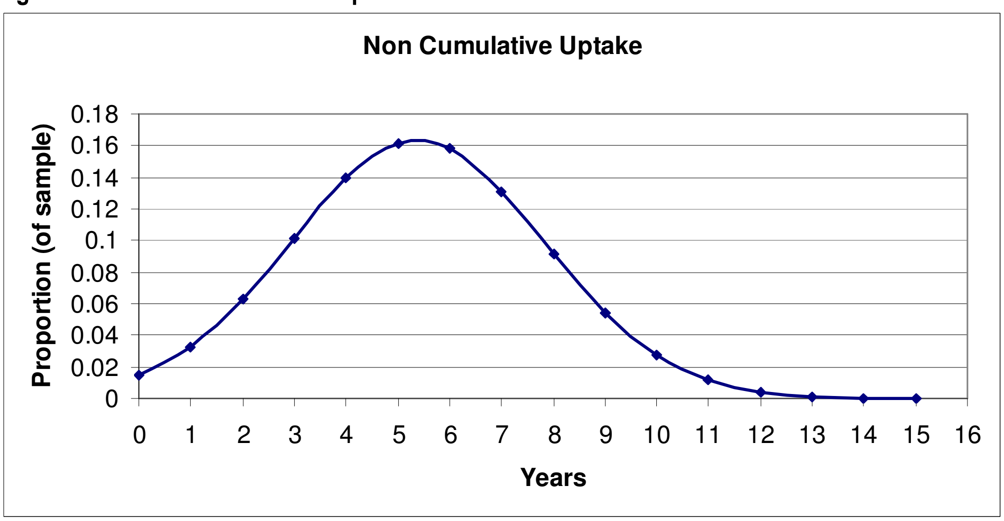
The distribution of responses are shown in the following three figures, for electric bus (single deck). Again, the 15 year outlier response was removed. This produced a mean of 5.3 with a Standard Deviation of 2.4.

Figure 4.7 Required payback times on electric bus



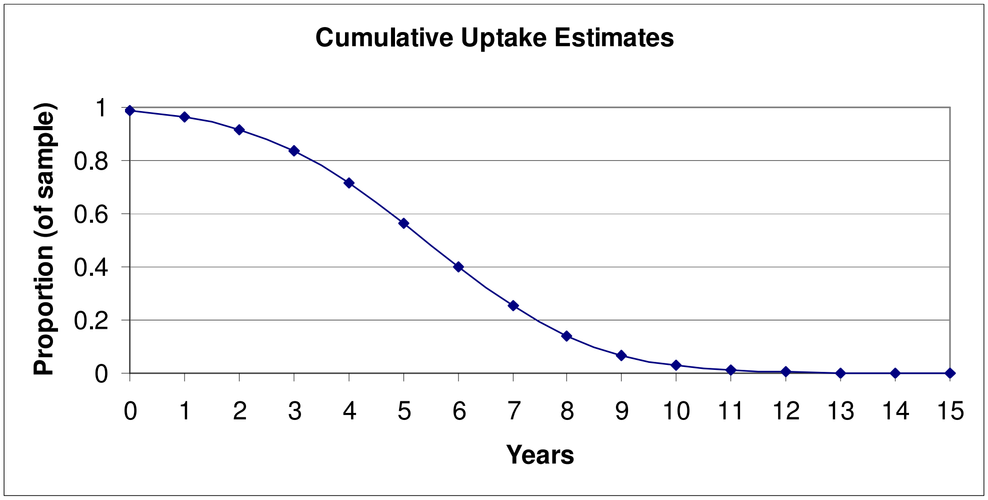
To generate the probit curve a decision was made to include the one survey response in the sample of *'no investment at any payback rate'* as a zero value, because without this value the curve appeared too optimistic. Using the mean and SD figure a curve is generated to represent the wider market and intermediate points.

Figure 4.8 Non-cumulative take-up rates on electric bus



The cumulative chart is interpreted as representing the bus operator market appetite for this technology option, based on its payback time (i.e. time to break even). For example, for electric bus, if the break even time is 8 years then around 14% of the market should be interested to consider the purchase this vehicle. However, if the payback time is reduced to 5 years then around 56% of the market thinks this is a reasonable payback time for their business and *they would consider investing in this technology.*

