MANSTON DCO: SUBMISSION FOR DEADLINE 4
COMMENTS ON APPLICANT'S RESPONSE TO ExA's FIRST WRITTEN QUESTIONS (Climate Change) SUBMITTED BY FIVE10TWELVE LTD

Dated: 8 MARCH 2019

FOREWORD

- Our comments have been highlighted in yellow for ease of identification

- We respectfully request the questions in red below the comments are considered by the ExA and/or asked of Applicant as appropriate

- As a general comment, we would like to take this opportunity to point out that the Applicant does not appear to have provided any independent evidence to support any of the statements it has made throughout its responses in the Climate Change section, unless such underlying third party documents have been specifically referred to by the ExA in its original questions, (e.g. Aviation National Policy Statements, ("NPS"). **Any and all footnotes in this document** are therefore provided by Five10Twelve Ltd as independent evidence to support our comments

- Comment or question (or lack of) does not mean agreement with or support for Applicant.

FIVE10TWELVE LTD STATEMENT REGARDING CONFLICT OF INTEREST AND IMPARTIALITY

For the avoidance of any doubt and in the interests of full transparency, we hereby confirm that neither Five10Twelve Ltd or its subsidiary, Love Ramsgate Ltd, or any of our Directors have any interests, either financial or otherwise, in the Manston site or any other rival development beyond those of a local business and local residents with strong concerns regarding the devastating impacts of the proposed development on the local area, economy, environment and population.Neither Five10Twelve Ltd, or Love Ramsgate Ltd, or any of our directors have accepted any payments or any other form of compensation or inducements for presenting this or any of our other submissions or representations to the ExA. Any offers or suggestions of such from any party will be refused and immediately reported to the ExA.

GENERAL COMMENTS

A. Sustainable Aviation is committed to delivering a cleaner future for [its] industry. [The] goal is to **reduce net CO2 emissions by 50%** by 2050 while accommodating a doubling of demand and play [its] part, alongside national and local government, in **improving air quality** around airport[1].

B. Applicant has speculated that there is a market for dedicated freight for perishables such as food.

C. Transport of food by air has the **highest CO2 emissions per tonne**[2].

D. There has been a move away from air freight to transport of food by air either as belly freight or by sea. For example: the decrease in air food kilometres in 2008 was driven by a reduction of the proportions of fresh grapes imported by air from the USA and South Africa, with more being transported by sea[3]. This trend has continued, tomatoes are transported almost entirely in [sea] containers as are certain fresh produce like capsicum, fresh fish, lettuce and pineapples, along with tomatoes.[4] As well as avocados, bananas and asparagus[5] and blueberries and lychees[6] for example again by sea.

E. Nevertheless, Applicant has speculated that it believes there is a market for dedicated freight for perishables as well as pharmaceuticals (we further evidence elsewhere this is against typical market practice of shipment as belly freight).

F. To service this market warehouses Applicant will need **temperature controlled storage facilities**[7] **and large warehouses** which utilise a lot of energy. In addition to being located in a region that is noted for its East Kent micro-climate.

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[1] https://www.sustainableaviation.co.uk/cleaner
[2] 10 January 2012, DEFRA, Food Transport Indicators to 2010 Page 8 **CC-001**
[3] 10 January 2012, DEFRA, Food Transport Indicators to 2010 Page 8 **CC-001**
[4] 3 March 2015 Perishables modal shift fuelled by technology AirCargo News **CC-002**
[5] MAERSK The Fruits of Your Labour **CC-003**
[6] How Blueberries are Transported Around the World **CC-004**
[7] DHL Temperature Controlled Logistics **CC-005**

G. Heavy goods vehicles (HGVs) are currently estimated to account for around **17%[8] of UK GHG emissions from road transport and around 21%[9] of road transport NOx emission**s, while making up just 5% of vehicle miles[10] .

H. Applicant is solely dependent on road transport for freight, fuel tankers, passengers and workers. Passenger and worker's access to Bus services and Rail travel are limited in frequency, destinations, operational hours and are expensive modes of transport relative to salary take home pay and low cost passenger carrier price points. Adding the cost of travel both in time and in money to a low cost carrier ticket will make it a relatively expensive ticket and for workers it will mean up 2-3 hours of daily salary will be spent on daily travel.

I. Applicant has **not provided a budget line** within its Capital Expenditure for the project as a whole at F.1.6 **REP3-187 to move to rail operations for freight or fuel movements.**

J. Applicant **has not provided a budget line** within its Capital Expenditure for the project as a whole at F.1.6 **REP3-187** to **improve access to rail and bus services for passengers and workers**.

K. By using countryside (Northern Grass) Applicant's Proposal is contrary to Objective 2 of the Department for Environment: Food and Rural Affairs single developmental plan updated 23 May 2018. In particular objectives: 2.1, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7, 2.8, 2.9, 2.10.

L. The Independent Transport Commission report: The sustainability of UK Aviation: Trends in the mitigation of noise and emissions states:
"Traditionally, freight has been carried in the bellies of large passenger aircraft, particularly those operating in and out of hub airports (as these offer opportunities for onward connections and therefore economies of scale). This is a highly efficient means of transporting freight, as it is on-board flights that are already carrying revenue passengers and therefore the marginal cost of transporting the freight is extremely low. The use of dedicated freighters is not necessarily inefficient in itself if the loads are high for both the outbound and return legs (demand for freight can often be mono-directional), however these aircraft are usually either conversions of older passenger aircraft or the last aircraft from a given aircraft production line. This means that the rates of technology implementation for

[8] https://www.gov.uk/government/statistical-data-sets/tsgb03 - 2014 data, calculated from Table TSGB0306 (ENV0202)
[9] https://www.gov.uk/government/statistical-data-sets/tsgb03 - 2014 data, calculated from Table TSGB0308 (ENV0301)
[10] Department of Transport, 2017, Freight Carbon Review, Moving Britain Ahead Page 7 Paragraph 3 **CC-006**

dedicated freighter airlines are among the lowest in the industry[55].

M. The Independent Transport Commission report: The sustainability of UK Aviation: Trends in the mitigation of noise and emissions states that:
"Sustainability for air freight is most likely to be achieved through the use of existing passenger airline hub networks supplemented by large-scale freight aggregators with dedicated aircraft fleets linking logistics hubs. This will minimise the need for extra flights, ensure economies of scale from larger aircraft, and utilise the most modern and efficient technologies available[56]." Applicant does not meet this threshold.

Questions

Given the above, we respectfully ask the ExA to ask Applicant to identify and quantify worst case environmental factors in relation to:

1.

1) energy consumption for each of its large temperature controlled storage facilities..
2) energy consumption for each of the other large warehouses.
3) energy consumption for night time use of aviation facilities.
4) sole dependency on poor/ medium road surface access by HGVs, fuel tankers, passengers and workers for the lifetime of the development.

2. Further, we respectfully ask the ExA to determine whether Applicant sits positively within the goals of sustainable aviation given the its high energy consumption, sole dependency on road surface access, limited target markets and lack of an existing passenger airline hub network, dedicated aircraft fleets and linking logistic hubs.

3. We note that Applicant has inserted the words at **REP 3-196**:

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[11] Peter Hind and RDC Aviation, March 2016, The Sustainability of UK Aviation: Trends in the mitigation of noise and emissions (Independent Transport Commission) Para 4.23. **CC-007**

[12] Peter Hind and RDC Aviation, March 2016, The Sustainability of UK Aviation: Trends in the mitigation of noise and emissions (Independent Transport Commission) Para 4.24. **CC-007**

"The airport will be subject to a total annual transport movement limit of **26,468**".

4. We make the following comments - a) as there is no means to enforce this 'cap' it is purely aspirational; b) Applicant works are proposed for actual capacity of **83,220** ATMs; c) the Environmental statement has been prepared for 17,170 ATMS.

5. The aspirational cap is **150%** more flights and traffic and cumulative effects than what has been assessed within the Environmental Statement and consulted upon (albeit inadequately). The actual capacity cap is **480**% more more flights and traffic than what has been assessed within the Environmental Statement and cumulative effects (albeit inadequately).

6. We respectfully request the ExA to determine that the Environmental Statement is insufficient.

Ref No.	Respondent	Question
CC.1 Climate Change		
CC.1.1	The Applicant	**UK Climate Projections** Detailed consideration must be given to the range of potential impacts of climate change using the latest UK Climate Projections available at the time, and to ensuring any Environmental Statement (ES) that is prepared identifies appropriate mitigation or adaptation measures. This should cover the estimated lifetime of the new infrastructure. A new set of UK Climate Projections have become available after the preparation of the ES. The next generation of UK climate projections, UKCP18, was released in November 2018.

Ref No.	Respondent	Question
		Provide an assessment of how this next generation of UK climate projections would affect the conclusions of Chapter 16 of the ES [APP-034].
		Applicant's Response: The new generation of UK climate projections would not affect the conclusions of Chapter 16 of the Environmental Statement (ES) [APP-034]. The new generation of UK climate change projections for the UK, UKCP18, was released between the submission of the ES and the beginning of the DCO examination. The predecessor of UKCP18, UKCP09, was used to complete a preliminary climate change impact assessment during the development of the ES but was not developed into a full assessment for Chapter 16. The rationale for this is given in paragraph 16.5.5 of the ES [APP-034], which is still valid. UKCP18 provides a new set of projections and tools to consider climate change impacts in risk assessments and adaptation plans. However, the trends and key messages in UKCP18 are largely consistent with those in UKCP09. UKCP18 will be used to update the climate change risk assessment post-DCO approval, should consent be granted, which will in-turn inform the development of the Climate Change Adaptation Strategy (see Question CC.1.3). Given that a detailed examination using UKCP09 was not deemed necessary for Chapter 16 of the ES [APP-034], there will be no change to the conclusions of the chapter.
CC.1.2	The Applicant	**Climate Change Assessment Chapter 16 of ES [APP-034]** **Demonstrate that there are no critical features of infrastructure design which may be seriously affected by more radical changes to the climate beyond those projected in the latest set of UK Climate Projections ie UKCP18.**
		Applicant's Response:

Ref No.	Respondent	Question
		Given the level of design, the relevant impacts that need to consider more radical changes in climate all relate to flooding. High-end but still plausible climate change projections, known as H++ scenarios, have been developed by the Met Office to sensitivity test for climate change impacts (see Appendix CC.1.2 in TR020002/D3/FWQ/Appendices). There is no flood risk from rivers on site, so using the H++ scenario of 120% uplift in flows does not increase risk to infrastructure design or receptors. There are no H++ scenarios for surface water flooding so this has not been tested. However, the infiltration capacity of the underlying chalk and the elevation of the site above rivers means the risk remains very low. The drainage strategy is to discharge surface water to sea, and the proposed drainage strategy addresses any potential issues associated with surface flooding Given the elevation of the site (~54m), the Proposed Development site is not at threat of sea level rise even in radical changes to the climate beyond those in UKCP18. The H++ scenario for sea level rise across the UK is 1.9m. Given the steep fall from the site to Pegwell Bay, and the large diameter of the pipe, there is no potential for the water drained from site to be backed up onto site or to have a limited flow into Pegwell Bay during storm surges with the increased sea levels. As stated in paragraph 16.5.5 of the ES [APP-034], a full assessment will be undertaken to inform a Climate Change Adaptation Strategy following DCO approval, when detailed design information is available. Radical changes in climate are being considered in the Climate Change Adaptation Strategy, a framework version for which will be provided at Deadline 4. The Climate Change Adaptation Strategy will be continually developed throughout detailed design stages post-DCO approval.
CC.1.3	The Applicant	**Climate Change Adaptation Section 16.5 and paragraph 16.6.7 of ES [APP-034]** **What is the current status of the Applicant's Climate Change Adaptation Strategy?**

Ref No.	Respondent	Question
		Point to where in its Masterplan [APP-079] the Climate Change Adaptation Strategy features.
		Applicant's Response: i. The Applicant is continually developing its Climate Change Adaptation Strategy, a framework version of which will be provided at Deadline 4. A preliminary climate change impact assessment has been carried out using UKCP09, which was used to inform the climate change statements in the ES (APP-034). The assessment will be updated to use UKCP18 as the Climate Change Adaptation Strategy develops. A full version of the Climate Change Adaptation Strategy will be provided following DCO approval, as stated in paragraph 16.5.6 of the ES [APP-034]. The strategy ensures that climate change is embedded as a design principle throughout detailed design, construction and operation of the Proposed Development, and is of the correct level of detail for the stage of design. ii. Climate change was considered in the development of the Masterplan [APP-079]. Climate change allowances have been used in the development of the flood risk assessment and drainage design (see Table 8.14 in the ES [APP-033]), so are implicitly reflected in the Masterplan layout. Measures to build the resilience of Manston Airport for all other impacts will be continually embedded into the design process through the developing Climate Change Adaptation Strategy. Operational measures to ensure resilience are considered in the developing Climate Change Adaptation Strategy, a framework version of which will be provided at Deadline 4.

Department for Environment Food and Rural Affairs

10 January 2012

Food Transport Indicators to 2010

Four key indicators measure the environmental and social impact of food transport for UK consumers: urban food kilometres, HGV food kilometres, air food kilometres and CO_2 emissions from food transport. Transport of exported food is not covered.

This statistics notice updates the four indicators with data for 2010 and revises previous data.

Key Messages

- No strong evidence of change in the impacts of food transport
- Despite rises in 3 of the 4 indicators, the underlying trends may not have changed
  - Increase in Indicator 1 is not statistically significant
  - Increase in Indicator 2 is thought to be a re-adjustment broadly in line with changes to other national economic outputs measures
  - Increase in feed imports from USA due to short term demand is unlikely to be sustained

Indicator	Rationale when indicators were first developed in 2005
Urban food km in the UK to 2010, split by car, LGV, HGV. (Proxy for urban road congestion)	Urban food km account for most of the accident and congestion costs. The impact of air pollution is also much higher in urban areas. An alternative proxy for congestion and accident costs would be car food km.
HGV food km to 2010, split by HGV transport in the UK and HGV transport overseas. (Proxy for infrastructure costs)	This covers HGV transport both in the UK and overseas. HGV transport is responsible for the majority of infrastructure, noise and air pollution costs.
Air food km to 2010	Air freight of food was rapidly growing and has a high environmental impact relative to other modes of transport.
Total CO_2 emissions from food transport to 2010	Emissions of CO_2 from the transport sector are highly significant and were growing. This indicator includes estimated CO_2 from transport fuel use both in the UK and other countries. Currently excludes CO_2 and other greenhouse gas emissions from refrigeration during transport.

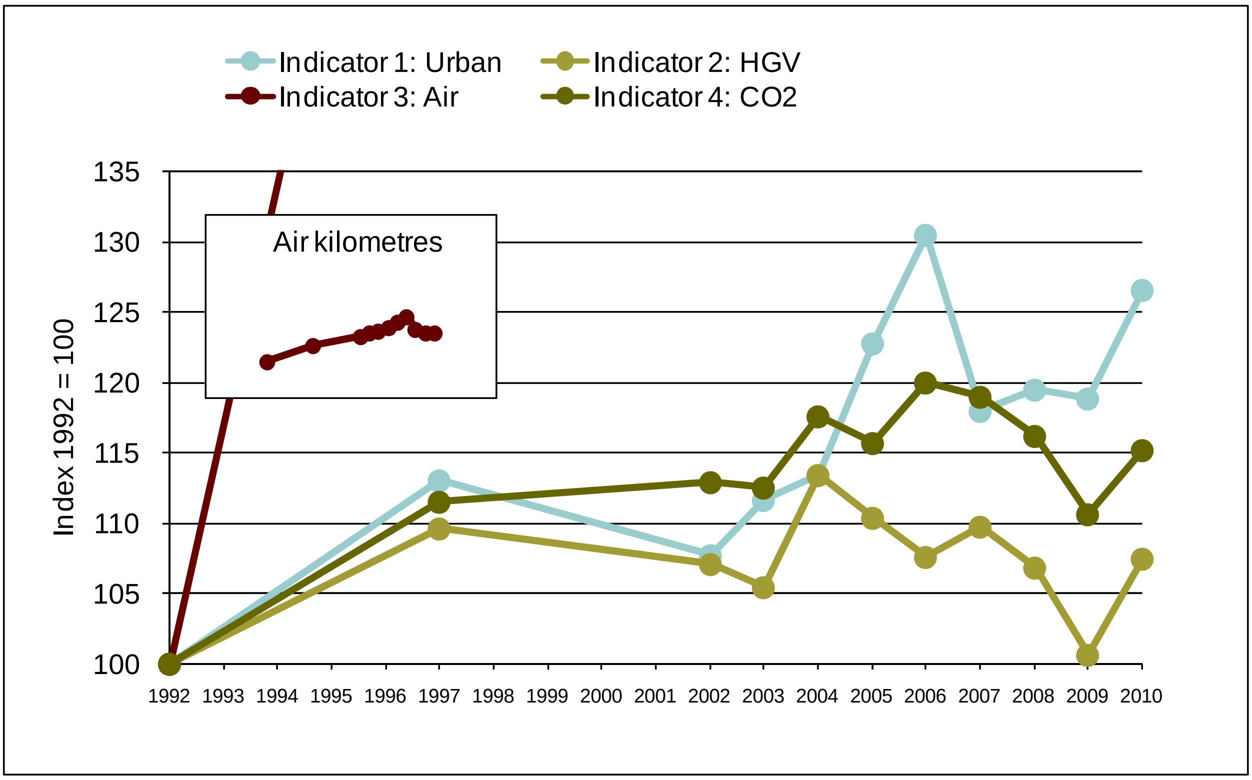
Enquiries to: Jim Holding, Department for Environment, Food and Rural Affairs, Room 146, Foss House, Kings Pool, 1 - 2 Peasholme Green, York YO1 7PX. Tel: ++ 44 (0)1904 455069, email:jim.holding@defra.gsi.gov.uk

Indicators overview

Indicators of the External Impact of Food Transport for UK Consumers

	Indicator 1		Indicator 2		Indicator 3		Indicator 4	
	UK Urban food kilometres (millions)	Index 1992 = 100	HGV food kilometres (millions)	Index 1992 = 100	Air food kilometres (millions)	Index 1992 = 100	Carbon dioxide emissions (kilotonnes)	Index 1992 = 100
1992	10,620	100	6,467	100	10	100	13,359	100
1997	12,009	113	7,092	110	18	186	14,893	111
2002	11,438	108	6,927	107	23	236	15,081	113
2003	11,862	112	6,819	105	25	263	15,028	112
2004	12,043	113	7,334	113	26	269	15,702	118
2005	13,040	123	7,140	110	28	288	15,448	116
2006	13,855	130	6,960	108	31	321	16,024	120
2007	12,524	118	7,099	110	34	351	15,897	119
2008	12,688	119	6,908	107	27	285	15,522	116
2009	12,620	119	6,505	101	26	265	14,775	111
2010	13,433	126	6,953	108	25	262	15,382	115
Change 2009/10	6.4%		6.9%		-1.4%		4.1%	
Change 2006/10	-3.0%		-0.1%		-18.4%		-4.0%	

(a) The drops in 2002 and 2007 coincide with changes to the way the National Travel Survey was run. The direction of the change is considered to be reliable however the scale of the change may be less reliable. In 2002 there was a change of contractor to run the survey. In 2007 there was a redesign of the survey diary.



- Indicator 1: UK urban food kilometres increased by 6.4 per cent from 2009 to 2010. The increase in this indicator is not expected to be statistically significant as the change in car travel is not. There is little evidence of a clear trend in the data.

- Indicator 2: HGV food kilometres increased by 6.9 per cent in 2010 broadly in line with other national economic outputs measures. A downward trend in HGV food kilometres since 2004 is apparent despite the increase in 2010.

- Indicator 3: Air food kilometres have fallen after a period of rapid growth up to 2007, with some evidence that this is stabilising at about the levels in 2003.

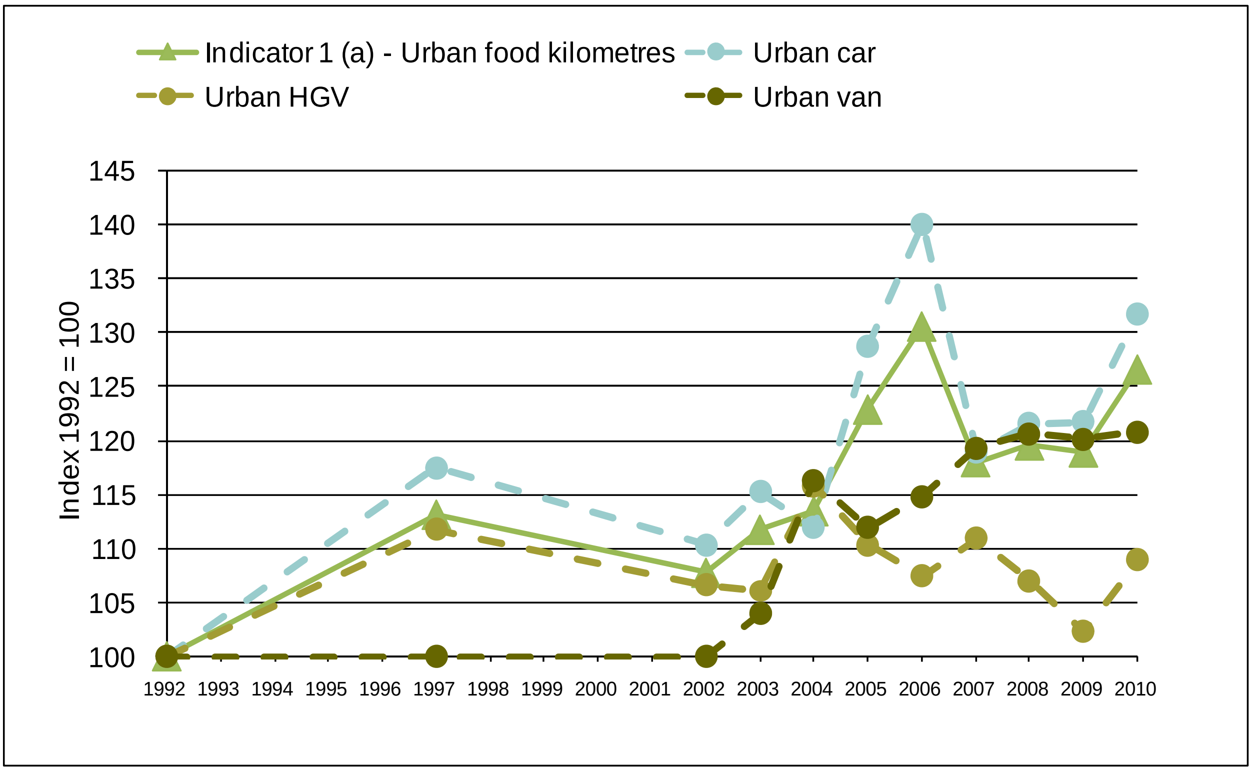
- Indicator 4: Despite an increase in 2010, indicator 4 remains 4 per cent lower than it was in 2006 suggesting an underlying downward trend remains.

Indicator 1. UK urban food transport (proxy for urban road congestion)

Urban food kilometres are a proxy for the impact that food transport has on road congestion. Urban food kilometres include car shopping journeys, light goods vehicles (vans) transporting food and heavy goods vehicles transporting food. No allowance is made for the time of day of the transport.

	Indicator 1 (a) Index 1992 = 100	Urban food kilometres (millions)	of which car (a)	of which HGV	of which LGV(b)
1992	100	10,620	6,998	1,389	2,234
1997	113	12,009	8,223	1,552	2,234
2002	108	11,438	7,723	1,481	2,234
2003	112	11,862	8,066	1,473	2,323
2004	113	12,043	7,835	1,608	2,600
2005	123	13,040	9,007	1,532	2,501
2006	130	13,855	9,797	1,492	2,565
2007	118	12,524	8,317	1,541	2,667
2008	119	12,688	8,506	1,487	2,695
2009	119	12,620	8,514	1,421	2,685
2010	126	13,433	9,221	1,513	2,699
Change 2009/10	6.4%	6.4%	8.3%	6.5%	0.5%
Change 2006/10	-3.0%	-3.0%	-5.9%	1.4%	5.2%

(a) The drops in 2002 and 2007 coincide with changes to the way the National Travel Survey was run. The direction of the change is considered to be reliable however the scale of the change may be less reliable. In 2002 there was a change of contractor to run the survey. In 2007 there was a redesign of the survey diary.
(b) Data for food transport by van is not available for years prior to 2003. An estimation for these years is based on a 1992/93 study by the Department for Transport. For more information see Annex 1 of the report by AEA Technology Environment, http://www.defra.gov.uk/statistics/files/defra-stats-foodfarm-food-transport-foodmiles-050715.pdf



- UK urban food kilometres increased by 6.4per cent from 2009 to 2010. This increase was mostly due to an increase in car travel which accounts for about 90 per cent of this indicator. The increase in this indicator is not expected to be statistically significant as the change in car travel is not.

- There is little evidence of a clear trend in the data. In making this interpretation it is relevant to note that the scale of the drops in urban car food kilometres in 2002 and 2007 are less reliable since these coincide with moderate changes in the way the National Travel Survey was run.

- The NTS is primarily designed to track long-term development of trends and so care should be taken when drawing conclusions from short-term changes, in particular year-on-year changes. Typically, year on year changes of above 10 per cent can be considered to be statistically significant.

- HGV figures have been revised down slightly following revisions to the Department for Transport's (DfT) vehicle licensing data for 2006 to 2009 – see revisions section on page 11.

- The LGV data for 1992, 1997 and 2002 is estimated based on a 1992/93 study by DfT. There has been no survey of LGV activity which collects information on commodities since 2005[1]. 2006 to 2010 figures are based on 2005 figures and adjusted to reflect changes in LGV population. LGV data was revised down by around 1 per cent from 2006 to 2009 due to revisions to DfTs vehicle licensing data.

