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Opportunities to overcome the barriers to uptake of low emission technologies for each commercial vehicle duty cycle

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Contact:

Duncan Kay
Ricardo-AEA Ltd
Marble Arch Tower, 55 Bryanston Street, London W1H 7AA
t: 0870 190 6357
e: duncan.kay@ricardo-aea.com

Ricardo-AEA Ltd is certificated to ISO9001 and ISO14001

Authors:

Duncan Kay, Nikolas Hill

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Approved By:

Sujith Kollamthodi

Date:

30th November 2012

Signed:

Executive summary

The Task Force on Fuel Efficient, Low Emission HGV (heavy goods vehicle) Technologies is a joint industry/Government initiative aimed at promoting the use of fuel efficient, low emission road freight technologies. The Task Force's objectives include identifying measures for reducing greenhouse gas emissions without detriment to air quality, and making suggestions on how to implement these measures in a way that would minimise burdens to industry.

This report identifies typical HGV duty cycles, their share of CO_2 emissions and which technologies and alternative fuels (excluding liquid biofuel) could best reduce these emissions. It then examines the opportunities to overcome the barriers to uptake of these low emission technologies and fuels that offer the greatest potential greenhouse gas savings for different duty cycles.

Long haul and regional delivery account for 70 % of UK HGV CO_2 emissions

Five duty cycles were defined and their contributions to overall UK HGV CO_2 emissions were calculated:

	Duty cycle	Duty cycle description	Share of CO_2
1	Long Haul	Delivery to national and international sites (mainly highway operation and a small share of regional roads).	**45 %**
2	Regional Delivery	Regional delivery of consumer goods from a central warehouse to local stores (inner-city, suburban, regional and also rural and mountainous roads).	**25 %**
3	Construction	Construction site vehicles with delivery from central store to very few local customers (inner-city, suburban and regional roads; only small share of off-road driving).	**16 %**
4	Urban Delivery	Urban delivery of consumer goods from a central store to selling points (inner-city and partly suburban roads).	**10 %**
5	Municipal Delivery	Urban truck operation like refuse collection (many stops, partly low vehicle speed operation, driving to and from a central base point).	**4 %**

For each of the five duty cycles, the technologies and fuels with the greatest potential for CO_2 reduction in the short to medium term (while also considering the estimated payback period) were then identified. This process took into account that not all technologies and fuels are suitable for all vehicle types or duty cycles, and some may only be applicable to a proportion of the total fleet.

The biggest barrier to uptake is uncertainty over the business case

A series of 23 interviews were then conducted with fleet operators, vehicle manufacturers, technology providers (covering engine conversions, hybrid systems, aerodynamic equipment and tyres) and fuel providers to establish what the key barriers to uptake of these technologies are and how they might be overcome. In addition an online survey was used to gather a further 50 responses. These identified the following ten key barriers:

- Increased upfront costs
- Uncertainty over payback period (fuel savings / residuals / duty rates / incentives etc.)
- Lack of trust in technology provider's fuel economy claims and difficulty in measuring smaller real world fuel savings
- High cost and lack of availability of gas refuelling infrastructure / limited availability of gas vehicles
- Concerns over reliability - new technologies and fuels can be seen as too risky
- Loss of payload due to increased weight of low emission technologies

- Loss of flexibility / limited range (pure electric and to an extent CNG technologies)
- Driver training and the use of telematics are believed to give equivalent fuel savings with lower cost and risk
- Dimensions legislation (restricts aerodynamic features)
- Difficulties in calculating / claiming greenhouse gas savings

There are three key areas of opportunity

There are some clear opportunities to promote uptake of low emission HGV technologies and fuels. Continued work by Government and industry to develop a strategy and vision for the reduction of CO_2 emissions, building on work that is already under way such as the Low Carbon Truck and Infrastructure Trial, should aim to provide the framework and confidence that freight operators and fuel suppliers need to make the necessary investments.

No one technology or fuel will achieve the reductions required

Currently the UK's HGV fleet is almost exclusively made up of diesel fuelled vehicles. To achieve the emission reductions required in future years, there is a need to support a range of solutions and encourage efficiency improvements through the use of vehicles which are tailored to their operating requirements.

The three key areas with the greatest potential to achieve CO_2 emission reductions are:

- **Switching to gas - up to 65 % (biomethane) / 16% (methane) WTW savings**

  One of the most effective strategies to achieve well-to-wheels (WTW) CO_2e emission reduction in this sector is to encourage a large scale shift to the use of gas as a fuel to replace diesel. The UK has an opportunity to support economic growth and export technology with two leading UK companies specialising in dual fuel technology. Non-renewable CNG and LNG could provide significant CO_2e reduction (5-16 % saving in UK HGV CO_2e for CNG). In the longer term, biomethane could offer even greater reductions (33-65 % saving in UK HGV CO_2e). Running HGVs on gas, whether non-renewable natural gas (CNG/LNG) or biomethane (gas or liquid) has the additional benefit of achieving substantial improvements in air pollution.

- **Improving aerodynamic efficiency / reducing rolling resistance - up to 10 % WTW savings**

  More than half of the energy transmitted to the wheels of a typical long haul HGV is estimated to be lost in rolling resistance, and over a third as aerodynamic drag.[1] Long haul and regional delivery vehicles are estimated to account for 70% of total HGV CO_2 emissions. These vehicles, as well as many construction vehicles, spend a significant portion of their working life at speeds of 40mph or more. While there is general acceptance and use of some aerodynamic devices, more could be done to encourage uptake which would in many cases result in short payback periods for vehicle operators. Low rolling resistance and single wide tyres offer further CO_2e savings while potentially reducing overall costs for vehicle operators. In total it is estimated up to 10% WTW and TTW (tank-to-wheels, i.e. direct) emissions savings are possible.

- **Supporting uptake of hybrid and pure electric vehicles - up to 8 % WTW savings**

  Hybrid and pure electric vehicle technologies are particularly suitable for urban delivery and municipal utility duty cycles. While these duty cycles only account for about 14% of total HGV CO_2e emissions, these technologies have the potential to reduce this contribution by 20-50%[2] on a WTW basis. They also provide additional benefits of lower noise and reduce, or in the case of pure electric vehicles, eliminate tailpipe emissions of air pollutants, which is particularly important to improve air quality in urban areas. Hybrid technology can also be applied to HGVs fitted with engines capable of running on gas.

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[1] Ricardo, Review of Low Carbon Technologies for Heavy Goods Vehicles – Annex 1, page 10, March 2010. Available online at: www.lowcvp.org.uk\\assets\\reports\\Review of low carbon technologies for heavy goods vehicles Annex.pdf

[2] Based on the current UK national grid electricity mix – future decarbonisation of electricity would lead to an even greater CO_2e savings potential

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1 Background

The Task Force on Fuel Efficient, Low Emission HGV (heavy goods vehicle) Technologies was formally announced in the Department for Transport (DfT)'s Logistics Growth Review.[3] This is a joint industry/Government initiative aimed at promoting the use of fuel efficient, low emission road freight technologies. Membership includes the Freight Transport Association, Road Haulage Association, Chartered Institute of Logistics and Transport, the Society of Motor Manufacturers and Traders, Low Carbon Vehicle Partnership (LowCVP) and the Technology Strategy Board's Transport Knowledge Transfer Network and is supported by the Department for Transport, CLG and Defra.

1.1 Objectives

The Task Force's objectives include identifying measures for reducing greenhouse gas emissions without detriment to air quality, and making suggestions on how to implement these measures in a way that would minimise burdens to industry. The objective of the project was to identify the opportunities to overcome the barriers to uptake of the low emission technologies and fuels which offer the greatest potential greenhouse gas savings for different HGV duty cycles.

1.2 Scope

The project was aimed at identifying technologies which can be applied to heavy goods vehicles of 3.5 tonne gross vehicle weight (GVW) upwards, in the short to medium term. Alternative fuels were considered however liquid biofuels were specifically excluded from the scope of this project. The project excluded buses and coaches, and its scope did not extend to include technologies for influencing driver behaviour or increasing efficiency through improved logistics. While the focus was on achieving greenhouse gas reductions, HGVs also contribute significantly to air pollution. Measures which reduce greenhouse gas may also help to improve air quality at the same time. The wider environmental impacts of the introduction of new technologies, for instance energy and resource use in manufacturing and potential hazards and difficulties in end of life recycling or disposal were also considered where appropriate.

1.3 Methodology

The project builds on an existing body of work examining options to reduce greenhouse gas emissions from HGVs, specifically the Automotive Council's Commercial Vehicle and Off-highway Low Carbon Technology Roadmap[4], and the Technology Roadmap for Low Carbon HGVs completed for LowCVP/DfT. In addition it drew on previous work conducted by AEA for the Committee on Climate Change and the European Commission[5] to establish the most common duty cycles for HGVs, and the typical savings and payback periods associated with the technologies and fuels available to reduce CO_2e emissions from HGVs. The barriers to uptake of these technologies and fuels, and the opportunities to overcome them were then explored through an initial literature review, followed by a series of interviews conducted with fleet operators, industry bodies, vehicle manufacturers, technology providers and fuel suppliers. Finally an online survey of barriers and opportunities was used to obtain the views of a wider audience. All findings were tested against the views of both the project steering group and individual interviewees to ensure relevance to the UK situation and industry experience.

[3] Department for Transport, The Logistics Growth Review - Connecting People with Goods, November 2011, available at: http://assets.dft.gov.uk/publications/logistics-growth-review/logistics-growth-review.pdf
[4] http://www.automotivecouncil.co.uk/wp-content/uploads/2011/07/COM-OH-Roadmap.pdf
[5] See: http://ec.europa.eu/clima/policies/transport/vehicles/docs/ec_hdv_ghg_strategy_en.pdf

2 Defining duty cycles

Heavy commercial vehicles are used in a very wide range of operations with very variable mission profiles / duty cycles. Significant work has been carried in the last few years to better characterise at a more aggregate level the main modes of operation. An ACEA working group on heavy duty vehicles originally identified seven duty cycles. In more recent work conducted by AEA and Ricardo for the European Commission [6] a simplified sub-set of five of these duty cycles was used; ACEA is now working with this shorter list and it was agreed that these should be used for this project.

Table 1: Simplified sub-set of commercial vehicle duty cycles

	Duty cycle	Duty cycle description
1	Urban Delivery	Urban delivery of consumer goods from a central store to selling points (inner-city and partly suburban roads).
2	Regional Delivery	Regional delivery of consumer goods from a central warehouse to local stores (inner-city, suburban, regional and also rural and mountainous roads).
3	Long Haul	Delivery to national and international sites (mainly highway operation and a small share of regional roads).
4	Municipal Delivery	Urban truck operation like refuse collection (many stops, partly low vehicle speed operation, driving to and from a central base point).
5	Construction	Construction site vehicles with delivery from central store to very few local customers (inner-city, suburban and regional roads; only small share of off-road driving).

It was then necessary to define the types of vehicles utilised on these duty cycles, the typical annual distances they cover and the typical fuel economy they achieve. Ricardo-AEA's initial estimates were reviewed and refined with the project steering group and during interviews with stakeholders. The results are shown in Table 2.

Table 2: Typical vehicles, mileages and fuel economy by duty cycle

	Duty Cycle	Typical vehicles	Typical annual mileage covered	Typical mpg
1	Urban Delivery	Rigid trucks, mostly below 18 tonne (all two axle). Significant volumes of 7.5 tonne vehicles (partly due to UK licensing – see below). Increasing numbers of 3.5 tonne and 12 tonne vehicles.	15-40,000 miles	10-17 mpg
2	Regional Delivery	A mixture of rigid and articulated trucks. Rigids are typically 18-26 tonnes with increasing numbers of three-axle vehicles. Articulated trucks up to the maximum 44 tonnes.	18-75,000 miles	8-14 mpg
3	Long Haul	33-44 tonne articulated lorries form the vast majority, but also some rigid vehicles up to 26 tonnes and some draw-bars at 44 tonnes (used for volume rather than load).	50-150,000 miles (higher if triple-shifting)	7-12 mpg
4	Municipal utility	Rigid vehicles, mainly refuse collection vehicles (RCVs) mostly at 26 tonne, but also street sweepers mostly at 15 tonnes.	5-18,000 miles	2-5 mpg
5	Construction	Primarily rigid tipper trucks (small - up to 7.5 tonne) and large (over 26 tonne); articulated tippers (which account for over 8 % of semi-trailers); some flat-beds; skip loaders; concrete mixers etc. Construction vehicles account for ~20 % of all rigid HGVs and 16 % of all UK HGVs. Unlike other categories, heavy construction trucks often utilise four-axle configurations.	Rigids: 14-30,000 miles Artics: 30-45,000 miles	6-13 mpg

[6] See: AEA and Ricardo, 'Reduction and Testing of Greenhouse Gas (GHG) Emissions from Heavy Duty Vehicles – Lot 1: Strategy', 2011. available online at: http://ec.europa.eu/clima/policies/transport/vehicles/docs/ec_hdv_ghg_strategy_en.pdf

3 Calculating duty cycle CO_2 shares

It is important to understand the relative contributions of each duty cycle to total CO_2 emissions from the UK heavy goods vehicle (HGV) fleet. To do this, a 'bottom-up' approach was used utilising data from the Department for Transport (DfT)[7]:

Average annual distance travelled x **Fuel consumption** x **Numbers of vehicles** x **CO_2 content of fuel** = **Total CO_2 emissions**

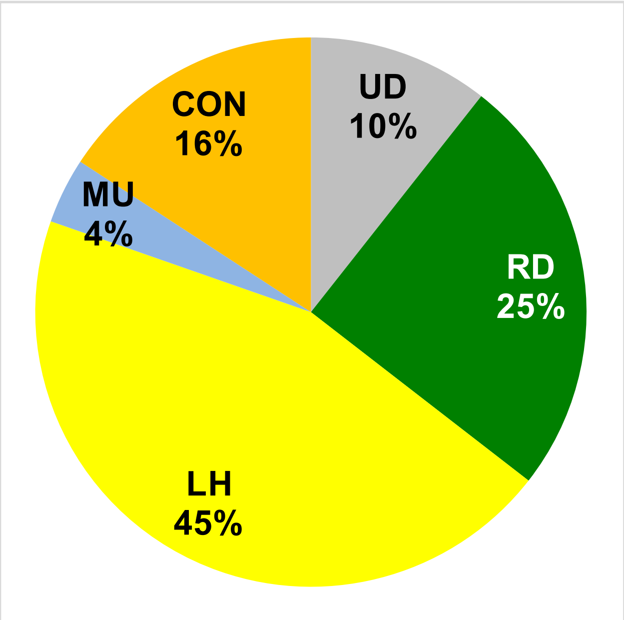
Department for Transport (DfT) data is published according to gross vehicle weight categories rather than vehicle operating cycles, so different weight classes and types of vehicle had to be allocated to each duty cycle. Since this allocation was an estimate, two different approaches were used. However it was found that final CO_2 shares attributable to each duty cycle were insensitive to these allocations. (For further details see Appendix 2). Sensitivity analysis was carried out using low, central and high distance estimates (see Appendix 3 for further details).