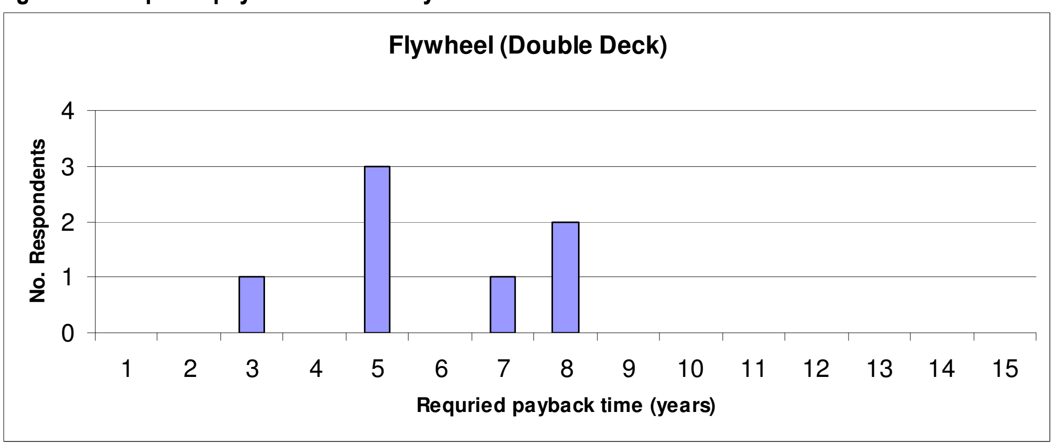
Figure 4.9 Cumulative (probit curve) take-up rates on electric bus



4.2.4 Flywheel

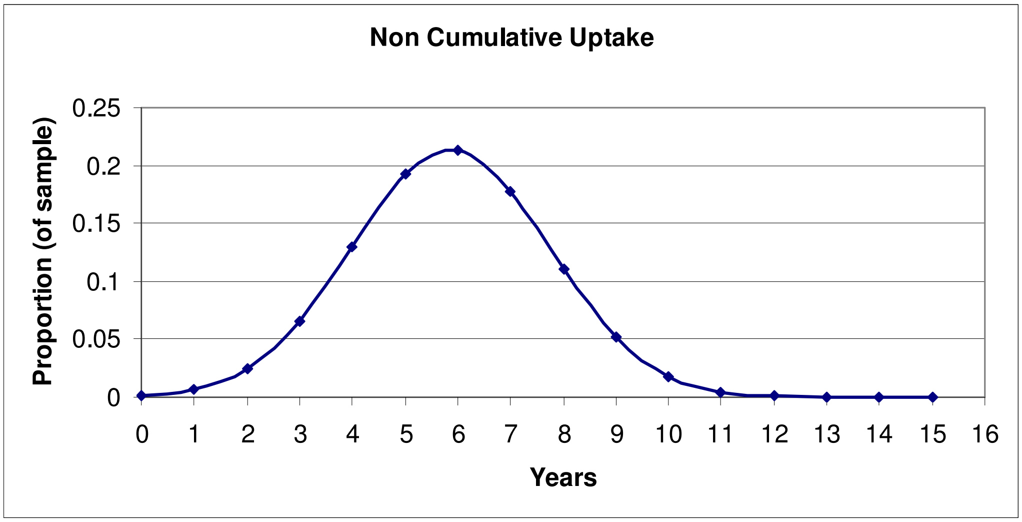
The distribution of responses are shown in the following three figures, for flywheel bus (double deck), operating at around a 15% fuel saving over standard diesel bus. Cost of technology figures were not provided in this example, so the respondents had to make assumptions, which is an acceptable approach for this methodology. The responses included some low payback rates (3 years) but also some appetite for longer payback (8 years). Again, the 15 year outlier response was removed. This produced a mean of 5.86 with a Standard Deviation of 1.86.

Figure 4.7 Required payback times on flywheel bus



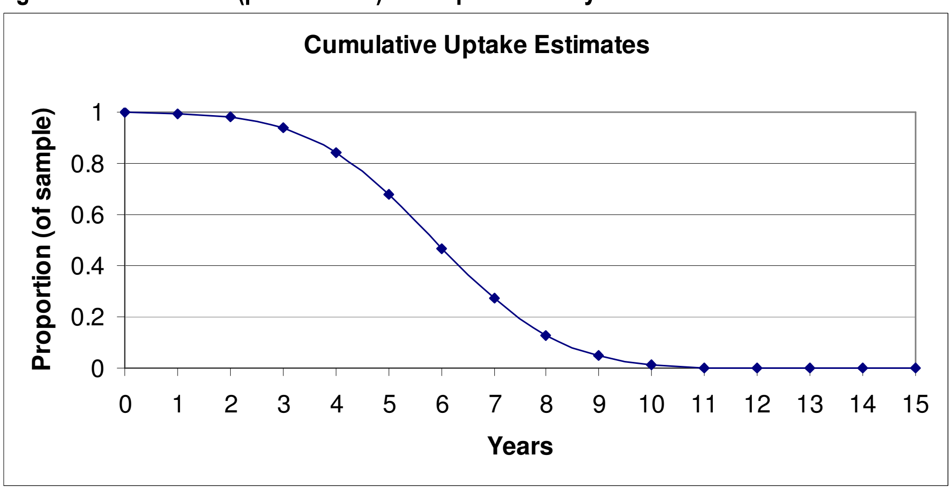
Using the mean and SD figure a curve is generated to represent the wider market and intermediate points.