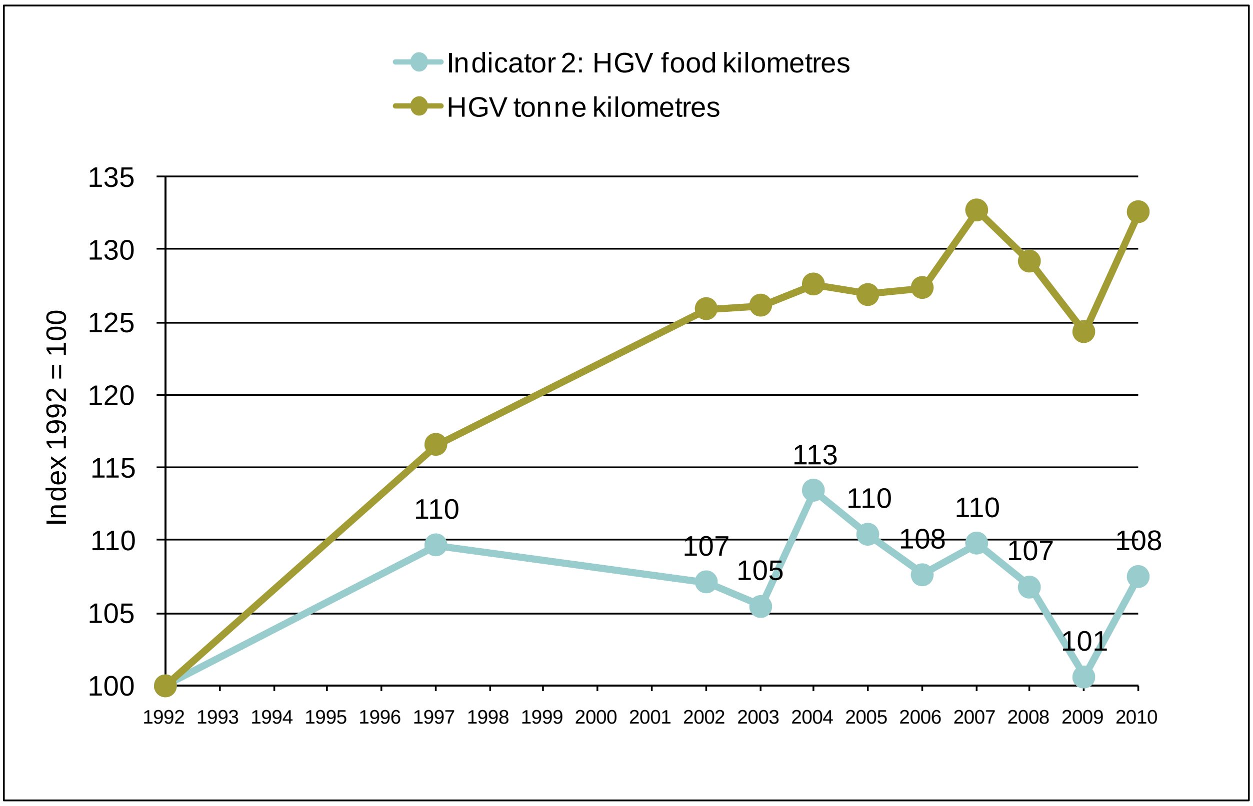
- Whilst there have been dramatic changes in food prices and also GDP over the last 5 years, this does not appear to have translated into changes in urban food kilometres.

[1] There was a van survey conducted in 2008, but this did not collect commodity information.

Indicator 2. HGV transport of food for UK consumption (proxy for infrastructure costs)

Vehicle kilometres covered by HGV transport of food are a proxy for the impact of food transport on infrastructure damage to the road network. The indicator includes all HGV transport in the supply of food for UK consumption, but excludes journeys exporting food. HGV tonne kilometres are shown alongside the indicator to show the extent to which the amount of food transported by HGV has changed without having an effect on the indicator.

	Indicator 2 Index 1992 = 100	**HGV food kilometres (millions)** [(b)]	**of which overseas**	**of which within UK**	**HGV tonne kilometres (millions)**
1992	100	6,467	1,837	4,631	47,506
1997	110	7,092	1,917	5,174	55,377
2002	107	6,927	1,988	4,940	59,815
2003	105	6,819	2,043	4,776	59,922
2004	113	7,334	2,163	5,171	60,601
2005	110	7,140	2,186	4,954	60,285
2006	108	6,960	2,092	4,868	60,515
2007	110	7,099	2,068	5,031	63,024
2008	107	6,908	2,071	4,837	61,354
2009	101	6,505	1,882	4,623	59,041
2010	108	6,953	2,030	4,922	62,960
Change 2009/10	6.9%	6.9%	7.9%	6.5%	6.6%
Change 2006/10	-0.1%	-0.1%	-3.0%	1.1%	4.0%



- HGV food kilometres increased by 6.9 per cent in 2010, after a 6.0 per cent decrease between 2008 and 2009. The indicator remains 5.2 per cent lower than its level in 2004.

- HGV food kilometres can be split into UK kilometres and overseas kilometres. UK HGV food kilometres saw a 6.5 per cent increase in 2010 following a 4 per cent decline in 2009. Overseas HGV food kilometres rose by 7.9 per cent in 2010 and cover 28 per cent of all HGV food kilometres.

- A downward trend in HGV food kilometres since 2004 is apparent despite an increase in 2010.

- HGV tonne kilometres, a measure of the amount of food moved by HGV, increased by 6.6 per cent in 2010, returning to their 2007 level.

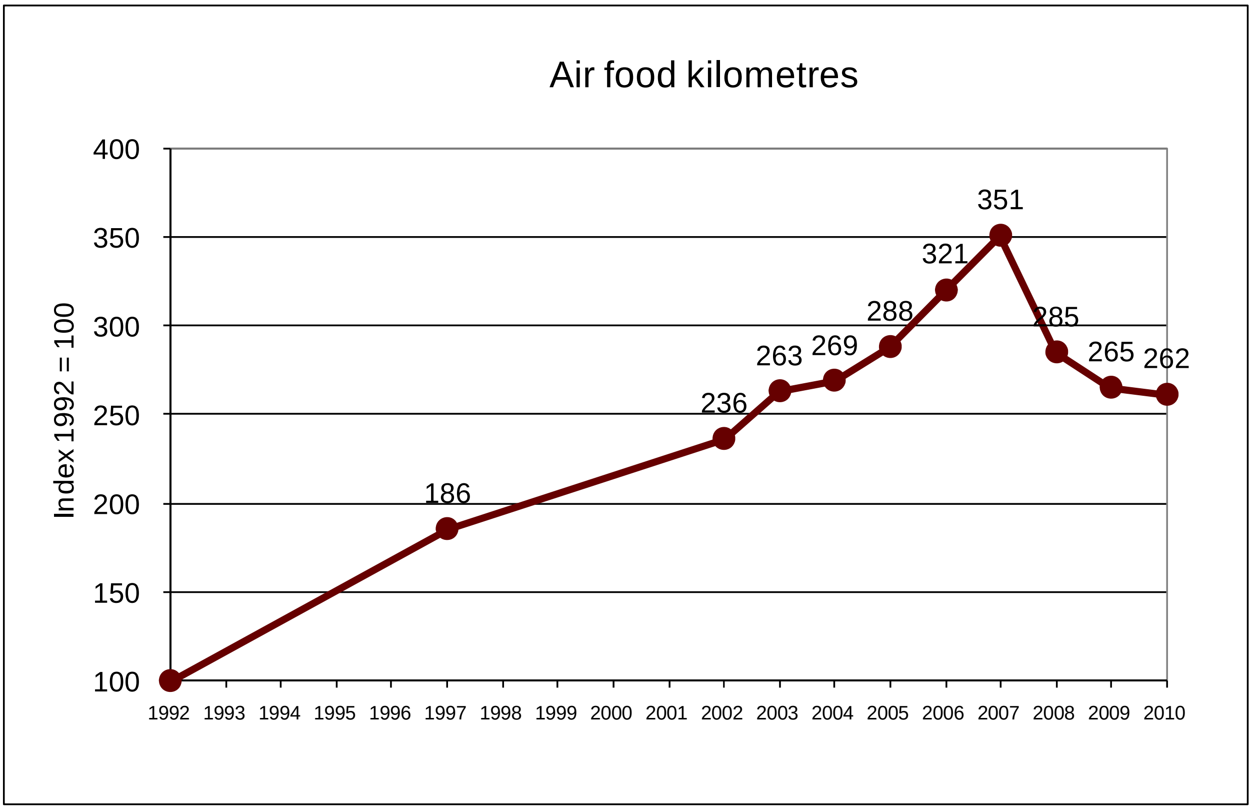
- A combined measure of uncertainty for the full indicator is not available. However, considering all the sources and available information on sampling errors, the increase in Indicator 2 from 2009 to 2010 is overall expected to be statistically significant; the downward trend over the period 2004 to 2010 is also expected to be genuine.

- Between 2007 and 2009, the amount of HGV food kilometres and HGV tonne kilometres decreased by 8.4 per cent and 6.3 per cent respectively before rising by 6.9 and 6.6 per cent in 2010. In recent years, these trends in the amount of goods moved by road have been broadly in line with other national economic outputs measures such as manufacturing and construction output and to a lesser extent GDP.

- A rise of 2 per cent in the volume of all food imports increased the external impacts of food transport in 2010. The majority of this rise can be attributed to increases in imports of animal feed compounds and their ingredients (such as soya meal and brewing waste) from the USA. The extra demand for these products was a result of shortages of winter forage stocks as well as high cereals and oilseed prices in 2010, necessitating increased use of compounds by UK livestock farmers. The milder winter and settling down of prices from harvest 2011 should mean demand for extra compounds is overall lower in 2011.

Indicator 3. Air freight of food

Transport of food by air has the highest CO_2 emissions per tonne, and has been the fastest growing mode. Although air freight of food accounts for only 1 per cent of food tonne kilometres and 0.1 per cent of vehicle kilometres, it produces 12 per cent of the food transport CO_2 equivalent emissions.

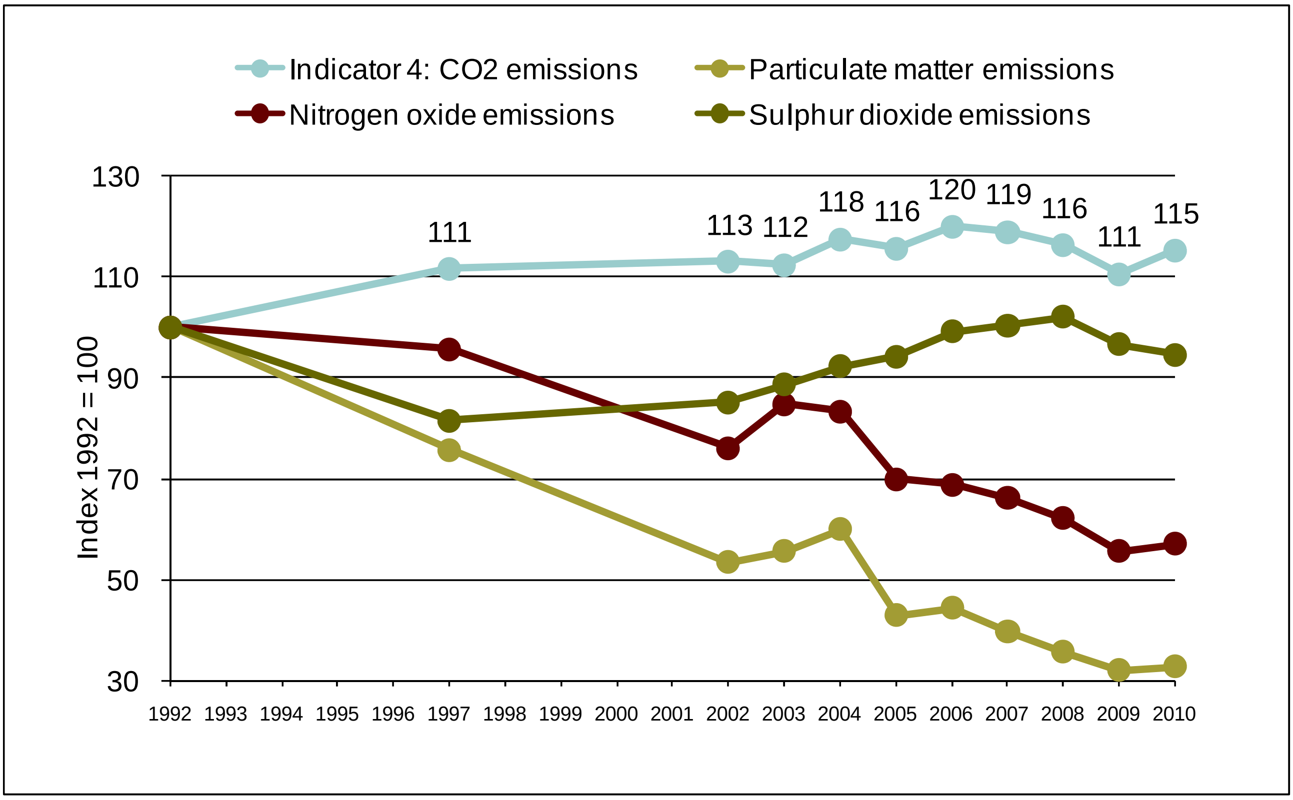


- Food transport by air experienced the most rapid growth of any mode between 1992 and 2007, with air kilometres more than tripling.
- Since 2007 air food kilometres have decreased to around 2003/2004 levels, with a 19 per cent decrease in 2008, a 7 per cent decrease in 2009 and a 1 per cent decrease in 2010.
- The decrease in air food kilometres in 2008 was driven by a reduction of the proportions of fresh grapes imported by air from the USA and South Africa, with more being transported by sea. A reduction in the imported tonnage of air freighted fresh green beans from Kenya also contributed to the decrease.
- Air freight of food has the highest environmental impact per tonne of any mode and in 2010 accounted for 12 per cent of CO_2 emissions from food transport.

Indicator 4. Total CO_2 emissions from food transport

Around 9 per cent of Greenhouse Gas (GHG) emissions in the UK food chain are attributed to commercial transportation of food for UK consumption (based on estimates across the food chain in 2007). This indicator also includes emissions from household food shopping trips.

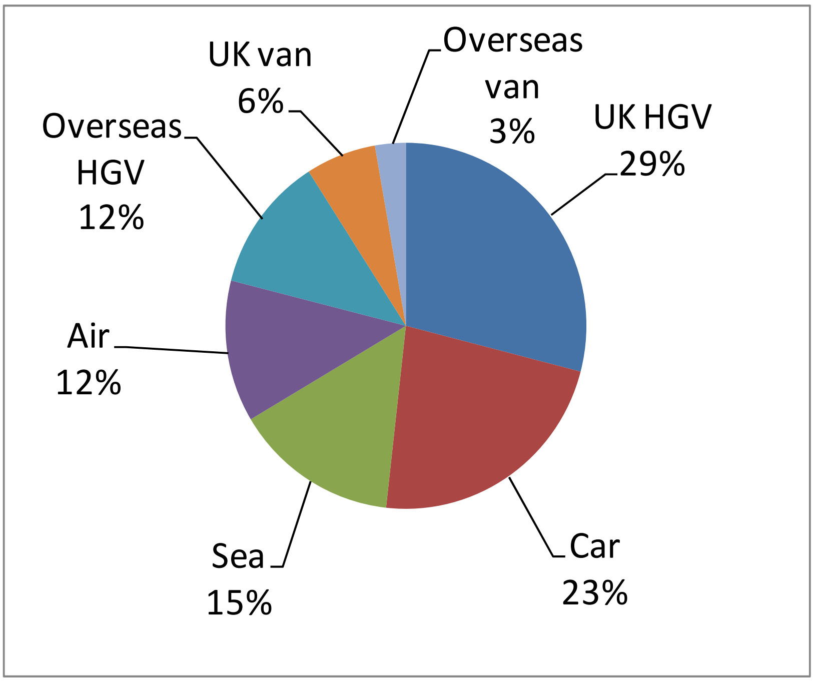
emissions in kilotonnes	Indicator 4 Index 1992 = 100	Carbon dioxide emissions (CO2)	Particulate matter (PM10)	Nitrogen oxides (NOx)	Sulphur dioxide (SO2)
1992	100	13,359	7	158	41
1997	111	14,893	6	151	33
2002	113	15,081	4	120	35
2003	112	15,028	4	134	36
2004	118	15,702	4	132	38
2005	116	15,448	3	111	38
2006	120	16,024	3	109	40
2007	119	15,897	3	105	41
2008	116	15,522	3	98	42
2009	111	14,775	2	88	39
2010	115	15,382	2	90	38
Change 2009/10	4.1%	4.1%	1.9%	2.5%	-2.2%
Change 2006/10	-4.0%	-4.0%	-26.3%	-17.1%	-4.6%



- Emissions of CO_2 from food transport, including emissions from overseas transport, increased by 4 per cent in 2010 following a decrease of 5 per cent in 2009.

- Despite an increase in 2010, indicator 4 remains 4 per cent lower than it was in 2006 suggesting an underlying downward trend remains.

- In 2010, UK HGV food kilometres contributed the most to CO_2 emissions. UK HGV accounted for 29 per cent of the emissions, car for 23 per cent, sea for 15 per cent, air for 12 per cent and overseas HGV 12 per cent.



- In 2010, 99 per cent of food imports travelled by sea compared with less than 1 per cent by air. However, air transport of food accounts for 12 per cent of CO_2 emissions.

- Emissions of PM_{10} and NO_x from food transport have decreased significantly since 1992 with the introduction of European emission standards for road vehicles. In 2010 emissions of all pollutants apart from SO_2 increased.

Revisions

Since the previous publication of the indicators in March 2011, revisions have been made to the HGV and emissions data. Full details are given in the note on method and assumptions which accompanies this publication. The changes are:

- Figures for activity by UK registered HGVs in the UK for 2006-2009 have been revised downwards as a result of revisions to DfT's vehicle licensing data. These reduced the licensed vehicle stock figures and resulted in a decrease in the HGV population of about 3.5 per cent. These revisions have resulted in changes to Indicator 2 and small changes to Indicator 1 and Indicator 4. For more information on the revisions to vehicle licensing data, see note 2.e. on page 4 of http://assets.dft.gov.uk/statistics/releases/road-freight-statistics-2010/notes-and-definitions.pdf

- Indicator 4 has been revised downwards due mainly to reductions in HGV kilometres as mentioned above but also the use of higher quality emissions factors for 2009. Revisions to the emissions factors account for around half of the change in 2009.

Indicators of the External Impact of Food Transport for UK Consumers		2004	2005	2006	2007	2008	2009
Indicator 1							
UK Urban food kilometres	2011 publication	12,043	13,040	13,939	12,611	12,799	12,731
	Revised	12,043	13,040	13,855	12,524	12,688	12,620
	Change	0.0%	0.0%	-0.6%	-0.7%	-0.9%	-0.9%
Indicator 2							
HGV food kilometres	2011 publication	7,330	7,135	7,136	7,271	7,137	6,746
	Revised	7,334	7,140	6,960	7,099	6,908	6,505
	Change	0.1%	0.1%	-2.5%	-2.4%	-3.2%	-3.6%
of which within UK	2011 publication	5,171	4,954	5,033	5,200	5,063	4,867
	Revised	5,171	4,954	4,868	5,031	4,837	4,623
	Change	0.0%	0.0%	-3.3%	-3.3%	-4.5%	-5.0%
of which overseas	2011 publication	2,160	2,180	2,103	2,070	2,073	1,879
	Revised	2,163	2,186	2,092	2,068	2,071	1,882
	Change	0.2%	0.3%	-0.5%	-0.1%	-0.1%	0.2%
Indicator 3							
Air food kilometres	No revisions						
Indicator 4							
CO_2 emissions	2011 publication	15,697	15,556	16,299	16,177	15,616	14,976
	Revised	15,702	15,448	16,024	15,897	15,522	14,775
	Change	0.0%	-0.7%	-1.7%	-1.7%	-0.6%	-1.3%

Uses of the indicators

The indicators are used by Defra and the Food and Drink Federation to monitor progress towards reductions in the external impacts of the food chain (they were used to track progress towards the Food Industry Sustainability Strategy target for the food chain to reduce its external impacts by 20% by 2012 compared to 2002). The Institute of Grocery Distributors (IGD) Efficient Consumer Response UK Sustainable Distribution Initiative aims to save 80 million HGV miles over the period 2010-12 in the grocery sector.

Indicators 1 and 2 feature in theme 2 of the Food Strategy "Ensuring a resilient, profitable and competitive food system" in terms of congestion and infrastructure costs of transport (Food Transport).

Indicator 4 is incorporated into Defra's overarching estimates of greenhouse gas emissions from the UK food supply chain (2007). In 2007 this showed that food transport accounted for 9 per cent of food chain emissions.

Reliability of the indicators

In general the trends revealed by the indicators are reliable but individual year on year changes are subject to sampling errors. Sampling errors may be as much as 5 per cent, therefore we can only detect year on year changes above 10 per cent. Non-sampling errors occur as well but are difficult to quantify. A summary of sampling and non-sampling errors for each of the indicators is given in the methodological note which accompanies this notice.

Two cases of non-sampling errors are visible in the indicators:

a. Indicator 1, food shopping trips by car. The drops in 2002 and 2007 coincide with changes to the way the National Travel Survey was run. In 2002 there was a change of contractor to run the survey and a substantial increase in the sample size. In 2007 a redesigned survey diary was introduced for respondents to record their car journeys resulting in a drop in short shopping trips by car, although it is likely that some of the decrease is genuine.

b. Indicator 2, HGV kilometres. There is a small spike apparent in 2004 which coincides with and is partly explained by an improved method to estimate the amount of empty running. For both 2003 and 2004 the estimates are the best available, although the reliability of the apparent rise in HGV kilometres between 2003 and 2004 is low.

Although there are both sampling errors and non-sampling errors in the data the trends revealed by the indicators detailed in this notice are considered reliable.

Glossary

Tonne kilometres	The distance travelled in kilometres multiplied by the weight in tonnes for each foodstuff. For example, a load of 12 tonnes transported 100 kilometres represents 1200 tonne kilometres.
Vehicle kilometres	The sum of the distances travelled by each vehicle carrying food regardless of the amount carried.
HGV	Heavy Goods Vehicle. In the Continuing Survey of Road Goods Transport for Great Britain and Northern Ireland, these are defined as vehicles of more than 3.5 tonnes gross plated weight, but excluding certain special categories such as recovery vehicles and mobile cranes that are heavy vehicles but do not carry freight.
LGV	Light goods vehicle. These are defined as vehicles not exceeding 3.5 tonnes gross vehicle weight in the light goods taxation class with van body types according to DVLA records
Urban roads	Urban roads are major and minor roads within an urban area with a population of 10,000 or more.
Overseas	Ireland is counted as overseas.

Notes for editors

1) The food transport indicators and a methodology were originally proposed in the report "The Validity of Food Miles as an Indicator of Sustainable Development" by AEA Technology Environment, published on the Defra website in July 2005.
2) The report concluded that the major external cost was in terms of road congestion and that a single figure of total number of vehicle kilometres transporting food was too simplistic.
3) The four food transport indicators are updated periodically by Defra.
4) The food transport indicators are included in the 'Indicators for a sustainable food system' which provide evidence to track progress of Food 2030
5) The four indicators were included in the Food Industry Sustainability Strategy as key performance indicators.
6) An associated note on method and assumptions describes the data sources, how the data is combined and clarifies the important assumptions.
7) Most of the data is sourced from National Statistics published by the Department for Transport and HM Revenue and Customs. Information on other data sources is detailed in the note on method and assumptions

Perishables modal shift fuelled by technology

03 / 03 / 2015

NEW technology in controlled-atmosphere containers (CAC), such as Maersk Container Industry's (MCI) Star Cool CA product line, has the potential to further accelerate the modal shift in the transportation of perishables, a report reveals.

The technology's ability to slow down the ripening process potentially opens up ocean transport as a viable alternative to air cargo on some of the longer trade routes, observes Derek Brand, maritime advisor for research company Seabury and author of the report.

"Whereas previously some fresh foods could only be transported in [sea] containers for short or medium-length voyages, controlled-atmosphere containers remove this limitation," he argues. "Even on some trade routes that are already within range for regular reefer containers, controlled-atmosphere technology could still improve the status quo by extending shelf life."

A decade ago, tomatoes were just as likely to be transported by air as in a reefer container. "Today, tomatoes are transported almost entirely in [sea] containers. The same holds true for numerous other perishable

We care for the fruits of your labour

We move more than half a million containers loaded with fruits and vegetables every year. We're talking about the fruits of your labour – literally – and we take our role in your supply chain very seriously.

As experts in shipping fruit and vegetables, we know that your cargo is both precious and perishable. Whether you are shipping avocados, citrus, grapes or plums, we will make sure that your goods arrive in peak condition – whatever their destination.

FIND YOUR LOCAL OFFICE

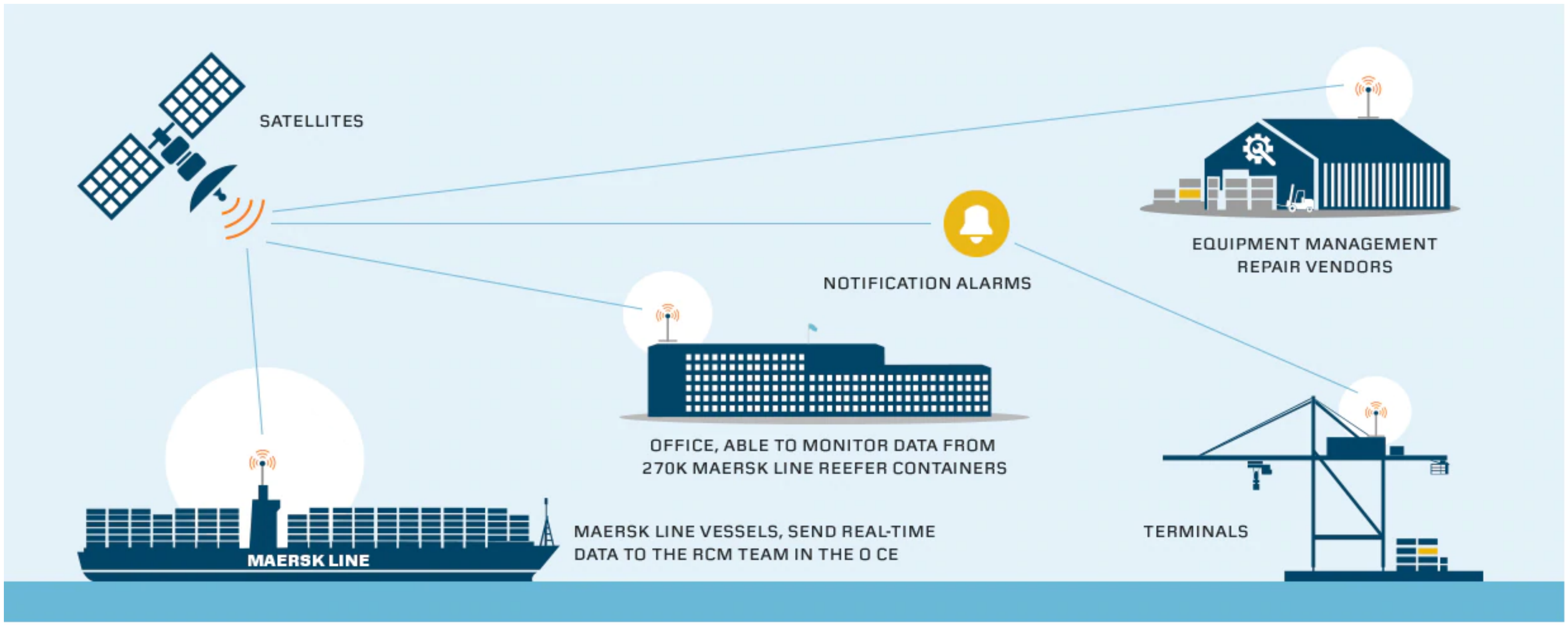
FIND A PRICE

Unique cold chain transparency with Remote Container Management (RCM)

To improve the visibility of your cold chain, we have developed a platform that provides you with full access to your reefer performance data.