Long haul and regional delivery account for around 70% of total UK HGV CO_2.

From these calculations it is clear that the long haul duty cycle dominates overall UK HGV CO_2 emissions, being responsible for almost half of the total. Regional delivery accounts for a further quarter with construction vehicles contributing a further 15-16%.

Urban delivery accounts for 10-12% and despite their very low fuel efficiency, municipal utility vehicles only account for a 4% share of the total.

Table 3: Total UK HGV CO_2 emissions share by duty cycle (central distance estimate)



Ranking of duty cycles by CO_2 emissions share:

1. **Long haul (44-46 %)**
2. **Regional Delivery (24-25 %)**
3. **Construction (15-16 %)**
4. **Urban Delivery (10-12 %)**
5. **Municipal Utility (4 %)**

The ranges indicate the variation due to low, central and high distance estimates.

Note: UD = urban delivery; RD = regional delivery; LH = long haul; MU= municipal utility; CON= construction.

[7] Table RFS0115, Average vehicle kilometres per vehicle per year, by vehicle type, annual 2000 – 2010
Table RFS0141, Fuel consumption by HGV vehicle type in Great Britain, 1993-2010

4 Recommended technologies & fuels

For each of the five duty cycles, the most appropriate technologies and fuels were selected. This was decided on the basis of technologies with the greatest potential for CO_2 reduction in the short to medium term, while also considering the estimated payback period. Not all technologies and fuels are suitable for all vehicle types or duty cycles, and some may only be applicable to a proportion of the total fleet. Details of how this was addressed are shown in Appendix 4.

The "estimated duty cycle CO_2e saving" figures give the percentage saving that would be possible if the technology was fitted to all relevant vehicles operating on that duty cycle compared to the currently estimated CO_2e emissions from that duty cycle. Well to wheel (WTW) and Tank to Wheel (TTW) figures are presented. Except where indicated, these are calculated using the 2012 Defra/DECC GHG Conversion Factors[8] for the relevant fuel sources. The figures do not include any additional manufacturing or end of life emissions associated with the technologies presented.

Further details regarding the calculation of CO_2e savings, payback periods and additional considerations are given in Appendix 5. There are a multitude of potential pathways for gas as a road fuel from sourcing through transmission/distribution, compression or liquefaction and on vehicle storage. The Defra / DECC factors have been used for this analysis but to confirm the optimum source, pathways and true WTW savings possible, further work is required as detailed in Appendix 9.

Table 4: Technology recommendations by duty cycle

	Technology / fuel	Estimated duty cycle WTW CO_2e saving*	Estimated duty cycle TTW CO_2e saving*	Payback range***
1. Long haul				
1=	Dual fuel engine	16 % (CNG) 9-12 % (LNG)** 42 % (biomethane)	14 % (CNG / LNG / biomethane)	2-4 years
1=	Dedicated natural gas engine	5-16 % (CNG) 11 % worse to 8 % better (LNG)** 61-65 % (biomethane)	0-12% (CNG / LNG / biomethane)	1-3 years
2	Aerodynamic improvements	6-9 %	6-9 %	3-12 months
3	Predictive cruise control	1-2 %	1-2 %	1-2 months
4	Reduced ancillary loads	1-2 %	1-2 %	1-3 months
5	Stop / Start and idle shut-off	1 %	1 %	2-3 years
2. Regional delivery				
1=	Dual fuel engine	13 % (CNG) 35 % (biomethane)	12 % (CNG / biomethane)	5-10 years
1=	Dedicated natural gas engine	5-16 % (CNG) 61-65 % (biomethane)	0-12% (CNG / biomethane)	3-6 years
2	Aerodynamic improvements	2-5 %	2-5 %	1-2½ years
3	Predictive cruise control	1-2 %	1-2 %	2-4 months
4	Reduced ancillary	1 %	1 %	6-11 months

[8] Defra / DECC, 2012 Guidelines to Defra / DECC's GHG Conversion Factors for Company Reporting. Available online at: www.defra.gov.uk/publications/2012/05/30/pb13773-2012-ghg-conversion/

	Technology / fuel	Estimated duty cycle WTW CO_2e saving*	Estimated duty cycle TTW CO_2e saving*	Payback range***
	loads			
5	Stop / Start and idle shut-off	3 %	3 %	1-2 years
	3. Construction			
1 =	Dual fuel engine	13 % (CNG) 35 % (biomethane)	12 % (CNG / biomethane)	3-5 years
1 =	Dedicated natural gas engine	5-16 % (CNG) 61-65 % (biomethane)	0-12 % (CNG / biomethane)	2-4 years
2	Aerodynamic improvements (where applicable)	Up to 3 %	Up to 3 %	5-10 months
3	Predictive cruise control	1-2 %	1-2 %	1-3 months
4	Reduced ancillary loads	1 %	1 %	2-5 months
5	Alternatively fuelled bodies	6 %	6 %	3-6 years
	4. Urban delivery			
1	Stop / Start and idle shut-off	6 %	6 %	1-1½ years
2=	Hybrid electric vehicles / flywheel hybrid vehicles	15-30 % (15 % expected for flywheel hybrids)	15-30 %	5-8 years
2=	Dedicated natural gas engine	5-16 % (CNG) 61-65 % (biomethane)	12 % (CNG / biomethane)	4-7 years
3	Pure electric vehicles	50 % ****	100%	4-10 years*****
	5. Municipal utility			
1	Stop / Start and idle shut-off	5 %	5 %	<1-2½ years
2=	Hybrid electric / hydraulic vehicles	15-25 % (15 % expected for hydraulic hybrids)	15-25 %	4-16 years
2=	Dedicated natural gas engine	5-16 % (CNG) 61-65 % (biomethane)	0-12 % (CNG / biomethane)	6-18 years
3	Alternatively fuelled bodies	10-12 %	10-12 %	9 years plus

Note: CNG = compressed natural gas; LNG = liquefied natural gas

* CO_2e savings figures for dedicated natural gas engines are presented as a range to reflect uncertainty regarding the increased fuel energy consumed by a natural gas spark-ignition engine compared to a diesel engine. The lower saving assumes a 30% increase in required fuel energy; the upper saving figure uses a 15% increase which reflects an engine which is better optimised for gas. Tailpipe CO_2e savings for biomethane are shown as the same as CNG / LNG. However under Defra/DECC reporting guidelines, biomethane should be reported as giving up to 99.8% tailpipe savings since the same amount of CO_2 is embedded in the feedstock as is released in combustion. These tailpipe savings are achieved irrespective of production route (e.g. anaerobic digestion, landfill gas etc.). As for all fuels, well to wheel CO_2e savings for biomethane will vary according to the exact production route – see Appendix 9 for recommended further work in this area.

** CO_2e savings for LNG are also presented as a range. The lower saving is based on the standard Defra/DECC WTW figure, which represents LNG shipped to the UK from the Middle East. The upper saving is based on CNG liquefied in the UK - details in Appendix 5. LNG is most likely to be used for long haul operations where it may be difficult to provide sufficient CNG storage for the required vehicle range.

*** Based on current technology marginal capital costs, fuel cost savings and low-high mileage sensitivities.

**** Based on the current UK national grid electricity mix – future decarbonisation of electricity would lead to an even greater CO_2e savings potential

***** Depending on duty cycle and congestion charge exemption.

Taking these results and combining with the estimates for the percentage share of CO_2 associated with each of the five duty cycles, a summary was then created showing the potential CO_2e reduction available from each technology. The "total UK HGV CO_2e saving potential" figure gives the percentage saving compared to the currently estimated total UK HGV CO_2e emissions.

Table 5: Technologies and fuels with highest overall potential for HGV CO_2 savings

	Technology / fuel	Applicable duty cycles	Total UK HGV WTW CO_2e saving potential*	Additional considerations
1	Dedicated natural gas engines	All	5-16% (methane) 61-65% (biomethane)	Significant particulate emission & noise reduction benefits. CO_2 reduction benefit substantially greater when running on biomethane.
2	Dual fuel engines	Long haul, regional delivery and construction	13% (methane) 33% (biomethane)	Some particulate emissions & noise reduction benefits when running on gas. Payback and CO_2 savings very dependent on gas substitution rates (higher for higher speed duty cycles). CO_2 reduction benefit substantially greater when running on biomethane.
3	Aerodynamic improvements	Long haul, regional delivery and construction	5-6%	Benefits dependent on correct fitting / adjustment / average duty cycle speeds. Does not suit some body types / operations.
4	Pure electric vehicles	Urban delivery	5% **	Highest local air quality and noise reduction benefits. Lifecycle impacts of batteries need to be considered. Currently maximum available GVW is 12 tonnes.
5	Hybrid electric / hydraulic / flywheel vehicles	Urban delivery and municipal utility	3-4%	Air quality and noise reduction benefits particularly if able to run in electric only mode. Lifecycle impacts of batteries need to be considered. Flywheel hybrids are not yet commercially available, but are expected to offer a lighter weight and possibly lower cost alternative to battery-electric hybrid systems.
6	Low rolling resistance tyres / single wide tyres	All	1-5%	Lower rolling resistance tyres are available for all duty cycles. May have slightly shorter lifespan than standard tyres but CO_2 and fuel cost savings are expected to outweigh any negative environmental impact.

Note:

*The overall percentage saving of total UK HGV CO_2e emissions if technology/fuel applied to all relevant vehicles/duty cycles.

** Based on the current UK national grid electricity mix – future decarbonisation of electricity would lead to an even greater CO_2e savings potential

The barriers and opportunities surrounding these six priority technologies and fuels were then investigated in more detail as described in the next section.

5 Barriers

The main focus of this project was to identify the barriers which currently prevent greater uptake of low emission technologies and fuels for HGVs, and the opportunities for overcoming them.

In order to identify both barriers and opportunities, a series of 23 interviews were held with selected representatives from industry. These included:

- Fleet operators (ranging from a small haulage company to very large third party logistics companies, as well as large retail groups with their own vehicle fleets and industry representative bodies)
- Vehicle manufacturers
- Technology providers (covering engine conversions, hybrid systems, aerodynamic equipment and tyres)
- Fuel providers

More detailed explanations of all the barriers presented are provided in Appendix 6.

In addition an online survey was conducted which received 50 responses, primarily from fleet operators (see Appendix 8 for the results).

5.1 General industry barriers

A number of barriers were identified which were either associated specifically with the HGV and freight haulage industry in general or were applicable across all the technologies and fuels under consideration. These are shown in Table 6. Each point is explained in more detail in Appendix 6.

Table 6: General industry barriers

General industry barriers	
1	Lack of trust in technology provider's fuel economy claims and difficulty in measuring smaller real world fuel savings.
2	Operators are strongly focused on reliability. New technologies and fuels can be seen as too risky.
3	The freight haulage sector often has low margins which limit scope for upfront investment.
4	Any increased weight due to low emission technologies reduces payload.
5	Residual values for vehicles using new technologies and fuels are often low or unknown.
6	Driver training and the use of telematics are generally felt to provide fuel savings at least as great as technological measures and with reduced cost and risk.

5.2 Technology specific barriers

A more detailed list of barriers was identified during the interviews. These related to specific aspects of the various technologies and fuels which were identified as having the best CO_2e reduction potential. They are listed in Table 7. Each point is explained in more detail in Appendix 6.

Table 7: Technology specific barriers

Technology specific barriers	
Barriers to uptake of dual fuel and dedicated gas technologies	
1	High cost and lack of availability of gas refuelling infrastructure.
2	Upfront cost and limited availability of gas vehicles.
3	Uncertainty over likely payback period.
4	Concerns over reliability and manufacturer's warranty.
5	Limited package space for gas tanks (particularly for EURO VI dual fuel).
6	Concern over limited range for CNG.
7	Difficulty in calculating and claiming CO_2 savings for gas vehicles.
8	Limited availability of biomethane.
Barriers to uptake of aerodynamic improvements and measures to reduce rolling resistance	
1	Scepticism of real world benefits of aerodynamic measures and low rolling resistance tyres
2	Upfront costs of low rolling resistance tyres are higher.
3	Concern of increased wear rates with low rolling resistance tyres.
4	Difficulty ensuring correct adjustment of aerodynamic features
5	Legislation on vehicle dimensions restricts aerodynamic improvements
6	Aerodynamic features can limit payload and be vulnerable to damage
7	Trailer owners and the rental sector do not pay for the fuel used
8	Worn tyres have lower rolling resistance which can mask the benefits of new low rolling resistance tyres
9	More than half of HGV tyres fitted are retreads (which are not covered by new tyre information provision requirements)
10	UK legislation does not allow the use of 'single wide tyres' (lower weight / reduced rolling resistance) on drive axles of vehicles of 40 tonnes and over.
Barriers to uptake of hybrid and pure electric vehicles	
1	High upfront cost of hybrid and pure electric options.
2	Uncertainty over likely fuel cost savings.
3	Concern over vehicle residual values and long payback periods.
4	Hybrid and pure electric vehicle reliability is critical to achieve payback (since depreciation dominates cost calculation).
5	Charging requirements may require new local grid connections (to charge multiple pure electric HGVs).
6	Pure electric vehicles cannot be triple-shifted due to the need for recharging.
7	Concerns over lack of range for pure electric vehicles
8	Payload reduction due to the weight of batteries.
9	Lack of marketing for hybrid and pure electric HGV vehicles

6 Opportunities

The results of this research indicate some clear opportunities to promote uptake of low emission HGV technologies and fuels. Continued work by Government and industry to develop a strategy and vision for the reduction of CO_2 emissions, building on work that is already under way such as the Low Carbon Truck and Infrastructure Trial, should aim to provide the framework and confidence that freight operators and fuel suppliers need to make the necessary investments.