Figure 4.8 Non-cumulative take-up rates on (flywheel) bus



The cumulative chart is interpreted as representing the bus operator market appetite for this technology option, based on its payback time (i.e. time to break even). For example, if the break even time is 8 years then around 13% of the market should be interested to consider the purchase this vehicle. However, if the payback time is reduced to 5 years then around 65% of the market thinks this is a reasonable payback time for their business and *they would consider investing in this technology.*

Figure 4.9 Cumulative (probit curve) take-up rates on flywheel bus



4.3 Conclusions

The probit curve analysis indicates that payback times of 10 years or longer is not acceptable to anything but the very minority of the market (i.e. 2-3% for those considering hybrid or electric buses). This is not unexpected.

However, once the payback time is considered on shorter timescales, such as 8 years, there is a significant interest in considering a range of technologies as candidates for investment, ranging from 10% to 20%. There is a difference in which technologies are of interest at this payback rate, with hybrid being more favoured and gas the least (but still with some interest). Electric and flywheel were both registering around 13% take up rates at a 8 year payback, so its clear that it is the hybrid that is the most favoured option.

If the payback is considered at yet shorter timescales of 5 years the analysis also proves interesting. Again the rates vary by technology as before (indicating which are the most ‘desirable’). The rates of uptake (or, strictly, consideration for investment) by the market varies by technology, with: flywheel (65%), electric (56%), gas (50%) and hybrid (85%) hybrid.

However, because a 5 year payback may be already achievable for some of the technology options in the current incentive environment this does add an additional factor: some of the seemingly less ‘desirable’ technologies (flywheel, gas) might in fact higher uptake *because* they can deliver the payback rate desired by a significant proportion (> 50%) of operators. A factor feeding this response may be operators expectation of payback times, as they will be aware of the potential of the lower cost technologies.

5 POTENTIAL IMPACT ON EMISSIONS FROM NEW BUS FLEET

5.1 Introduction

Exploratory analysis has been done to consider the impact of the forecast take-up rates of LCEB on emissions from the new vehicle fleet. This has been done for four current technologies: diesel electric hybrid; flywheel; gas and electric. The analysis indicates the potential scope of emission benefits from replacing diesel buses with various LCEB options on a rolling annual basis.

It is acknowledged that LCEB technologies may achieve their best results from being used on specific types of route or services, and not all perform to their optimum in all circumstances. This is due to factors including: requirement for capacity of a double deck bus (relevant for hybrids); length of route between re-fuelling (relevant for electric); and refuelling infrastructure and its location (for gas). For this reason, we have made the hypothesis that only a subset of the approximately 3,000 new buses sold into the UK local bus market each year will be suitable for LCEB technology in one of its forms. Further, for sake of comparability the illustration has used a potential maximum demand of 1000 vehicles (based on route/location suitability).

The probit curve is used to estimate what proportion of the market would consider a LCEB for their operations. We have combined this with the illustrative figure of 1000 vehicles to determine a 'new' fleet, with a proportion of LCEB included. The number of LCEB in the 1000 is dependant on the proportion of market the probit curve indicates would consider operating LCEB, at a given payback time for their additional investment costs. Given the steer from the project brief the payback time is set at 5 years for this analysis. This would require cost reductions or subsidy for some LCEB technologies. This payback rate generates an estimate of LCEB take-up, based on appetite for each technology (as determined through the survey reported in Chapter 3).

The intention was to consider pollutant emissions for all vehicles, these data to be provided from previous a LowCVP study[1] and by project Steering Group members providing various non-published data. The benefit was to be g/km data from real-world driving conditions. The data was compiled in preparation for use, which revealed a number of issues. The data characteristics are:

- The most complete and comparable data is for specific TfL monitored diesel electric hybrids and their closest diesel equivalents. These were a mixture of Euro IV and V standard vehicles, of double deck size. However, the mix of Euro standards means only one Euro V hybrid LCEB is directly comparable to a diesel equivalent and for this vehicle the NOx data does not appear reliable;
- For the gas and flywheel buses no equivalent diesel vehicles were tested at the same time;
- Data for the gas and flywheel buses are from single deck vehicles and the TfL data on diesel vehicles that might be matched against it is of different size / manufacturer, and Euro IV diesel vehicle.
- There is no Euro VI vehicle data, so the value of forward predictions based on this intended analysis (of pollutant emissions) may be limited.