Thanks to this unique innovation, you are able to make better and more informed decisions regarding your reefer cargo and optimise your supply chain based on the data – enabling you to deliver your promise to your customers.

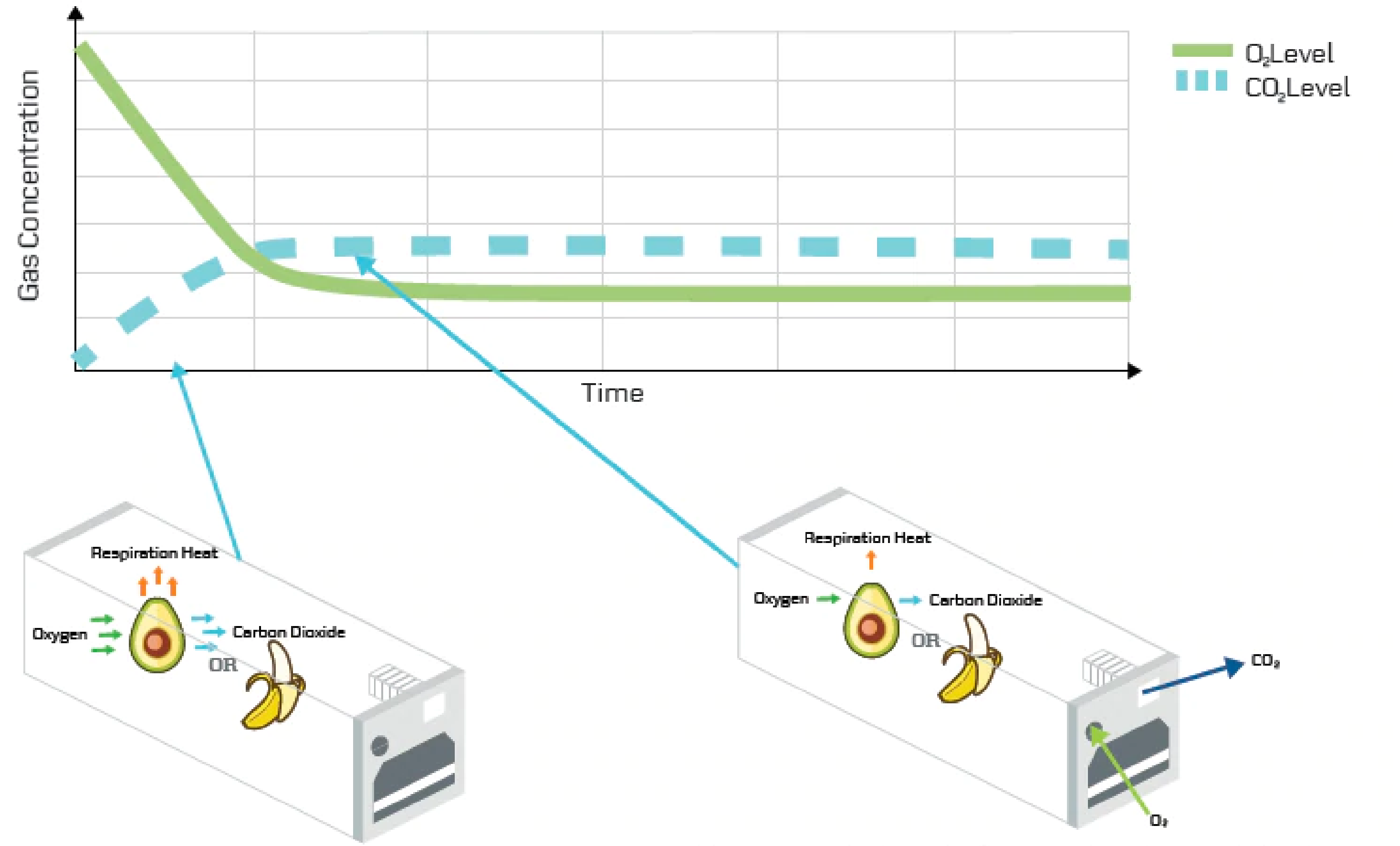
We are very excited to take part in this innovative journey together with you!



Perfect ripeness upon arrival

Our Starcare™ Controlled Atmosphere containers extend the shelf life of your fruit and vegetables by slowing down the ripening process during transit. As an example, transit times for avocados can be extended to as much as 34 days, so you can ship to any part of the globe without damaging your cargo.

Starcare™ is particularly suited to avocados, bananas and asparagus because it maintains an ideal blend of oxygen and carbon dioxide within the reefer unit. This means your goods respire at the perfect rate throughout the voyage, and they arrive at the perfect stage in the ripening process.



High respiration fruit breathe in O_2, and out CO_2
It is the ripening process.

Once the desired levels of gasses have been obtained, we regulate and maintain the levels of O_2 and CO_2 hence lowering the respiration of the fruit, and its ripening process.

Cold treatments that keep fruit flies and larvae away

If you are exporting fruits and vegetables to countries that are subject to cold treatment regulations, such as Australia, Japan, Korea, New Zealand, Taiwan or the United States, you can rely on us.

Thanks to our remote-controlled reefer containers, we can accurately monitor and adjust the temperatures inside your container to ensure that cold treatment protocols are followed, without damaging your cargo.

This means that your containerised cargo can be treated to safeguard against fruit fly and larvae infestation while in transit, rather than requiring time-consuming land-based cold treatment. As a result, you can optimise the speed of your deliveries while complying with cold treatment regulations.

Our in-transit cold treatment monitored via our remote-controlled containers:

- Effectively eliminates fruit flies and larvae – without damaging your cargo
- Eliminates the need for chemical fumigation
- Gets your cargo to your markets faster by removing the need for land-based cold treatments

LiquiCool™ for your fruit juices

A cool technology, LiquiCool™ is the most cost-efficient way of transporting fruit and vegetable juices.

LiquiCool™ bags are easy to fill and pre-fitted to our containers to make handling simple. And, because the LiquiCool™ bags can be transported from origin to destination without opening, your fruit and vegetable juices are kept at a perfect temperature throughout the journey. The result? Your fruit and vegetable juices are perfectly fresh upon arrival.

LiquiCool™ bags mean:

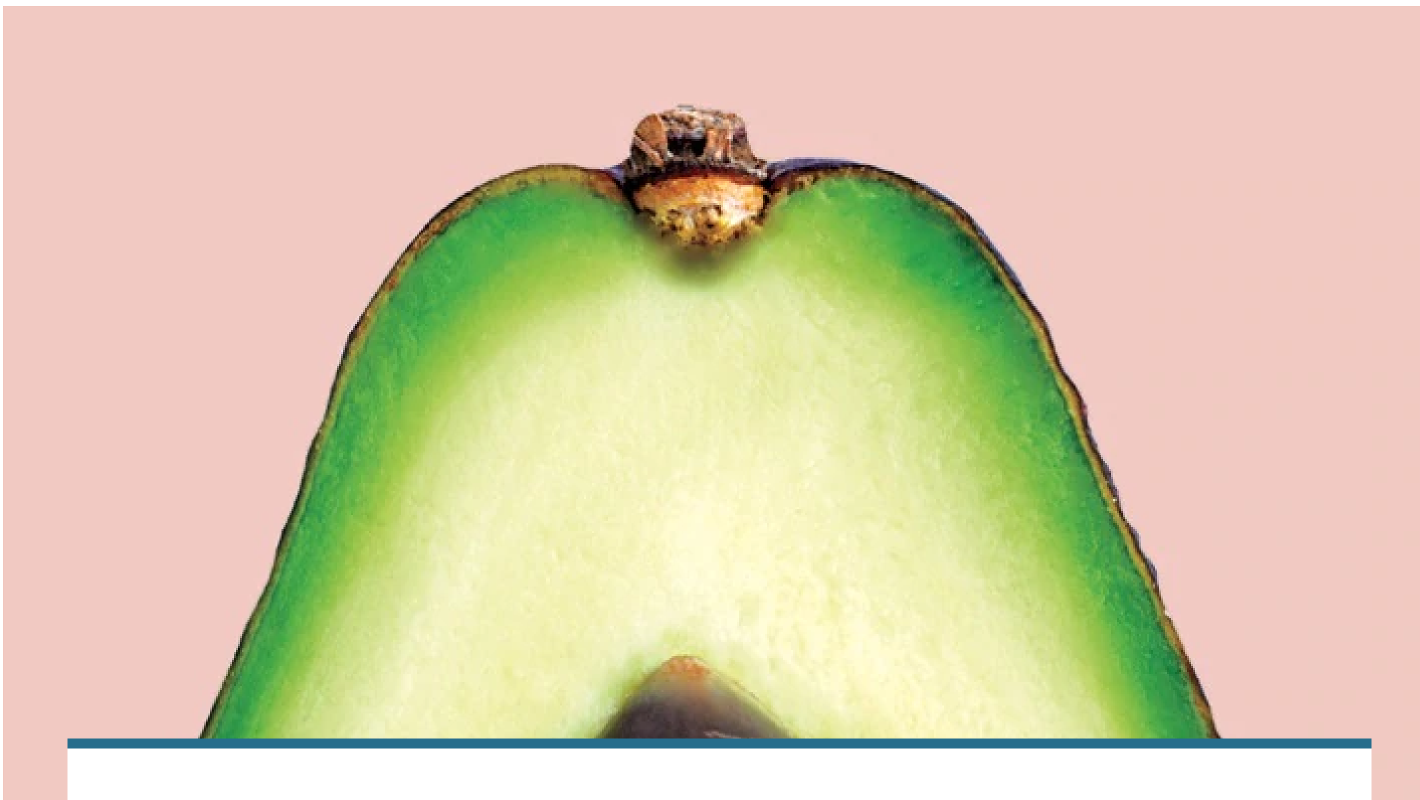
- Zero rehandling: One packaging solution for the entire journey
- No investment needed – just pay per bag per use
- Reduced loading time – from 20 man-hours to just 90 minutes
- More room for your juice: LiquiCool™ bags take up less room, increasing the volume of your shipment by 5%
- Reduced waste – thanks to a residue level below 30 litres

WITH LiquiCool

Anything you need, we're here to help

Bananas and pineapples

Bananas and pineapples are precious, delicate, and in demand all over the world – read about our unique services in this field.



Remote Container Management

This groundbreaking innovation in refrigerated technology allows you to monitor the conditions inside your container at all times.

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Hapag-Lloyd

JAN 30, 2018

How Blueberries are transported around the world

Every year, over 20 thousand TEUs of blueberries are transported worldwide. Rated as one of the world's healthiest foods due to its high level of antioxidants, blueberries have become a popular fruit that is a part of every healthy diet.

With much of the supply being exported from South America and South Africa, there is limited time to bring fresh blueberries to the North American and European markets. Consumers expect the very best produce while shopping and producers are constantly under pressure to deliver the best quality produce.

After fruits are harvested, the fruit is still "alive". To transport these delicate commodities, an environment where the atmosphere is controlled, and the ripening process is slowed down is required. Without this process, fruits would ripen and quickly deteriorate. Just think of how fast bananas ripen when you take them home from the supermarket.

This is where Controlled Atmosphere Technology comes in. This technology is used to help these sensitive commodities travel longer distances, like those between Chile and Europe. Hapag-Lloyd typically uses its ExtraFresh technology to control the interior atmosphere of a **reefer container (https://www.hapag-lloyd.com/en/products/cargo/reefer/overview-reefer.html)** to slow respiration so that the shelf life of fruits and vegetables can be extended.

This works for high respiring fruits such as bananas and avocadoes as the ExtraFresh technology relies on the fruit respiration to create the optimal atmosphere of oxygen (O_2), carbon dioxide (CO_2), and nitrogen (N_2).

Fruits like blueberries and lychees are even more sensitive. Knowing this Hapag-Lloyd has introduced ExtraFresh Plus. ExtraFresh Plus targets high-value, highly perishable but low respiring fruit like blueberries and lychees.

Blueberries are extremely sensitive and require an environment where the atmosphere is controlled and the ripening process is slowed down during the transport.

Much like ExtraFresh, ExtraFresh Plus' goal is to slow the ripening and prevent gray mold and other decay-causing organisms. This allows shippers to ship their produce on longer journeys and enables them to reach new markets that were previously out of range due to the ripening process. ExtraFresh Plus ensures that the shipper delivers a higher quality of fruit to their customer when it arrives.

How ExtraFresh Plus works

To assist the cargo in reaching the optimum atmosphere, an initial gas mixture of carbon dioxide (CO_2) and nitrogen (N_2) is first injected (flushed) into the container at a Hapag-Lloyd depot after the container is stuffed.

Many technologies currently available in the market rely on fresh air intake of oxygen (O_2) to reduce the carbon dioxide (CO_2) created from the respiring fruit inside the reefer. As the level of nitrogen (N_2) inside the reefer is higher than the outside atmosphere, small amounts of nitrogen (N_2) will also escape the container whenever vents open to help bring down the carbon dioxide (CO_2) level in the reefer.

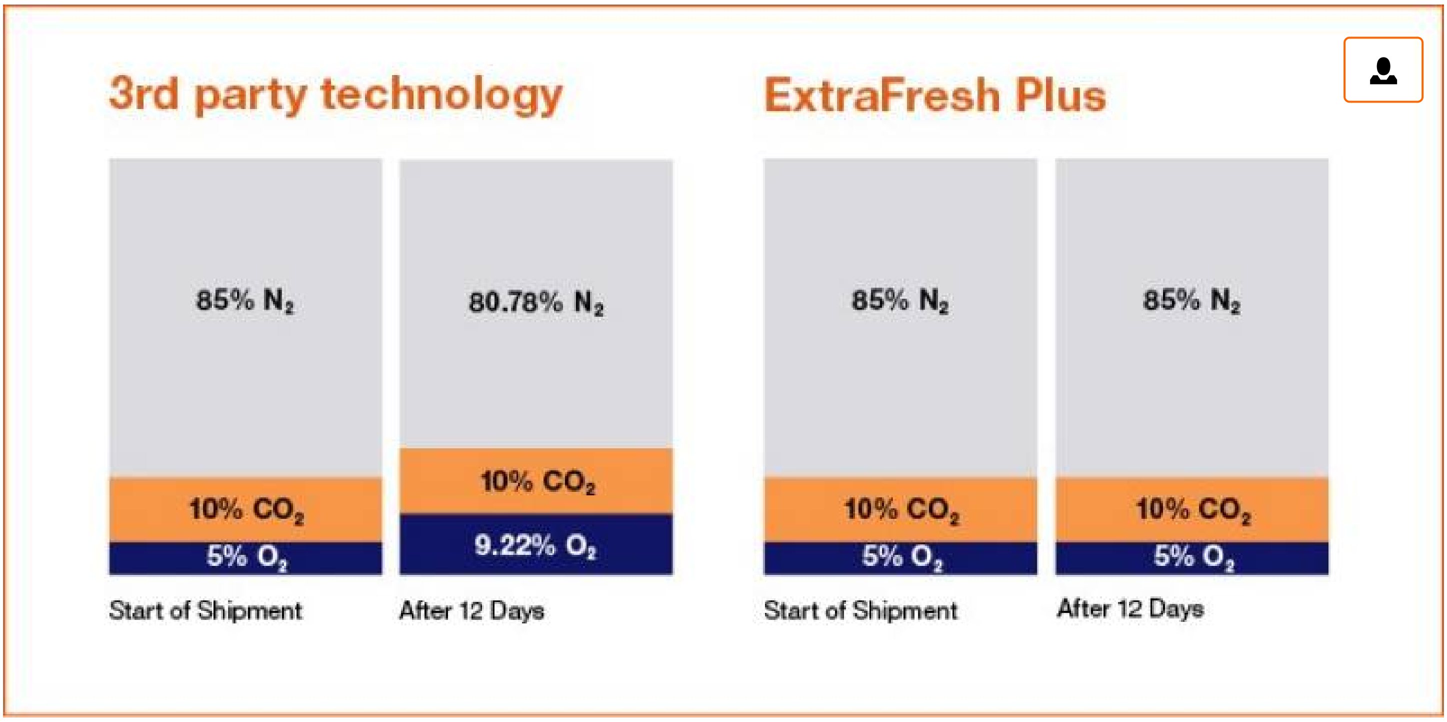
Much like ExtraFresh, ExtraFresh Plus' goal is to slow the ripening and prevent gray mold and other decay-causing organisms.

The only thing going into the reefer is oxygen (O_2), which means that oxygen (O_2) will replace the escaping nitrogen (N_2). As a result, the nitrogen (N_2) will inevitably decrease towards the atmospheric level outside of the container. The amount of oxygen (O_2) going into the reefer is equal to the amount of nitrogen (N_2) escaping from the reefer unit.

Consider the following example:

A container carrying blueberries is initially gassed to 85% nitrogen (N_2) and 10% carbon dioxide (CO_2) leaving 5% oxygen (O_2) inside the container. At a respiration rate of 1% carbon dioxide (CO_2) per day, which is not uncommon for blueberries, the oxygen (O_2) would increase to over 9% in just 12 days to keep the carbon dioxide (CO_2) from rising above the setpoint.

In comparison, ExtraFresh Plus has the capability to filter and remove the carbon dioxide (CO_2) from the atmosphere without increasing the oxygen level (O_2) or decreasing the level of nitrogen (N_2). The system is equipped with both oxygen (O_2) and carbon dioxide (CO_2) sensors, which actively monitor the levels inside the reefer and ensures the technology maintains the correct levels. Having stable levels of both oxygen (O_2) and carbon dioxide (CO_2) is the key to providing producers, exporters, importers and buyers with fruit that can travel longer distances while maintaining the optimal quality.



Due to the ExtraFresh Plus technology sensitive fruits maintain the optimal quality even during a long journey.

For fruit exporters, technology such as ExtraFresh Plus keeps fruit in the best possible condition and will extend the shelf life of the product by up to as much as one and half weeks. This provides a win-win situation for the growers, exporters, importers and supermarkets by giving them an extended window where their produce can still be commercially viable.

At the same time, consumers are happy to have fresh fruit on their store shelves no matter the time of year.

005

Temperature Controlled Logistics

DHL has a wide range of transportation, storage and end-to-end supply chain solutions, which cater for all your temperature specific needs.

Life Sciences & Healthcare | **Food & Perishables**

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- Refrigerated, frozen and meat products transportation across Europe
- Experienced in sensitive goods, including, fresh products, fruit and vegetables
- Liquid food transported professionally and appropriately by tank truck and tank wagon
- Equipped according to the latest requirements of the products: refrigerated and deep-freeze trucks, double decker and trucks with isolation barrier, temperature recording

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compliance of perishables such as flowers, fruits, vegetables, cheese, sausages, fresh meat and fish across the supply chain.

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- Document preparation and customs formalities
- Prioritized space allocation
- Prioritized handling at origin and destination
- Control of temperature, quantity and damages throughout the transport
- Sanitary inspections and quality checks

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Department for Transport

Freight Carbon Review 2017

Moving Britain Ahead

February 2017

Department for Transport
Great Minster House
33 Horseferry Road
London SW1P 4DR
Telephone 0300 330 3000
Website www.gov.uk/dft
General enquiries: https://forms.dft.gov.uk

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Foreword

The road freight sector is a hugely important and growing part of the UK economy, contributing £11.9 billion in 2015 and employing around 248,000 people. Many of the more than 44,500 businesses in this sector are small or medium enterprises. The Government is committed to supporting this business sector and enabling it to achieve its full potential.

Road freight's positive contribution to our economy extends beyond its direct employment and financial benefits - the sector is a critical enabler of wider business across the UK - of all sizes, from internet entrepreneurs to large distribution businesses.

However, I am also aware that heavy goods vehicles (HGVs) account for a significant portion of the UK's air quality impacts from transport, and am committed to working collaboratively with industry to address these issues.

I am therefore delighted to be publishing this Freight Carbon Review, which is designed to help the road freight sector reduce its emissions in a cost-effective way that drives efficiency and innovation. In meeting this challenge, the Government will work collaboratively with the freight and logistics industry, to build on existing good practice. Your work will help us achieve our long-term target of reducing UK emissions by at least 80% on 1990 levels by 2050, whilst supporting the continued development of the freight and logistics sector. This work will inform the Government's Emissions Reduction Plan, which will set out how we will reduce emissions through the 2020s and so provide an important signal to the markets, businesses and investors. It will also support the development of further measures on air quality under our forthcoming Air Quality Plan.

And this is not just about delivering environmental benefits. Measures to reduce emissions can also reduce fuel consumption and therefore costs. Fuel accounts for a significant portion of HGV operating costs, in an industry where margins are tight; and I want businesses to enjoy the economic benefits associated with the deployment of fuel efficient technologies and best operational practice.

This Review has enabled the Government to gather evidence on the key opportunities for and barriers to reducing road freight emissions, and identify a range of potential routes for decarbonising the sector. As an outcome of this work, the Government has committed to a number of new measures to support industry, including the piloting of an HGV fleet review scheme to advise small and medium fleet operators on reducing fuel consumption and costs. The Review has also identified areas for further analysis and policy development, including the potential role for alternative fuels, modal shift, and longer term pathways for reducing road freight emissions. So we have not reached the end of this work and are exploring further measures, with a focus on reducing emissions and improving our air quality while supporting industry.

I recognise that there are considerable challenges, but am confident that the road freight sector can play its part in meeting our climate change targets. By working together we can create a low carbon economy and support the UK freight industry at the same time. Decarbonising the road freight sector is the right thing to do for our economy and the common good.

This Review has not been developed in isolation. I am grateful to all the organisations in the freight and logistics industry who have generously given their time to support and inform this work.

[redacted]

The Rt Hon John Hayes CBE MP

Minister of State for Transport

Executive summary

Overview

1 The 2008 Climate Change Act sets a legally binding target to reduce the UK's greenhouse gas (GHG) emissions by at least 80% by 2050, relative to 1990 levels. The Act requires the Government to cap GHG emissions over successive five-year periods, known as 'carbon budgets'. The fifth carbon budget, covering the period 2028-2032, was set in legislation in July 2016. Meeting our climate change targets will require action across all sectors of the economy, including road freight.

2 Alongside meeting these targets, improving air quality continues to be a priority. The 2008 Ambient Air Quality Directive (2008/50/EC) sets legally binding limits for concentrations of major pollutants that impact public health including particulate matter (PM10 and PM2.5) and nitrogen dioxide (NO_2). The Government is taking forward a programme of work to set up Clean Air Zones. These Zones will discourage the most polluting vehicles from entering a number of city centres, alongside national action and continued investment in clean technologies such as electric and ultra-low emission vehicles. In addition, we are developing a new Air Quality Plan for nitrogen dioxide, for publication in 2017, which will set out further measures to improve air quality.

3 Heavy goods vehicles (HGVs) are currently estimated to account for around 17%[1] of UK GHG emissions from road transport and around 21%[2] of road transport NOx emissions, while making up just 5% of vehicle miles[3].

4 Developing a decarbonisation strategy for HGVs is challenging for two key reasons. Firstly, although electric drivetrain options are available for smaller HGVs, the technological solutions for larger HGVs are at a relatively early stage of development and not yet available for deployment across the HGV fleet. Secondly, the complex nature of the road freight sector, which comprises a diverse mix of vehicle configurations, vehicle weights, duty cycles and fleet sizes, means there is not a single industry-wide decarbonisation solution and a range of measures will be needed.

5 However, as set out in this Freight Carbon Review, policy options are already available to reduce emissions from HGVs, and many of the approaches outlined in this report could save businesses money whilst cutting carbon and improving UK air quality.

6 The Freight Carbon Review was commissioned in 2015 to bring together the evidence on the key opportunities for and barriers to reducing road freight GHG emissions, to identify key evidence gaps, and to consider potential policy solutions. This report sets out the key findings of the Review, identifies a range of Government-

[1] https://www.gov.uk/government/statistical-data-sets/tsgb03 - 2014 data, calculated from Table TSGB0306 (ENV0202)
[2] https://www.gov.uk/government/statistical-data-sets/tsgb03 - 2014 data, calculated from Table TSGB0308 (ENV0301)
[3] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/545212/prov-road-traffic-estimates-july-2015-to-June-2016.pdf

and industry-led decarbonisation options, and outlines a number of measures that the Government will put in place to support GHG emission reductions within the road freight sector.

7 This report does not attempt to set out comprehensively all the steps that will be needed to deliver the necessary emissions reductions from road freight. The forthcoming Emissions Reduction Plan will outline the steps Government is taking to decarbonise across the transport sector. Due to the current uncertainty regarding the 'right' solutions for road freight, this will necessarily be an evolving picture over time as HGV technologies continue to emerge and develop. The Government is clear, however, that further measures need to be explored in order for freight to contribute to our long term climate change targets.