No one technology or fuel will achieve the reductions required

Currently the UK's HGV fleet is almost exclusively made up of diesel fuelled vehicles. To achieve the emission reductions required in future years, there is a need to support a range of solutions and encourage efficiency improvements through the use of vehicles which are tailored to their operating requirements.

There are three key areas of opportunity

The three key areas with the greatest potential to achieve CO_2 emission reductions are:

- **Switching to gas - up to 65 % (biomethane) / 16% (methane) WTW savings**

  The analysis indicates that one of the most effective strategies to achieve well to wheel CO_2e emission reduction in this sector is to encourage a large scale shift to the use of gas as a fuel to replace diesel. In addition the UK has an opportunity to support economic growth and export technology with two leading UK companies specialising in dual fuel technology. Non-renewable CNG and LNG could provide significant CO_2e reduction (5-16 % saving in UK HGV CO_2e for CNG). In the longer term, biomethane could offer even greater reductions (33-65 % saving in UK HGV CO_2e). Running HGVs on gas, whether non-renewable natural gas (CNG/LNG) or biomethane (gas or liquid) has the additional benefit of achieving substantial improvements in air pollution. Switching to gas as the primary fuel for HGVs will require substantial investment to create the necessary refuelling infrastructure and to purchase or convert vehicles.

- **Improving aerodynamic efficiency / reducing rolling resistance - up to 10 %**

  More than half of the energy transmitted to the wheels of a typical long haul HGV is estimated to be lost in rolling resistance, and over a third as aerodynamic drag.[9] Long haul and regional delivery vehicles are estimated to account for 70% of total HGV CO_2 emissions. These vehicles, as well as many construction vehicles, spend a significant portion of their working life at speeds of 40mph or more. While there is general acceptance and use of some aerodynamic devices, more could be done to encourage uptake which would in many cases result in short payback periods for vehicle operators. Low rolling resistance and single wide tyres offer further CO_2e savings while potentially reducing overall costs for vehicle operators. In total it is estimated up to 10% WTW and TTW savings are possible.

- **Supporting uptake of hybrid / pure electric vehicles - up to 8 % WTW saving**

  Hybrid and pure electric vehicle technologies are particularly suitable for urban delivery and municipal utility duty cycles. While these duty cycles only account for about 14% of total HGV CO_2 emissions, these technologies have the potential to reduce this contribution by 20-50%[10]. They also provide additional benefits of lower noise and reduce, or in the case of pure electric vehicles, eliminate tailpipe emissions of air pollutants, which is particularly important to improve air quality in urban areas. Hybrid technology can also be applied to HGVs fitted with engines capable of running on gas.

[9] Ricardo, Review of Low Carbon Technologies for Heavy Goods Vehicles – Annex 1, page 10, March 2010. Available online at: www.lowcvp.org.uk\\assets\\reports\\Review of low carbon technologies for heavy goods vehicles Annex.pdf

[10] Based on the current UK national grid electricity mix – future decarbonisation of electricity would lead to an even greater CO_2e savings potential

6.1 Detailed opportunities

For each of these three high level opportunities, a series of more detailed recommendations have been developed based on the findings from this study. Further details on each can be found in Appendix 7:

Table 8: More detailed recommendations

More detailed recommendations	
Switching to gas	
1.	Set out a clear strategy for switching HGVs to gas.
2.	Guarantee a fuel duty differential between gas and diesel for a rolling 10 years.
3.	Continue to support creation of gas refuelling infrastructure.
4.	Encourage greater production and use of biomethane for transport.
5.	Encourage uptake of gas vehicles through incentives.
6.	Ensure methane emissions from gas vehicles are minimised.
Improving aerodynamic efficiency / reducing rolling resistance	
1.	Creation of an accreditation scheme to provide independent test results for aerodynamic and rolling resistance improvements.
2.	Offering free, independent “fleet health check” reviews to advise operators on the best technologies.
3.	Reviewing legislation on vehicle dimensions to allow more aerodynamic designs.
4.	Working with the HGV industry to raise awareness and understanding of the benefits of aerodynamic and rolling resistance improvements.
5.	Request that retread tyres are included in HGV tyre information provision requirements.
6.	Consider revising UK legislation to allow use of single wide tyres on driven axles at 40 tonnes and over.
Supporting uptake of hybrid and pure electric vehicles	
1.	Expansion of the OLEV plug-in van grant to include vehicles up to 12 tonnes and/or creation of a ‘Green Lorry Fund’.
2.	Encourage local authorities to provide exemptions / allowances which improve the business case for hybrid and pure electric vehicles.
Supporting uptake of all low emission HGV technologies and fuels	
1.	Derogation to allow the payloads of low emission HGVs to match conventional vehicles.
2.	Enhanced Capital Allowances for purchase of low emission HGV technologies and fuels.
3.	Greater public procurement of low emission HGV options through contracts.
4.	Differentiated charging for HGV road use according to air pollution and CO_2e emission reduction.
5.	Encouraging increased use of telematics systems.

Note: The evidence gathered during this study suggests that some of the most cost effective and fast acting ways of reducing CO_2e emissions from the HGV sector lie in the area of modifying driver behaviour and reducing vehicle speeds. However the scope of this study was limited to considering only technologies and fuels.

Appendices

Appendix 1 – Duty cycle definitions

The following boxes give additional information relating to each of the duty cycles used for this project. Information on vehicle types, annual mileages, fuel economy and additional considerations is based on a combination of information obtained from interviewees and the Department for Transport's statistics.

Table 9: Urban delivery duty cycle definition

Urban delivery	 
Description:	Urban delivery of consumer goods from a central store to selling points (inner-city and partly suburban roads). Distribution in cities or suburban areas including frequent stop start driving.
Vehicle types:	Rigid trucks, mostly below 18 tonne (all 2 axle). Significant volumes of 7.5 tonne vehicles (partly due to UK licensing – see below). Increasing numbers of 3.5 tonne and 12 tonne vehicles.
Annual mileage:	15-40,000 miles
Fuel economy:	10-17 mpg depending on vehicle weight, loading and duty cycle
Additional considerations:	Holders of pre-1997 standard driving licences are permitted to drive vehicles up to 7.5 tonnes. Post 1997 this was reduced to 3.5 tonnes. Above these limits, an operator licence ("o-licence") is required.

Table 10: Regional delivery duty cycle definition

Regional delivery	 
Description:	Regional delivery of consumer goods from a central warehouse or regional distribution centre (RDC) to local stores (inner-city, suburban, and regional roads). Includes periods of constant high speed and urban operation.
Vehicle types:	A mixture of rigids and articulated trucks. Rigids typically 18-26 tonnes with increasing numbers of 3-axle vehicles. Articulated trucks up to the maximum 44 tonnes, particularly for supermarkets making deliveries from regional distribution centres.
Annual mileage:	18-75,000 miles
Fuel economy:	8-14mpg depending on vehicle weight, loading and duty cycle
Additional considerations:	The UK has a somewhat different logistics network dynamic and vehicle mix from the rest of Europe. Articulated vehicles are increasingly used to make deliveries to stores in urban areas.

Table 11: Long haul duty cycle definition

Long haul	 
Description:	Delivery to national and international sites (mainly highway operation and a small share of regional roads). Long periods of constant high speed travel with very few periods of urban operation.
Vehicle types:	33-44 tonne articulated lorries form the large majority, but also some rigid vehicles up to 26 tonnes and some draw-bars at 44 tonnes (used for volume rather than load).
Annual mileage:	50-150,000 miles (higher if triple-shifting)
Fuel economy:	7-12 mpg depending on vehicle weight, loading and duty cycle
Additional considerations:	Commonly referred to as ‘trunking’ or ‘line-haul’ operations. An increasing focus on maximising ‘back-haul’ may lead to greater use of 44 tonne vehicles for flexibility. In comparison to mainland Europe, UK long haul journey distances are typically shorter.

Table 12: Municipal utility duty cycle definition

Municipal utility	 
Description:	Urban truck operation like refuse collection (many stops, partly low vehicle speed operation, driving to and from a central base point).
Vehicle types:	Rigid vehicles, mainly refuse collection vehicles (RCVs) mostly at 26 tonne, but also street sweepers mostly at 15 tonnes.
Annual mileage:	5-18,000 miles
Fuel economy:	2-5 mpg depending on vehicle weight and duty cycle
Additional considerations:	Street sweepers use second engine to power brushes.

Table 13: Construction duty cycle definition

Construction	 
Description:	Construction site vehicles with delivery from central store to very few local customers (inner-city, suburban and regional roads; only small share of off-road).
Vehicle types:	Primarily rigid tipper lorries (small - up to 7.5 tonne) and large (over 26 tonne); articulated tippers (which account for over 8 % of semi-trailers); some flat-beds; skip loaders; concrete mixers etc. Construction vehicles account for ~20 % of all rigid HGVs and 16 % of all UK HGVs. Unlike other categories, heavy construction trucks often utilise 4-axle configurations. This is the only duty cycle which extensively utilises high weight rigid trucks.
Annual mileage:	Rigids: 14-30,000 miles; Artics: up to 45,000 miles
Fuel economy:	6-13 mpg depending on vehicle weight, loading and duty cycle
Additional considerations:	Operators of aggregates vehicles paid by tonne-km so very sensitive to vehicle weight. “Muck-away” vehicle operators prioritise durability over maximum payload.

Appendix 2 – Allocation of vehicle GVWs to duty cycle

In order to calculate the estimated share of CO_2 emissions associated with each duty cycle, it was necessary to allocate the different categories into the five different duty cycles. For rigid goods vehicles, DfT publishes disaggregated licensing statistics by gross weight and body type.[11] This was used to identify numbers of rigid vehicles in the municipal utility duty cycle (listed as 'refuse disposal' and 'street cleansing') and construction duty cycle (listed as 'tipper', 'skip loader', and 'concrete mixer').

In addition data relating to the numbers and types of articulated trailers in circulation in the UK was used to determine the number of articulated tipper trailers. These were also allocated to the construction duty cycle.

The remaining stock of HGVs was then allocated to urban delivery, regional delivery and long haul by estimating percentage splits. Two alternative approaches were tried – a 'simple' assumption and a more nuanced 'shared' assumption as shown in Table 14:

Table 14: Allocation of vehicles to duty cycles

		Rigids						Artics			
Basis	**Body Type**	**>3.5t to 7.5t**	**>7.5t to 15t**	**>15t to 18t**	**>18t to 26t**	**>26t**	**Total Rigid**	**>3.5t to 33t**	**>33t**	**Total Artic**	**Total HGV**
'Simple' Assumption	*Urban Delivery*	*100%*	*100%*	-	-	-	***62%***	-	-	***0%***	***42%***
	Regional Delivery	-	-	*100%*	*100%*	-	***35%***	*100%*	-	***29%***	***33%***
	Long Haul	-	-	-	-	*100%*	***4%***	-	*100%*	***71%***	***26%***
'Share' Assumption	*Urban Delivery*	*80 %*	*60 %*	*30 %*	*10 %*	-	***55 %***	-	-	***0 %***	***37 %***
	Regional Delivery	*20 %*	*40 %*	*70 %*	*80 %*	*80 %*	***41 %***	*100 %*	-	***29 %***	***37 %***
	Long Haul	-	-	-	*10 %*	*20 %*	***4 %***	-	*100 %*	***71 %***	***26 %***

The calculations resulted in the total allocations of vehicle stock and activity by duty cycles shown in Figure 1 (simple assumption) and Figure 2 (shared assumption).

