Bus technology and fuel choice

Introduction

This record of evidence forms part of the work undertaken by UKERC's Technology and Policy Assessment team relating to its project on policy strategy for carbon emissions reduction in the passenger transport sector. The material was produced alongside the project's main report and since it supports that report, it was judged appropriate to make this material available to a wider audience. The main report itself '*What Policies are Effective at Reducing Carbon Emissions from Surface Passenger Transport*?', and the supporting evidence can be found at:

http://www.ukerc.ac.uk/ResearchProgrammes/TechnologyandPolicyAssessment/TPAProjects.aspx

Explanation of Content

Evidence on this policy measure has been collected by the TPA team on the basis that it has, or may have, the potential to result in carbon dioxide emissions reductions in the passenger transport sector. This evidence document begins with a summarised description of the policy measure. The evidence itself follows the summary and is presented in table form.

Each piece of evidence has been assigned a separate row and tabulated using four columns:

- Year of publication, arranged chronologically, beginning with the most recent year
- Name of author, including where applicable additional cited authors (and year); and a Reference ID number.
- Type of evidence:
  - Evidence containing quantitative information is denoted by the letter 'Q'
  - Qualitative evidence is denoted by the letter 'C' for 'comment'
- The evidence itself

The evidence was originally gathered and assessed using several sub-headings. The purpose of this was primarily internal i.e. to facilitate the handling of evidence and the production of the main report. These sub-headings have been retained here as follows:

- Policy Measures and Carbon Savings
- Other potential CO_2 Impacts i.e. outside of the immediate policy influence
- Other Benefits e.g. air quality improvement or traffic congestion reduction
- Policy Costs and/or Revenues i.e. to local or national government
- Business and Consumer Costs
- Unintended Consequences e.g. rebound effect
- Reasons/Arguments for Carbon Savings Achievement or Failure
- Policy Suitability for the UK

A list of references follows the evidence tables. Note that the Reference ID numbers are allocated by Reference Manager, the referencing software used by the TPA team.

Any charts, figures and tables referenced in the evidence are not reproduced here but can be found in the original publication or evidence material.

Where no relevant evidence was found for a particular sub-heading, this has been noted.

Policy Description

The evidence recorded here covers policies that influence bus and fuel choice via the two basic technology options available:

1. Retrofitting which allows the continued usage of the existing (diesel) fleet while improving its environmental performance at moderate costs e.g.:
    - Alternative fuel formulas: purified / low sulphur diesel, ethanol, biogas, water-diesel emulsion
    - Filter technologies: particulate filters (PM10), oxidation catalyst (CO, HC)
2. The use of alternative fuels which usually requires purchasing new engines or vehicles e.g.:
    - Compressed Natural Gas (CNG)
    - Liquified Petroleum Gas (LPG)
    - Electric vehicles / fuel cell vehicles
    - Hybrid vehicles

Evidence Tables

Carbon Savings and Policy Measures

Year	Author	Type	Evidence
2007	Anable & Bristow (ref 12297) citing LowCVP (2006b) and NAEI UK Emissions Factors Database; citing E4tech (2006b); Overgaard and Folkesson (2007)	Q	Potential savings of CO2 /km from switching to diesel-electric hybrids or electric buses in urban operation are estimated to be in excess of 50%. However, since urban buses make up only 62% of bus km travelled and potential savings from rural bus routes are negligible, this equates to an overall saving of 38.5% (citing LowCVP, 2006b, and 'The UK Emissions Factors Database', accessed August 2007). Others estimate a potential 34% CO2/km saving (citing E4tech (2006b) and Overgaard and Folkesson (2007).
2007	Anable and Bristow (ref 12297) citing Mayer and Davies, 2003	Q	Estimated potential saving of 0.82 MtC based on switching from diesel fleet (doing 0.5 litres per km) to electric vehicles with regenerative braking (1600 g/km to around 300 g/km), assuming a bus fleet of 50,000 with each vehicle averaging 45,000 km a year (citing Mayer and Davies (2003): Economics of Bus Drivelines. Report to the Department for Transport.)
2005	Kollamthodi (ref 11467)	Q	In Table 3.76, Kollamthodi gives estimates of reductions in total CO2 emissions from road transport due to the increased uptake of low CO2 hybrid buses (2% of the bus fleet by 2010). (It is assumed that the use of low carbon hybrid buses, results in a reduction of NOx and PM10 emissions of 30%, and a 30% reduction in CO2 emissions compared to a conventional diesel bus.)
2005	Wolfram et al. (ref 11380) citing	C	CNG and LNG fuelled buses emit similar CO2 emissions per km to diesel-fuelled buses.

Year	Author	Type	Evidence
	Martin, 2003		
2005	Wolfram et al. (11380) citing Martin, 2003	C	Water Emulsion Diesel may deliver CO2 reduction compared to conventional diesel, but there is only one supplier in the UK.
2005	Wolfram et al. (11380) citing Martin, 2003	C	CO2 emissions of Battery Electric buses depend on the source of electricity generation.