8 The Government recognises the road freight sector's vital contribution to the UK's economy, and the challenging economic climate in which many fleets operate. The Freight Carbon Review has therefore considered options for supporting industry, particularly small and medium sized enterprises (SMEs), to reduce emissions in a cost-effective way without imposing unnecessary burdens.

9 The primary focus of this work has been on road freight GHG emissions and identifying measures with the potential to reduce these by 2032, in line with the fifth carbon budget timelines. However, we have also considered longer term road freight decarbonisation options to get the sector on a pathway towards meeting our 2050 target.

10 In recognition of the UK's ongoing priorities on air quality, the Freight Carbon Review has taken account of the wider environmental co-benefits from GHG-related measures where appropriate and where evidence is available. The Government is keen to prioritise interventions that tackle both GHG and air pollutant emissions. The Review has also considered the economic benefits to industry that could be derived from improved fuel efficiency and enhanced operational practice.

11 In developing the Freight Carbon Review, the Department for Transport (DfT) has engaged with other Government departments, devolved bodies, academic experts, and the freight and logistics industry.

12 Following an initial evidence review and early consultation with stakeholders, five key themes were identified for further consideration. This report has been structured in accordance with these themes, which are summarised below:

- Improving fuel economy through efficient driving and in-cab driver monitoring technologies.
- Optimising fleet design through retrofit technologies and improved engine efficiency.
- Reducing road miles through modal shift, longer-semi trailers and further industry collaboration.
- Reducing emissions through wider use of alternative fuels.
- Shifting the focus to future, more radical, solutions such as electric trucks, e-highways and hydrogen fuel cell technologies.

Efficient driving and in-cab technologies

13 Efficient driving (commonly referred to as 'eco-driving') describes a set of driving techniques, maintenance procedures and vehicle checks designed to achieve greater vehicle fuel efficiency and thereby reduce emissions and costs. Efficient driving can be supplemented by using a range of in-cab technologies that monitor driving on an ongoing basis and provide performance feedback to drivers and fleet managers. Keeping vehicles well maintained and optimising the mix of vehicles within the fleet can also contribute to improved fuel efficiency.

14 The Committee on Climate Change (CCC)[4] has identified opportunities to significantly reduce HGV GHG emissions by 2035 through 'demand side' measures, including improved logistics, driver training and retrofitting existing vehicles with fuel saving technologies. The CCC attributes a significant portion of these savings to driver monitoring and fuel efficiency training, which has been found to be highly cost effective[5].

15 In addition to reducing GHG emissions, efficient driving reduces hauliers' expenditure on fuel, which, according to Freight Transport Association (FTA) data, can account for up to 30% of HGV operator costs[6]. Wider deployment of efficient driving techniques therefore represents a key opportunity for fleet operators to reduce costs in an industry where profit margins are tight.

16 Building on the CCC's work, DfT commissioned a study to further assess the economic and environmental impacts of efficient driving and in-cab monitoring technologies within the road freight sector[7]. It found that the key barriers to wider uptake among SMEs relate to the associated up-front costs and a lack of evidence on the economic benefits. The study recommended that the Government should:

- Work with industry to promote and encourage wider uptake of efficient driving training through supporting communication campaigns on the associated economic and environmental benefits.
- Consider subsidising the costs of eco-driving courses and in-cab technologies so that they are more accessible to SMEs.

17 As an outcome of the Freight Carbon Review DfT will work with the Energy Saving Trust to pilot an HGV fleet review scheme, which will advise SME fleet operators on reducing fuel consumption and costs, with the aim of delivering GHG emission savings. This will focus on selecting the best vehicle for the job, driver behaviour, technology to improve existing vehicle performance, route optimisation and fuel management.

18 This pilot will be evaluated with a view to wider roll out should it prove successful. It will help build our evidence base to determine the extent to which the emissions savings identified by the CCC might be practically deliverable, and how any barriers might be overcome.

[4] The Committee on Climate Change (CCC) is an independent, statutory body established under the Climate Change Act 2008. The CCC advises the UK Government and Devolved Administrations on emissions targets and report to Parliament on progress made in reducing greenhouse gas emissions and preparing for climate change.

[5] https://www.theccc.org.uk/wp-content/uploads/2015/11/Sectoral-scenarios-for-the-fifth-carbon-budget-Committee-on-Climate-Change.pdf

[6] http://www.fta.co.uk/policy_and_compliance/fuel_prices_and_economy/fuel_prices/fuel_fractions.html

[7] AECOM, 2017, 'Eco-driving for HGVs'

Fleet design

19 Technologies to reduce HGV fuel consumption are widely available, but uptake is currently limited, particularly among smaller operators. Retrofit equipment such as aerodynamic devices and fairings[8] and low rolling resistance tyres can offer fleets a cost-effective GHG emission reduction solution. Although some large fleet operators already use vehicles that feature these technologies, wider uptake has been hindered by a lack of trusted information on the associated fuel savings, as well as the costs of purchasing and installing equipment and wider pressures on driver and fleet managers' time.

20 The Freight Carbon Review has identified a need for the Government to encourage further uptake of these technologies by providing businesses with access to independent information on associated fuel savings. In June 2016, the Office for Low Emission Vehicles (OLEV) in conjunction with the Low Carbon Vehicle Partnership (LowCVP) launched an HGV technology accreditation scheme. This has been designed to provide independent validation of fuel savings from a range of retrofit technologies, providing transparency and greater certainty to operators. It is intended that the scheme will accelerate the adoption of fuel saving technologies and thereby reduce fuel costs for fleet operators while saving GHG emissions[9].

21 Discussions with stakeholders suggest that there is significant scope for increasing communication, advocacy and knowledge sharing between larger and smaller operators on the benefits of these technologies. FTA will be renewing its Logistics Carbon Reduction Scheme (LCRS) later this year, with a focus on encouraging SME participation. The Government welcomes FTA's ongoing work in this area and is supportive of wider participation amongst the freight and logistics industry.

Reducing road miles

22 The Freight Carbon Review has considered options for making more effective use of current capacity on the rail, water and road networks through increased use of rail freight, deployment of longer semi-trailers, and improved logistical efficiency through more widespread industry collaboration.

23 The Rail Freight Strategy, published in September 2016, highlights the GHG emissions reduction potential from modal shift from road to rail and identifies a range of issues that would need to be addressed to realise this potential[10]. The Strategy was supported by an assessment from Arup of the likely scale of GHG emission savings out to 2030 from shifting freight from road to rail, which suggests that savings could be significant[11]. Further work will be needed to understand in more detail the likely costs and feasibility of these measures, particularly considering the significant infrastructure investment that would be required.

24 In addition to opportunities to make better use of the rail network, further efficiencies can be achieved through more effective use of the road network. DfT's ongoing Longer Semi-Trailer (LST) trial was launched in 2012 and is enabling the use of longer vehicles, up to an extra 2.05m in length, to be trialled in Great Britain for ten

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[8] Fairings are three-dimensional mouldings that can be fitted to the cab roof, container front or cab sides to streamline the vehicle's shape, and bridge gaps between the cab and container - thereby improving aerodynamics. Available as new or retrofit, fairings work by presenting the airflow with a smooth transition from the cab roof to the container.
[9] http://www.lowcvp.org.uk/projects/commercial-vehicle-working-group/hgv-accreditation-scheme.htm
[10] https://www.gov.uk/government/publications/rail-freight-transport
[11] http://www.arup.com/railfreightmarket

years. Results from the trial to date suggest major benefits by way of improved operational efficiency and potential CO_2 savings. Estimates suggest that up to 10.6 million HGV km have been removed from the road since September 2012, which equates to removing up to 90,000 HGV journeys[12]. It is anticipated that over 3,000 tonnes of CO_2 will be saved over the course of the trial. In light of these positive results, DfT has recently announced a five year extension to the trial and an increase in the number of permitted LSTs by an additional 1,000, which will take the number of LSTs from 1,800 to approximately 2,800 over the next 12 months.

25 Encouraging the freight industry to collaborate effectively so that vehicles are used to their maximum capacity wherever possible could also decrease the number of HGVs on the road, thereby reducing GHG emissions. To inform the Freight Carbon Review's evidence base, DfT commissioned a study which explored the opportunities for and barriers to wider industry collaboration[13]. Building on this work, DfT will consider the case for further measures to help overcome some of the barriers to industry collaboration.

Alternative fuels

26 The Freight Carbon Review has considered the future role of alternative fuels in reducing both GHG and air pollutant emissions from the road freight sector. It has focussed in particular on liquefied and compressed natural gas (LNG and CNG), biomethane, and liquid biofuels (e.g. biodiesel), which are considered suitable for use in the current generation of HGV engines.

27 Sustainable renewable fuels, in particular biomethane and biodiesel from waste feedstocks, offer significant potential to decarbonise the road freight sector in the short to medium term. However use of these fuels in HGVs is currently limited and wider deployment is likely to depend upon overcoming significant barriers to supply and uptake. Many fleet operators have expressed a desire to use biomethane in their vehicles, but at present it is only supplied to the transport sector in small quantities.

28 The GHG emissions reduction potential from switching from diesel to natural gas (fossil methane) is less certain. In particular, tailpipe emissions of unburnt methane, referred to as 'methane slip', is a known issue for dual fuel (diesel/gas) retrofit conversions and can offset any CO_2 savings derived from natural gas. The Government will continue to monitor the emissions performance of dedicated gas and dual fuel HGVs, and direct future support towards fuels and technologies with proven emissions reduction capabilities.

29 Renewable low carbon road fuels are already supported in the UK through the Renewable Transport Fuel Obligation (RTFO). The Government has recently concluded a public consultation on possible amendments to the RTFO to increase supply of these fuels. This invited views from the freight industry on options to incentivise the use of biofuels in this sector, which we are now considering[14]. In addition, the new Advanced Renewable Fuel Demonstration Competition will provide £20m of capital grant funding to build demonstration scale renewable fuel plants in the UK. This will be matched by significant private sector investment and will target the difficult-to-decarbonise aviation and HGV sectors.

[12] https://www.gov.uk/government/publications/longer-semi-trailer-trial-evaluation-annual-report-2015
[13] TRL, 2017, 'Freight Industry Collaboration Study'
[14] https://www.gov.uk/government/consultations/renewable-transport-fuel-obligation-proposed-changes-for-2017

30 Earlier this year the Government announced the winners of the Low Emission Freight and Logistics Trial competition, through which £20 million funding will be awarded to enable the freight and logistics sector to trial innovative low and zero emission vehicle technologies in their fleets. The funding will also support the deployment of refuelling and recharging infrastructure[15].

Shifting the focus to low and zero emission technologies

31 Opportunities are now emerging for HGV electrification through developments in battery electric and hydrogen fuel cell technologies. These already provide a feasible option for reducing emissions from vans and lighter HGVs, particularly those operating to urban and regional duty cycles. However, at present these options are unsuitable for deployment in larger HGVs.

32 Looking ahead to 2050, the Freight Carbon Review has considered a range of future technologies including electrification of the largest HGVs, inductive and overhead dynamic charging, and connected and autonomous vehicles.

33 The Government is currently developing proposals to seek an EU derogation that would allow Category B driving licence holders to operate alternatively fuelled vehicles up to 4,250 kg (the current limit is 3,500 kg). This would help achieve payload parity with conventional diesel vehicles and should therefore address a key barrier to the adoption of alternative fuels, which require heavier drivetrains.

34 We have recently concluded a consultation on the transposition of the General Circulation Directive on vehicle weights and dimensions. This included proposals to allow operators up to an extra tonne in weight to account for the heavier drivetrains of alternatively-fuelled HGVs, including those using electricity, hydrogen, natural gas and biomethane[16].

35 The European Commission plans to publish regulatory proposals on the monitoring and reporting of fuel consumption and CO_2 emissions from all new HGVs by 2018. It is anticipated that these proposals will help inform purchasing behaviour, and potentially be used to set CO_2 emissions standards within the EU in the longer term. Under current plans, manufacturers will be required to measure fuel consumption and CO_2 emissions for new types of vehicle at type approval. It is envisaged that the reporting and monitoring of this information will help reduce emissions and operating costs through the provision of better market information.

36 In the future it is possible that manufacturers selling new HGVs into the EU market will face regulatory limits on their fleet average CO_2 emissions in a similar way to that seen for cars and vans. We anticipate that these regulations will therefore serve to influence innovation in the UK HGV market.

EU considerations

37 The Government is considering carefully all the potential implications arising from the UK's exit of the European Union. Until exit negotiations are concluded, the UK remains a full member of the EU and all the rights and obligations of EU membership remain in force. During this period the Government will continue to negotiate, implement and apply EU legislation. The outcome of these negotiations will

[15] https://www.gov.uk/government/news/low-emmission-freight-and-logistics-trial-competition-winners-announced
[16] https://www.gov.uk/government/consultations/incentivising-cleaner-fuel-technologies-permissible-vehicle-weights-and-dimension-amendments

determine what arrangements apply in relation to EU legislation in future once the UK has left the EU.

38 As set out above, the EU is currently improving its ability to monitor emissions from HGVs with a view to informing the development of CO_2 regulations over the coming years. As with existing CO_2 regulations for cars and vans, the forthcoming regulations could be pivotal in driving technological development and delivering CO_2 emission reductions from the road freight sector.

39 We will need to consider the implications of these regulations for UK industry and ensure that appropriate safeguards are put in place to encourage and maintain innovation in our HGV market. This should have a positive impact on the efficiency and competitiveness of the sector, while reducing air pollution and GHG emissions from road freight.

Actions and next steps

40 The Freight Carbon Review has considered a range of existing and newly-commissioned evidence as well as stakeholder views to develop an overview of the key opportunities for and barriers to reducing GHG emissions from the road freight sector. It has identified key evidence gaps, and outlined a number of potential options for reducing emissions.

41 We have recently announced a range of measures to support the decarbonisation of the road freight sector, including:

- An extension of the OLEV Plug-in Van Grant to encompass heavier, category N2 and N3, vehicles[17]. This includes an increase in support of up to £20,000 for the first 200 eligible vehicle sales.
- £20m grant support for industry-led trials of alternative propulsion technologies for commercial vehicles.
- A £20m capital grant competition to support the development and deployment of fuels capable of tackling HGV and aviation GHG emissions.
- An HGV accreditation scheme to assess fuel and GHG emission savings from a range of aftermarket technologies.

42 As we develop the Emissions Reduction Plan we are considering additional steps that could be taken to further support GHG emission reductions in the road freight sector out to the 2030s.

Support for efficient driving and in-cab technologies

- We are working with the Energy Saving Trust to pilot an HGV fleet review scheme, which will advise SME fleet operators on reducing fuel consumption and costs, with the aim of delivering GHG emission savings. Evidence collected from the evaluation of this pilot will inform future policy.

Fleet design

- We will continue to work with LowCVP and industry to support the roll-out of the HGV accreditation scheme, and will consider options for encouraging increased industry uptake.

[17] Vehicles designed and constructed for the carriage of goods and having a maximum mass exceeding 3.5 tonnes but not exceeding 12 tonnes (N2), and vehicles designed and constructed for the carriage of goods and having a maximum mass exceeding 12 tonnes (N3).

- We will work with the FTA to support and encourage wider uptake of the Logistics Carbon Reduction Scheme, particularly among smaller operators.

Reducing road miles

- We will consider the scope for further modal shift from road to rail, including through further work to quantify the costs and benefits of opportunities identified in the Rail Freight Strategy.
- We will take forward work over the next year to extend the Longer Semi-Trailer Trial, in collaboration with industry. Operators will be invited to bid for a share of the additional allocation in the coming months, and details on how to apply will be available soon.
- We will consider the scope for developing further measures to support wider industry collaboration and address barriers within the road freight sector.

Alternative fuels

- We have recently consulted on biofuels policy, including on measures to increase renewable fuel supply across the road transport sector and to support advanced fuels suitable for freight under the Renewable Transport Fuel Obligation. We will consider the responses and set out our next steps for biofuels policy later this year.
- We will work to transpose amendments to the General Circulation Directive by May 2017, including the adoption into UK law of measures to allow operators of alternatively-fuelled HGVs up to an extra tonne in weight to account for their heavier drivetrains.
- We will continue to gather evidence on the environmental and economic performance of alternatively-fuelled commercial vehicles.
- We will engage industry with the development of our £20m Advanced Renewable Fuel Demonstration Competition.

Shifting the focus to low and zero emission technologies

- We are developing proposals that would allow Category B driving licence holders to operate alternatively-fuelled vans up to 4,250 kg to account for their heavier drivetrains, and plan to consult on these proposals later this year.
- OLEV will continue to encourage the development of low and zero emission vehicle technologies for heavier trucks through its research and development support programme.
- We will work with Defra and the local authorities involved in establishing Clean Air Zones to consider the use of incentives to encourage hauliers to use cleaner, quieter vehicles.

43 We will work closely with the road freight industry, as well other Government departments and the devolved administrations, to take forward these actions. We recognise that further work is needed and will build on the findings of this Review to identify additional freight decarbonisation measures. Our goal is to ensure that future work in this area is supportive of our freight and logistics industry, and that we encourage its development in a way that is compatible with meeting our environmental goals. Further measures are being considered as part of work to develop the Emissions Reduction Plan as well as the new Air Quality Plan for nitrogen dioxide.

1. Introduction

Overview of the road freight sector

44 The road freight sector is an important and growing part of the UK economy, contributing £11.9 billion in 2015. There were more than 44,500 road freight enterprises in the road freight sector in 2015, employing around 248,000 individuals[18]. In addition to making a direct economic contribution, road freight is a critically important enabler of the success of other businesses of all sizes and from all sectors.

45 At the end of 2015, there were 483,400 Heavy Goods Vehicles (HGVs) over 3.5 tonnes licensed in Great Britain[19]. Their average gross vehicle weight was 21.8 tonnes, compared with 17.5 tonnes in 1994, and 21% had a gross vehicle weight of over 41 tonnes. Hardly any fell into this category prior to 2001 when the general weight limit for articulated vehicles was increased from 41 to 44 tonnes[20].

46 A 2013 Energy & Utility Skills report highlights the diversity of the sector, estimating that 94% of UK HGV fleet operators had fewer than ten vehicles and approximately 50% of operators were 'owner drives', licensing just one vehicle. At the other end of the spectrum, the report found that just 300 operators ran fleets of over 100 vehicles, accounting for 15% of all HGV numbers[21].

47 Department for Transport (DfT) data show that the number of goods vehicle operator licences in issue in Great Britain declined from 110,000 in 1999-2000 to 76,000 in 2014-15. Over the same time period, the average size of operators' fleets has increased from 3.6 to 4.5 vehicles. This means fewer licences are in issue but more vehicles are being specified under these licences[22].

48 An HGV Technology Survey conducted by DfT on a random sample of 700 vehicles in early 2015 captured information on HGV ownership arrangements, which were found to differ substantially depending on the number of HGVs operated by individual companies. For companies with 1-4 HGVs, 25% of vehicles were new and 70% of vehicles were second hand owned. However for companies that owned over 150 vehicles, the percentage of new and second hand owned vehicles changed to 61% and 3% respectively. Further details are provided in Appendix B.

49 This is an important distinction as new HGVs are likely to be more fuel efficient and offer some carbon savings over older vehicles. The results of this survey therefore indicate that the least efficient vehicles are owned by smaller firms, and highlight the important role that larger operators play in determining which vehicles enter the HGV parc.

[18] https://www.ons.gov.uk/businessindustryandtrade/business/businessservices/bulletins/uknonfinancialbusinesseconomy/2015provisionalresults#links-to-related-statistics
[19] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/546346/domestic-road-freight-statistics-2015.pdf
[20] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/516429/vehicle-licensing-statistics-2015.pdf
[21] http://networks.euskills.co.uk/sites/default/files/UK%20Market%20Review%20-%20The%20Role%20of%20Natural%20Gas%20in%20Road%20Transport%2019%20Dec%2013.pdf
[22] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/546346/domestic-road-freight-statistics-2015.pdf

GHG emissions from road freight

50 The 2008 Climate Change Act sets a legally binding target to reduce the UK's greenhouse gas (GHG) emissions by at least 80% by 2050, relative to 1990 levels. The Act requires that the Government caps emissions over successive five-year periods, known as 'carbon budgets'. The fifth carbon budget, covering the period 2028-2032, was set in legislation in July 2016 and requires a 57% reduction in GHG emissions compared to 1990 levels.

51 Meeting our climate change targets will require GHG emission reductions across all sectors of the economy, including road freight. Domestic transport accounted for almost a quarter of UK GHG emissions in 2014, as shown in Figure 1.1 below[23].

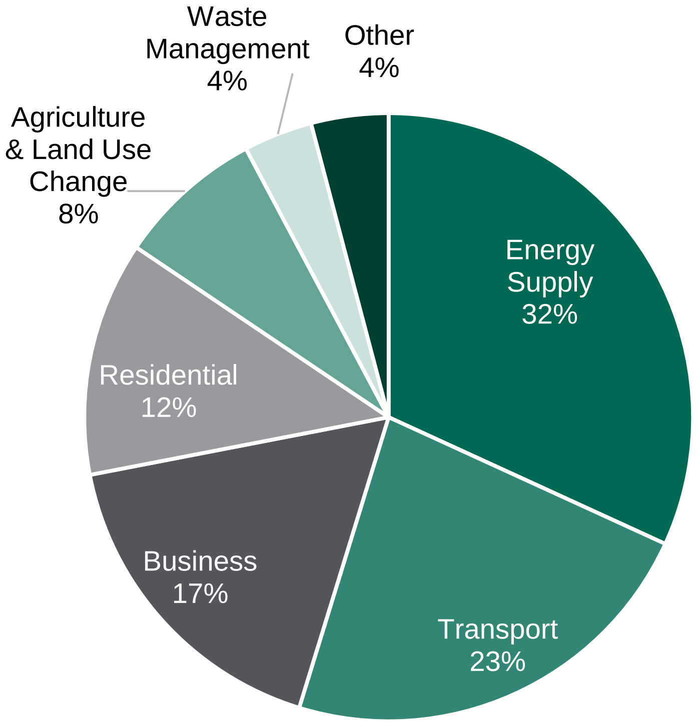

Figure 1.1: GHG emissions by sector (2014)

52 As shown in Figure 1.2 below, HGVs (above 3.5 tonnes) are currently estimated to account for around 16%[24] of UK GHG emissions from domestic transport, despite making up just 5% of vehicle miles[25] [26].

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[23] https://www.gov.uk/government/statistics/final-uk-greenhouse-gas-emissions-national-statistics-1990-2014
[24] https://www.gov.uk/government/statistical-data-sets/tsgb03 - 2014 data, calculated from Table TSGB0306
[25] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/545212/prov-road-traffic-estimates-july-2015-to-June-2016.pdf
[26] From 2014, reported HGV emissions reflect changes in the allocation of fuel consumption across vehicle types in the greenhouse gas emissions inventory. This has reduced estimated HGV emissions by about 25% for 2013. Some of the analyses cited in this report will have been completed before changes to the greenhouse gas emissions inventory reduced the historic HGV emissions series.

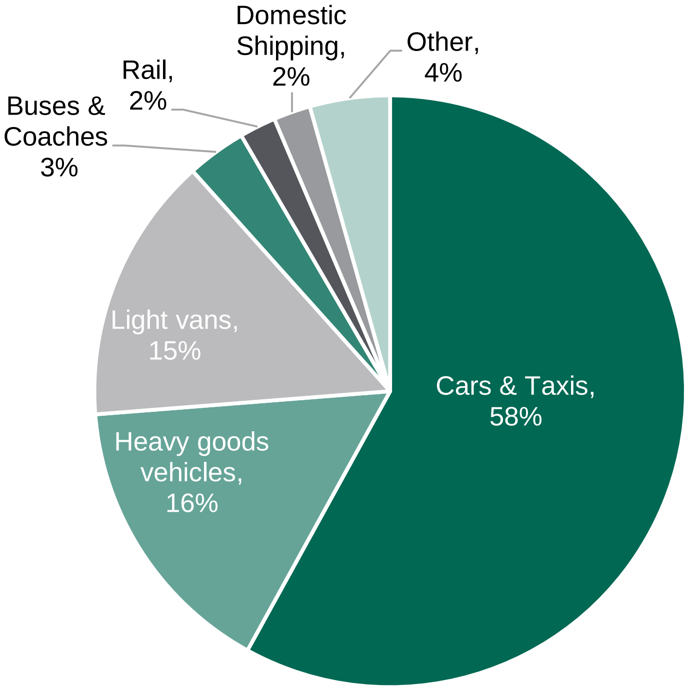

Figure 1.2: GHG emissions by transport mode (2014)[27]

53 The 2015 DfT HGV Technology Survey captured information on vehicle duty cycles, and found that regional delivery was the most common by number of vehicles, followed by construction, urban delivery, long haul, and municipal utility. The results of that survey have been combined with an estimated breakdown of GHG emissions across different duty cycles, taken from a 2012 report by Ricardo-AEA (now Ricardo Energy & Environment)[28]. The combined results are shown in Table 1.1 below.

54 The Ricardo-AEA report found that long haul duty cycles account for the largest portion of HGV GHG emissions despite, according to the DfT survey, making up a relatively small proportion of HGVs on the road. This is likely to be due to the vehicle weights and relatively high mileages associated with long haul freight transport. It suggests that there may be an opportunity to significantly reduce road freight emissions if an effective decarbonisation solution can be identified for this segment of the logistics industry.