[11] Table VEH0522, Rigid goods vehicles over 3.5 tonnes licensed by gross weight and body type, Great Britain, annually: 2010

Figure 1: Allocation of vehicle stock and activity to duty cycles (Simple assumption)

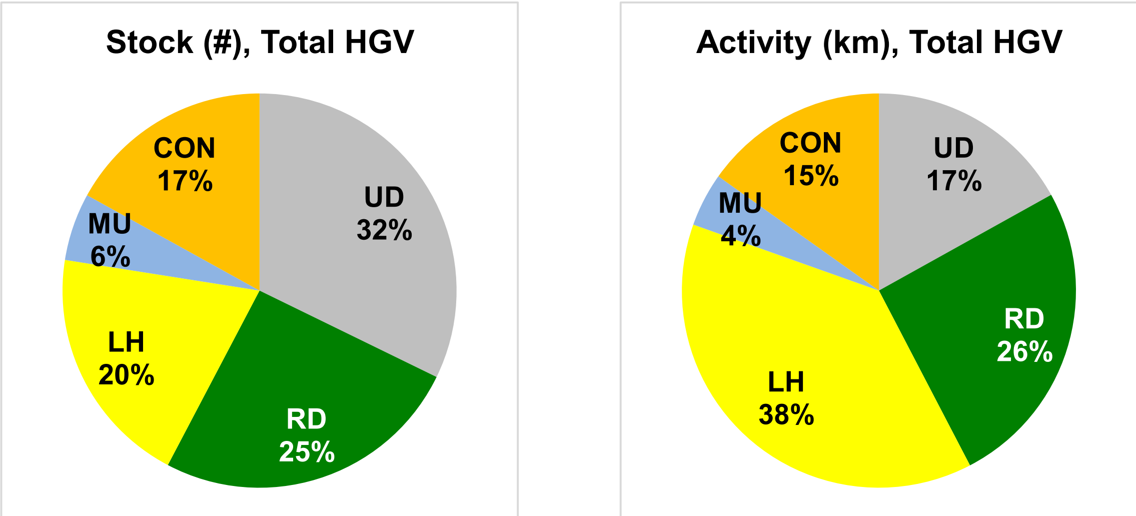
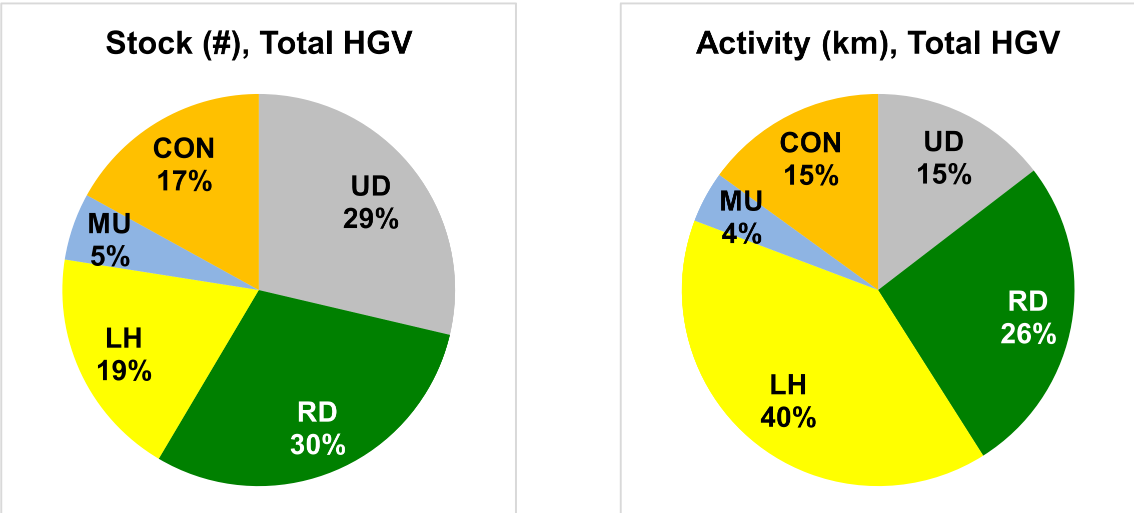


Figure 2: Allocation of vehicle stock and activity to duty cycles (Shared assumption)



Note: UD = urban delivery; RD = regional delivery; LH = long haul; MU= municipal utility; CON= construction.

Appendix 3 – Sensitivity analysis for annual distance data

The Department for Transport (DfT) estimates for annual distances travelled by HGVs are based on the Continuing Survey of Road Goods Transport (CSRGT). The distances were felt to be unrepresentatively low by the project steering group and this was queried with DfT statisticians. The DfT's response indicated three possible reasons for this:

1) Under-reporting in CSRGT - There is almost certainly going to be under-reporting in the CSRGT. The nature of the return that DfT is legally required to supply to the EU under statutory council regulations is at individual trip level. This means that hauliers are asked to supply, for one designated week, for a designated HGV, every trip that the HGV made. This process may be onerous so hauliers may not fill out all the trips. DfT is trying to understand what that level of underreporting might be. Some work done about 8 years ago suggests that the level might be 10%-15% of vehicle kilometres.

2) Base for calculation - The base for the calculation of the figures in table RFS0115 includes all vehicles that are surveyed in the CSRGT, including those that are off-road in the survey week for various reasons (unlicensed, scrapped, vehicles in for repair etc). In 2010 this was approximately 30% of the forms that were received back. Dividing by the number of vehicles that supplied a return with valid kilometres would naturally increase the average kilometres per year.

3) Foreign travel - CSRGT estimates exclude, significantly, travel abroad by HGVs (this is covered by DfT's separate international survey) and is probably not insignificantly. It also excludes site work, travel to and from MOTs or repairs and other journeys that did not involve carrying freight (although empty journeys as part of the freight business are included).

For these reasons, Ricardo-AEA conducted sensitivity analysis in the calculation of CO_2 shares attributable to each duty cycle using three different sets of distance data. CSRGT figures were use as a low estimate, central and upper estimates were based on information received from the project steering group, as shown in Table 15.

Table 15: Low, central and high estimates for annual distance travelled by weight class

Annual distance travelled (km)										
Body Type	**>3.5t to 7.5t rigid**	**>7.5t to 15t rigid**	**>15t to 18t rigid**	**>18t to 26t rigid**	**>26t rigid**	**Total Rigid**	**>3.5t to 33t artic**	**>33t artic**	**Total Artic**	**Total HGV**
Low	23,000	29,000	35,500	42,000	41,000	**30,952**	64,000	93,000	**84,500**	**47,000**
Central	25,000	32,000	40,000	50,000	50,000	**35,230**	80,000	120,000	**108,276**	**55,386**
High	28,000	35,000	50,000	80,000	60,000	**44,754**	100,000	160,000	**142,414**	**71,701**

Appendix 4 – Technology compatibility and application limits

Not all technologies are suitable for all vehicle types or duty cycles. Where this is the case, vehicle licensing data was used to estimate the maximum percentage of vehicles where the technology could be applied. In some cases a technology is not compatible with a duty cycle. In other cases the application of a technology has been limited according to the percentage of suitable vehicles. For example, in the case of aerodynamic improvements and alternatively fuelled bodies, these were limited according to data obtained regarding registered numbers of body or trailer types.

Details of the compatibilities and application limits utilised are shown in Table 16, Table 17 and Table 18.

Table 16: Powertrain technologies considered

Type	Technology	Mapping compatibility to duty cycles				
		Urban delivery	Regional delivery	Long haul	Municipal utility	Constr-uction
Powertrain	Diesel ICE	✓	✓	✓	✓	✓
	Diesel Flywheel Hybrid Vehicle	✓	✓	✓	✓	✓
	Diesel Hydraulic Hybrid Vehicle	✓	✓	✓	✓	✓
	Diesel Hybrid Electric Vehicle	✓	✓	✓	✓	✓
	Pure Electric Vehicle	✓	No	No	✓	No
	Hydrogen Fuel Cell Vehicle	✓	✓	✓	✓	✓
	Dual-fuel (diesel-natural gas)	✓	✓	✓	✓	✓
	Dedicated natural gas	✓	✓	✓	✓	✓
Powertrain enhance-ments	Mechanical turbo-compound	✓	✓	✓	✓	✓
	Electrical turbo-compound	✓	✓	✓	✓	✓
	Heat recovery (bottoming cycles)	✓	✓	✓	✓	✓
	Controllable air compressor	✓	✓	✓	✓	✓
	Automated Transmission	✓	✓	✓	✓	✓
	Stop / start system	✓	✓	✓	✓	✓
	Pneumatic booster – air hybrid	✓	✓	✓	✓	✓

Table 17: Vehicle technologies considered

Type	Technology	Mapping compatibility to duty cycles				
		Urban delivery	Regional delivery	Long haul	Municipal utility	Constr-uction
Aerodynamics	Aerodynamic fairings	✓	✓	✓	✓	✓
	Spray reduction mud flaps	✓	✓	✓	✓	✓
	Aerodynamic trailers / bodies	69 %	45 %	75 %	0 %	0 %
	Aerodynamics (irregular body type)	31 %	55 %	25 %	0 %	100 %
	Active aero	69 %	45 %	75 %	0 %	0 %
Rolling Resistance	Low rolling resistance tyres	✓	✓	✓	✓	✓
	Single wide tyres	✓	✓	✓	✓	✓
	Automatic tyre pressure adjustment	✓	✓	✓	✓	✓
Weight	Light weighting	✓	✓	✓	✓	✓
Others	Predictive cruise control	No	✓	✓	No	✓
	Smart alternator, battery sensor & AGM battery	✓	✓	✓	✓	✓
	Alternative fuel bodies (for refuse collection vehicle / refrigeration / tipper)	11 %	23 %	16 %	76 %	79 %
	Advanced predictive cruise control	No	✓	✓	No	✓

Table 18: Alternative fuels considered

Type	Technology	Mapping compatibility to duty cycles				
		Urban delivery	Regional delivery	Long haul	Municipal utility	Constr-uction
Alternative Fuels	Biomethane	✓	✓	✓	✓	✓
	Natural Gas	✓	✓	✓	✓	✓
	Electricity	✓	No	No	✓	No
	Hydrogen	✓	✓	✓	✓	✓

Appendix 5 – Technology recommendations by duty cycle

Work previously carried out for the Committee on Climate Change and the European Commission has resulted in Ricardo-AEA developing a database and model which enables calculation of the estimated CO_2 savings and costs for a wide range of potential technologies and fuels which could be applied to HGVs. A cost-effectiveness model that was developed for the previous low carbon HGV market background study[12] carried out by AEA for LowCVP was adapted to estimate simple payback times for all these technologies (based on marginal capital costs, maintenance costs and fuel cost savings). These have been supplemented with payback periods for certain technologies based on actual operator experiences where available, e.g. for pure electric and natural gas fuelled vehicles.

Potential CO_2 savings and costs for different technologies are based on previous research work by both AEA and Ricardo. Updates to costs to reflect UK specific conditions and technological developments have been incorporated during AEA's work for the Committee on Climate Change and from further information gathered through the course of this new project for LowCVP. Payback calculations are based on the marginal technology cost plus an indicative 25 % margin[13], at 2010 costs.

CO_2e saving calculations

Well to wheel (WTW) and tank to wheel (TTW) CO_2e savings figures are calculated using conversion factors for the relevant fuel sources taken from the Defra/DECC GHG Conversion Factors (CNG from table 1a, diesel and biomethane from annex 9).[14]

The "duty cycle CO_2e saving" figure gives the percentage saving that would be possible if the technology was fitted to all relevant vehicles operating on that duty cycle compared to the currently estimated CO_2e emissions for that duty cycle. The "total UK HGV CO_2e saving" figure gives the resulting saving compared to the currently estimated total UK HGV CO_2e emissions.

LNG calculation

CO_2e savings figures for use of LNG are presented as a range. The lower saving is based on the standard Defra/DECC WTW figure (table 1a), which represents LNG shipped to the UK from the Middle East. The upper saving is based on a calculation representing CNG received by pipeline to the UK, then liquefied and transported by truck to filling stations. The lifecycle emissions factors were obtained from JRC/Concawe's July 2011 Well to Tank report.[15] The calculation uses extraction, processing and transport figures for "current average composition of NG supply in EU" (pathway GMCG1) and a liquefaction figure from pathway GRGC2. A distribution figure of 3.8gCO_2e/MJ was then applied.

[12] Low Carbon HGVs - Market Background Study, prepared by AEA for the Low Carbon Vehicle Partnership/Department for Transport, Work Specification Ref No: FLD401O, August 2010: http://www.lowcvp.org.uk/assets/reports/AEA+Market+Background+Study+v2+FINAL.pdf

[13] This manufacturer and dealer margin is based on that identified for cars in previous work for LowCVP, and was also used in the CCC project for all road vehicles. During this project it was noted that the margin may be somewhat higher for HGVs, however no suitable alternative figure could be identified.

[14] Defra / DECC, 2012 Guidelines to Defra / DECC's GHG Conversion Factors for Company Reporting. Available online at: www.defra.gov.uk/publications/2012/05/30/pb13773-2012-ghg-conversion/

[15] JRC/CONCAWE, *Well-to-wheels Analysis of Future Automotive Fuels and Powertrains in the European Context - WTT APPENDIX 2 Description and detailed energy and GHG balance of individual pathways*. July 2011. Available online at: http://iet.jrc.ec.europa.eu/about-jec/sites/iet.jrc.ec.europa.eu.about-jec/files/documents/wtw3_wtt_appendix2_eurformat.pdf

Table 19: Technology recommendations for urban delivery duty cycle

Urban delivery – technology recommendations				
	Technology / fuel	**WTW CO_2e saving**	**Payback range***	**Additional considerations**
1	Stop / Start and idle shut-off	6 %	1-1½ years	Small air quality and noise reduction benefits in congested urban areas. Marginal increase in lifecycle impact due to additional components.
2=	Hybrid electric vehicles / flywheel hybrid vehicles	15-30 % (15 % expected for flywheel hybrids)	5-8 years	Air quality and noise reduction benefits particularly if able to run in electric only mode. Lifecycle impacts of batteries need to be considered. Flywheel hybrids are not yet commercially available, but are expected to offer a lighter weight and possibly lower cost alternative to battery-electric hybrid systems.
2=	Dedicated natural gas vehicles	5-16 % (CNG) 61-65 % (biomethane)	4-7 years	Air quality and noise reduction benefits; requires additional refuelling infrastructure. Substantially larger CO_2e reduction benefits with biomethane.
3	Pure electric vehicles	50 % **	4-10 years (depending on duty cycle and congestion charge exemption)	Highest local air quality and noise reduction benefits. Lifecycle impacts of batteries need to be considered. Currently maximum available GVW is 12 tonnes.

* Based on current technology marginal capital costs fuel cost savings and low-high mileage sensitivities.