[1] Air Quality Emissions Impacts of Low CO2 Technology for Buses, report for LowCVP (Ricardo-AEA, 2013)

Therefore, the dataset is not comparable or complete. It was already highlighted, earlier in this study, that operators had a need for in-use emission data on vehicles under representative duty cycles, comparable with equivalent diesel bus (for all emissions of interest) for the purpose of comparing LCEB options.

An exploratory emissions analysis has however been carried out, based on a blend of sources and by using this project's Task 2 outputs (on fuel consumption/carbon) for each LCEB and a diesel equivalent. In this way the common comparator can be carbon emissions. As the majority of the costs are due to fuel, followed by carbon values, it was decided to proceed with this illustration even with such limitations. Where input data supports it the analysis is broadened to fuel costs and pollutant emissions for some vehicle types. PM and NOx emissions are valued lower level than carbon emissions on a per kg basis. It is therefore possible from the data available to make an initial quantification for the total (carbon) emissions plus value the fuel savings that may have arisen from additional take-up of LCEB (at Euro IV and V standards).

5.2 Impact per LCEB technology

5.2.1 Hybrid

The probit curve indicates what proportion of vehicles sales might be achieved by LCEB based on how long they take to pay back the additional upfront costs. The probit curve for hybrid buses indicates that if they could payback in 5 years then 85% of the operators (surveyed) would consider purchasing these vehicles. We have set the 'suitability number' at 1000 vehicles, as discussed above, and assumed that these are double-deck vehicles, which show improved performance in hybrid mode compared to single deck vehicles where there are other LCEB options.

Assumptions:

New Bus Sales/Year:	1000 (double deck)
Payback Time (LCEB):	5 years
Take- up:	85% of market
New Buses LCEB:	849 no.
New Buses standard diesel:	151 no.

A comparison is made of emission rates and fuel consumption of the standard diesel and hybrid (LCEB) technology. This is based on this projects Task 2 values.

Comparator:	Reduction	Unit	Diesel	LCEB
% Fuel Saved	27%	Lt /km	0.55	0.4
%CO2 WTW per km	28%	CO2 WTW / km	1653.8	1194.4

Given the fuel usage of one bus per year could be over 39,000 litres of diesel factoring this up to a fleet of 1000 vehicles leads to a considerable fuel consumption, at a cost of many millions of pounds. If fuel consumption can be reduced by deploying LCEB for these new vehicle purchases it is possible to envisage a considerable benefit.

The emissions of the 1000 vehicle fleet is estimated for a business as usual (diesel) fleet and then for the scenario with 85% of the market buying hybrids. The fuel and carbon savings per year are estimated and a cumulative 15 year emission saving shown to illustrate the upper range of savings.

Impact on emissions:

Standard Diesel Vehicle	BAU (diesel)	Scenario (mixed fleet, with hybrid)	Savings/year (mixed fleet p.a.)	Lifetime saving (15yr)
Fuel/year (l)	39,822,750	30,601,973	9,220,777	138,311,651
CO2/year WTW (kg)	119,739,769	91,501,140	28,238,629	423,579,432

The monetary value of emissions were estimated using the Defra damage cost calculator[2]. The fuel cost savings are also estimated, based on values used in the Task 2 report.

Impact on costs:

Savings p.a.		Cost saving p.a. £	Cost saving (15yr) £	
Fuel/year (l)	10,849,889	£9,953,829	£149,307,428	Fuel (lt)
CO2/year WTW (kg)	30,886,018	£830,197	£12,452,958	CO2 (kg)
Total		**£10,784,026**	**£161,760,386**	

This shows a significant total £ cost saving p.a., with the majority accruing from fuel efficiencies (valued at nearly £10m p.a.) and a smaller amount (over £830,000 p.a.) based on the standard value assigned to carbon emissions. This is an annual cost saving, and once these vehicle enter service the savings are made year on year. An upper range of 15 years is set, resulting in many millions of savings over the lifetime of this one year of new vehicle purchases.

5.2.2 Flywheel

The probit curve forecasts, based on operator feedback, what proportion of vehicles sales might be LCEB at different payback timescales. This suggests that if flywheel buses could payback in 5 years then 68% of the operator market would consider purchasing these vehicles. We have set the 'suitability number' at 1000 vehicles, as discussed above, and assumed that these are double-deck vehicles.

It is thought that the lower take-up rate compared to a full hybrid is because of a combination of lower upfront cost and lower fuel saving potential in the scenarios presented to the survey respondents. Therefore respondents would expect to payback in a short time and fewer are interested in waiting as long as 5 years.

The survey respondents were presented with a system with around a 15% fuel saving, and other options exist at varying cost points. The recommendation from Task 2 was for a graduated (sliding scale) incentive, so that technologies with lower carbon savings were incentivised, but at a lower rate than those with higher carbon savings.