[27] https://www.gov.uk/government/statistical-data-sets/env02-greenhouse-gas-emissions - table ENV0201
[28] Ricardo-AEA ‘Opportunities to overcome the barriers to uptake of low emission technologies for each commercial vehicle duty cycle’ - available at: http://www.lowcvp.org.uk/news,new-report-identifies-clear-opportunities-for-cutting-carbon-and-lowering-costs-from-road-freight-operations_1924.htm

Table 1.1: Duty cycle definitions and GHG emissions

Duty Cycle	Duty Cycle Description	% Vehicles*	% GHG Emissions**
Long Haul	Delivery to national and international sites (mainly highway operation and a small share of regional roads).	18	44-46
Regional Delivery	Regional delivery of consumer goods from a central warehouse to local stores (inner-city, suburban, regional and also rural and mountainous roads).	29	24-45
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).	22	15-16
Urban Delivery	Urban delivery of consumer goods from a central store to selling points (inner-city and partly suburban roads).	21	10-12
Municipal Utility	Urban truck operation like refuse collection (many stops, partly low vehicle speed operation, driving to and from a central base point).	10	4

*From DfT HGV Technology Survey, **From Ricardo-AEA (2012)

GHG emission projections

55 BEIS emission projections for HGVs displayed in Figure 1.3 below show that HGV CO_2 emissions are projected to fall gradually out to 2025 reflecting fuel efficiency improvements across the HGV fleet driven by Government-backed industry-led action as well as incremental improvements in new HGV efficiency year on year. By 2025, rising HGV kilometres outweigh those improvements in fuel efficiency and emissions flatten out. This suggests that continuing along a ‘business as usual’ path would make it increasingly challenging to meet our climate change targets within the road freight sector, which would in turn require further action to be taken to reduce emissions in other areas.

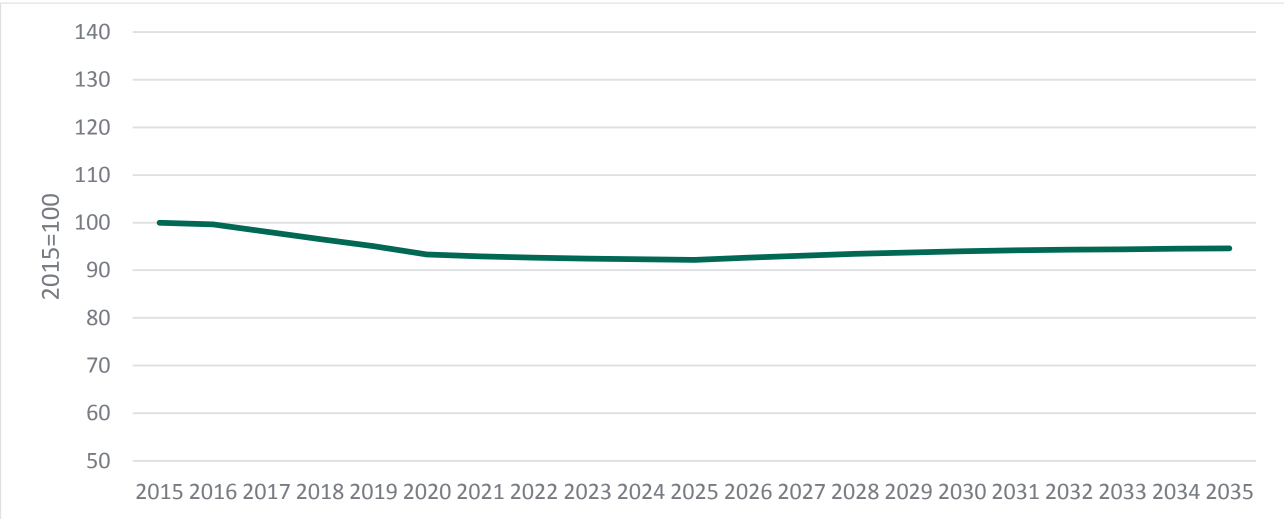

Figure 1.3: Forecast HGV CO_2 emissions - indexed to 2015[29]

[29] BEIS energy and emissions projections 2015

NOx emissions from road freight

56 HGVs currently account for around 21% of UK surface transport NOx emissions[30]. In addition to meeting national GHG emissions reduction targets, improving air quality in our cities and towns is a priority for Government. The 2008 Ambient Air Quality Directive (2008/50/EC) sets legally binding limits for concentrations in outdoor air of major air pollutants that impact public health such as particulate matter (PM10 and PM2.5) and nitrogen dioxide (NO_2). As one of a range of measures to ensure the UK meets legal limit values for nitrogen dioxide in the UK, some older polluting vehicles, including HGVs, will be discouraged from entering a number of city-centres through the implementation of Clean Air Zones. The Government is considering additional measures to meet legal limits for nitrogen dioxide and will set out further plans in 2017.

Existing measures to reduce road freight emissions

57 As outlined above, there is considerable diversity within the road freight sector, which comprises a mix of vehicle configurations, vehicle weights, duty cycles and fleet sizes. These factors will determine the suitability and cost effectiveness of available GHG emissions reduction measures. The diverse nature of the road freight sector means that there is not a single industry-wide decarbonisation solution and a range of interventions need to be considered.

58 There are a number of existing policies and measures already in place to support a reduction in GHG emissions from the road freight sector, alongside the efficiency improvements that are expected to come forward. A selection of measures are summarised below, with further details provided as appropriate throughout this report.

- The use of sustainable biofuels in the UK is encouraged primarily through the **Renewable Transport Fuel Obligation**, which requires refiners, importers and any others who supply more than 450,000 litres of transport fuel per year to the UK market to redeem a number of Renewable Transport Fuel Certificates in proportion to the volume of fossil fuel (and any unsustainable biofuel) they supply. The scheme was amended in 2015 to increase the rewards available for those supplying bioLPG and biomethane.
- A **fuel duty differential** is in place for road fuel gases, which are taxed at a lower rate than petrol and diesel. The duty differential is currently approximately £0.33 per litre, and was initially guaranteed for three years – up to and including 2015-16. The 2013 Autumn Statement extended the duty differential for ten years, up to 2024, with a review in 2018.
- The Office for Low Emission Vehicles (OLEV) and Innovate UK have recently announced the winners of a new £20m **Low Emission Freight and Logistics Trial** competition to stimulate the real-world, on-road demonstration of innovative ‘near to market’ low and zero emission vehicle technologies for freight and logistics vehicles.
- In June 2016, the Government launched an OLEV-funded **HGV accreditation scheme**, developed by the Low Carbon Vehicle Partnership (LowCVP). The scheme has been designed to independently measure fuel savings from a range

[30] https://www.gov.uk/government/statistical-data-sets/tsgb03 - 2014 data, calculated from Table TSGB0308 (ENV0301).

of aftermarket technologies, providing fleet operators with an independent validation of likely fuel and GHG savings.

- DfT is conducting an operational **trial of longer semi-trailers**, which is authorising longer articulated goods vehicles to run on Great Britain's roads. The Government has recently agreed to increase the number of LSTs by an additional 1,000 and to extend the trial by five years. This increase will take the number of LSTs from 1,800 to approximately 2,800 over the next 12 months.

59 Industry-led initiatives have also played an important role in reducing GHG emissions. The Freight Transport Association's Logistics Carbon Reduction Scheme, for example, is a free voluntary initiative to record, report and reduce GHG emissions[31]. It allows the UK logistics sector to publicly report its contribution towards national carbon reduction targets. The scheme's target is an 8% reduction in emissions intensity by 2015, based on 2010 levels[32]. Other initiatives such as the Fleet Operator Recognition Scheme and Eco-Stars further help operators to focus on best practice opportunities to improve fuel consumption and reduce their environmental impacts.

Background to the Freight Carbon Review

60 The Freight Carbon Review was commissioned in 2015 to bring together the evidence on the opportunities for and barriers to reducing road freight GHG emissions, to identify key evidence gaps, and to propose potential policy solutions. This report sets out the Review's key findings, identifies a range of Government- and industry-led emissions reduction options, and outlines a number of measures that the Government will put in place to support the road freight industry in reducing GHG emissions from the sector.

61 The Freight Carbon Review lays the groundwork upon which the Government will build to determine how we will achieve further GHG emissions savings out to the 2030s and beyond. However, it does not attempt to set out comprehensively all the steps that will be needed to deliver the necessary emission reductions from road freight. The forthcoming Emissions Reduction Plan will set out the steps being taken across the economy to reduce carbon emissions, including the potential contribution from the road freight sector. However, due to the current uncertainty regarding the 'right' solutions for road freight this will necessarily be an evolving picture over time as HGV technologies continue to emerge and develop.

Methodology

62 The Freight Carbon Review commenced with an evidence gathering and stakeholder engagement phase to understand industry priorities and identify key themes for further focus. Following this initial phase, the Review was split into five strands, which are outlined below and discussed in subsequent chapters of this report, as follows:

- Improving fuel economy through efficient driving and in-cab driver monitoring technologies (Chapter 2).

[31] http://www.fta.co.uk/policy_and_compliance/environment/logistics_carbon_reduction_scheme.html.
[32] At the time of publication 2015 data are not yet available.

- Optimising fleet design through retrofit technologies and improved engine efficiency (Chapter 3).
- Reducing road miles through modal shift, longer-semi trailers and further industry collaboration (Chapter 4).
- Reducing emissions through wider use of alternative fuels (Chapter 5).
- Shifting the focus to future, more radical, solutions such as electric trucks, e-highways and hydrogen fuel cell technologies (Chapter 6).

63 To supplement the evidence captured through the literature review, two research studies were commissioned on efficient driving and industry collaboration, led by AECOM and Transport Research Laboratory (TRL) respectively.

64 Based on the available evidence, a number of policy options were identified. The GHG abatement potential (measured in million tonnes of CO_2 equivalent saved ($MtCO_2e$)) and cost-effectiveness (the net cost per tonne of carbon saved) of each measure was assessed where there was sufficient evidence to do so. The analysis is presented throughout this report. In order to determine whether a measure is cost-effective, a benchmark carbon value for the relevant time period is used. For measures delivering GHG savings over the fifth carbon budget period, the benchmark value taken is the central non-traded carbon value in 2030, £78/tCO_2e in 2030 (in 2015 prices)[33]. Measures can be considered to be statically cost-effective if the net cost is lower than £78/tCO_2e.

65 However a static assessment of cost-effectiveness should not be the only consideration when deciding which options to take forward. There may be more expensive options that are not considered cost-effective in the short to medium term but may be required to meet the UK's 2050 climate change target. In some cases these may need to be taken forward earlier so that the necessary technology develops sufficiently or is rolled out across the fleet in time to meet longer term targets.

66 There is considerable uncertainty regarding both the mix of technologies that will be available by 2050 and the extent to which emerging technologies will penetrate the HGV market; and it is not possible to be definitive at this time on what will emerge as the most cost-effective approach. While technologies are not mutually exclusive, not all will necessarily be progressed. Developments in battery technologies might, for example, preclude the need for other major infrastructure projects, but it is also possible that hydrogen or electric infrastructure will prove a more cost-effective option for decarbonising long-haul freight.

67 In developing the Freight Carbon Review, DfT has engaged with other Government departments, devolved bodies, academic experts, and the freight and logistics industry. This engagement has improved our understanding of the key opportunities for and challenges and barriers to reducing road freight GHG emissions, and has highlighted existing and emerging freight decarbonisation options.

[33] https://www.gov.uk/government/collections/carbon-valuation--2

2. Efficient driving and in-cab technologies

Key messages

- There is evidence to suggest that use of efficient driving techniques and in-cab monitoring technologies can deliver significant fuel savings and a corresponding reduction in GHG emissions from HGVs.
- The relationship between driving techniques and air quality is less clear cut and further research is needed to better quantify this.
- Evidence on current efficient driver training uptake rates is inconclusive. However, anecdotal evidence suggests that larger operators are more likely than smaller operators to engage with training and invest in telematics equipment.
- The key barriers to wider uptake of efficient driving training include upfront costs, lack of evidence of economic benefits, and challenges associated with sustaining initial benefits over time.
- DfT will work with the Energy Saving Trust to pilot an HGV fleet review scheme to advise small and medium fleet operators on reducing fuel consumption and costs, including through providing advice on efficient driving and in-cab monitoring technologies - with the aim of delivering GHG emission savings.

Introduction

68 'Efficient driving' is a term used to describe the energy efficient operation of vehicles and consists of a combination of safe, responsible and anticipatory driving techniques. It encourages drivers to use their vehicles in an ecological and economical way to increase fuel efficiency, improve road safety and reduce greenhouse gas (GHG) and other emissions. Broader definitions of efficient driving encompass keeping the vehicle well maintained and undertaking routine checks to reduce unnecessary weight, rolling resistance and drag. Efficient driving can be supplemented by using a range of in-cab technologies that monitor driving on an ongoing basis and provide performance feedback to drivers and fleet managers.

69 There is evidence to suggest that efficient driving techniques and ongoing performance monitoring can deliver significant fuel savings and a corresponding reduction in GHG emissions from HGVs.

70 Analysis commissioned by the Committee on Climate Change (CCC) in 2015 suggests that efficient driving is a highly cost-effective way of reducing GHG emissions from road freight and, with the introduction of further supportive measures, could reduce emissions by a central estimate of 2.5 MtCO_2e by 2035 against a business as usual baseline scenario[34].

71 In addition to delivering GHG emission savings, the adoption of efficient driving practices potentially reduces pollutant emissions and helps improve air quality. However, the relationship between driving techniques and air quality is not necessarily a simple one and further research is needed to better quantify this.

72 Building on the above CCC analysis, DfT commissioned AECOM to assess the economic and environmental benefits of efficient driving training for HGV drivers, to explore the barriers to wider uptake and to identify potential measures to help overcome these barriers.

73 The AECOM study reviewed relevant literature in this field and surveyed 40 fleet operators (of which 19 were small, 19 were medium and two were large), 10 telematics system providers and 12 driver training providers to capture industry views on efficient driving uptake rates, costs, benefits and barriers. The operators included in the survey deployed vehicles across a range of duty cycles, including long haul, regional delivery, urban delivery, construction and municipal utility.

74 A report of the AECOM study has been published alongside the Freight Carbon Review and its findings are reflected in this chapter[35].

Efficient driving training

75 The AECOM study found that a variety of classroom-based and in-cab driver training is currently available, some of which focuses solely on efficient driving techniques, with other training also incorporating safety aspects. There is also variation in terms of training suppliers, ranging from in-house providers, to independent trainers, to large national suppliers. Table 2.1 below outlines some examples of efficient driving courses currently available to fleets.

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[34] http://www.csrf.ac.uk/wp-content/uploads/2015/11/CUED-C-SRF_TR_108-Greening.pdf
[35] AECOM, 2017, 'Eco-driving for HGVs'

Table 2.1: Examples of existing efficient driving courses

Course	Description
Driver Certificate of Professional Competence (CPC)	• HGV drivers are required hold a Driver Certificate of Professional Competence (CPC) qualification. • There are four elements to this qualification, which cover theory, case studies, driving ability and practical demonstration. • To stay qualified, an HGV driver must undertake a mandatory 35 hours of CPC periodic training every five years. • CPC course costs range from £50 to £100 per driver per day. • Although there is a syllabus, drivers are free to choose from a large number of accredited courses and efficient driving training is not mandated.
Safe and Fuel Efficient Driving (SAFED)	• The candidate’s driving is initially assessed by a qualified instructor. Training on best practice in safe and fuel efficient driving techniques is then given. The candidate’s driving is then reassessed to record improvements in driving performance and actual fuel consumption. • Historically SAFED driver training has received elements of subsidy from DfT for various transport sectors. However, these subsidies have now expired due to the full commercialisation of the programme via the Driver and Vehicle Standards Agency (DVSA), which is responsible for its day-to-day management. • Course costs range from £150 to £300 per driver per day.
Other efficient driving training options	• There are many training providers that deliver training for commercial vehicle drivers. Although this training is not specifically badged as ‘SAFED’, it includes many of the fundamentals of the SAFED programme, focussing on defensive and fuel efficient driving techniques.

76 Efficient driving training is delivered through a number of channels, with variable levels of success in terms of engaging drivers and achieving widespread coverage. A 2011 TNS-BMRB study explored how eco-driving training could be provided and promoted in a more engaging way to increase uptake amongst all types of existing Category B driving licence holders. It assessed four established training delivery modes, which are summarised in Table 2.2 below[36].

Table 2.2: Examples of efficient driving course formats

Course	Description
In-vehicle training	• Usually a one or two day course in a specially-prepared lorry. • The course consists of a test drive prior to training. The trainer then works alongside the driver to develop a new driving style which incorporates efficient driving techniques. A second test-drive then follows and an analysis of the improvement is conducted. The fuel consumption, speed and rate of gear change will generally be evaluated through the use of telematics or some equally effective monitoring equipment.
Simulator training	• Training simulators utilise software programmes to create a range of driving scenarios and can be a cost-effective option for training drivers outside the vehicle.

[36] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/142536/Eco_safe_driving.pdf

Online / CD-ROM / Classroom	• Includes a range of formats, ranging from theoretical approaches to more practical online simulation games. • Examples include ECOdrive - a computer programme (driving simulator) that can be installed on most computers.
Pamphlets	• Short printed documents, which provide information on efficient driving techniques.

77 The two most popular interventions were in-vehicle training, and the distribution of pamphlets with eco-driving information. In-vehicle training scored very highly on effectiveness and engagement and poorly on cost, flexibility and potential coverage. Conversely, the pamphlet option scored highly on likely cost, flexibility and potential coverage and poorly on effectiveness and engagement[37].

78 Although this study was not focussed on HGV operators, it does suggest that a range of interventions may be needed to increase awareness and uptake of efficient driving techniques and that a single, narrowly focussed solution may have limited impact.

Driver performance monitoring

79 In addition to driver training, ongoing monitoring of behaviour is integral to maintaining improved performance. A 2015 study by the Centre for Sustainable Road Freight (SRF) notes that, with the development of telematics, companies can now closely monitor the behaviour of their drivers against a series of criteria, such as speed, gear changes, braking profile and overall fuel efficiency[38]. 'Traffic-light' systems are increasingly being used to rate drivers' performance against these criteria and identify the need for additional training and support.

80 The AECOM study notes that with the advent and widespread adoption of smartphones, several mobile applications have been developed to support driver monitoring, which utilise the phone’s in-built functions, including GPS, and accelerometer, which measures acceleration forces. The study also highlights that a number of driver performance monitoring solutions are available, which aim to reduce costs and improve fuel efficiency, as outlined in Table 2.3 below[39].

Table 2.3: Examples of driver monitoring systems

Technology	Description

Telematics	• A vehicle telematics system usually integrates telecommunications and informatics, allowing the monitoring of and therefore improvement in the efficiency of a transport operation.
	• Costs for telematics systems range from around £10 to £25 per month, with additional installation costs.
	• While all telematics systems have the primary aim of recording data from the vehicle, this can be captured in different ways, including through:
	  ○ Connecting to the vehicle Controller Area Network (CANBus)
	  ○ Using GPS technology

[37] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/142536/Eco_safe_driving.pdf
[38] http://www.csrf.ac.uk/wp-content/uploads/2015/11/CUED-C-SRF_TR_108-Greening.pdf
[39] AECOM, 2017, ‘Eco-driving for HGVs’

	○ Using accelerometer technology
Key Performance Indicators (KPIs)	• The following KPIs are often recorded and monitored by operators to influence training needs and driver behaviour: ○ Green band driving[40] ○ Engine idling ○ Harsh breaking ○ Harsh acceleration ○ Excessive speeding
Driver performance league tables	• Driver performance league table reporting allows operators to compare the relative driving performance of individuals and groups of employees, and identify drivers that require additional support. This approach can also form the basis of incentive and reward schemes to boost employee engagement.

Benefits of efficient driving and driver performance monitoring

Economic and environmental benefits

81 The AECOM study drew on existing literature as well as conducting primary research to identify a range of economic, environmental and wider benefits from efficient driving training and use of in-cab monitoring technologies. It found evidence to suggest that these measures can deliver significant fuel savings and a corresponding reduction in GHG emissions from HGVs.

82 According to the 2015 SRF report, drivers undergoing training as part of the Government-sponsored Safe and Fuel Efficient Driving programme for HGVs (SAFED) have, on average, managed to improve the fuel efficiency of their driving by around 7%. SRF notes that some companies have reported fuel efficiency gains of 15% from these schemes, although it can be difficult to determine the extent to which this improvement is due to driver training as opposed to subsequent monitoring, de-briefing and incentives[41].

83 The percentage saving will also depend on the average driving standard prior to the introduction of the scheme as well as the nature of the delivery operation, age of the fleet and other factors, making generalisation difficult. However, SRF suggests that a 4-5% fuel and GHG saving is likely to be a realistic estimate for a company with a good record of fuel management and driver training[42].

84 In a 2015 study, the US-based National Center for Sustainable Transportation (NCST) collated the findings of a range of international eco-driving studies, as set out in table 2.4. Although limited, this evidence base suggests that HGV eco-driving can save fuel and reduce GHG emissions in the range of 5% to 15%[43].

[40] Modern engines have been developed to produce maximum fuel efficiency at low engine revs. The green band represents the rev band where the engine produces the best fuel efficiency and drivers should aim to drive within this band as much as possible.

[41] http://www.csrf.ac.uk/wp-content/uploads/2015/11/CUED-C-SRF_TR_108-Greening.pdf
[42] http://www.csrf.ac.uk/wp-content/uploads/2015/11/CUED-C-SRF_TR_108-Greening.pdf
[43] http://ncst.ucdavis.edu/wp-content/uploads/2014/08/06-24-2015-NCST_WP_Truck-eco-drivingFINAL.pdf

Table 2.4: Summary of HGV eco-driving evaluation studies[44]

Year	Country	Training method	Evaluation setting	Number of drivers	Fuel economy improvement
2005	UK	Driving simulator	Driving simulator	>600	3.5% immediately after training
2007	US	Class	Closed driving course	36	33.6% to 40.5% immediately after training
2009	Australia	Class	Prescribed real-world route	12	27.3% immediately after training; 26.9% after 3 months
2010	European countries	Class followed by monthly feedback and regular refreshing class	Actual real-world routes	322	9.4% over an unknown period
2011	U.S	Individualized coaching and in-vehicle real-time feedback system	Actual real-world routes	695	13.7% after 2 months
2013	Japan	Class	No information available	~3,000	8.7% immediately after training
2014	US	Individualised coaching and in-vehicle real-time feedback system (plus financial incentives)	Actual real-world routes	46	2.6% (5.4% with financial incentives) for sleeper cabs and 5.2% (9.9% with financial incentives) for day cabs after two months

85 Survey work undertaken through the AECOM study appears to support these findings. Here, 89% of survey respondents that deployed efficient driving training within their fleets reported an improvement in fuel consumption, with 76% reporting an increase in miles per gallon (MPG) and 71% reporting a reduction in engine idling. Although the extent to which these results can be extrapolated is limited by the small sample size, they indicate that fleets are realising economic benefits and making GHG emission savings through adopting efficient driving techniques[45].

86 The survey found that for 80% of respondents using efficient driving techniques, the payback period was one year or less, which appears to correlate with the CCC's assessment that this is a cost-effective measure. Survey responses from training providers suggest that the payback period can be variable, depending on the behaviour and standards of individual drivers prior to undertaking the training.

87 Uncertainty around the potential benefits of using efficient driving techniques and, in particular, the length of time over which those benefits persist, makes it difficult to

[44] http://ncst.ucdavis.edu/wp-content/uploads/2014/08/06-24-2015-NCST_WP_Truck-eco-drivingFINAL.pdf
[45] AECOM, 2017, 'Eco-driving for HGVs'

make a firm assessment of the cost-effectiveness of eco-driving training. In general, the longer the benefits last following an intervention, the more cost-effective that intervention will be.

88 In addition to delivering GHG emission savings, the deployment of efficient driving practices could potentially reduce air pollutant emissions. However, the Freight Carbon Review did not find any conclusive evidence to suggest a direct relationship between improved driving techniques and air quality benefits.

Wider benefits

89 The AECOM study identified a range of wider benefits from efficient driving, including professional and personal benefits for drivers. It noted that such training enables drivers to develop skills that promote their safety and that of their vehicle, load and other road users - particularly where schemes involve moderation of driver speed and observation and anticipation of the road ahead.

90 The study also noted that fleet operators can benefit from upskilling their drivers. In particular, the use of efficient driving techniques can increase productivity and vehicle utilisation, improve fleet resale values, reduce running costs (particularly relating to vehicle maintenance and tyres) and lead to reductions in insurance premiums by decreasing vehicle and personal injury incidents. Use of efficient driving can also create Corporate Social Responsibility opportunities for companies, as it enables operators to demonstrate their commitment to reducing their impact on the environment.

Current and projected uptake rates

Current uptake rates

91 The AECOM study notes that there is no published evidence on precise rates of efficient driving training in the road freight sector. Of the 40 operators that participated in the AECOM survey, 88% stated that their company utilised eco-driving techniques and/or driver monitoring. This comprises 100% of the large operators, 84% of the medium operators and 89% of the small operators surveyed[46].

92 This finding is striking as it suggests that a large majority of smaller operators already deploy efficient driving techniques or utilise telematics, which does not correlate with anecdotal evidence gathered through the Freight Carbon Review. However, it should be noted that these results may not provide a true representation of smaller operator practices due to the limited number of hauliers surveyed. It is also possible that, due to the self-selecting nature of the survey, participants had a pre-existing interest in efficient driving and were therefore more inclined to use efficient driving techniques than the average small operator. This conclusion is supported by the survey feedback from training providers and telematics suppliers, which suggests that uptake among small operators is around 20%, with limited engagement from operators running fleets with less than five vehicles.

[46] AECOM, 2017, 'Eco-driving for HGVs'

Projected uptake rates

93 The SRF report provides projected uptake rates for driver training and monitoring out to 2030 under a central scenario which, as set out in Table 2.7, suggests a significant increase in uptake by 2030.

94 The SRF also notes that there is some evidence of an increasing use of measures to improve routing amongst HGV operators. Between 2003 and 2010 the proportion of vehicles fitted with on-board computer systems, GPS systems and/or telematics in the freight sector grew sharply, increasing year on year for all measures[47].

Table 2.5: SRF take-up rates for behavioural efficiency measures, central commercial scenario[48]

Measures aimed at improving driving style	2010			2030		
	Small rigid	Large rigid	Attics	Small rigid	Large rigid	Artics
Give drivers training in fuel efficiency	8%	8%	8%	67%	67%	67%
Monitor and manage driver fuel performance (including use of telematics)	8%	8%	8%	67%	67%	67%

Barriers to wider uptake

95 Despite the economic and environmental benefits available from use of efficient driving and in-cab technologies, as outlined below, a number of barriers currently prevent wider uptake of these measures within the road freight sector.