** Based on the current UK grid electricity mix – future electricity decarbonisation will increase the CO_2e savings potential

Table 20: Technology recommendations for regional delivery duty cycle

Regional delivery – technology recommendations				
	Technology / fuel	**WTW CO_2e saving**	**Payback range***	**Additional considerations**
1 =	Dual fuel	13 % (CNG) 35 % (biomethane)	5-10 years	Some particulate emissions & noise reduction benefits when running on gas. Payback and CO_2e savings very dependent on gas substitution rates (higher for higher speed duty cycles). CO_2e reduction benefit substantially greater when running on biomethane. Requires additional refuelling infrastructure.
1 =	Dedicated natural gas	5-16 % (CNG) 61-65 % (biomethane)	3-6 years	CO_2 reduction benefit substantially greater when running on biomethane. Significant particulate emission & noise reduction benefits.
2	Aerodynamic improvements	2-5 %	1-2½ years	Benefits dependent on correct fitting / adjustment / average duty cycle speeds. Does not suit some body types / operations.
3	Predictive cruise control	1-2 %	2-4 months	Journey times can increase by up to 2 %. Most applicable for longer journeys where CO_2e savings could be significantly higher dependent on the route driven.
4	Reduced ancillary loads	1 %	6-11 months	Declutching the air compressor rather than venting should give a small noise reduction benefit. Small increase in manufacturing and disposal emissions due to extra components.
5	Stop / Start and idle shut-off	3 %	1-2 years	Small air quality and noise reduction benefits in congested urban areas. Marginal increase in lifecycle impact due to additional components.

* Based on current technology marginal capital costs fuel cost savings and low-high mileage sensitivities.

Table 21: Technology recommendations for long haul duty cycle

Long haul – technology recommendations				
	Technology / fuel	**WTW CO_2e saving**	**Payback range***	**Additional considerations**
1 =	Dual fuel	16 % (CNG) 9-12 % (LNG) 42 % (biomethane)	2-4 years	Some particulate emissions & noise reduction benefits when running on gas. Payback and CO_2e savings very dependent on gas substitution rates (higher for higher speed duty cycles). Requires additional refuelling infrastructure. CO_2e reduction benefit substantially greater when running on biomethane and lower when running on LNG.
1 =	Dedicated natural gas	5-16 % (CNG) 11 % worse to 8 % better (LNG) 61-65 % (biomethane)	1-3 years	CO_2 reduction benefit substantially greater when running on biomethane. Significant particulate emission & noise reduction benefits. Requires additional refuelling infrastructure.
2	Aerodynamic improvements	6-9 %	3-12 months	Benefits dependent on correct fitting / adjustment / average duty cycle speeds. Does not suit some body types / operations.
3	Predictive cruise control	1-2 %	1-2 months	Journey times can increase by up to 2 %. Most applicable for longer journeys where CO_2 savings could be significantly higher dependent on the route driven.
4	Reduced ancillary loads	1-2 %	1-3 months	Declutching the air compressor rather than venting should give a small noise reduction benefit. Small increase in manufacturing and disposal emissions due to extra components.
5	Stop / Start and idle shut-off	1 %	2-3 years	Small air quality and noise reduction benefits in congested urban areas. Marginal increase in lifecycle impact due to additional components.

* Based on current technology marginal capital costs fuel cost savings and low-high mileage sensitivities.

Table 22: Technology recommendations for municipal utility duty cycle

Municipal utility – technology recommendations				
	Technology / fuel	**WTW CO_2e saving**	**Payback range***	**Additional considerations**
1	Stop / Start and idle shut-off	5 %	<1-2½ years	Small air quality and noise reduction benefits in congested urban areas. Marginal increase in lifecycle impact due to additional components.
2=	Hybrid electric / hydraulic hybrid vehicles	15-25 % (15 % expected for hydraulic hybrids)	4-16 years	Air quality and noise reduction benefits particularly if able to run in electric only mode. Lifecycle impacts of batteries need to be considered.
2=	Dedicated natural gas vehicles	5-16 % (CNG) 61-65 % (biomethane)	6-18 years	Significant particulate emission & noise reduction benefits; requires additional refuelling infrastructure. Substantially larger CO_2e reduction benefits with biomethane.
3	Alternatively fuelled bodies	10-12 %	9 years plus	Electrically powered refuse truck bodies can reduce noise and air pollution.

* Based on current technology marginal capital costs fuel cost savings and low-high mileage sensitivities.

Table 23: Technology recommendations for construction duty cycle

Construction – technology recommendations				
	Technology / fuel	**WTW CO_2e saving**	**Payback range***	**Additional considerations**
1 =	Dual fuel	13 % (CNG) (35 % using biomethane)	3-5 years	Some particulate emissions & noise reduction benefits when running on gas. Payback and CO_2e savings very dependent on gas substitution rates (higher for higher speed duty cycles). CO_2e reduction benefit substantially greater when running on biomethane. Requires additional refuelling infrastructure.
1 =	Dedicated natural gas	5-16 % (CNG) 61-65 % (biomethane)	2-4 years	CO_2 reduction benefit substantially greater when running on biomethane. Significant particulate emission & noise reduction benefits. Requires additional refuelling infrastructure.
2	Aerodynamic improvements (where applicable)	Up to 3 %	5-10 months	Options for aerodynamic improvement for construction vehicles are more limited than in other duty cycles, however they also typically cost less. For example, “sheeting” (covering) the contents of a tipper. Benefits are dependent on correct fitting / adjustment / average duty cycle speeds. Does not suit some body types / operations.
3	Predictive cruise control	1-2 %	1-3 months	Journey times can increase by up to 2 %. Most applicable for longer journeys where CO_2 savings could be significantly higher dependent on the route driven.
4	Reduced ancillary loads	1 %	2-5 months	Declutching the air compressor rather than venting should give a small noise reduction benefit. Small increase in manufacturing and disposal emissions due to extra components.
5	Alternatively fuelled bodies	6 %	3-6 years	Based on estimated energy consumption reduction of switching to electrically powered tippers. Electrically powered tipper bodies could help reduce noise and emissions.

* Based on current technology marginal capital costs fuel cost savings and low-high mileage sensitivities.

This table shows the top 20 technology/duty cycle combinations ranked according to the highest potential overall reductions in well to wheel CO_2e emissions from the UK HGV fleet.

Table 24: Prioritised technology recommendations for all duty cycles

Prioritised technology mapping by duty cycle					
	Duty cycle	**Technology / fuel**	**Duty cycle CO_2e WTW saving**	**Total UK HGV WTW CO_2e saving**	**Payback range*** **
1	Long haul	Dual fuel	16 % (CNG) 9-12 % (LNG) 42 % (biomethane)	7 % (CNG) (19% biomethane)	2-4 years
2	Long haul	Dedicated natural gas vehicles	5-16 % (CNG) 11 % worse to 8 % better (LNG) 61-65 % (biomethane)	2-7 % (CNG) 5 % worse to 4 % better (LNG) 27-29 % (biomethane)	1-3 years
3	Urban delivery	Pure electric vehicles	50 % ****	5 %	4-10 years*****
4	Regional delivery	Dedicated natural gas vehicles	5-16 % (CNG) 61-65 % (biomethane)	1-4 % (CNG) 15-16 % (biomethane)	3-6 years
5	Regional delivery	Dual fuel	13 % (CNG) 35 % (biomethane)	3 % (CNG) 9 % (biomethane)	5-10 years
6	Long haul	Aerodynamic improvements	6-9 %	3-4 %	3-12 months
7	Construction	Dedicated natural gas	5-16 % (CNG) 61-65 % (biomethane)	1-3 % (CNG) 10 % (biomethane)	2-4 years
8	Construction	Dual fuel	13 % (CNG) 35 % (biomethane)	2 % (CNG) 6 % (biomethane)	3-5 years
9	Urban delivery	Hybrid electric / flywheel hybrid vehicles	15-30 % (15% expected for flywheel hybrids)	2-3 %	5-8 years
10	Urban delivery	Dedicated natural gas vehicles	5-16 % (CNG) 61-65 % (biomethane)	1-2 % (CNG) 6-7 % (biomethane)	4-7 years
11	ALL	Low rolling resistance tyres	1-5 %	1-5 %	2 months-18 years
12	Construction	Alternatively fuelled bodies	5-10 %	1-2 %	3-6 years
13	Regional delivery	Stop / Start and idle shut-off	3%	1 %	1-2 years
14	Urban delivery	Stop / Start and idle shut-off	6%	1 %	1-1½ years
15	Municipal utility	Hybrid electric / hydraulic hybrid vehicles	15-25 % (15% expected for hydraulic hybrids)	1 %	4-16 years
16	Municipal utility	Dedicated natural gas vehicles	5-16 % (CNG) 61-65 % (biomethane)	0-1 % (CNG) 2-3 % (biomethane)	6-18 years
17	Regional delivery	Aerodynamic improvements	2-5 %	1 %	1-2½ years
18	Construction	Aerodynamic improvements (where applicable)	Up to 3 %	1 %	5-10 months
19	Long haul	Predictive cruise control	1-2 %	1 %	1-2 months

Prioritised technology mapping by duty cycle					
	Duty cycle	Technology / fuel	Duty cycle CO_2e WTW saving	Total UK HGV WTW CO_2e saving	Payback range***
20	Long haul	Reduced ancillary loads	1-2 %	1 %	1-3 months
21	Municipal utility	Alternatively fuelled bodies	10-12 %	0.5 %	9 years plus

Note:

***** CO_2e savings figures for dedicated natural gas engines are presented as a range to reflect uncertainty regarding the increased fuel energy consumption of a natural gas spark-ignition engine compared to a diesel engine. The lower saving is calculated assuming a 30% increase in required fuel energy; the upper saving figure uses a 15% increase which reflects an engine which is better optimised for gas.

** CO_2e savings for LNG are also presented as a range. The lower saving is based on the standard Defra/DECC WTW figure, which represents LNG shipped to the UK from the Middle East. The upper saving is based on CNG liquefied in the UK - details in Appendix 5. LNG is most likely to be used for long haul operations where it may be difficult to provide sufficient CNG storage for the required vehicle range.

*** Based on current technology marginal capital costs, fuel cost savings and low-high mileage sensitivities.

**** Based on the current UK national grid electricity mix – future decarbonisation of electricity would lead to an even greater CO_2e savings potential

***** Depending on duty cycle and congestion charge exemption.

Appendix 6 – Details of barriers

Table 25: Details of general industry barriers

General industry barriers	
Barrier	**Details**
Lack of trust in technology provider's fuel economy claims and difficulty in measuring smaller real world fuel savings.	Interviewees often expressed scepticism of claimed fuel economy benefits for some technologies. While large fleet operators are often able to provide accurate assessments of their overall fleet fuel efficiency, measuring the effect of some technologies (particularly aerodynamic improvements and low rolling resistance tyres) can be extremely challenging given the variability present in real world operating conditions. Some fleet operators pay to utilise controlled conditions at test facilities, however most cannot afford this.
Operators are strongly focused on reliability. New technologies and fuels can be seen as too risky.	Given the very competitive nature of the general industry, reliability is absolutely essential. While reducing fuel costs is a strong driver to invest in low emission technologies, this cannot be at the risk of introducing any reliability or operating issues.* The individual responsible for specifying fleet vehicles and equipment is often directly responsible for reliability issues, but in many cases only has indirect responsibility for fuel costs. As a result the 'safer' option of conventional diesel which is a reliable, known technology is often chosen. Operators cannot afford to risk worsening reliability and hence losing business / increasing costs.
The freight haulage sector often has low margins which limit scope for upfront investment.	Transport of goods by road is an extremely competitive industry, often with low operating margins. As a result many fleet operators do not have the available access to capital to invest in new technologies and fuels.
Any increased weight due to low emission technologies reduces payload.	Any technology which results in an increased vehicle weight in comparison to a conventional diesel alternative will reduce the maximum vehicle payload. For smaller (3.5 to 12 tonne vehicles) and for trucking of aggregates (where payment is commonly by tonne-km) this is particularly problematic.
Residual values for vehicles using new technologies and fuels are often low or unknown.	The generally conservative nature of the industry means that those investing in new technologies and fuels may have to risk lower residual values for their vehicles. Several interviewees highlighted the concern over uncertain residual values making it difficult to calculate the business case to invest. Many operators need to see a return on any investment within two years. Certainly returns must be achieved within the length of a contract or vehicle lease period. One interviewee highlighted that even fitting more unusual tyres (e.g. more fuel efficient single wide tyres) could adversely affect the residual value of a trailer.
Driver training and the use of telematics are generally felt to provide fuel savings at least as great as technological measures and with reduced cost and risk.	Many interviewees highlighted the benefits of driver training and feedback, particularly in conjunction with the use of telematics systems. Given limited time and finance this was often felt to be a more cost effective approach than investing in low emission technologies and fuels. Some operators have also saved fuel by reducing maximum vehicle speeds to 50mph.**

*One interviewee highlighted that some fleet operators over specify engine size to ensure reliability / longevity when treble shifting vehicles.
**One interviewee stated this had achieved a 4% reduction in fuel consumption while having a negligible impact on journey times.