Assumptions:

New Bus Sales/Year:	1000 vehicles
Payback Time/years:	5 years
Take-up:	68%
New Buses LCEB:	1015
New Buses standard diesel:	485

[2] IGCB Damage Cost Calculator, 2008 update.

It should be noted that the emission rates are a derived from the value of fuel saving, assumed earlier in this study (Task 2) for a double deck bus[3]. However, these do appear to also match well with real-world test data (for LCEB certification) of a comparable flywheel fitted bus that was reviewed in this project.

Comparator:	Reduction	Unit	Diesel	Flywheel
% Fuel Saved	15%	Lt km	0.55	0.47
% CO2 WTW km	15%	CO2 / km	1653.8	1413.2

The emissions of the new vehicle fleet is estimated for a business as usual (diesel) fleet and then for the scenario with 68% of the market buying flywheel buses. The fuel and carbon savings per year are estimated and a cumulative 15 year emission saving shown to illustrate the upper range of savings

Impact on fuel and carbon emissions:

Standard Diesel Vehicle		BAU (diesel fleet)	Scenario (mixed fleet)	Savings/year (mixed fleet p.a.)	Lifetime saving (15yr)
Fuel/year (l)	39,823	39,822,750	35,901,295	3,921,455	58,821,822
CO2 (WTW) /year (kg)	119,740	119,739,769	107,948,667	11,791,102	176,866,524

The monetary value of emissions can be estimated using the Defra damage cost calculator[4]. The fuel cost savings are also estimated, based on values used in the Task 2 report.

Impact on costs:

Savings p.a.		Cost saving p.a. £	Cost saving (15yr) £	
Fuel/year (l)	3,921,455	£4,233,210	£63,498,157	Fuel (lt)
CO2 WTW / year (kg)	11,791,102	£346,655	£5,199,831	CO2 (kg)
Total		**£4,579,866**	**£68,697,988**	

This shows a large total cost saving p.a., with the majority accruing from fuel cost savings (of 4.2m p.a.) and a smaller amount (£346,000 p.a.) based on the standard value assigned to carbon emissions. This is an annual cost saving, and once these 849 LCEB enter service the savings are made year on year, as illustrated by the upper range of 15 years

5.2.3 Gas

The probit curve indicates what proportion of vehicles sales might be achieved by LCEB based on how long they take to pay back the additional upfront costs. The probit curve for gas bus indicates that if they could payback in 5 years then 50% of the operator market would consider purchasing these vehicles. We have set the 'suitability number' at 1000 vehicles, as discussed above, and assumed that these are single-deck vehicles.

Assumptions:

New Bus Sales/Year:	1000
Payback Time/years:	5

[3] Note, the Task 2 incentives work was based on a flywheel fitted single deck bus. The Task 3 survey encompassed both single and double deck vehicles, and a decision has been made to model double deck as fuel savings (in total) are higher).
[4] IGCB Damage Cost Calculator, 2008 update.

Take-up rate:	5%
New Buses LCEB (no.):	500
New Buses standard diesel (no):	500

The lower take-up rate compared to hybrid may be due to a combination of lower demand for gas bus and/or an expectation (or knowledge) they can payback in less than 5 years.

A comparison was made of carbon emissions of a single deck gas bus and the lowest pollutant emission rates in the TfL data (which was from a hybrid Euro V/EEV double deck bus). We have adjusted the fuel consumption to be somewhat higher (in kg per km) in relation to the diesel consumption (in l per km). This falls within the range of test data provided to the study for gas bus. Carbon values are for WTW emissions, with the gas bus being fuelled by biomethane.

Comparator:	Reduction	Unit	Euro V/EEV Hybrid	Gas
% Fuel Saved	-5%	Lt/kg per km	0.40	0.42
% NOx/km improvement	93%	NOx / km	6.738	0.5
%PM km Improvement	98%	PM /km	0.043	0.001
%CO2 WTW km	70%	CO2 / km	1194.4	357.0

The emissions of the 1000 vehicle fleet is estimated for a business as usual (diesel) fleet and then for the scenario with 50% of the market buying gas buses and the remainder diesel. The fuel and carbon savings per year are estimated and a cumulative 15 year emission saving shown to illustrate the upper range of savings.

It was decided to estimate the fuel £ cost savings for based on the values for Task 2 with fuel provided under a wet-leasing arrangement of 94ppkg (to include all filling station install and operating costs). This is compared to 107ppl for diesel.