Costs

96 The AECOM survey found that, amongst those consulted, the upfront costs associated with accessing efficient driving training and in-cab monitoring technologies were the most significant barrier to uptake. This correlates with findings from the 2011 TNS-BMRB report, which found that Category B drivers and employers were unwilling to invest in training without evidence of reduced fuel consumption or a reduction in vehicle insurance, and that without a financial incentive, drivers and employers were unlikely to view eco-driving training as a necessity[49].

97 According to the NCST study, economic incentive is perhaps the most influential factor in encouraging HGV operators and drivers to adopt efficient driving techniques. Economic benefits are strongly tied to fuel prices, and therefore when fuel prices are low, the incentive for drivers to change their driving habits and for companies to adopt efficient driving training and technologies is reduced[50].

98 The AECOM study found costs to be a particular barrier for smaller operators, who can lack the required financial resource and capacity to invest in efficient driving training and technologies and noted that, for this group, financial incentives may be

[47] http://www.csrf.ac.uk/wp-content/uploads/2015/11/CUED-C-SRF_TR_108-Greening.pdf
[48] http://www.csrf.ac.uk/wp-content/uploads/2015/11/CUED-C-SRF_TR_108-Greening.pdf
[49] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/142536/Eco_safe_driving.pdf
[50] http://ncst.ucdavis.edu/wp-content/uploads/2014/08/06-24-2015-NCST_WP_Truck-eco-drivingFINAL.pdf

necessary to encourage uptake. Smaller operators are also less likely to be in a position to realise economies of scale benefits associated with training large groups of drivers in one sitting with one trainer, as opposed to individual driver training, or to receive discounts from bulk purchase of telematics systems.

99 A European Commission paper notes that the average payback period for efficient driving training is 12-18 months and that payback periods vary amongst SMEs and are influenced by the cost of the selected training, the realised fuel savings, the total mileage per year and fuel prices. The paper concludes that medium-sized companies may have shorter payback times than small companies due to their relative fleet sizes[51].

100 The SRF report notes that SAFED sessions cost from £150-300 per session and that most companies have experienced a payback period of less than two years[52].

101 The AECOM study found that, aside from the upfront costs of accessing training, there are wider costs to industry. These are associated with the need for driver downtime to attend training courses, the costs of hiring agency drivers to provide to cover for course attendees and, in some cases, travel and accommodation expenses. Again, these costs are likely to be relatively more significant for smaller operators.

102 For driver monitoring systems, wider costs include vehicle downtime needed for system installation, financial outlay for drivers and managers to undertake system training, and costs associated with the analysis of telematics data.

Lack of evidence on benefits

103 The training providers surveyed by AECOM noted that small companies were less likely than larger operators to see a direct benefit from undertaking training or purchasing telematics equipment and were consequently relatively hard to reach. Small operators cited a lack of available information on the benefits of efficient driving training as a barrier to uptake as they were unconvinced that they would see a return on their investment[53].

104 This correlates with the TNS-BMRB survey which found that respondents felt there was insufficient proof that a reduction in fuel consumption or accidents was the direct result of eco-driving training rather than other mitigating factors[54].

105 When asked how the barriers to greater/more rapid uptake of efficient driving techniques could be overcome, around half of the operators surveyed suggested that this could be achieved through the development of guidance documents to increase awareness of the benefits.

Maintenance of benefits

106 There is broad consensus that driver training must be accompanied by monitoring, debriefing, publicity and incentive schemes to ensure that the ‘eco-driving’ practices are embedded after the training period[55]. In addition, anecdotal evidence gathered through the Freight Carbon Review suggests that while many fleet managers have access to telematics equipment, some require training and support in interpreting and optimising available benefits from telematics data.

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[51] https://ec.europa.eu/growth/tools-databases/resat/en/node/126
[52] http://www.csrf.ac.uk/wp-content/uploads/2015/11/CUED-C-SRF_TR_108-Greening.pdf
[53] AECOM, 2017, ‘Eco-driving for HGVs’
[54] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/142536/Eco_safe_driving.pdf
[55] http://www.csrf.ac.uk/wp-content/uploads/2015/11/CUED-C-SRF_TR_108-Greening.pdf

107 The TNS-BMRB report highlighted a concern that many drivers would not maintain efficient driving techniques after training, thereby limiting the impact and lifespan of such approaches. This was found to be a particular issue for smaller companies with smaller fleets and without tracking equipment, for whom it was virtually impossible to monitor the sustainability of eco-driving techniques[56].

108 The NCST study suggests that high turnover rates of HGV drivers may lead operators to be reluctant to invest in efficient driving training due to concerns about losing trained drivers. For drivers, requirements that they adhere to tight delivery schedules may sometimes cause them to prioritise speed over fuel savings. The study suggests that a well-structured driver performance monitoring programme that balances fuel efficiency with productivity and other goals is required to keep drivers' job satisfaction at a high level, which should in turn reduce the turnover rate[57].

Existing measures to encourage efficient driving

Fleet Operator Recognition Scheme

109 The Fleet Operator Recognition Scheme (FORS) is a voluntary three-stage – Bronze to Silver to Gold – European accreditation programme, which drives best practice across the European fleet industry in terms of safety, efficiency and environmental protection. It also offers guidance and training to help operators attain the Standard[58].

110 FORS mandates training for drivers designed to demonstrate their abilities in driving both safely and economically. The latest available FORS data (2015) shows that members reported a 4.3% improvement in fuel usage compared with 2014[59].

ECO Stars

111 Launched in 2009, the ECO Stars Fleet Recognition Scheme is a free scheme that aims to help fleet operators improve efficiency, reduce fuel consumption and emissions and make cost savings[60].

112 ECO Stars provides recognition for best operational practices, and guidance for making improvements. On joining the scheme, members are awarded an ECO Star rating (from 1 to 5 stars). This is based on existing individual vehicle performance as well as across the fleet. Eco Stars then provides a 'Road Map' which gives tailored advice to help improve fleet efficiency.

Energy Saving Trust Green Fleet Reviews

113 The Energy Saving Trust (EST) provides a number of bespoke consultancy services to car and van fleet operators, which help fleets save energy, reduce operating costs, reduce CO_2 and air pollution emissions, and improve road safety.

114 Green Fleet Reviews are currently available for SMEs in England with a fleet size of between 20-100 vehicles and for vehicles up to 3.5t and are designed to help improve the sustainability of individual fleets. EST calculates individual fleets' carbon footprints and makes recommendations to improve fuel and mileage management, including through driver behaviour change.

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[56] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/142536/Eco_safe_driving.pdf
[57] http://ncst.ucdavis.edu/wp-content/uploads/2014/08/06-24-2015-NCST_WP_Truck-eco-drivingFINAL.pdf
[58] https://www.fors-online.org.uk/cms/
[59] https://www.fors-online.org.uk/cms/wp-content/uploads/2016/03/FORS_Annual_Report_2015.pdf (based on data reported during 2014 and 2015 for a sample of 22,464 vehicles)
[60] http://www.ecostars-uk.com/

Next steps

115 As an outcome of the Freight Carbon Review, DfT is funding EST to pilot an HGV fleet review scheme for small and medium-sized operators. This service will deliver five days bespoke consultancy for each participating fleet, designed to reduce fuel and operating costs and improve profitability whilst also improving environmental performance.

116 The consultancy component will initially aim to understand current fleet operations and practices through analysis of the fleet. This information will then be used to calculate the current carbon footprint and air quality impact, from which recommendations on a range of best practice measures together with an action plan for improvement will be generated.

117 This consultancy will cover:

- Choosing the best vehicle for the job
- Driver behaviour
- Technology to improve existing vehicle performance
- Route optimisation
- Fuel management

118 Each participating fleet will receive a tailored report produced by EST using its advanced online report builder tool that can accurately calculate potential cost and emission savings for individual operators. There will be a five pilot project this year, which will be evaluated with a view to wider roll-out should it prove successful. This work will help build our evidence base to determine the extent to which the emissions savings identified by the CCC might be practically deliverable, and how any barriers might be overcome.

119 We recognise that the barriers to wider uptake of efficient driving training and in-vehicle monitoring technologies are complex and that further evidence is needed to understand they could be overcome, including the role for Government in supporting further uptake of these measures.

3. Fleet design

Key messages

- Fuel efficient technologies, such as aerodynamic devices and low rolling resistance tyres, can deliver fuel savings for operators and provide a cost-effective means of reducing GHG emissions.
- While many fleet operators are already using these technologies, evidence suggests that uptake amongst parts of the industry, notably smaller operators, is more limited. This is due in part to an unwillingness or lack of capacity to invest in these technologies, even though they can be relatively low cost options.
- A number of tools already exist to inform fleet purchasing decisions. An HGV accreditation scheme has recently been developed and launched by the Low Carbon Vehicle Partnership to provide independent validation of the fuel and carbon savings available from aftermarket technologies.
- There is a role for Government and industry in ensuring that operators have the knowledge and confidence to invest in these technologies and achieve the associated fuel and GHG emission savings.

Introduction

120 Technologies, such as aerodynamic devices and low rolling resistance tyres, aim to improve the fuel efficiency of HGVs and therefore reduce GHG emissions. These technologies can either be installed on new vehicles at the point of manufacture or retrofitted by operators. While some freight and logistics companies currently use these technologies, they are not installed across the whole vehicle fleet and there is an opportunity to make further GHG savings by increasing uptake. If we are to see significant reductions in GHG emissions from road freight by the 2030s, it will be important to encourage wider industry use of fuel saving equipment.

121 Until recently, the majority of available evidence on the GHG abatement potential of fuel efficient technologies related to new vehicles. However work undertaken in 2015 by the Centre for Sustainable Road Freight (SRF), on behalf of the Committee on Climate Change (CCC), to assess the potential fuel savings available from a range of demand-side measures within the road freight sector suggests that a saving of 0.9 $MtCO_2e$ by 2035 could potentially be achieved by retrofitting such technologies to existing commercial vehicles. Of these savings, 0.5$MtCO_2e$ would come from aerodynamic improvements and 0.4$MtCO_2e$ from measures to reduce rolling resistance. This represents a saving of around 5% relative to the CCC baseline for HGV emissions. The SRF report suggests that the majority of these savings would come from vehicles operating on long haul duty cycles, which usually carry heavier payloads and therefore experience relatively high fuel consumption[61].

122 The costs and benefits associated with specific fuel saving technologies vary according to the vehicle, driver, duty cycle, fuel type and driving conditions. There is not a single solution to fit all vehicles and individual operators are best placed to make investment decisions based on their own fleets and circumstances. The evidence we do have suggests that some of these technologies offer a low cost GHG emissions reduction solution for businesses, and that their wider adoption could deliver near-term improvements. There is a role for Government and industry in ensuring that operators have the knowledge and confidence to invest in these technologies and achieve the associated fuel and GHG emission savings.

Overview of available technologies

Aerodynamics

123 When a vehicle moves, the surrounding air exerts a force on the vehicle that opposes its motion. This force is the aerodynamic drag, and it has a significant effect on the fuel consumption of a vehicle. Drag is affected by vehicle shape, frontal area and speed. The greater the frontal area of a vehicle and the higher the vehicle speed, the greater the aerodynamic drag will be. Approximately half of the energy used by an HGV travelling at 50 mph is needed simply to move through the air around the vehicle[62].

124 Aerodynamic styling can be specified by operators at the point of manufacture, to reduce aerodynamic drag, fuel consumption and operational costs. There is also a range of add-on features available, which can be retrofitted to existing vehicles to improve their aerodynamics. Options can include:

[61] http://www.csrf.ac.uk/wp-content/uploads/2015/11/CUED-C-SRF_TR_108-Greening.pdf
[62] http://www.transport.gov.scot/system/files/uploaded_content/documents/tsc_basic_pages/Road/Fuel_savings_in_a_Scottish_haulage_fleet_.pdf

- **Cab features** such as roof deflectors, roof fairings, cab side-edge fairings and cab collars, which smooth aerodynamic airflow by minimising the gap between the cab and trailer to reduce total air drag.
- **Chassis features** such as tractor side panels, filler panels and trailer side panels that can save fuel by limiting the interaction of the airflow along the vehicle side with the vehicle chassis.
- **Aerodynamic trailers**, which are designed to follow a teardrop shape rising up from a standard 4m height of cab to a max of 4.5m and then reducing to the rear. The design can also feature full side skirts to help minimise aerodynamic drag.
- **Add-on front fairings and gap seals**, which can be added to trailers and containers to help reduce the aerodynamic drag.

Tyres

125 Low rolling resistance tyres are designed to minimise the rolling resistance of a tyre whilst maintaining the required levels of grip on the road. Maintaining optimal pressure through regular checks by the driver or the use of tyre pressure monitoring systems is important both for safety and for reducing fuel consumption. Automatic tyre pressure monitoring systems use the air compressor on a vehicle to automatically monitor and inflate the tyres when required, and some types of light commercial vehicle may be fitted with a tyre pressure monitoring system to alert the driver to a slow puncture.

Engine efficiency improvements

126 Vehicle manufacturers are working to improve the thermal and mechanical efficiency of the engine as this is a key factor in reducing fuel consumption and improving overall HGV fuel efficiency. For example, the friction of an engine's internal moving parts can reduce potential horsepower and it is therefore beneficial for manufacturers to reduce this friction as much as possible. There are also significant thermal losses within the engine and exhaust system. Waste heat recovery systems can convert engine thermal losses into energy, which can be used to supplement power to the vehicle. Although at an early stage of implementation, this technology can be used on both hybrids and conventional vehicles and produces either electric energy for batteries or mechanical energy that can drive ancillary equipment.

In-cab technologies

127 Telematics-based technologies facilitate the transmission of information to and from vehicles. Telematics systems are able to monitor the location of vehicles and the way in which they are being driven in order to improve efficiency and reduce business costs, and are discussed in Chapter 2 of this report.

Cost effectiveness and GHG abatement potential of retrofit technologies

Private costs and benefits

128 Analysis undertaken by AEA (now Ricardo Energy & Environment) in 2012 shows the potential costs and benefits associated with a selection of the technologies outlined above.

129 The costs to operators of installing these technologies vary according to technology type and are dependent on numerous operator-specific factors. Based on the figures

estimated by AEA, DfT has estimated the payback period for these technologies. These can range from a few months for spray reduction mud flaps, to several years for automatic tyre pressure adjustment equipment. The results, which are set out in Table 3.1 below, show that aerodynamic trailers/bodies are relatively more cost-effective for artic than for rigid trucks.

Table 3.1: Technology costs, efficiency improvements and payback periods[63]

Technology	Efficiency Improvement		Capital Cost		Estimated Payback Period	
	Small Rigid (<15t)	**Artic Truck**	**Small Rigid** (<15t)	**Artic Truck**	**Small Rigid** (<15t)	**Artic Truck**
Low rolling resistance tyres	1%	5%	£200	£280	1.5 – 2 years	2 months
Aerodynamic trailers / bodies	1%	11%	£1,200	£2,800	> 10 years	6 months
Automatic tyre pressure adjustment	1%	3%	£7,708	£11,156	> 10 years	7-8 years
Light weighting	4%	2.2%	£577	£1,826	1 – 1.5 years	1.5 – 2 years
Predictive Cruise Control	N/A	1.5%	N/A	£62	N/A	1 month

130 The above costs do not take into account the time cost to operators of installing these technologies. In certain circumstances, particularly for smaller operators who rely on their vehicle(s) being on the road at all times, there may be significant costs associated with taking it off the road while kit is being installed.

131 SRF has developed an Optimiser tool that aims to provide tailored advice to fleet operators on GHG saving technologies to inform investment decisions[64]. An illustrative example is presented in Table 3.2, which shows Optimiser results based on an operator running one HGV above 32 tonnes gross vehicle weight, with average fuel efficiency, travelling 100,000 km a year.

132 It is also important to consider the cumulative impact of installing multiple technologies on the same vehicle. Combining certain technologies may increase a vehicle's fuel efficiency to a greater extent than could be achieved by separate installation or, conversely, combining technologies may reduce the overall savings that could be derived from a series of improvements.

[63] Source of costs and efficiency improvements: AEA (2012) 'A review of the efficiency and cost assumptions for road transport vehicles to 2050'. Source of estimated payback periods: DfT Modelling.
[64] http://www.csrf.ac.uk/srf-optimiser-2/

Table 3.2: Results from SRF Optimiser

Carbon-saving measure	Net Present Value (£)	Cost savings per annum (£)	CO_2 savings per annum ($KgCO_2$)	Fuel saved (Litres)	Payback period (Years)
Telematics	11,400	3,600	7,900	3,100	0.8
Tear-drop trailer	11,300	4,400	9,600	3,700	2.3
Side skirts	6,300	1,800	4,000	1,600	1.4
Cab-roof fairing	6,100	1,800	3,900	1,500	1.5
Boat-tail	5,100	1,800	4,000	1,600	2.1

Social costs and benefits

New vehicles

133 The CCC has used the 2012 AEA report[65] to project the efficiency improvement to conventional HGVs through measures such as heat recovery, low rolling resistance tyres and weight reduction. This analysis suggests that:

- Between 2010 and 2030, small rigid HGVs (<15t) could see efficiency improvements of around 13%, and larger articulated HGVs could see improvements of around 33%. This is equivalent to a real-world CO_2 intensity of 580-660 gCO_2/km[66].
- The average abatement cost associated with these efficiency improvements for a new HGV in 2030 is £-79/tCO_2, representing a net benefit to society.

134 This figure varies according to vehicle type, with efficiency improvements for new small rigid HGVs having an abatement cost of £17/tCO_2 and a cost saving of £151/tCO_2 for new articulated HGV efficiency improvements. The positive abatement cost for small rigid HGVs suggests that the technologies are not privately cost-effective and that operators may not see the benefit in using them. However, to assess social cost-effectiveness, the abatement cost can be compared to the Government's published carbon values (£78/tCO_2e in 2030, growing steadily to £220/t in 2050)[67]. This suggests that while an abatement cost of £17/tCO_2 may not be cost saving for an operator, it is a cost-effective way of reducing emissions in line with the UK's climate change targets.

135 These figures are influenced by a range of wider factors including duty cycle, selected technologies, driver behaviour, and vehicle miles. For example, cost effectiveness is expected to be greater for vehicles with higher annual mileages as there is increased potential to make fuel savings.

Retrofit technologies

136 SRF has analysed the potential HGV carbon savings from retrofitting fuel efficient technologies to existing vehicles, and found this to be generally cost effective and in some cases cost saving, depending on the specific technologies and vehicle type[68].

137 Other work suggests that the potential for fuel savings through improved aerodynamic styling will be greatest in cases where a vehicle is most affected by one of the three key pointers to aerodynamic drag:

[65] http://ee.ricardo.com/cms/assets/Documents-for-Insight-pages/8.-Review-of-cost-and-efficiency.pdf
[66] https://www.theccc.org.uk/wp-content/uploads/2015/11/Sectoral-scenarios-for-the-fifth-carbon-budget-Committee-on-Climate-Change.pdf
[67] https://www.gov.uk/government/collections/carbon-valuation--2
[68] http://www.csrf.ac.uk/wp-content/uploads/2015/11/CUED-C-SRF_TR_108-Greening.pdf

- High-speed travel
- Large vehicle frontal area
- Poor initial aerodynamic design

138 It has been noted that savings of up to 13% in fuel can be achieved by investment in an aerodynamics package, which is estimated to payback in a little over one year[69].

Uptake rates

DfT HGV technology survey

139 In 2015, DfT undertook a survey to capture data on current levels of uptake of fuel efficient technologies among HGV operators. The survey sample of 1,000 HGV owners was drawn from respondents to the annual Continuing Survey of Road Goods Transport (CSRGT). Around 700 responses were received, providing a representative sample of the UK's HGV fleet.

140 As shown in Table 3.3 below, spray reduction mud flaps were the most commonly fitted of the technologies listed, with over 70% of respondents stating that they were installed on their vehicle. However, it is possible that some respondents may not have made the distinction between standard spray reduction mud flaps and those types specifically marketed as providing fuel cost savings when responding to the survey, and incorrectly identified themselves as using this technology.

Table 3.3: Results from DfT HGV technology survey

Technology	Uptake amongst survey respondents
Spray reduction mud flaps	74%
Voluntary speed limiter	58%
Cab roof air deflector	52%
Automated Manual Transmission	49%
Telematics to optimise vehicle routing	41%
Electronic driver performance monitoring	35%
Technology to reduce engine idling	33%
Low rolling resistance tyres	25%
Cab collar	25%
Predictive cruise control	25%
Body skirts	16%
Voluntary rev limiter	16%
Full gap fairings	16%
Tyre pressure monitoring system	11%
Trailer rear end (taper/boat-tail)	2%
Teardrop-shaped trailer	1%
Automatic tyre inflation	1%

141 The survey also found that larger fleet operators were more likely than smaller operators to install certain technologies on their vehicles. The differences in uptake between larger and smaller operators was found to be less pronounced for the less commonly installed technologies. As shown in Figure 3.1, there was not much

[69] http://www.transport.gov.scot/system/files/uploaded_content/documents/tsc_basic_pages/Road/Fuel_savings_in_a_Scottish_haulage_fleet_.pdf

disparity between large and small fleet operators in the uptake of predictive cruise control, body skirts, voluntary rev limiters, and tyre pressure monitoring systems. However, for more popular technologies such as cab roof air deflectors, automated manual transmission, and telematics to optimise vehicle routing, a more marked difference can be seen.

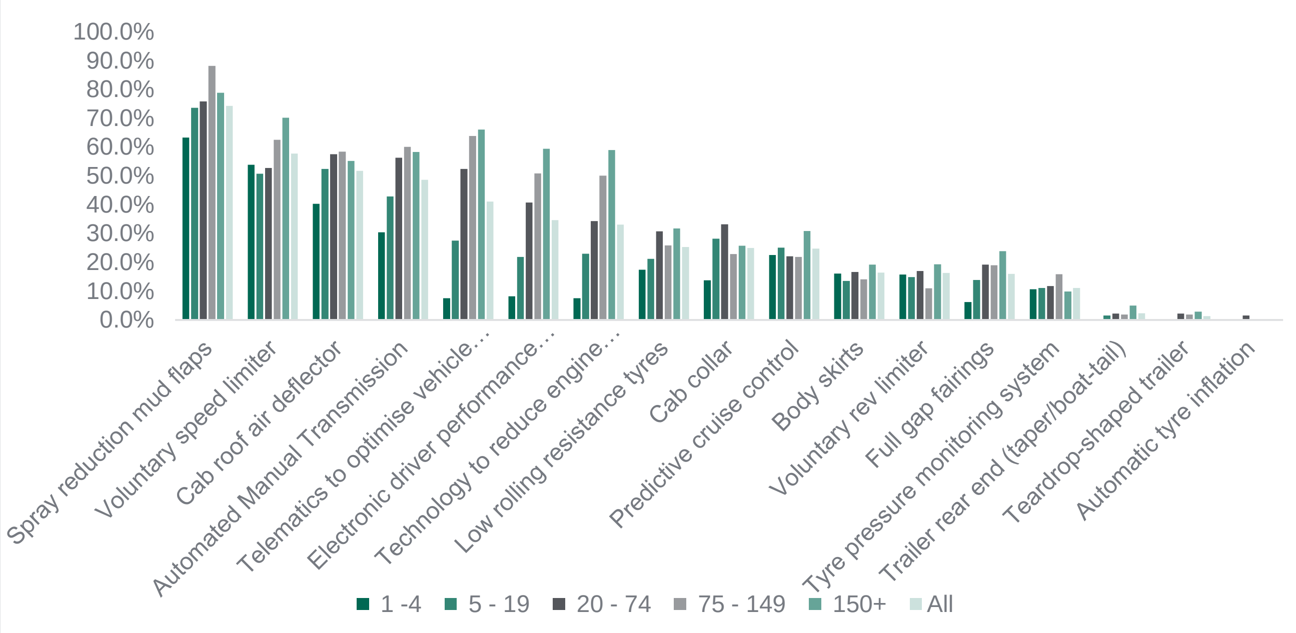

Figure 3.1: Uptake of technologies by operator fleet size

142 9% of survey participants did not have any of the listed technologies installed. This finding primarily relates to owners of construction vehicles. Furthermore, 43% of respondents with no listed technologies installed were small operators with 1-4 HGVs. Following the survey, DfT contacted a number of these respondents to understand their decision making processes and the key barriers to technology uptake. Respondents commented that the key barriers related to the cost of the technologies and a lack of clear evidence of the benefits from authoritative sources.

Future uptake rates

143 As part of its study for the CCC on demand side measures, SRF considered potential future uptake rates for retrofit technologies, and developed a number of uptake scenarios, covering varying fuel prices and payback periods. None of the scenarios modelled included significant policy change from the current situation. For each of the scenarios, future annual uptake was estimated for each technology. These estimates were derived from the results of focus groups and survey findings, and suggest relatively slow uptake of most technologies[70].

144 The 2012 AEA study also estimated future deployment of fuel saving technologies on new vehicles. These estimates differed according to the size of the vehicle and the individual technology, and a sizeable range was provided. The analysis suggests that some in-cab and engine technologies could potentially be installed in all new vehicles. The aerodynamic technologies are more specific to certain vehicles, so maximum deployment for these technologies encompasses a much greater range. AEA's baseline scenario shows maximum deployment potential being reached between 2040 and 2050, depending on the technology, under current policies and

[70] http://www.csrf.ac.uk/wp-content/uploads/2015/11/CUED-C-SRF_TR_108-Greening.pdf

regulations[71].

145 It is unlikely that we will see universal uptake across the entire HGV fleet due to the diverse range of HGVs and duty cycles. Maximum potential uptake is therefore highly uncertain and very dependent on the specific technology.

Barriers

146 Informal stakeholder consultation undertaken through the Freight Carbon Review indicates that the main barriers to further uptake of retrofit fuel efficient technologies relate to uncertainty around the costs of purchasing and installing retrofit kit, and the associated fuel economy benefits.

Costs

147 As shown in Table 3.1 above, the costs of these technologies differ broadly, ranging from approximately £11 for spray reduction mud flaps to £1,000s for an automated transmission system. At the more affordable end of the scale, stakeholders have suggested, anecdotally, that costs are not a major barrier to increased uptake. However, technologies with relatively high upfront costs are not within reach of some operators, and high capital costs can deter industry investment, particularly if operators are not confident that they will see the efficiency benefits that are claimed.