Table 26: Details of barriers to dual fuel and dedicated gas vehicles

Dual fuel and dedicated gas vehicles	
Barrier	**Details**
High cost and lack of availability of gas refuelling infrastructure.	The biggest barrier to uptake of gas vehicles is the lack of existing refuelling infrastructure and the costs associated with installing new infrastructure (ranges from £250,000 to £2m were quoted compared to £17,000 for a standard diesel fuel tank and pump). There are currently less than 30 CNG/LNG refuelling stations across the UK in comparison with 8,700 public filling stations and many private facilities and shared fuel bunkers. Lack of access to gas refuelling can be a critical issue for those using dual fuel technologies as it leads to lower substitution rates and longer payback periods.
Upfront cost and limited availability of gas vehicles.	While dedicated gas engined vehicles are available, they are primarily offered at the smaller / lower GVW and the vehicle range is limited. There is no current offering for a dedicated gas 6x2 tractor unit (the most common format in the UK). Dedicated gas vehicle costs for a tractor unit can be £25-30,000 more than a diesel equivalent. Dual fuel variants are available for the larger, higher powered tractor units. The additional cost is approximately £25-30,000 and payback time is dependent on the achieved diesel to gas substitution rate.
Uncertainty over likely payback period.	Interviewees and survey respondents highlighted concerns about the likely payback period for dual fuel and dedicated gas vehicles. Interviewees were uncertain of what real-world fuel cost savings would be for their operations and particularly whether the lower gas fuel duty rates would be maintained. In addition there is insufficient data on gas vehicle resale values.
Concerns over reliability and manufacturer's warranty.	Dedicated gas engines have been available for many years, but in the past there were reliability problems. Much of this was associated with moisture in the gas used (likely due to low pressure gas being used from city centre gas holder sites). A further barrier for dual fuel is that only one vehicle manufacturer offers this within their own warranty and some fleet operators do not want to have to deal with multiple warranties.
Limited package space for gas tanks (particularly for EURO VI dual fuel).	Package space for gas storage tanks for dual fuel is increasingly limited with EURO VI vehicles (in particular for the popular 6x2 tractor unit option). EURO VI aftertreatment is typically packaged in the space that has previously been used for dual fuel gas tanks. Currently no OEMs are offering a EURO VI dual fuel vehicle, however this may be due to dedicating R&D resources on meeting EURO VI requirements. Dedicated natural gas vehicles have no alternative fuel option if unable to refuel on gas, so providing sufficient range is critical.
Concern over limited range for CNG.	For long haul operations, it is critical to have sufficient range. Currently in many cases an LNG dual fuel conversion is being specified. This may be at least partly due to the difficulty of packaging sufficient CNG tanks. However one interviewee stated that even 6x2 CNG conversions can allow a 450-500 mile range.
Difficulty in calculating and claiming CO_2 savings for gas vehicles.	Most operators looking to achieve CO_2e savings focus on 'tailpipe' numbers (some mentioned this was to avoid the risk of double counting). As a result some interviewees had been advised that dedicated gas engines would not offer a CO_2 emission reduction benefit compared to conventional diesel. This may be true on a tailpipe basis, but on well to wheel, dedicated gas engines can offer CO_2 savings, and when running on biomethane, offer greater savings than dual fuel.
Limited availability of biomethane.	Limited availability of biomethane (which offers much greater CO_2 savings) was also mentioned as a barrier. One landfill site is currently utilised to make liquid biomethane, but it is difficult to identify further sites as most landfill utilises methane for combined heat and power. The inability to claim 'credits' (Green Gas Certificates) for injection of biomethane into the gas grid which could then be 'cashed-in' to fuel vehicles from grid gas was cited as a potential reason not to invest in this technology.

Table 27: Details of barriers to aerodynamic improvements and reduced rolling resistance

Aerodynamic improvements and reduced rolling resistance	
Barrier	**Details**
Scepticism of real world benefits of aerodynamic measures and low rolling resistance tyres	Many fleet operators interviewed were sceptical of the real world fuel savings achievable from aerodynamic equipment. Some felt there would be no benefit unless operating speeds were 50mph or higher, others questioned whether the increased weight could make fuel consumption worse. Use of aerodynamic features other than cab deflectors on tractor units has low take-up, particularly for rigid vehicles. There was widespread scepticism of the benefits of low rolling resistance tyres too. It is difficult to get accurate back to back real world measurements of their impact on fuel economy. This is particularly true for tyres as whole life tests must be conducted.
Upfront costs of low rolling resistance tyres are higher	While data suggests that the fuel saving benefits would significantly outweigh any additional costs, many interviewees highlighted that low rolling resistance tyres are generally more expensive. The upfront cost is clear and tangible. The potential benefit is often less certain.
Concern of increased wear rates with low rolling resistance tyres	Many interviewees felt that low rolling resistance tyres wear out quicker than standard tyres. A tyre manufacturer said this may have been true of early low rolling resistance tyres but that the latest generation has very similar wear rates to standard tyres. UK operating conditions were felt by many interviewees to be harsher on tyre life than for continental Europe with more cornering and shorter journey lengths.
Difficulty ensuring correct adjustment of aerodynamic features	While cab deflectors are now fitted to nearly all tractor units, these are often poorly adjusted to suit the trailer (exacerbated by the wide range of trailer heights in use in the UK). One interviewee highlighted that automatic adjust variants often seize or malfunction.
Legislation on vehicle dimensions restricts aerodynamic improvements	European legislation governs the overall length of HGVs as well as other dimensions. In order to maximise payload space, the tractor unit of an articulated vehicle is flat fronted. Length limitations also restrict use of ‘boat-tails’ and ‘tapered ends’ for trailers.
Aerodynamic features can limit payload and be vulnerable to damage	Operational considerations such as maximising load capacity act as a barrier to more aerodynamic body or trailer shapes. It can be difficult to fully utilise the space of a teardrop shaped trailer and features such as tapered ends and boat-tails can restrict loading and unloading operations. Aerodynamic features can be vulnerable to damage. One interview felt that the savings from a trailer side skirt would not be sufficient to outweigh the cost if it had to be replaced. Others mentioned the fragility of fuel saving ‘Spraydown’ mud flaps.
Trailer owners and the rental sector do not pay for the fuel used	In many cases hauliers will be using their own tractor units to pull clients trailers for an agreed contract price. There is therefore little direct incentive for the trailer owner to fit fuel saving technologies. Equally for rental vehicles, where customers pay for the fuel, there is less incentive for the vehicle owner to fit fuel saving technology.
Worn tyres have lower rolling resistance which can mask the benefits of new low rolling resistance tyres	One particular issue is that worn tyres with lower tread depth naturally have lower rolling resistance. This can mask any fuel economy benefit when they are replaced with a set of brand new low rolling resistance tyres.

Aerodynamic improvements and reduced rolling resistance	
Barrier	**Details**
More than half of HGV tyres fitted are retreads (which are not covered by new tyre information provision requirements)	Due to the costs of HGV tyres the majority of vehicle operators will regroove and retread tyres before purchasing new tyres. This is not considered a problem and can equally well be done with low rolling resistance tyres. However these tyres may have lower rolling resistance than brand new low rolling resistance tyres. There is a further issue that retread tyres are not currently covered by the requirements for HGV tyre information provision which can help vehicle operators choose the lowest rolling resistance tyres.
UK legislation does not allow the use of ‘single wide tyres’ (lower weight / reduced rolling resistance) on drive axles of vehicles of 40 tonnes and over.	Unlike continental Europe, the UK does not allow use of ‘single wide tyres’ on the drive axles of vehicles of 40 tonnes and over. Use of these tyres can save approximately 120kg per driven axle as well as reducing rolling resistance.

Table 28: Details of barriers to hybrid and pure electric vehicles

Hybrid and pure electric vehicles	
Barrier	**Details**
High upfront cost of hybrid and pure electric options	Many interviewees had trialled both hybrid and pure electric vehicles, and several were very positive about their potential benefits. However the very high upfront costs and resulting long payback periods are the main barrier. It should be noted that these costs are decreasing and some recently launched smaller hybrid models have an on-cost of around £7-8,000 and may expect payback periods of around five years. However the typical on-cost for a larger 12 tonne hybrid might still be £35,000. For pure electric vehicles, the upfront cost can be two or three times that of a conventional vehicle.
Uncertainty over likely fuel cost savings	While there have been several successful trials of hybrid vehicles in urban and municipal fleets which have demonstrated 20-30% (or more) fuel savings, operators are still uncertain whether these results would be replicated in their operating conditions. Manufacturers also tend to demonstrate technology which achieves good results but can be unaffordable.
Concern over vehicle residual values and long payback periods	Hybrid electric and pure electric vehicles face a particular concern over residuals due to lack of confidence in battery lifetimes. A particular problem was highlighted for pure electric vehicles if the payback period is calculated to be longer than the potential battery life in which case payback may never be achieved.
Hybrid and pure electric vehicle reliability is critical	Concerns over reliability were highlighted by interviewees and in the survey as a particularly issue for hybrid and pure electric vehicles. Hybrid technology is seen as more complex and risky. It should be noted that for pure electric vehicles reliability is also crucial as they have low fuel costs but high depreciation costs which means total costs are almost as much when being repaired/serviced as when utilised.
Charging may require new grid connection	Recharging battery several electric heavy goods vehicles in one location may require an upgraded grid connection due to the current requirements.
Pure electric vehicles cannot be triple-shifted	The fact that pure electric vehicles require recharging also means that they cannot be triple-shifted, only managing a maximum of two shorter shifts.
Concerns over lack of range for pure electric vehicles	In survey results, concerns over the maximum range of pure electric vehicles were commonly raised. Many fleet operators are used to the flexibility of conventional diesel vehicles which can cover long distances easily even if this is not usually required.
Reduced payload	Payload reduction is a particular issue for pure electric and to a lesser extent hybrid electric vehicles due to the weight of their batteries.
Lack of marketing for hybrid and pure electric HGV vehicles	There is an impression that technologies such as hybrid and pure electric vehicles could be better publicised and marketed to vehicle operators. It is felt these technologies and their potential benefits are not sufficiently well highlighted.

Appendix 7 – Details of recommendations

Further details regarding the recommendations under the three key headings are provided.

Table 29: Details of switching to gas opportunities

Switching to gas	
Opportunities	**Details**
Set out a clear strategy for switching HGVs to gas.	Many interviewees expressed their desire for a clear lead from Government signalling that this is the desired direction for the future, to provide the confidence needed to make the substantial investments involved in switching to gas. Setting a clear strategy may also encourage vehicle manufacturers to develop and market a greater range of dedicated gas and dual fuel vehicles for the UK HGV fleet. The UK is fortunate to have UK companies leading the way in designing and installing innovative dual fuel engine technology, including Clean Air Power Ltd. and Hardstaff Group.
Guarantee a fuel duty differential between gas and diesel for a rolling 10 years.	A very effective way of providing confidence to invest in shifting HGVs to gas would be to guarantee the differential in duty between diesel and road fuel natural gas. Interviewees were clear that such a guarantee would need to be for a minimum of 10 years (on a rolling basis) in order to have confidence in the return on their investment particularly for refuelling infrastructure. In 2001 the German Government committed to keep natural gas duty rates low for a fixed 20 year period. This guarantee, combined with rapid development of a public CNG refuelling network, resulted in rapid growth in the use of gas powered vehicles with Germany now having the second largest fleet in Europe.[16] The largest fleet is in Italy, where the tax on CNG as a road fuel is less than 0.5% of the rate for Gasoline (on an energy basis).[17] Sweden has zero tax on biomethane as a road fuel, and has the largest use of biomethane in vehicles in Europe: 60% of all methane used in Swedish vehicles is biomethane.[18]
Continue to support creation of a gas refuelling infrastructure.	The TSB Low Carbon Truck Trial has proven successful in encouraging a number of applicants from industry to invest in a switch to gas. Interviewees highlighted that one of the most important aspects of this trial is its focus on creating new refuelling infrastructure. While the vehicles purchased will typically have a working life of perhaps 10 years, the refuelling infrastructure will provide a much longer term legacy. However the competition approach may result in a gas refuelling hub network being developed in a piecemeal way. It is important to create a coherent network which reflects the wider gas demand potential of the logistics sector. The TSB trial will also help to build confidence in the real-world cost savings available to vehicle operators through measurement, analysis and dissemination of results (as has been successfully done with the Green Bus Fund).
Encourage greater production and use of biomethane for transport.	By far the largest well to wheel CO_2e emission reductions from gas engines are achieved through the use of biomethane gas. The UK has the potential to significantly increase production of biomethane (see appendix 5). Policies relating to biomethane production and use should be reviewed to maximise CO_2 savings. One option is to allow those injecting biomethane into the gas grid to claim 'Green Gas Certificates' which can then be used when refuelling gas vehicles from the grid. Several interviewees expressed the view that official recognition of this way of reducing their transport CO_2 emissions would be important to provide the incentive needed to invest in gas technology and biomethane generation.
Encourage uptake of gas vehicles through incentives	Recognition of the air quality and noise reduction benefits of running on dedicated natural gas in urban areas could be provided through incentives in congestion charging and/or low emission zone schemes.

[16] NGVA Europe, *NGV Success stories – Germany*, available online at: http://www.ngvaeurope.eu/germany
[17] NGVA Europe, *NGV Success stories – Italy*, available online at: http://www.ngvaeurope.eu/italy
[18] NGVA Europe, *NGV Success stories – Sweden*, available online at: http://www.ngvaeurope.eu/sweden

Switching to gas	
Ensure methane emissions from gas vehicles are minimised.	Given that encouraging a switch to gas is intended to reduce CO_2e emissions, it is important to ensure tailpipe emissions of unburned methane from gas vehicles are minimised. Methane catalyst technology is available to do this however the catalysts have high precious metal loadings and are expensive. It is important that any initiatives to encourage switching to gas ensure that this issue is considered.