Impact on fuel and carbon emissions:

Standard Diesel Vehicle		BAU (diesel fleet)	Scenario (mixed fleet)	Savings/year (mixed fleet p.a.)	Lifetime saving (15yr)
Fuel/year (l)	28,826	28,826,241	29,618,170	-791,930	-11,878,945
NOx/year (kg)	488	487,865	262,034	225,831	3,387,468
PM/year (kg)	3	3,113	1,593	1,521	22,808
CO2 (WTW) /year (kg)	86,479	86,478,722	56,163,653	30,315,068	454,726,027

The impact on fuel consumption is negative because of the assumption of slightly higher fuel consumption (in kg) compared to diesel (in litre). However, this impact on pollutant and particularly carbon emissions is very positive due to the nature of biomethane.

Impact on costs:

	Savings p.a.	Cost saving p.a. £	Cost saving (15yr) £
Fuel/year (l)	-791,930	£1,266,216	£18,993,246
NOx/year (kg)	225,831	£241,091	£3,616,360
PM/year (kg)	1,521	£81,641	£1,224,609

CO2 WTW / year (kg)	30,315,068	£960,586	£14,408,793
Total		**£2,549,534**	**£38,243,008**

This shows a large total cost saving p.a. from operation 500 gas bus, with the majority accruing from fuel cost savings (of 1.2m p.a.) and an equal amount based on the standard value assigned to carbon and pollutant emissions. This is an annual cost saving, and once these vehicle enter service the savings are made year on year, as illustrated by the upper range of 15 years

5.2.4 Electric

The probit curve indicates what proportion of vehicles sales might be achieved by LCEB based on how long they take to pay back the additional upfront costs. The probit curve for electric bus indicates that if they could payback in 5 years then 56% of the operator market would consider purchasing these vehicles. We have set the 'suitability number' at 1000 vehicles, as discussed above, and assumed that these are single-deck vehicles.

Assumptions:

New Bus Sales/Year:	1000
Payback Time/years:	5
Take-up rate:	56%
New Buses LCEB:	560
New Buses standard diesel:	440

A comparison is made of carbon emissions of against a single deck diesel bus and the pollutant emission rates from a hybrid Euro V/EEV double deck bus (choosing the lowest values from the TfL data reported in the LowCVP air quality study). We have not made fuel consumption comparison between diesel and electricity. Carbon values are included however, for WTW emissions, with the electric bus being fuelled by grid mix electricity. Pollutant emissions are set at zero, due to lack of tailpipe emissions, although there will be some exposure to pollutants if populations are nearby where the supplying power stations are sited (and not if powered by green electricity).

Comparator:	Reduction	Unit	Euro V/ EEV Hybrid	Gas
% Fuel Saved	N.A.	Lt/ kw/H km	0.55	1.3
% NOx/km improvement	100%	NOx / km	8.792	0
%PM km Improvement	100%	PM /km	0.045	0
%CO2 WTW km	52%	CO2 / km	1194	579

The emissions of the 1000 vehicle fleet is estimated for a business as usual (diesel) fleet and then for the scenario with 56% of the market buying electric. The fuel and carbon savings per year are estimated and a cumulative 15 year emission saving shown to illustrate the upper range of savings.

It was decided to estimate the fuel cost savings with electricity at the same rate as assumed for Task 2 of 8.5p per kw/H vs. 107ppl for diesel. This does not include any consideration of infrastructure costs for charging, so is not comparable to the gas bus estimates.

Impact on fuel and carbon emissions:

Standard Diesel Vehicle		BAU (diesel fleet)	Scenario (mixed fleet)	Savings/year (mixed fleet p.a.)	Lifetime saving (15yr)
Fuel/year (l)	39,823	39,822,750	N.a.	N.a.	N.a
NOx/year (kg)	637	636,585	280,097	356,487	5,347,312
PM/year (kg)	3	3,258	1,434	1,825	27,369
CO2 (WTW) /year (kg)	86,452	86,451,570	61,515,288	24,936,282	374,044,230

The impact on costs includes the cost of diesel fuel and electricity and a value (via Defra damage cost values) for the key pollutant emissions and CO_2 emissions.

Impact on costs:

	Savings p.a.	Cost saving p.a. £	Cost saving (15yr) £
Fuel/year (l)		£20,553,318	£308,299,766
NOx/year (kg)	356,487	£374,185	£5,612,780
PM/year (kg)	1,825	£141,089	£2,116,338
CO2 WTW / year (kg)	24,936,282	£702,605	£10,539,072
Total		**£21,771,197**	**£326,567,956**

The cost analysis shows a large total cost saving p.a., from the 560 electric buses, with the vast majority accruing from fuel cost savings (of 20m p.a.) and a smaller amount (of £1.2m p.a.) based on the standard value assigned to carbon and pollutant emissions. This is an annual cost saving, and once these vehicle enter service the savings are made year on year, as illustrated by the upper range of 15 years

5.3 Conclusions

Given the fuel usage for one bus over one year could be over 39,000 litres of diesel then multiplying this to a fleet of 1000 new vehicles leads to a considerable fuel consumption and a bill of many millions of pounds. If fuel consumption can be reduced by deploying LCEB for more new vehicle purchases it is possible to gain a considerable benefit. In Table 5.1 the take-up rates presented in the sections above are combined with the resulting fuel and emission savings (in terms of their value) for all the LCEB options being modelled.