148 The evidence we have reviewed does not suggest that the most expensive technologies are necessarily the most effective in improving fuel efficiency. However as already outlined, there is not a single industry-wide solution, and what works for one operator may not be effective for another.

149 Allocating time and resource to research and install fuel saving technologies can generate further costs to industry, particularly for small operators. Larger firms may have employees dedicated to improving the company's sustainability performance and therefore have the capacity to carefully consider a number of cost-effective fuel saving technologies. Smaller firms, however, may not be resourced to identify and investigate these technologies, and doing so would potentially divert staff from paid work and therefore impose costs on the business. The vehicle downtime required to install retrofit kit depends on the technology type and is likely to range from an hour to a couple of days, creating a further barrier for smaller fleets that are reliant on their vehicles running to full capacity.

Uncertainty about the benefits

150 HGV operators may be unlikely to invest in technologies with uncertain payback periods. Margins in the road freight sector are tight, so operators need to be confident that capital costs will be recouped within an acceptable time frame. Anecdotal evidence gathered through the Freight Carbon Review suggests that there can be significant differences in the behaviour of larger and smaller operators, with larger operators having greater capacity to make initial investments and higher levels of tolerance for extended payback periods.

151 This focus on payback periods for operators means that it is important to improve levels of understanding of costs and benefits. As it stands, the level of evidence and detail available on the various fuel saving technologies is mixed and information can be difficult to locate and compare. Engagement with industry through the Freight Carbon Review has suggested that having an authoritative source of comprehensive,

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[71] http://ee.ricardo.com/cms/assets/Documents-for-Insight-pages/8.-Review-of-cost-and-efficiency.pdf

independent information would enable operators to make sound, evidence-based investment decisions and would go some way towards addressing this barrier.

Current and forthcoming measures

152 A number of measures are already in place to support the uptake of fuel saving retrofit technologies within the road freight sector, some of which are summarised below.

HGV technology accreditation scheme

153 In June 2016, the Office for Low Emission Vehicles in conjunction with the Low Carbon Vehicle Partnership (LowCVP) launched an HGV technology accreditation scheme. This scheme has been designed to provide independent validation of fuel savings from a range of retrofit technologies, providing transparency and greater certainty to operators. The scheme has been designed to accelerate the adoption of fuel saving technologies and thereby reduce fuel costs for fleet operators while delivering GHG savings[72].

Logistics Carbon Reduction Scheme

154 Anecdotal evidence collected through the Freight Carbon Review suggests that there is significant scope for increasing communication, advocacy and knowledge sharing between different parts of the freight and logistics industry on the benefits of fuel saving technologies.

155 The Freight Transport Association's (FTA's) Logistics Carbon Reduction Scheme (LCRS) is a free voluntary industry initiative that encourages best practice by enabling members to record, report and reduce carbon emissions. The LCRS, which now has over 125 members - accounting for over 88,000 commercial vehicles, has been running for over seven years and has made considerable progress towards its target to reduce carbon emissions by 8% by 2015 compared to 2010 levels[73]. In 2016, the LCRS began collecting data on the take up of Euro VI/6 commercial vehicles to improve air quality[74]. LCRS members have commented that being a part of the scheme enables them to network with other like-minded logistics companies and share best practice. One of the objectives of the LCRS is to continue to provide industry leadership on the adoption of low carbon fuels and technologies.

156 The FTA will be renewing the LCRS later in 2017, with a focus on encouraging participation from smaller operators. The Government welcomes the FTA's work in this area and is supportive of wider participation amongst the freight and logistics industry.

Energy Saving Opportunity Scheme (ESOS)

157 ESOS is a mandatory energy assessment scheme for organisations in the UK that meet the qualification criteria. Organisations that qualify for ESOS must carry out ESOS assessments every four years. These assessments include audits of the energy used by their buildings, industrial processes and transport - to identify cost-effective energy saving measures. ESOS applies to large UK undertakings and their corporate groups. A large undertaking is defined as a company that carries out a trade or business which employs 250 or more people, or employs fewer than 250 people but has both an annual turnover exceeding €50m and a balance sheet

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[72] http://www.lowcvp.org.uk/projects/commercial-vehicle-working-group/hgv-accreditation-scheme.htm
[73] Data covering 2015 were not available at the time of publication.
[74] This will be reported in the FTA's Logistics Carbon Review 2017 available later this year.

exceeding €43m. Any freight company that meets these criteria would qualify for ESOS.

Centre for Sustainable Road Freight (SRF) Optimiser tool

158 SRF is a collaboration between Cambridge and Heriot-Watt Universities and other industry stakeholders with a five-year grant from the Engineering and Physical Sciences Research Council and an industrial consortium. The purpose of the SRF is to research engineering and organisational solutions to make road freight economically, socially and environmentally sustainable.

159 SRF has developed an Optimiser tool in collaboration with Value Chain Lab. This is a free-to-use, web-based tool which calculates GHG emissions, energy consumption and costs to an operator of 29 carbon-reducing measures. The tool supports decision making amongst fleet owners and operators looking to invest in fuel efficient technology, and can be used by any organisation, business or company that is involved in road freight transport operations. It can be used to generate an energy savings report to help with the requirements of ESOS.

Eco Stars

160 The Eco Stars scheme aims to highlight best operational practices and provides guidance to fleet operators for making efficiency improvements. Further information on Eco Stars is provided in Chapter 2 of this report.

Amendments to the General Circulation Directive (96/53/EC)

161 The General Circulation Directive (96/53/EC) sets the maximum weights and dimensions of vehicles circulating across the EU. In May 2015 an amending Directive, (EU) 2015/719, was published in the European Commission Official Journal. The new Directive includes proposals to permit additional length at the front and rear of vehicles to allow manufacturers to develop more aerodynamic, fuel-efficient and safer vehicles.

162 The European Commission will propose amendments to type approval legislation to set out the technical requirements for more aerodynamic cabs and rear aerodynamic devices that are permitted under the amending Directive 2015/719. We will look to work with our European counterparts and the European Commission to develop the technical requirements.

Next steps

163 The Freight Carbon Review has identified a role for Government in addressing the barriers to wider uptake of fuel saving technologies and communicating the associated benefits to industry.

164 The HGV Accreditation Scheme provides a ready-made tool to enable operators to make informed technology investment decisions and promote the uptake of equipment with proven fuel-saving capabilities. We will consider options for encouraging wider use of the HGV accreditation scheme across the freight and logistics sector.

4. Reducing road miles

Key messages

- There is potential to optimise use of the road, rail and water networks to reduce GHG emissions through increased use of rail and waterborne freight, deployment of longer semi-trailers and more effective industry collaboration.
- Shifting freight from road to rail can result in significant GHG emission savings, as well as economic and safety co-benefits. However there are significant barriers that would need to be overcome in order for such modal shift to be optimised.
- The current trial of longer semi-trailers is delivering promising economic and environmental results. The Government has recently announced its intention to extend the size and duration of the trial.
- There is scope to improve the efficiency of freight operations and reduce emissions through wider industry collaboration if existing barriers can be addressed. In particular, further work is needed to understand the costs and benefits of available measures to support wider industry collaboration.

Introduction

165 There is potential to optimise the use of the road, rail and water networks to reduce GHG emissions through increased use of rail and waterborne freight, deployment of longer semi-trailers and more effective industry collaboration.

166 The Rail Freight Strategy[75], published in September 2016, highlights the GHG abatement potential from modal shift from road to rail and identifies a range of issues that would need to be addressed to realise this potential. The Strategy was supported by an assessment from Arup of the likely scale of GHG emission savings out to 2030 from shifting freight from road to rail, and the types of policy intervention that would be needed in order to achieve this. The study suggests that savings could be significant[76].

167 In addition to opportunities to make better use of the rail network, further efficiencies can be achieved through more effective use of the road network. DfT's ongoing Longer Semi-Trailer Trial was launched in 2012 and is enabling the use of longer vehicles, up to an extra 2.05m in length, to be trialled in Great Britain for ten years. Results from the trial to date suggest major benefits by way of improved efficiency and potential CO_2 savings[77].

168 A further aspect of improved efficiency is encouraging the freight industry to collaborate effectively so that vehicles are used to their maximum capacity wherever possible. Increasing vehicle fill decreases the number of HGVs on the road, thereby reducing emissions. To inform the Freight Carbon Review's evidence base, DfT commissioned Transport Research Laboratory (TRL) to undertake a study which explored the opportunities for and barriers to wider industry collaboration, the results of which are summarised in this chapter. The full TRL report has been published alongside the Freight Carbon Review[78].

Summary of measures to reduce road miles

Modal shift to rail

169 The 2016 Rail Freight Strategy sets out the Government's vision for how rail freight, in its traditional sense, can continue to grow, even though some of its traditional core markets such as coal are now in decline. It outlines the potential opportunities for the broader logistics sector and rail industry to collaborate and innovate in order to help relieve congestion pressures on our road network while delivering environmental and safety benefits[79].

170 The Arup study notes that modal shift reduces carbon emissions by an estimated 76% as each freight train removes the equivalent of 25-76 HGVs from the British road network[80]. The Government recognises the environmental benefits provided by rail freight, and remains keen to encourage modal shift from road to rail, in a cost-effective way.

171 The Arup study identified ten illustrative measures which, if combined, could potentially lead to emission savings of over 2.35 $MtCO_2e$ in 2030. These include

[75] https://www.gov.uk/government/publications/rail-freight-transport
[76] http://www.arup.com/railfreightmarket
[77] https://www.gov.uk/government/publications/longer-semi-trailer-trial-evaluation-annual-report-2015
[78] TRL, 2017, 'Freight Industry Collaboration Study'
[79] https://www.gov.uk/government/publications/rail-freight-transport
[80] http://www.arup.com/railfreightmarket

new-build rail freight terminals, capacity and gauge enhancements and alternative locomotive technologies[81]. As some of the illustrative measures overlap, the potential benefits may be lower than a simple aggregation of the figures would imply. However, it is clear that if this figure could be achieved in practice, it would make a significant contribution to reducing emissions from transport.

172 It should be noted, however, that some of the proposed measures identified by Arup are complex and challenging and would require extensive investment in new infrastructure, and therefore need to be considered in the context of other strategic priorities.

Modal shift to water

173 Whilst rail freight is often considered to be the main alternative to road freight, that is to overlook the significant benefits of moving freight by water. Waterborne freight, namely coastwise shipping[82], and that on inland waterways, continues to provide a viable alternative to other freight modes.

174 Although levels of waterborne freight have declined from their peak, use of our inland waterways, particularly our major rivers, and coastwise shipping has continued to provide a valuable route for freight transport. In fact these two markets are stable, or showing a degree of resurgence, as they become increasingly more attractive for the environmental benefits they provide, and the reliable congestion-free freight access they offer over alternate modes.

175 In 2015 the total amount of goods moved for all domestic waterborne freight increased by 16% to 31.4 billion tonne kilometres, and accounted for 15% of total domestic freight transport in the UK. The positive result within this is coastwise traffic where there was a 26% growth in goods moved in 2015, continuing a trend of ongoing growth since 2012[83].

Longer semi-trailers

176 The use of higher capacity vehicles provides an opportunity to deliver more freight in a single journey, reducing fuel consumption and GHG emissions per tonne-km of freight movement[84]. The ten year Longer Semi-Trailer (LST) Trial is enabling the use of vehicles up to an extra 2.05m longer than the standard 13.6m units in length within current weight limits in Great Britain. The Vehicle Certification Agency has granted Vehicle Special Orders to 1,800 operators as part of the trial, which is designed to evaluate the impact of LST operations on efficiency, emissions and safety.

177 A reduction in emissions is expected because the increased trailer length should enable the same quantity of goods to be transported in fewer journeys. The ongoing evaluation of the trial will determine whether this potential reduction in emissions is realised; however initial results indicate major benefits by way of reduced journeys and CO_2 savings[85].

178 As a result of the positive results seen to date, and following informal consultation with the freight and logistics industry, the Government has agreed to increase the number of LSTs by an additional 1,000 and to extend the trial by five years. This increase will take the number of LSTs from 1,800 to approximately 2,800 over the next 12 months.

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81 http://www.arup.com/railfreightmarket
82 Coastwise shipping is traffic carried around the coast from one UK port to another.
83 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/575274/dwf-2015.pdf
84 http://www.csrf.ac.uk/wp-content/uploads/2015/11/CUED-C-SRF_TR_108-Greening.pdf
85 https://www.gov.uk/government/publications/longer-semi-trailer-trial-evaluation-annual-report-2015

Industry collaboration

179 Analysis undertaken by the Centre for Sustainable Road Freight (SRF) suggests that 2.5 $MtCO_2$ could potentially be saved by 2035 through measures to reduce HGV km. The SRF attributes these improvements to measures such as improved routing, use of consolidation and distribution centres, higher lading factors, a reduction in empty running[86] and use of computerised technologies. These measures are expected to reduce emissions by reducing overall distances driven by HGVs[87].

180 The aforementioned TRL study explored opportunities for and barriers to wider industry collaboration. Findings from this research were based on a literature review, which was supplemented by a fleet operator survey, including both hire and reward and own account operators as well as a mix of large, medium and small operators[88].

181 The study defined ‘collaboration’ within the context of the road freight sector as a joint initiative enabling operators to work more closely together in order to reduce the number of HGVs on the road and therefore decrease GHG emissions. TRL noted that this collaboration can be used to reduce empty running by identifying routes and journeys where operators can consolidate loads into single vehicle trips. Examples of collaboration are described below:

Route scheduling and planning to create more efficient supply chains

- Organisations that undertake logistics will do some form of route scheduling and planning as part of their supply chain operation. The effectiveness of this process varies between operators and there may be opportunities to optimise supply chain planning through collaborating with other parts of the business’s wider supply chain - for example by working vertically with suppliers and customers to optimise order cycles and delivery schedules.

Backhauling to reduce empty running

- Operators can reduce empty running by backhauling (returning from a delivery with a new load). An extension of this is ‘forward hauling’, which makes use of available capacity *en route* to pick up loads on vehicles that would otherwise be running empty. Back and forward hauling are a means of filling completely empty loads or increasing loads for vehicles that would otherwise be running under capacity. This can be arranged between organisations independently, or through the use of a third party freight exchange.

Freight exchange

- A freight exchange is an online service for haulage companies, logistics providers, freight forwarders and transport companies. It allows participants to search a database of available loads awaiting delivery and to advertise their available vehicle capacity. Such systems provide a platform that allows carriers to communicate freight traffic information to fellow operators. Online systems are usually subscription-based with a small charge for advertising and searching.

Consolidation centres

- Consolidation centres are logistics facilities from which consolidated deliveries are dispatched. These facilities enable companies to group loads together and allow

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86 Empty running refers to a vehicle which is running empty of product, recycling, defective products and so could potentially be used for another load.

87 http://www.csrf.ac.uk/wp-content/uploads/2015/11/CUED-C-SRF_TR_108-Greening.pdf

88 TRL, 2017, ‘Freight Industry Collaboration Study’

goods to be delivered on appropriate vehicles with a high level of load utilisation, thereby reducing the number of delivery vehicles in operation.

- SRF notes that urban consolidation centres (UCCs) are situated close to the urban areas that they serve – for example, a city centre or a specific site such as a shopping centre, airport or hospital. Goods to these locations are dropped off at a UCC by logistics companies, where they are sorted and consolidated to be delivered to final destinations. By improving the lading factor of goods vehicles making final deliveries in congested locations, UCCs can reduce the total distance travelled in urban areas. However as UCCs add an extra node and link to the supply chain, they can increase delivery costs, which need to be balanced against other benefits[89].

Delivery and servicing plans

- Delivery and servicing plans (DSPs) are designed to reduce the number of HGV trips generated by a premises or wider areas of multiple premises. DSPs are based on the principles of best practice in procurement - ensuring that goods are ordered within a single organisation and potentially across multiple organisations in partnership, to reduce the total number of trips generated to serve those premises.

182 In addition to the examples above, SRF has identified a number of other logistics-based measures with potential to deliver emissions reductions. These include:

Extending delivery times / relaxation of ‘just in time’ pressures

- Legal limits on driving time determine the maximum number of destinations that can be visited on a single delivery trip. Distances and congestion also play a significant role in limiting the number of deliveries and collections than can be made on a trip, and hence the vehicle loading. SRF notes that the limited available literature in this field suggests that due to the impact of dwell times at destinations (the amount of time it takes to load or unload a vehicle and address any related administration), 30 minutes should be allowed for the average articulated delivery, 20 minutes for rigid trucks and 10 minutes for vans[90].
- Accelerating delivery reception processes at factories, warehouses and shops can reduce these times, increasing the number of drops or collections per delivery and thereby cutting the number of trips. SRF notes that removing access restrictions on permissible delivery times would make it possible to reduce GHG emissions by up to 7%[91].

Rescheduling deliveries to inter-peak periods and evening / night

- SRF highlights that making deliveries outside peak periods avoids congestion, thereby reducing travel time by up to 16%. According to SRF, this infers that fewer load plans will be time constrained, resulting in higher load factors and fewer journeys, in turn resulting in a 3% reduction in km travelled. Further reductions in km travelled are possible if relaxed time constraints permit the extension of a journey plan to incorporate more destinations[92].

183 The TRL study found that it was difficult to quantify the extent to which industry collaboration already occurs due to variation in individuals’ definitions of

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89 http://www.csrf.ac.uk/wp-content/uploads/2015/11/CUED-C-SRF_TR_108-Greening.pdf
90 http://www.csrf.ac.uk/wp-content/uploads/2015/11/CUED-C-SRF_TR_108-Greening.pdf
91 http://www.csrf.ac.uk/wp-content/uploads/2015/11/CUED-C-SRF_TR_108-Greening.pdf
92 http://www.csrf.ac.uk/wp-content/uploads/2015/11/CUED-C-SRF_TR_108-Greening.pdf

‘collaboration’[93]. Definitions cited by the operators surveyed encompassed a range of behaviours – including:

- Working with preferred suppliers, either through integrated supply chains or on an ad-hoc basis.
- Working alongside industry associations to share best practice.
- Working in partnership with other organisations to share loads, often on a purely commercial basis, through organisations such as online freight exchange centres, or physical networks of partners.

184 Survey participants were positive about the future role of industry collaboration and recognised the need to reduce empty running as far as possible. In particular, the construction and parcel delivery sectors identified significant benefits from maximising load capacity though shared fleet and resource usage.

185 Three case studies on industry collaboration are outlined below, and further case studies are provided in the TRL report.

Kimberley Clark – transport consolidation[94]

Discussions between two manufacturers with compatible products identified that both were receiving less than full load orders for some smaller customers, and were unable to optimise these deliveries due to geographical delivery areas. Both companies wanted to improve the efficiency of these deliveries. Analysis showed commonality of delivery locations and compatible order profiles, and identified that significant reductions in empty km could be achieved through consolidation of these deliveries, including through the appointment of a third party logistics company. Whilst not quantified, the operators reported savings in vehicle km and reduced transport costs.

Sainsbury’s / NFT – depot consolidation[95]

Sainsbury’s has been working with third party logistics provider NFT for over 15 years in both primary and secondary distribution. NFT approached Sainsbury’s with a proposal to collect and consolidate suppliers’ products through one of three transhipment hubs strategically located within the UK. This enabled a reduction in inbound regional distribution centre (RDC) deliveries by optimising vehicle fill on each load as well as utilising the same vehicles to collect suppliers’ products *en route* following an RDC delivery.

Over 240 manufacturers across 120 collection points were involved in this process and, as a result, average vehicle fill has increased by 20% during that time, therefore reducing empty running substantially. By utilising Sainsbury’s secondary store fleet to undertake primary collections and deliveries, which now account for 26% of all journeys, this initiative has further reduced Sainsbury’s carbon footprint. 5.4 million km have been saved per annum, equivalent to 4.6 million kilograms of CO_2. Using some of the primary NFT fleet to undertake store deliveries has further reduced km and CO_2 emissions (2.2 million km, equivalent to 1.9 million kg of CO_2).

[93] TRL, 2017, ‘Freight Industry Collaboration Study’
[94] https://www.igd.com/Research/Supply-chain/Consolidated-Distribution/Case-Studies/Kimberly-Clark---Transport-Collaboration/
[95] https://www.igd.com/Research/Supply-chain/Consolidated-Distribution/Case-Studies/NFTSainsbury---Primary-Network/

Returnloads.net – freight exchange centre[96]

Returnloads.net was founded in 2000. Initially the site was set up as a noticeboard to help haulage companies around the UK advertise their excess loads and find return loads for their empty vehicles.

In 2006, with the advent of new technologies, Returnloads.net became a fully functioning online freight exchange. This included developing an intelligent load and vehicle matching system, which automatically alerts members to available loads and vehicles that match their requirements.

With ongoing development, Returnloads.net has continued to grow - with over 90,000 available haulage loads posted on the platform every month. It now has over 1,500 users from across the UK including owner drivers, freight forwarders and a number of the country's largest haulage firms. In 2016 loads totalling over 16.5 million miles were covered on the platform resulting in a potential saving of 25,514 tonnes of CO_2[97].

Costs and benefits

Modal shift to rail

186 As outlined above, the Arup report identified that further modal shift from road to rail could potentially lead to emissions savings of over 2.35 $MtCO_2e$ in 2030. However, achieving GHG abatement on this scale would be contingent upon implementing major infrastructure projects, the case for which would need to be considered within the context of other competing priorities.

187 In addition, as some of Arup's illustrative measures overlap, the potential benefits may be lower than a simple aggregation of the figures would imply. This potential saving is also considerably higher than that estimated by the SRF, which suggests that shifting around a third of the longest road freight journeys to a lower carbon mode, such as rail, could result in GHG emission savings of 0.3-1.1$MtCO_2$ by 2035[98]. However, it is clear that if this figure could be achieved in practice, it would make a significant contribution to reducing emissions from transport.

188 While the theoretical savings from modal shift to rail are potentially significant, further work is needed to understand in more detail the likely costs and feasibility of the measures identified by the Arup study. It is likely that not all of the identified measures would be deliverable or affordable before 2030. Nevertheless, this work provides an insight into the areas that the Government could focus on in order to support greater modal shift from road to rail to help the UK to meet its emission reduction targets.

189 The Arup study notes that in addition to delivering environmental benefits, increased use of rail freight could create a range of co-benefits in terms of road congestion relief, improvements to road safety and reductions in the need for trunk road investment, as well as wider economic benefits through cheaper logistics for customers[99]. Further work is needed to understand the costs and benefits associated with increased modal shift from road to rail.

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[96] https://www.returnloads.net/
[97] Saving is based on average 7.9 mpg, 2.68 kg of CO_2 per litre and an average load distance of 129 miles.
[98] http://www.csrf.ac.uk/wp-content/uploads/2015/11/CUED-C-SRF_TR_108-Greening.pdf
[99] http://www.arup.com/railfreightmarket

Modal shift to water

190 Waterborne freight continues to excel in its traditional freight categories such as bulk movements, where the capability to carry large and heavy loads has clear advantages over the road sector, but there remains potential for waterborne freight to move more unitised and general cargo. For example, where there is a regular volume of containers to move over distance (e.g. containers arriving in the South from the Far East, but destined for the North of Britain) there are potential environmental benefits to moving 200 containers on one vessel compared to 200 separate HGV journeys.

191 95% of the UK's freight by weight arrives at our ports and many of our major ports are located close to or within major conurbations. Onwards movement of freight by water, in particular where inland waterways can be used, offers the opportunity to move large amounts of freight whilst bypassing these large conurbations and avoiding additional congestion on the passenger focussed transport networks within them.

192 Such traffic is particularly efficacious where there are water-linked multimodal sites - for example, the Manchester Ship Canal allows freight from the Port of Liverpool to be taken to the outskirts of Manchester, as well as the opportunity to connect with multimodal sites along its 36 mile route that provide easy access to the wider strategic transport networks.

193 Similarly the River Thames, the UK's busiest inland waterway, is a vital part of the capital and region's freight infrastructure. The river has proven its freight value in the important logistics role it played in the 2012 Olympics with millions of items of cargo and equipment being moved from the Port of Tilbury to the Olympic site at Stratford without requiring road movement. In addition, large infrastructure projects such as the Thames Tideway Tunnel, and the Northern Line Battersea extension will see millions of tonnes of construction material taken by river rather than road.

194 Without those major projects, the underlying Thames freight levels for the last ten years average 2.3 million tonnes, and the Port of London Authority (PLA) has set itself a target of doubling and maintaining that figure at 4 million tonnes per annum and becoming the default choice for moving spoil and materials from infrastructure projects. The PLA estimates that every 1,000 tonne barge on the river takes 100 HGV movements off the roads[100] meaning that if the total 2014 figure of 5.5 million tonnes of river freight being carried is maintained, this is equivalent to taking 550,000 lorry trips off the region's roads per annum.

195 This delivers a number of wider benefits over HGV traffic. It reduces congestion on the roads, increasing wider traffic flow, and also has contingent benefits for road safety. It may benefit air quality, and is a positive environmentally sustainable option - significantly reducing GHG emissions compared to the equivalent journey by lorry[101].

196 As the urban and inter-urban road and rail networks face continuing environmental and capacity issues, the ability to move freight in an efficient and environmentally sustainable way from port to port, or distribution site, and its ability to efficiently support key infrastructure and construction projects means waterborne freight will continue to be an important segment in the UK freight landscape, with positive scope for further growth.

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[100] http://www.pla.co.uk/assets/thevisionforthetidalthames.pdf

[101] http://www.greenlogistics.org/SiteResources/d82cc048-4b92-4c2a-a014-af1eea7d76d0_CO2%20Emissions%20from%20Freight%20Transport%20-%20An%20Analysis%20of%20UK%20Data.pdf

Longer semi-trailers

197 Evidence from the LST trial suggests that there are considerable environmental benefits available from the deployment of longer semi-trailers on our roads. Analysis of trial results to date suggests that up to 10.6 million km of HGV journeys have been removed from the road since September 2012, which equates to removing up to 90,000 HGV journeys across the trial.

198 This is the equivalent of removing 1 in every 19 journeys (5% of distance travelled) made by LST trial participants. The highest saving achieved by an individual operator to date represents the equivalent of removing 1 in every 9 journeys (11.5%)[102]. Prior to the recently-announced extension, the trial was expected to save over 3,000 tonnes of CO_2 with overall economic benefits estimated at £33 million over the course of its ten years[103].