Table 30: Details of improving aerodynamics / rolling resistance opportunities

Improving aerodynamic efficiency / reducing rolling resistance	
Opportunities	**Details**
Creation of an accreditation scheme to provide independent test results for aerodynamic and rolling resistance improvements.	The biggest barrier to greater uptake of aerodynamic improvements is uncertainty regarding the likely fuel cost savings they will achieve. An independent test and accreditation scheme providing an indicated likely percentage fuel saving for aerodynamic equipment should help improve industry confidence and increase take-up. While it is accepted that laboratory and test track results may not be representative of all real world conditions, it should be possible to develop generic tests which will at least allow comparison of the relative results of different options. A scheme could perhaps be modelled on the successful Euro-NCAP crash safety ratings approach.
Offering free, independent "fleet health check" reviews to advise operators on the best technologies.	A scheme could be introduced to provide personalised advice on the most appropriate technologies, following a similar approach to the Energy Saving Trust's "Fleet Health Check" (currently only available for vehicles below 3.5 tonnes). The scheme would need to be operated using experienced professionals familiar with HGV operations and the suitability of aerodynamic and low rolling resistance options to specific requirements.
Reviewing legislation on vehicle dimensions to allow more aerodynamic designs.	Existing dimensions legislation can restrict the ability to optimise aerodynamic improvements. One example is the "2040 swing radius" regulation which limits the dimensions of aerodynamic 'bubble-fronted' trailers (particularly for double-decks – which are more efficient in terms of CO_2 per tkm or m^3km). A derogation to allow aerodynamic extensions at the top of the trailer to exceed this swing radius limit would allow greater fuel savings to be made.
Working with the HGV industry to raise awareness and understanding of the benefits	There are already some initiatives to raise awareness of fuel saving and CO_2 emissions reduction possibilities within the industry however scepticism remains regarding the benefits of aerodynamics and low rolling resistance tyres. Use of these options could be specifically monitored through the DfT's Freight Carbon Review survey. The effectiveness of using seminars and case studies or alternative approaches can then be measured.
Request that retread tyres are included in HGV tyre information provision requirements.	European legislation requires that information on rolling resistance of HGV tyres is made available from 1st November 2012. However this does not currently extend to retreads. Given that more than half the tyres fitted to HGVs are retreads, the UK Government should support the inclusion of retread tyres when the legislation is reviewed in 2016. In addition the UK Government could examine the potential to require that HGV tyres sold are at least grade "D" rolling resistance or better.
Consider revising UK legislation to allow use of single wide tyres on driven axles at 40 tonnes and over.	Single wide tyres offer both weight savings and lower rolling resistance, and may reduce overall tyre costs for vehicle operators. They can also help reduce aerodynamic drag by reducing overall vehicle frontal area through lower profile tyres. However current UK legislation does not permit their use on drive axles of any vehicle over 40 tonnes. This is not the case in continental Europe and the USA. The evidence base for the UK's current position should be reviewed.

Table 31: Details of supporting hybrid and pure electric vehicles details

Supporting uptake of hybrid and pure electric vehicles	
Opportunities	**Details**
Expansion of the OLEV plug-in van grant to include vehicles up to 12 tonnes or creation of a 'Green Lorry Fund'.	The primary barrier for hybrid and particularly pure electric vehicles is the higher upfront cost. Extending the plug-in van grant to include vehicles up to 12 tonnes would help to improve the business case for investing in these vehicles. Criteria would need to be developed to allow these vehicles to be included and if possible these should relate to their CO_2 emissions per unit of work done rather than distance. Alternatively the Green Bus Fund model could be used, requiring applicants to publish data on savings generated, helping to build confidence in these new technologies.
Encourage local authorities to provide exemptions / allowances.	The business case for adopting hybrid and pure electric technologies is very much stronger if they provide additional savings or opportunities. Examples which could be considered include discounts on the London Congestion Charge for hybrid HGVs recognising their lower emissions and noise levels, allowances for night-time deliveries / refuse collection in noise sensitive areas if able to use an 'engine-off' mode; use of 'engine-off' mode to comply with low-emission zones etc.

Table 32: Details of supporting uptake of all technologies and fuels opportunities

Supporting uptake of all low emission HGV technologies and fuels	
Opportunities	**Details**
Derogation to allow higher payloads for low emission HGVs	An issue for all low emission technologies is the additional weight resulting in a reduced payload. This is a particular issue in the 3.5-12 tonne range. Creating a derogation which would allow a low emission vehicle to operate at the same payload as its conventional diesel equivalent (provided this is still below the vehicle's safe design weight) would directly address this barrier to take-up.
Enhanced Capital Allowances	Allowing use of enhanced capital allowances for purchase of low emission HGV technologies and fuels would reduce upfront costs to business while being potentially less costly to Government than providing grants or funding for trials.
Public procurement of low emission HGV options through contracts	The Directive on the Promotion of Clean and Energy Efficient Road Transport Vehicles[19] places a mandatory requirement on public bodies to include energy and environmental impacts in their considerations when they are procuring road transport vehicles. This can be a useful way of increasing 'market pull' for new technologies and fuels, creating a visible commitment and increasing industry confidence.
Differentiated charging for HGV road use according to air pollution	The amended Eurovignette Directive (2011/76/EU)[20] relating to the charging of HGVs for use of major European motorways requires that Member States include air pollution in any charging structure from 2013. The Department for Transport has already stated "we are looking to apply different charges for vehicles with different environmental performance as soon as practical after the introduction of charging" in its charging heavy goods vehicles consultation.[21] These charges should provide an incentive for the use of technologies which reduce not only air pollution, but also CO_2 emissions.
Encouraging increased use of telematics systems.	While use of telematics systems was not a technological option for consideration in this study, interviewees repeatedly highlighted the benefits of these systems in monitoring and reducing fuel consumption. Fleet operators often stated they are a more cost effective means to reduce fuel use and CO_2 emissions than other technologies and fuels. Greater roll-out of telematics systems would directly reduce HGV CO_2 emissions and enable more accurate assessment of the benefits when trialling further new low emission technologies and fuels.

19 http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:120:0005:0012:EN:PDF
20 http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2011:269:0001:0016:EN:PDF
21 DfT, Charging Heavy Goods Vehicles - A consultation document, January 2012. http://assets.dft.gov.uk/consultations/dft-2012-03/main-document.pdf

Appendix 8 – Online survey results

As well as the 23 interviews conducted for this study, a web-based survey was also used to gather a wider range of opinions. The survey received 50 responses, 34 of which completed all questions.

Responses were received from a wide range of organisation types:

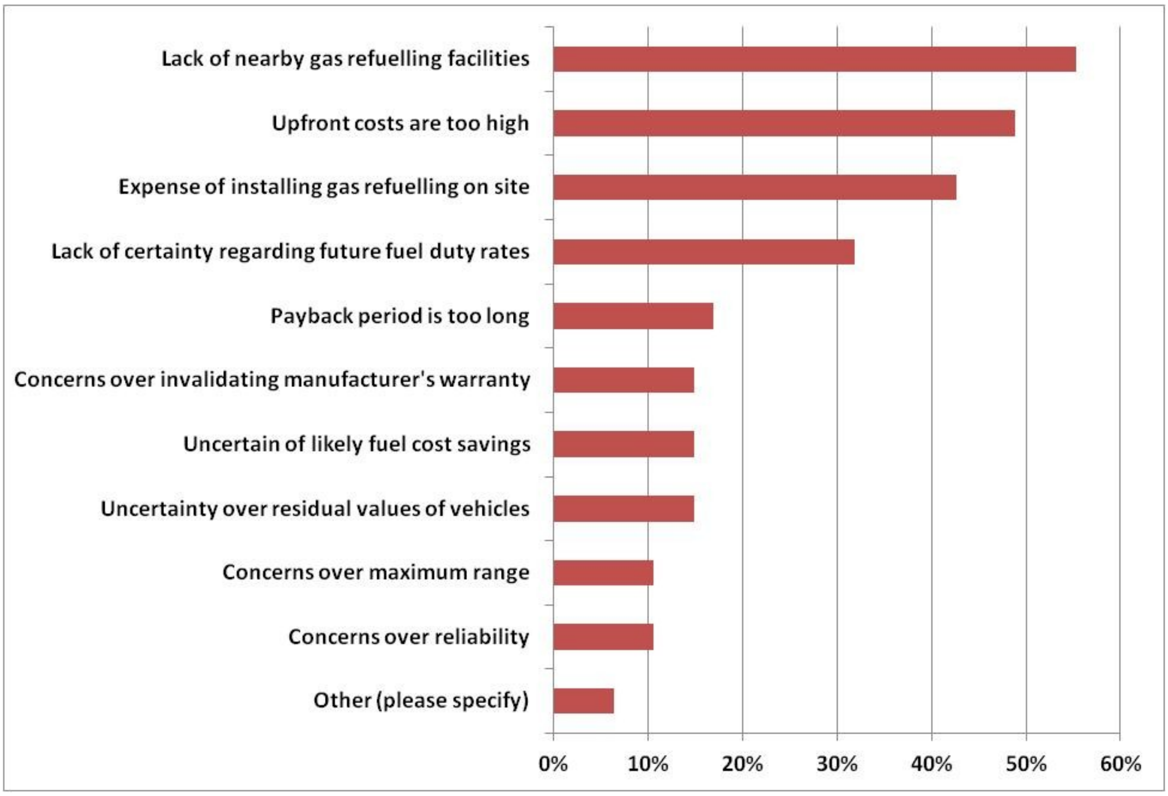
- Freight hauliers
- Private fleet operators
- Local authorities
- Vehicle manufacturers
- Technology suppliers
- Consultants

27 of the respondents completed a question asking which vehicle duty cycle description best described the most common usage of their vehicles. Of these:

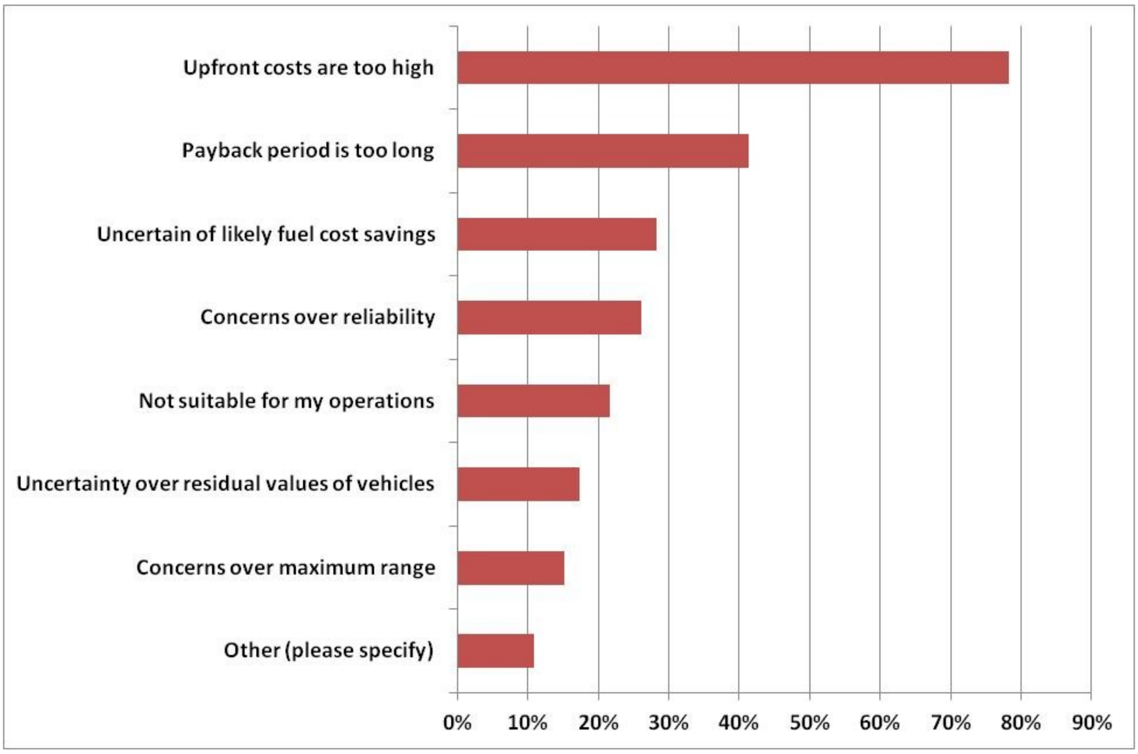
- 37 % long haul (10 respondents)
- 26 % regional delivery (7 respondents)
- 22 % municipal utility (6 respondents)
- 15 % urban delivery (4 respondents)

The questions and responses are shown here:

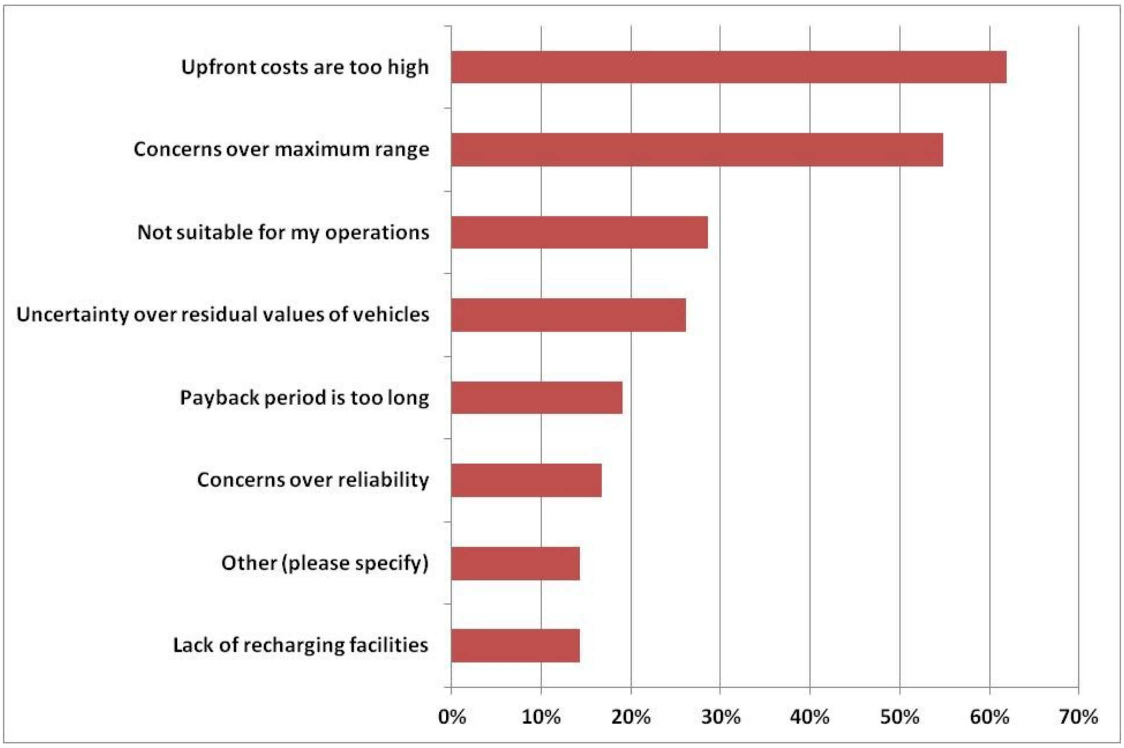
1. What are the main reasons for not purchasing dual fuel or dedicated natural gas vehicles? (Please select up to 3 responses).