Table 5.1 – Fuel and emission savings from LCEB take-up

Savings p.a.	Hybrid	Flywheel	Gas	Electric	**Total**
Number of vehicles	849	1015	500	560	2,924 vehicle
Fuel/year (l) - £	£9,953,829	£4,233,210	£1,266,216	£20,553,318*	**£36,006,573**
NOx/year (kg) - £	-	-	£241,091	£374,185	**£615,276**
PM/year (kg) £	-	-	£81,641	£141,089	**£222,730**
CO2 WTW / (kg) - £	£830,197	£346,655	£960,586	£702,605	**£2,840,043**
Total	**£10,784,026**	**£4,579,866**	**£2,549,534**	**£21,771,197**	**£39,684,623**

* Note: For electric bus the fuel cost savings are before paying for any recharging infrastructure, so this is not a true/total cost saving. Electric charging infrastructure at 20,000 per vehicle would total some £11m for 560 buses, therefore halving the total fuel savings if this was taken into account, for year 1. After year 1 the full fuel cost savings would then accrue. (For gas the cost of infrastructure is included in the fuel price, so accounted for.).

The value of emission savings is considerable, but savings against fuel costs are many times greater. This is the impact from just 1 year of LCEB market penetration at these levels, and once the vehicles are in use they would continue to make savings each year.

We suggest it is not appropriate to compare technologies to pick a 'winner' as all are relevant for different routes, locations and duties. There are different cost and payback rates, and the upper carbon savings per vehicle do vary (which is relevant). It is valuable to develop a range of reliable technologies from which can be selected those that best meet duty requirements and potential for lifetime cost savings. It should be noted that the level of subsidy required to bring all these technologies to 5 year payback will vary, and in some cases may be zero.

The analysis illustrates how a suite of LCEB options (and market take-up) can lead to a potentially significant reduction in emissions (greenhouse gas and air pollutant) and lead to fuel savings. These savings would then be available each and every year the take-up rates could be stimulated (whether by incentive, cost reductions, non-financial support mechanism or a mixture all three). This indicates the size of the prize, and leads to the question of what is this worth in terms of a public subsidy or private investment in order to achieve it?

6 CONCLUSIONS

6.1 Survey results

This report presents the results of the survey, focussed on experience and expectations of operating low carbon emission bus (LCEB) by UK based bus operators. The main objective was to collect quantifiable values on acceptable payback times for a range of specific LCEB technology.

The survey was completed by a lower number of respondents than anticipated, with 13 completed interviews (against a target of 40+). However, we are aware that the survey captured either the views of senior decision makers in some of the large bus operating groups and in one case the views were expressed after internal consultation and agreement on the group's response.

The survey produced payback time estimates for a range of LCEB technology options. The options were described in broad terms, with illustrative cost and fuel consumption values provided, or the respondents could refer to their own experience and data.

6.2 Generation of probit curves

The preferred payback times stated by bus operators varied by technology. The averages were in a relatively narrow range of 5 to 6.7 years but the standard deviation also varied. The mean and the standard deviation was used to generate a probit curve, from which it is possible to select any time (in years) along the axis and find the proportion of operators likely to consider investing in that particular LCEB.

The probit curve can be used to consider what impact a subsidy support would have: if the cost of the vehicle investment or operating costs is reduced then the change in payback rate will lead to a greater interest in purchasing those vehicles (or vica versa). The level of interest is expressed as the % of the market who would consider investing in that vehicle (technology) at that price.

The probit curve analysis indicates that payback times of 10 years or longer are only acceptable to a very small minority of the market i.e. 2-3% for those considering hybrid or electric buses. This is not unexpected.

However, once the payback time reaches a slightly shorter timescale of 8 years there starts to be a significant interest in LCEB as candidates for investment, ranging from 10% to 20%. There is a difference in which technologies are of interest at this payback rate, with hybrid being more favoured and gas the least (but still with some interest). Electric and flywheel were both registering around 13% take up rates at a 8 year payback, so its clear that it is the hybrid that is the most favoured option.

If the payback is considered at yet shorter timescales of 5 years the analysis also proves interesting. Again the rates vary by technology as before (indicating which are the most 'desirable'). The proportion of the market who would consider for investment varies by technology with: flywheel (at 65%), electric (at 56%), gas (at 50%) and hybrid (at 85%).