Other CO2 Impacts

Year	Author	Type	Evidence
			No specific evidence found

Other Benefits

Year	Author	Type	Evidence
2007	Anable and Bristow (ref 12297)	C	Significant air pollution benefits exist in urban areas from diesel-electric hybrids and electric buses (lower NO_x, PM10, CO).
2005	Wolfram et al. (11380) citing Martin, 2003	C	Biodiesel (blended with Ultra Low Sulphur Diesel) can have lower life-cycle CO_2 emissions, PM and HCs, than regular diesel, but can only be blended up to 5% to comply with some engine manufacturers' warranties. Biodiesel use can result in reduced particulates and hydrocarbon emissions, but can result in a marginal increase in NO_x emissions.
2005	Kollamthodi (ref 11467)	Q	Kollamthodi (2005) used multi-criteria analysis to construct a performance matrix of options for the 2005-2010 time period – see Table 6.1. The primary focus of this study was NO_x and PM10 emissions, but CO_2 emissions were included where possible.

Policy Costs and/or Revenues

Year	Author	Type	Evidence
2007	Anable & Bristow (ref 12297) citing E4tech, 2006b; and citing LowCVP, 2006c	Q	Estimates of cost per tonne of CO2: • £452/tCO_2 to replace London bus fleet with diesel-electric hybrids. • £930 per tonne [calculated by DfT but reported in Low Carbon Vehicle Partnership (2006c): Route Map – UK 2012 low carbon bus target. Bus Working Group]
2007	Anable & Bristow (ref 12297) citing E4tech, 2006b	Q	Diesel-electric hybrid is more cost effective than a conventional diesel at diesel prices over 55 pence per litre.

Year	Author	Type	Evidence
2007	Anable & Bristow (ref 12297) citing Mayer and Davies, 2003; and citing LowCVP	Q	£30,000 to £50,000 extra capital cost per low carbon bus vs. conventional bus was assumed by Mayer and Davies, 2003, and up to £100,000 total additional cost of a diesel electric hybrid or an electric vehicle relative to a EUROIII standard bus was assumed by LowCVP.
2005	Wolfram et al. (ref 11380) citing Martin, 2003	C	The total lifecycle costs of alternative cleaner fuelled vehicles are greater than those for the equivalent buses operating on ultra-low sulphur diesel fuel (taking into account the operating costs, capital expenditure and maintenance costs). At the moment the economic case for cleaner fuels is not commercially attractive to bus operators in the UK. Several alternative fuels have lower rates of fuel duty than are applied to ULSD, but the current UK Fuel Duty Rebate system (Bus Service Operators Grant) for bus operators reduces the incentive to switch to alternative fuels (citing Martin 2003: Cleaner Bus working group).

Business and Consumer Costs

Year	Author	Type	Evidence
2005	Kollamthodi (ref 11467)	Q	The capital costs (NPV) of replacing 2 % of the bus fleet with hybrid buses during the period 2010-2015 are estimated to be £45.2million (£75,000 per unit, annualised to £6,512).
2005	Kollamthodi (ref 11467)	Q	Low-carbon hybrid buses use approximately 30% less fuel than the equivalent conventional diesel bus, giving an estimated fuel consumption of 0.195 litres per km. Fuel costs have been calculated assuming a retail price of 85 pence per litre, but also taking into account the Bus Service Operators Grant, which provides bus operators with a rebate of 80% of the duty charged on road diesel. This yields a running cost saving (NPV, 2005-2010) of £10.08million.
2005	Wolfram et al. (ref 11380) citing Martin, 2003	C	The cost of the electricity to recharge battery electric buses can be extremely cheap, but the recharging systems, batteries and vehicles can be expensive.

Unintended Consequences

Year	Author	Type	Evidence
			No specific evidence found

Reasons/Arguments for Carbon Reduction Achievement and/or Failure

Year	Author	Type	Evidence
2007	Anable and Bristow (ref 12297)	C	The Bus Services Operators Grant is a barrier to implementation of lower carbon bus/fuel because it heavily subsidises diesel fuel.
2006	EAC (ref 11267)	C	Slow progress with low carbon buses in the UK is attributed to: (i) higher capital cost of low carbon buses (especially hydrogen fuel cell buses); (ii) the Bus Service Operators Grant (BSOG), which by subsidising fuel costs effectively works to offset the advantage in running costs that low carbon buses would otherwise enjoy (iii) the closure of DfT's Low Carbon Bus Grant programme, pending State Aid approval. Since then the Transport Minister announced that "the Low Carbon Bus Grant would not be reinstated."
2005	Wofram et al. (ref 11380) citing Martin, 2003	C	Limited range between charges and battery durability are barriers to take up of battery electric buses.

Policy suitability for UK

Year	Author	Type	Evidence
			No specific evidence found

References

Anable, J. & Bristow, A. L. 2007 – 12297 - Transport and Climate Change: Supporting document to the CfIT report, Commission for Integrated Transport.

Environmental Audit Committee 2006 (EAC) – 11267 - Reducing Carbon Emissions from Transport.

Kollamthodi, S. 2005 – 11467 - Technical and Non-technical Options to Reduce Emissions of Air Pollutants from Road Transport - Final Report to Defra, AEA Technology Environment, Didcot.

NAEI, 2007 – 11615 - The UK Emissions Factors Database. National Atmospheric Emissions Inventory

Wolfram, M. 2005 – 11380 - Sustainable Urban Transport Plans (SUTP) and urban environment: Policies, effects, and simulations - Review of European references regarding noise, air quality and CO2 emissions, EC, Brussels.