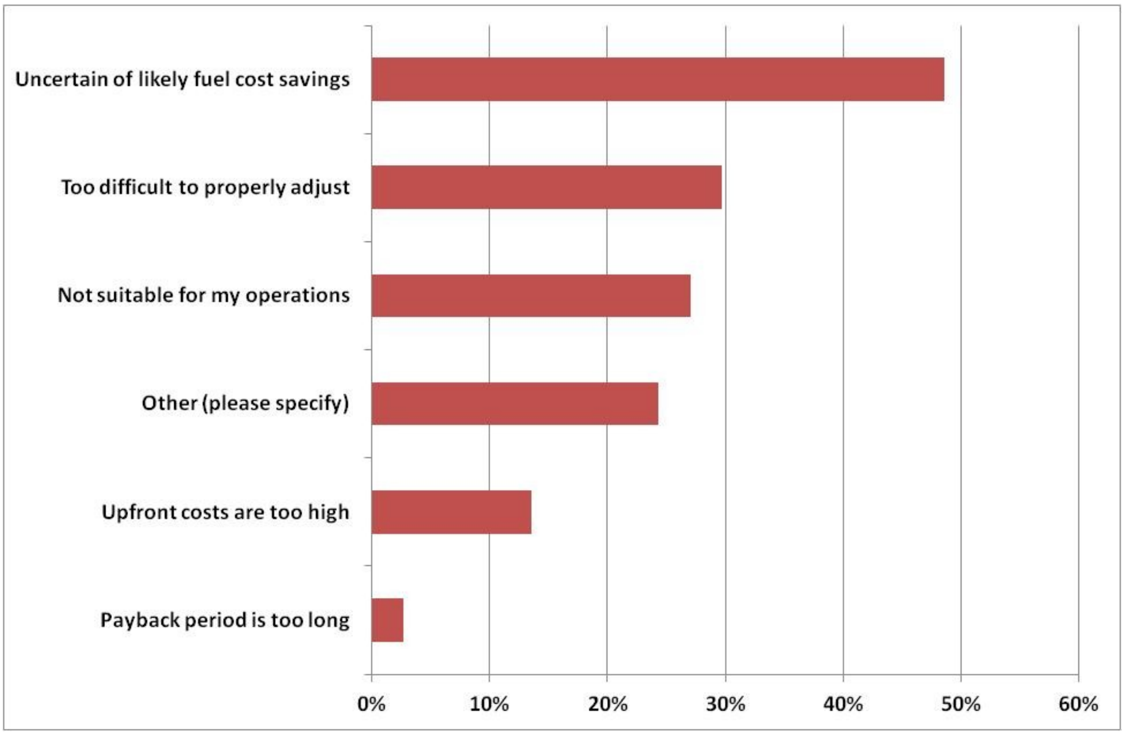
2. What are the main reasons for not purchasing hybrid vehicles? (Please select up to 3 responses).



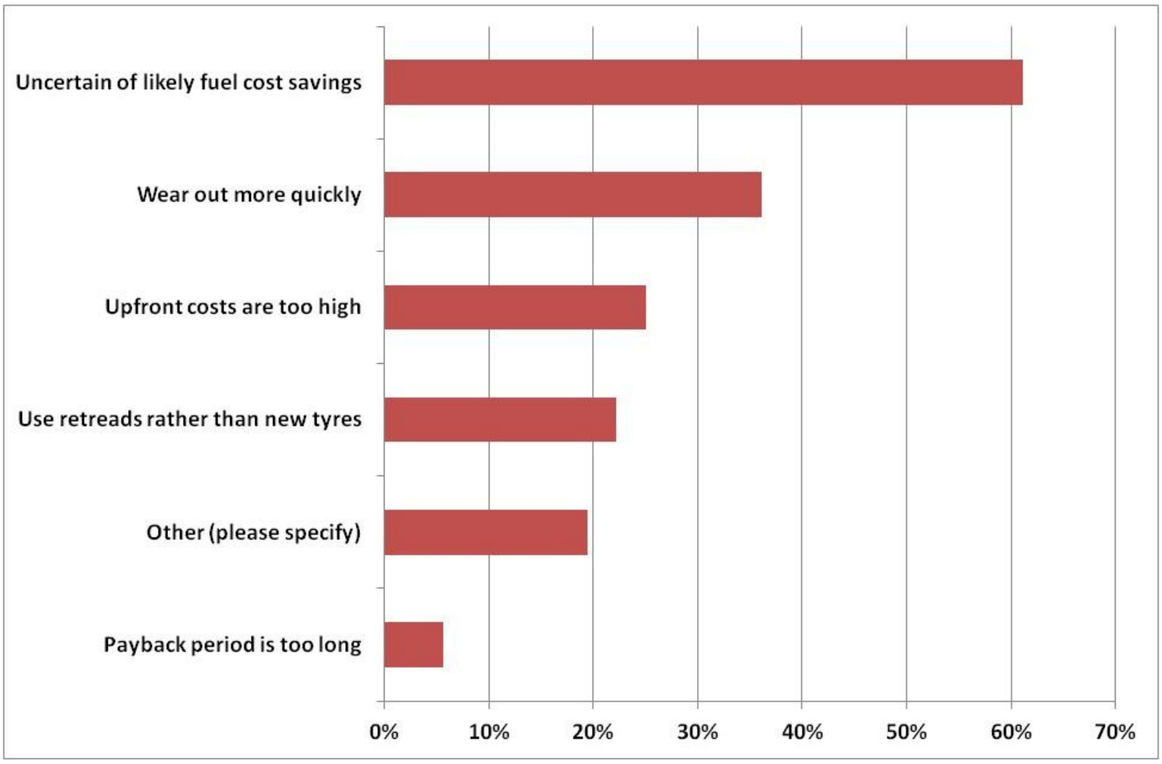
3. What are the main reasons for not purchasing pure electric vehicles? (Please select up to 3 responses).



4. What are the main reasons for not purchasing or using aerodynamic devices, for example cab roof deflectors; cab collars; aerodynamic trailers? (Please select up to 3 responses).



5. What are the main reasons for not purchasing low rolling resistance tyres? (Please select up to 3 responses).



6. What would encourage you to purchase dual fuel or dedicated gas vehicles? (Please rank in order, 1=best option)

1	Grants to assist with cost of vehicles
2	Grants to assist with cost of installing refuelling facilities
3	Guarantee of fuel duty difference between gas and diesel for next seven years
4	Enhanced capital allowance scheme for purchase of gas vehicles or refuelling infrastructure
5	Greater numbers of refuelling stations
6	Weight of gas tanks being excluded from payload
7	Exemption from the London Congestion Charge

7. What would encourage you to purchase hybrid or electric vehicles? (Please rank in order, 1=best option)

1	Grants to assist with cost of vehicles
2	Grants to assist with cost of installing recharging facilities
3	Guarantee of difference between electricity and diesel costs for next seven years
4	Enhanced capital allowance scheme for purchase of hybrid or electric vehicles or recharging infrastructure
5	Greater numbers of recharging stations
6	Weight of hybrid systems / batteries being excluded from payload
7	Exemption from the London Congestion Charge

8. What would encourage you to purchase aerodynamic aids or low rolling resistance tyres? (Please rank in order, 1=best option)

1	Example case studies from other operators
2	Personal fleet review service to advise on suitability for your fleet
3	Data from manufacturers showing fuel saving benefits
4	Data from Government showing fuel saving benefits
5	Low rolling resistance tyres available as retread tyres

Appendix 9 – Recommended further work

The research for this study involved examining the potential for CO_2e reduction of all possible low emission HGV technology and duty cycle combinations. This has enabled those with the largest apparent potential for reduction to be selected. As noted, the calculations were primarily based on the use of the 2012 Defra/DECC GHG Conversion Factors.[22]

However in the course of this study some areas were identified in which there was uncertainty regarding the potential for CO_2e savings. These were beyond the scope of the study and it is therefore recommended that these are explored in further work, although this is not intended to limit the further work of the Task Force on the opportunities identified in Chapter 6. There are two main areas recommended for further research:

1. The availability and supply of biomethane for the HGV sector

Biomethane has been identified as having the largest CO_2e reduction potential of the technologies and fuels examined in this study in the medium term. However a key question is how much biomethane will be available for use in HGVs in the short to medium term.

A paper published by National Grid in 2009 examined the potential for renewable gas (or biogas) in the UK. This estimated 2009 production of renewable gas at 1.4 billion cubic metres, equating to 14 TWh of energy per year. The paper estimated this would increase to between 56-182 TWh per year by 2020 ("baseline" and "stretch" scenarios). By comparison, the central estimate for energy consumption of the UK HGV fleet for this study was 72 TWh per year. These figures suggest that theoretically, if all this biomethane was available to power UK HGVs and the activity levels remained the same, then by 2020 UK biomethane could meet 67-219% of HGV energy needs (assuming the use of spark-ignition gas engines with an energy requirement 15% higher than diesel and overall HGV). However this ignores the fact that the biomethane being produced currently is already being used for other purposes and the National Grid figures assume that a significant proportion of biomethane will be produced through the growth of the energy crop, miscanthus. Work previously conducted by AEA / NERA estimated that the 'stretch' figure for biomethane that would be available to be injected into the gas grid in 2020 would be just 6TWh, or just 7% of current HGV energy requirements.

Stakeholders interviewed for this study also had differing views regarding the appropriate way of supplying biomethane for road transport use. Currently there appear to be two different approaches:

a) Larger scale biomethane production, followed by liquefaction and distribution by tanker lorries to key strategic refuelling locations primarily serving long-haul HGVs. In the case that there is insufficient liquid biomethane to meet demand, it may be mixed with LNG. The resulting CO_2e reductions will be dependent on the ratio of biomethane to LNG.

b) Encouraging distributed biomethane production and injection into the gas grid for distribution to CNG refuelling facilities for transport operators. In order to claim transport CO_2e reduction, organisations which inject biomethane into the grid and then refuel vehicles using grid gas would need "green gas certificates" to validate the savings. These certificates would operate in a similar way to green tariffs for electricity, where the green energy enters the grid and the same amount is assumed to be green when it is consumed from the grid by the green tariff holder.

Research is needed to clarify the CO_2e savings associated with these two approaches and the business case for each. It should be noted that both approaches may be needed given that many stakeholders interviewed for this study felt that LNG (and liquid biomethane) was

[22] Defra / DECC, 2012 Guidelines to Defra / DECC's GHG Conversion Factors for Company Reporting. Available online at: www.defra.gov.uk/publications/2012/05/30/pb13773-2012-ghg-conversion/

more appropriate for long haul given the reduced storage space requirements for a given range compared to CNG, and that different operators would have different requirements regarding the location of refuelling facilities. However it should also be noted that some interviewees are running long haul operations on CNG and have found space to package CNG storage tanks on a dual fuel tractor unit sufficient to provide a 450 mile range.

It is therefore recommended that further research is conducted to establish:

- What quantities of biomethane are likely to be produced in the UK in the near to mid future?
- How much of this production might be available for the HGV sector?
- What are the most appropriate routes for biomethane to be supplied to HGVs?
- What can be done to encourage greater production and use of biomethane in the HGV sector?

2. Examining the greenhouse gas savings potential of different sources of gas for use in HGVs

Stakeholders interviewed for this study had differing opinions regarding the CO_2e emissions associated with different types and sources of gas. The calculations for the study used standard figures from the 2012 Defra/DECC GHG Conversion Factors; however these figures may not be representative of some lifecycle pathways.

Equally if switching HGVs to gas leads to an increase in overall demand for methane, then it may be important to consider how this increased demand will be met – including calculating the resulting 'marginal' WTW CO_2e emissions. The UK currently imports LNG which is then re-gasified and injected into the national gas grid. If it is expected that LNG imports would be the primary route to meet increased demand due to the HGV sector then it will be important to understand the CO_2e emissions implications of this, whether the LNG is injected into the grid or distributed as LNG.

A policy to promote greater use of gas in the HGV sector will also need to consider the likely future mix of sources for UK gas supply in the medium-long term. Currently there is much discussion regarding the availability and environmental impacts of shale gas in the UK. Given that service lifetimes of gas vehicles may be 10 years and refuelling infrastructure significantly longer, it will be important to assess what the potential impact of the use of shale gas in HGVs would be on CO_2e emissions reduction. AEA has already conducted research into the climate impacts of shale gas for the European Commission. This found that emissions are slightly higher than those for conventional pipeline gas, but are lower than for imported LNG.[23]

It is therefore recommended that further research is conducted to establish:

- What are the key factors affecting potential greenhouse gas savings from running UK HGVs on gas?
- What are the best estimates for the 'well to tank' CO_2e emissions of biomethane (gaseous and liquid) / CNG / LNG / shale gas in the UK?
- How are these estimates affected by consideration of 'marginal' rather than 'average' well to tank emissions?

[23] http://ec.europa.eu/clima/policies/eccp/docs/120815_final_report_en.pdf

RICARDO-AEA

The Gemini Building
Fermi Avenue
Harwell
Didcot
Oxfordshire
OX11 0QR

Tel: 0870 190 1900
Fax: 0870 190 6318

www.ricardo-aea.com