However, because a 5 year payback may be already achievable for some of the technology options in the current incentive environment this does add an additional factor: some of the seemingly less 'desirable' technologies (flywheel, gas) might in fact higher uptake *because* they can deliver the payback speed desired by a significant proportion (> 50%) of operators. Another factor feeding this response may be operators expectation of shorter payback times for certain LCEB options, as they will be aware of their potential to be implemented at a lower cost.

6.3 Impact of take up rates

Exploratory analysis has been done to consider the impact of the forecast take-up rates of LCEB. This has been done for four current technologies: diesel electric hybrid; flywheel; gas; and electric. The analysis indicates the potential scope of emission benefits from replacing diesel buses with various LCEB options.

The probit curve is used to estimate what proportion of the market would consider a LCEB for their operations at a given payback time. We have combined this with the illustrative figure of 1000 vehicles suitable for potential operators to determine the 'new' fleet, with a proportion of LCEB included. The proportion of LCEB is dependant on the proportion of market the probit curve indicates would consider operating LCEB at a given payback time for their additional investment costs. Given the steer from the project brief the payback time is set at 5 years for this analysis. This would require cost reductions or subsidy for some LCEB technologies (but not all).

Given that the fuel used by one bus for one year could be over 39,000 litres of diesel then for a fleet of 1000 new vehicles there is a considerable fuel and cost impact of many millions of pounds. If fuel consumption can be reduced by deploying LCEB as part of the vehicle fleet purchased each year it is possible to envisage a considerable benefit.

The value of emission savings has been calculated as significant, but with savings against fuel costs many times greater still. This is the impact from just 1 year of LCEB market penetration at these levels, and once the vehicles are in use they would continue to make savings each year.

The value of emission savings is considerable, but savings against fuel costs are many times greater. This is the impact from just 1 year of LCEB market penetration at these levels, and once the vehicles are in use they would continue to make savings each year.

We suggest it is not appropriate to compare technologies to pick a 'winner' as all are relevant for different routes, locations and duties. There are different cost and payback rates, and the upper carbon savings per vehicle do vary (which is relevant). The level of subsidy required to bring all these technologies to 5 year payback will vary, and in some cases may be zero. It is valuable to develop a range of reliable technologies from which can be selected those that best meet duty requirements and potential for lifetime cost savings. The value of the carbon saving, and what value is placed on the most carbon efficient technologies will also depend on what the ambition there is for the transport sector to reduce its carbon output and how quickly this should happen.

It is recommended that the once a preferred set of incentive schemes, or value of total subsidy available, is indicated (by Government) then an estimate of the cost of these preferred incentive schemes can be estimated (based on Task 2) and combined with similar analysis as has been explored in Task 3 in order to indicate the benefits that would accrue.

Transport & Travel Research Ltd

Supporting Documentation

Appendix 1 Initial invitation to participants

Dear,

Research to explore barriers & opportunities to expand the UK low carbon bus market

I am writing to ask for your help with an important research study to inform DfT policy on low carbon buses. The Low Carbon Vehicle Partnership (LowCVP) are conducting a review of the barriers and opportunities to expand the low carbon bus market in the UK following the announcement of the 2012/13 tranche of the Green Bus Fund. We are interested in exploring your views on low carbon buses, including any experiences of buying and using these vehicles. This will help the government understand how the Green Bus Fund, enhanced BSOG and other support mechanism have supported purchase and use of these vehicles and what incentive mechanisms may be most appropriate in the future. If you do not have direct experience of low carbon bus we are still interested in your views.

LowCVP has appointed independent research companies, TTR (working with TRL), to conduct this research. We rely on your voluntary co-operation in this study and I do hope that you (or a colleague) will be able to take part.

The study is relying for stakeholder input at two distinct points:

- telephone interviews (of 45 min) during October to discuss barriers and opportunities for low carbon bus from your organisations perspective, and experience to date; and
- self-completion surveys, available from early January, asking for feedback on the cost/performance mix and level of interest in selected low carbon bus technologies.

We are writing to a large number of stakeholders such as yourself to make you aware of the study.

An interviewer, working on behalf of TRL/TTR, will contact a number of you to arrange an appointment to take part in a short telephone interview. If you are not contacted in the next 2 weeks it means that the Researchers have filled all the sample quotas for the initial interviews. However, there will be the opportunity for *all* stakeholders to use self-completion questionnaires later in the study, and you will be informed by email when this is ready. Also, if you would like to be kept in contact about other opportunities to engage in the study (e.g. webinar, workshop) then do let me know and you will receive an invite to those events.

All information you give during the interview will be treated in the strictest confidence. No information identifying you or your organisation will be passed to LowCVP, or to any other organisation, without your consent.

If you would like to know more about the study, please telephone one of the following key contacts: [contact details removed]

Best regards,

Andy Eastlake CEng FIMechE
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