Industry collaboration

199 The TRL study notes that measuring the benefits of collaboration is challenging, not least due to issues around the availability of data. One key challenge is that collaboration takes a number of different forms and identifying the benefits from specific individual actions can be difficult. However, available data on empty running and vehicle utilisation indicate the size of the opportunity for backhauling[104].

200 SRF, for example, note that there has been an upward trend in empty running of vehicles, and that the proportion of HGV km running empty increased from 27% in 2004 to 29% in 2013[105]. They suggest that the road freight industry could save £160 million in fuel a year and avoid 426,000 tonnes of GHG emissions, if it were able to reduce the empty running of vehicles to the lowest levels recorded at 27.2% for rigid and 25.2% for articulated trucks[106].

201 Figure 4.1 shows the results of SRF analysis, and covers the contribution made from a range of the logistics-based measures to GHG savings in 2035 under its central, commercial scenario assumptions. The SRF analysis shows that the highest potential GHG savings could be achieved through the use of urban consolidation centres, use of higher capacity vehicles and extending delivery times. Together, these account for nearly two-thirds of all savings from logistics measures, identified by SRF, by 2035[107].

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[102] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/548236/longer-semi-trailer-trial-annual-report-2015.pdf
[103] https://www.gov.uk/government/collections/longer-semi-trailer-trial
[104] TRL, 2017, 'Freight Industry Collaboration Study'
[105] http://www.csrf.ac.uk/wp-content/uploads/2015/11/CUED-C-SRF_TR_108-Greening.pdf
[106] SRF Roadmap – part 1, Road freight transport in the UK Technical Report, CUED/C-SRF/TR.1 - http://www.csrf.ac.uk/wp-content/uploads/2015/11/CUED.SRF_.TR1_Pieyck_2013_reduced-size2.pdf
[107] http://www.csrf.ac.uk/wp-content/uploads/2015/11/CUED-C-SRF_TR_108-Greening.pdf

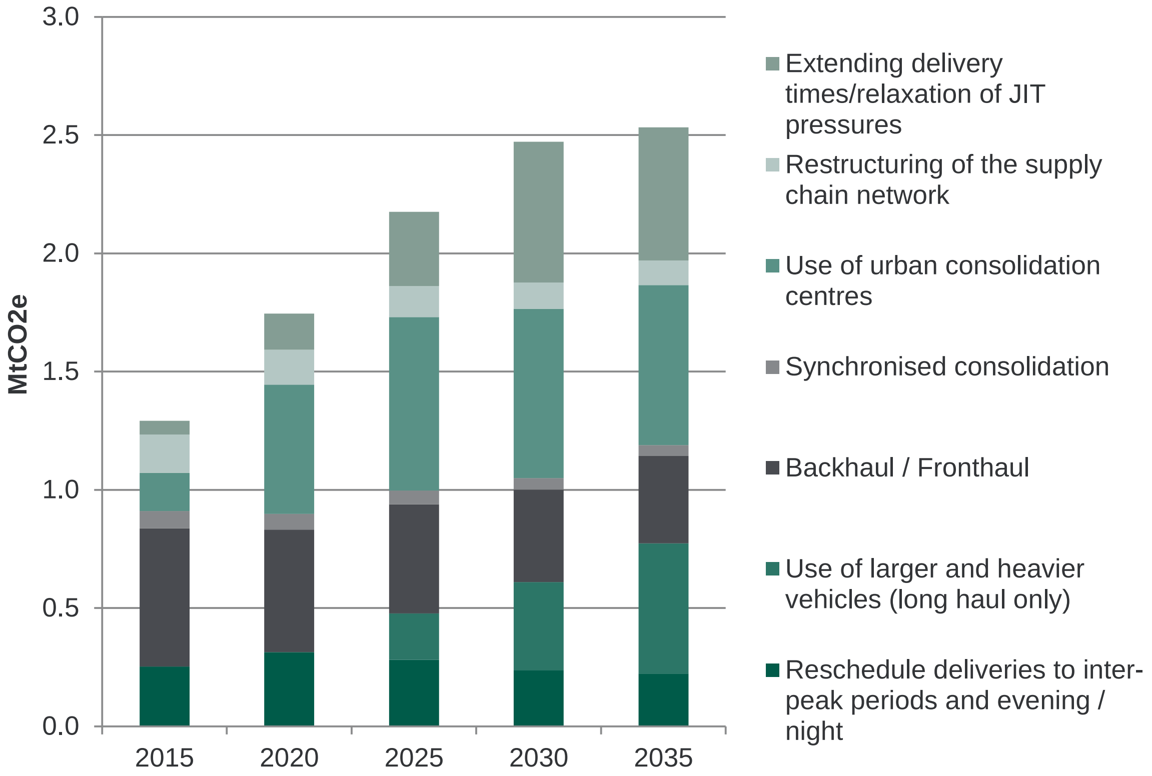

Figure 4.1: Modelled CO_2 savings from logistics measures – central take-up scenario (SRF)[108]

202 The TRL study conducted a cost/benefit analysis to estimate the impact of increased collaboration to reduce empty running, including through the use of freight exchanges. Results, which are indicative given limitations in the analysis relating to the assumptions made and data used, are shown in Table 4.1 below. Further information is provided in the TRL report[109].

[108] http://www.csrf.ac.uk/wp-content/uploads/2015/11/CUED-C-SRF_TR_108-Greening.pdf
[109] TRL, 2017, 'Freight Industry Collaboration Study'

Table 4.1: Cost/benefit analysis of industry collaboration measures[110]

Policy	Vehicle type	PV of cost per vehicle by 2020	PV of saving per vehicle by 2020	BCR	Mileage reduction	Value of GHG reduction by vehicle	Tonnes of GHG reduction by vehicle
Freight exchange	44 tonne artic	£1,323	£919	0.98	1%	£382	6.46
	rigid	£1,323	£674	0.72	1%	£281	4.74
	44 tonne artic	£1,323	£4,597	0.98	5%	£1,913	32.30
	rigid	£1,323	£3,371	3.61	5%	£1,403	23.68
Back or forward hauling	44 tonne artic	0	£919	Unknown	1%	£382	6.46
	rigid	0	£674	Unknown	1%	£281	4.74
	44 tonne artic	0	£4,597	Unknown	5%	£1,913	32.30
	rigid	0	£3,371	Unknown	5%	£1,403	23.68
Consolidation centres	44 tonne artic	Unknown	£3,953	Unknown	4.3%	£1,645	27.77
	rigid	Unknown	£2,899	Unknown	4.3%	£1,747	20.37
Delivery and servicing plans	44 tonne artic	Minimal, but unknown	£3,953	Unknown	4.3%	£1,646	27.77
	44 tonne artic	Minimal, but unknown	£2,899	Unknown	4.3%	£1,747	20.37

Barriers

Modal shift to rail

203 The Arup study identified a number of priority issues that would need to be addressed to support further modal shift from road to rail. These include availability of infrastructure capacity, cost and perceived cost barriers, ensuring that rail freight services are able to respond flexibly to changing customer demands, lack of knowledge of and misconceptions about rail freight, and skills and innovation requirements. These barriers are summarised below and further detail is provided in the Arup report:

[110] TRL, 2017, 'Freight Industry Collaboration Study'

- **Infrastructure capacity**, including addressing limitations in the network (such as gauge clearance and lack of direct rail access in key locations), supporting development of high capacity rail freight interchanges, wagon availability, and availability of efficient freight paths to improve journey times.
- **Cost barriers**, including costs of additional journey legs for door-to-door journeys with a rail leg, and high capital costs for new facilities (including new locomotives, wagons or equipment).
- **Flexibility of rail freight services**, including responsiveness of train path allocation, the improvement of freight train path speeds, the '7 day railway', the need for suitable and resilient diversionary routes for freight, and operators' ability to flex load sizes to attract smaller firms.
- **Attitudes and awareness**, including the need for easy-to-access information for current non-rail users, and the need to overcome cultural barriers and risk aversion among customers.
- **Skills, training and Innovation**, including the development of alternative technologies, the need to review business models to explore opportunities for greater aggregation of loads, and ensuring that the freight industry is fully engaged in the skills agenda.

204 These barriers broadly correlate with those identified in the SRF report, which noted that the mixed-use rail infrastructure in the UK results in timetabling priority being given to passenger trains when capacity is inadequate or disruptions occur. In addition, SRF found a lack of awareness, knowledge and skills to be a further issue, leading to environmental considerations being given too little weight in corporate decision making on freight transport modes.

205 SRF also identified a mismatch between the length of the investment cycle for rail and shorter-term public policy decisions and corporate requirements for short payback periods, and highlighted a need to consider how the availability of rolling stock will meet the requirements of future changes in commodity mix. Finally, SRF noted that innovative solutions, for example shorter, faster and more frequent rail services carrying containers and road trailers between locations, that are currently inaccessible to longer trains, could help to increase the demand for rail freight[111].

206 The Rail Freight Strategy highlights a range of measures that are already in place to address some of these barriers, as summarised below[112]:

- Investment in rail freight infrastructure via the Strategic Freight Network Fund has made available £235 million over CP5[113] for enhancements such as: improving the capacity of the Felixstowe Branch Line, enabling 775m train operations out of the port of Southampton, and improving rail access to the Port of Liverpool.
- The designation in January 2015 of the National Networks National Policy Statement has provided the Planning Inspectorate with a clear statement of Government policy on the development of Strategic Rail Freight Interchanges (SRFIs). This also provides developers with a clear indication of the evidence they need to submit in applying for planning permission. The National Networks National Policy Statement has been welcomed by the rail freight industry, which advises that proposals for SRFIs are now starting to come forward.

[111] http://www.csrf.ac.uk/wp-content/uploads/2015/11/CUED-C-SRF_TR_108-Greening.pdf
[112] https://www.gov.uk/government/publications/rail-freight-transport
[113] Control Period (CP): Investment in the railway is broken down into 5-year tranches known as control periods. Control Period 5 (CP5) is the period from April 2014 to March 2019.

- The Mode Shift Revenue Support scheme encourages modal shift from road to rail or inland waterway where the costs are higher than road, and where there are environmental benefits to be gained. It currently helps to remove around 800,000 lorry journeys a year from Britain's roads. A similar scheme, the Waterborne Freight Grant, can provide assistance with the operating costs associated with coastal or short sea shipping.
- Digital signalling is already deployed on parts of the rail network and will be in service from 2018 on the new Thameslink and Crossrail routes, and is key to enabling more train paths. We are working with industry to establish the strategy for accelerating the rollout of digital signalling, targeted at areas where network capacity is needed the most.

Longer semi-trailers

207 As noted above, the current trial of LSTs is showing promising results in terms of environmental and economic benefits. However, the Freight Carbon Review has identified a number of potential barriers to wider deployment of LSTs within the road freight sector.

208 The SRF study notes that increasing the capacity of road vehicles could potentially reduce the competitiveness of rail freight and therefore incentivise the shift from rail to road. However, it goes on to highlight that this impact could be mitigated by increasing the maximum length of HGVs, but not their weight limit[114].

209 SRF also notes that the use of higher capacity vehicles is often framed by negative public opinion due to safety concerns and the need to modify regulations to permit their widespread deployment[115]. However, results to date from the LST trial do not indicate an adverse impact on safety from the use of longer semi-trailers on GB roads and there is no evidence to date that the safety risk from LSTs is greater than that of conventional HGV trailers. Evidence collected from the trial indicates that there may indeed be an improved safety performance. However data collection will need to be continued until the end of 2017 in order to confirm this finding with statistical confidence.

Industry collaboration

210 The TRL report identified that whilst there are clearly opportunities for increased industry collaboration, there are also a number of key barriers, which are summarised below.

211 **Changing consumer trends** have caused a number of changes in the logistics sector. As opening times extend and consumer expectations grow around product availability, so has the need to meet these demands. This has led to an increase in the number of deliveries being made but with fewer goods per drop[116]. For the purposes of collaboration this creates complications as the vehicle fill varies throughout each trip and adds complexity to sharing or combining loads. However, this situation can serve to strengthen the case for collaboration on urban distribution - for example by using a consolidation centre.

212 There is a **lack of available data on the benefits of collaboration**. This could be due in part to the perceived confidentiality of information, as well as a lack of comparable standard data that can be shared. This issue was noted by SRF, who highlighted that a lack of comparable data restricts the ability to undertake joint

114 http://www.csrf.ac.uk/wp-content/uploads/2015/11/CUED-C-SRF_TR_108-Greening.pdf
115 http://www.csrf.ac.uk/wp-content/uploads/2015/11/CUED-C-SRF_TR_108-Greening.pdf
116 SRF Roadmap – part 1, Road freight transport in the UK Technical Report, CUED/C-SRF/TR.1

planning. Further to this, the SRF report identified that local authorities can struggle to see the benefits of consolidation centres, as local vehicle flows are not always understood, making benefits harder to identify[117]. TRL notes that the main constraint on urban consolidation centres is the difficulty of operating them viably without a public subsidy.

213 The TRL study found that **collaboration could be seen as anti-competitive** and avoided for fear of contravening competition law. This issue was investigated by the EU-funded Collaboration Concepts for Co-modality (CO3) project, which aimed to encourage a cultural change in the competitiveness and sustainability of European logistics by stimulating horizontal collaboration between European shippers[118]. The study noted that information sharing between direct competitors can be problematic from a legal perspective if there is a danger of either collusion or market protection. Furthermore, whether illegal collaboration occurs in practice strongly depends on the specific circumstances, and it is difficult to give generic rules regarding what is allowed and what is not[119].

214 **Trust between 'partners'** within a collaborative enterprise was also identified by TRL as a potential issue. Some survey participants were concerned that competitors may use the opportunity to under-cut them for future or new work if they shared potentially sensitive commercial information. However, it should be noted that where forward or backhauling occurs through freight exchange companies, there are strict guidelines and rules with regards to this practice and where members fail to adhere to them, they are removed from the group.

215 The TRL study noted that there are **regional imbalances in freight movement**, with high volumes of loads being transported from north to south and less in reverse. This can makes it challenging to find suitable backloads.

216 It should be noted that these barriers have differing degrees of significance and impact upon some sectors more than others.

Next steps

217 Research consulted through the Freight Carbon Review suggests that there is potential to reduce GHG emissions through increased use of rail freight. However, further work is needed to understand costs and benefits of available measures to encourage modal shift. We will consider the scope for further modal shift from road to rail, through work to further assess the costs and benefits of opportunities identified in the Rail Freight Strategy.

218 The ongoing trial of longer semi-trailers is delivering promising economic and environmental benefits. The Government has agreed to increase the number of LSTs by an additional 1,000 and to extend the trial by five years. This increase will take the number of LSTs from 1,800 to approximately 2,800 over the next 12 months. Operators will be invited to bid for a share of the additional allocation, in the coming month, and details on how to apply will be available soon.

219 Further work is needed to understand the costs and benefits of available measures to improve industry collaboration. As an outcome of the Freight Carbon Review and building on the findings of the TRL study, DfT will consider options for addressing

[117] http://www.csrf.ac.uk/wp-content/uploads/2015/11/CUED-C-SRF_TR_108-Greening.pdf
[118] http://www.co3-project.eu/
[119] http://www.co3-project.eu/wo3/wp-content/uploads/2011/12/CO3-D-2-1-Framework-for-collaboration-full-report-2.pdf

these evidence gaps and overcoming the barriers to wider industry collaboration.

220 The Government has recently consulted on a national framework, which will provide a consistent approach to the implementation of Clean Air Zones. The draft framework includes suggestions on how local authorities might reduce emissions from freight and encourage cleaner vehicles to be used for deliveries in a Clean Air Zone. For example it notes that, where compatible with other requirements such as noise and safety, local authorities could consider giving other exemptions to electric vehicles operating within a Clean Air Zone, such as allowing night-time deliveries or delivery access to pedestrian areas[120]. This type of approach could also create potential economic benefits for fleet operators and deliver GHG emission savings. We will work with industry and the Joint Air Quality Unit to explore opportunities for developing and supporting such measures.

[120] https://consult.defra.gov.uk/airquality/implementation-of-cazs/

5. Alternative fuels

Key messages

- The diverse nature of the road freight sector means that there is not a single industry-wide fuel-based decarbonisation solution and a range of options need to be considered.
- Sustainable renewable biofuels, in particular biomethane and biodiesel, offer significant potential to decarbonise the road freight sector in the short to medium term. However, use of these fuels in HGVs is currently limited and wider deployment will depend upon overcoming significant barriers to supply and uptake.
- Industry, with government support, is currently developing new ‘advanced’ biofuels, produced from wastes, which could deliver significant GHG savings without the sustainability concerns of biofuels derived from land-using feedstocks. Crucially, due to the use of high-tech, novel processing technologies, these fuels are also capable of fuelling HGVs in higher blends than conventional biodiesel.
- The recent consultation on the future of biofuels policy has gathered evidence on options and incentives for increasing biofuel supply to HGVs, which we are now considering. This was supported by the 2016 Autumn Statement, which committed £20m to support the development of advanced biofuels to decarbonise the HGV and aviation sectors.
- GHG emission savings from fossil-derived natural gas are uncertain. In particular, the tailpipe emission of unburned methane (methane slip) is a known issue for dual fuel (diesel/gas) retrofit conversions and can offset any available CO_2 savings. Advanced methane catalysts are currently being developed, and are expected to significantly reduce methane emissions from dual fuel trucks.
- Future policy on HGV fuels will need to take account of the evolving evidence base in this area, including any relevant findings from DfT’s ongoing transport energy work which is assessing a range of alternative energy pathways for road vehicles out to 2050.
- Further work is needed to assess the performance of new, potentially more efficient, gas powered commercial vehicles as they become available**.** The Government will continue to play an active role in developing this evidence base.

Introduction

221 This chapter considers the role of alternative fuels in reducing both GHG and air pollutant emissions from the road freight sector. It focusses on the fuels that are understood to offer the most potential in the short to medium term, out to the 2030s, in terms of suitability to the sector and GHG abatement potential; namely liquefied and compressed natural gas (LNG and CNG), biomethane, and liquid biofuels. Liquefied petroleum gas (LPG), and its biogenic equivalent, bioLPG, are also covered, although further evidence is needed to better understand LPG's GHG benefits and appropriateness as an HGV fuel. Hydrogen and electricity, which are considered to be longer-term road freight decarbonisation options, are discussed in Chapter 6.

222 This chapter considers the GHG emissions reduction potential associated with these fuels, discusses the key barriers to their wider deployment within the road freight sector, and reflects upon the scope to adapt existing, and introduce new measures to encourage further uptake.

Summary of fuels under consideration

223 A number of alternative fuels are currently considered suitable for use in heavy duty engines. Table 5.1 below summarises the key properties, benefits and disadvantages of the fuels that we consider to offer the most potential for decarbonising HGVs out to the 2030s.

Table 5.1: Overview of key alternative fuels

Fuel / Summary	Benefits	Disadvantages
Natural gas (LNG and CNG)		
Natural gas consists mainly of methane along with smaller quantities of other hydrocarbons. The UK's extensive national gas grid enables methane to be extracted from almost any location in the UK. The extracted methane can then be compressed and used in vehicles as a fuel, either in a dedicated gas engine or alongside diesel in a dual fuel engine. Compressed natural gas (CNG) is stored on the vehicle in high-pressure tanks at around 200 to 250 bar. Natural gas can also be converted to a liquid by cooling it to -162 degrees	There is interest amongst fleet operators in the use of methane as a road fuel. It attracts lower fuel duties than diesel and offers the potential for air quality benefits and lower greenhouse gas (GHG) emissions. Natural gas is available for deployment in trucks today. It can be relatively inexpensive to supply, particularly as CNG drawn from the high pressure grid. A number of leading businesses are already running trucks on natural gas, and the availability of refuelling infrastructure is improving.	Lifecycle GHG emissions from natural gas engines are heavily dependent on the origin and supply pathways of the gas. Methane slip from dual fuel (diesel/gas) trucks is a known issue and can offset any CO_2 savings from use of natural gas, in some cases increasing overall GHG emissions. DfT's HGV emission testing programme found high levels of methane emitted from both Euro V and Euro VI dual fuel trucks compared to diesel alternatives. These tests also show that Euro VI dedicated gas trucks do not exhibit significant methane slip. However, a spark ignition dedicated gas

Fuel / Summary	Benefits	Disadvantages
centigrade to form liquefied natural gas (LNG). On the vehicle LNG is stored in cryogenic tanks to maintain its temperature. LNG has a higher energy density than CNG, which means that more fuel can be stored in the same space, extending vehicle range and reducing refuelling frequency.	Provision of infrastructure and incentives to encourage uptake of natural gas as a road transport fuel could provide a route to wider use of biomethane in HGVs. A limited number of Euro VI gas trucks are already available, with further products expected to launch during the next few years.	engine is inherently less efficient than a Euro VI compression ignition diesel engine. The HGV emissions testing study, discussed in this chapter, found that when engine efficiency losses are taken into account, Euro VI dedicated gas vehicles, running on natural gas (rather than biomethane), are likely to have broadly similar GHG impacts to Euro VI diesel equivalents, to within +/- 10%. Gas vehicles attract a price premium and are currently prohibitively expensive for some operators. Data from the Low Carbon Truck Trial suggest that achieving payback within an acceptable time frame can be challenging.
Biomethane		
Biomethane is methane gas of biogenic, rather than fossil, origin. Biogas is produced by the anaerobic digestion of organic matter such as dead plant and animal material, manure, sewage and organic waste. The biogas collected from anaerobic digestion is upgraded and purified to form biomethane, which is suitable for use as a vehicle fuel. In the UK, biomethane supply to transport is currently supported under the Renewable Transport Fuel Obligation (RTFO).	There is considerable industry interest in using biomethane in HGVs. It is completely interchangeable with natural gas in a vehicle and can be used in existing gas refuelling infrastructure. Biomethane, particularly from waste landfill, has much lower lifecycle CO_2 emissions than fossil methane. Research indicates that using compressed biomethane in vehicles can deliver GHG emissions savings of between 60% and 90% compared to conventional liquid fossil fuels, when the biomethane feedstock is fully renewable. Biomethane is already supported under the RTFO and DfT has recently	Biomethane tends to be more expensive to produce than natural gas. The UK is a large producer of biogas from landfill and other organic waste streams. However the majority of this biogas is currently used exclusively to produce renewable electricity and for heating our homes, and at present a very limited quantity of biomethane is supplied directly to the transport sector. The financial returns for biomethane suppliers are generally better from power generation, or for injection to the grid under the Renewable Heat Incentive (RHI), when compared to rewards offered under the RTFO.

Fuel / Summary	Benefits	Disadvantages
	consulted on raising this support as part of a package of legislative amendments for 2017.	
Biodiesel		
There are different types of biodiesel, the most common form being fatty acid methyl ester (FAME), which is usually produced from vegetable oils. In the UK, biodiesel is mainly derived from wastes. Fuel standards specify that FAME is limited to 7% blends in diesel – though higher blends can be supplied and have been successfully used in HGVs. Higher blend fuels require agreements between the fuel supplier and the HGV operator to be in place regarding the fuel blend as they are outside the 7% fuel standard. Advanced biodiesel is produced from residues, wastes or non-food feedstocks. These fuels are considered to be more sustainable than crop derived biofuels as they do not use land which might lead to deforestation or other land use change, and do not compete for land which could be used for food crops.	Liquid biofuels, in particular waste derived biodiesel, can significantly improve the GHG performance of HGVs and rail freight. Biodiesel is capable of delivering significant GHG savings within the road freight sector. For example, results from the Low Carbon Truck Trial indicate that used cooking oil, which was trialled by one consortium, can reduce Well to Wheel CO_2 emissions by 84%. Biodiesel can be blended with conventional diesel and used in our existing infrastructure and vehicles. Some types of advanced biodiesel, for example HVO, can be used as a 'drop in' fuel within existing vehicles and infrastructure as it has the same chemical properties as fossil diesel, so can be supplied in higher blends.	The GHG emissions savings from biodiesel are dependent on the feedstock used and the manufacturing processes involved. If from a waste feedstock, biodiesel has the potential to deliver 80-90% savings or more, whereas some crop derived biodiesels may actually increase GHG emissions. Although there are clear GHG benefits associated with a shift to sustainable liquid biofuels, there is currently limited uptake within the road freight sector. There can be significant capital costs associated with converting some diesel engines to accommodate high biodiesel blends and evidence suggests that ongoing fuel costs are marginally higher than conventional diesel.
Liquefied petroleum gas (LPG)		
LPG is a mixture of liquefied propane and butane which is produced both from oil and gas extraction (it can be extracted from petroleum or natural gas streams as they emerge from the	LPG has potential to deliver significant air quality benefits compared to diesel in trucks classified as Euro V and below.	LPG is most commonly used in spark-ignition (petrol) engines in either purpose built or modified vehicles. As the HGV fleet is predominantly diesel, LPG

Fuel / Summary	Benefits	Disadvantages
ground) and also as a by-product of fossil fuel refining.	An extensive UK LPG refuelling network is already in place. DfT's HGV Emissions Testing study found the GHG emissions performance of LPG to be similar to that of diesel. However, use of LPG in HGVs could deliver air quality benefits through the retrofit of older diesel vehicles.	use has been extremely limited. It is, however, possible to re-engineer diesel engines to run on LPG or to burn a mixture of diesel and LPG (known as fumigation). However, this practice is not widespread and the viability of this technology is not well understood. Currently only a relatively small amount of LPG can be mixed with diesel before engine function becomes impaired, which limits fuel substitution ratios and therefore potential GHG and air quality benefits.
BioLPG		
BioLPG can be made from either crop or waste feedstocks and used as a drop-in replacement fuel for fossil LPG. In recognition of the potential GHG emission benefits of bioLPG, in 2015 the RTFO reward was increased from 1 to 1.75 Renewable Transport Fuel Certificates (RTFCs) per kg, and double that amount when the fuel is produced from wastes and residues.	Waste-derived bioLPG delivers greater GHG benefits than fossil LPG. BioLPG can be used in existing LPG refuelling infrastructure.	As set out above, LPG use in the HGV fleet has been extremely limited as it is primarily used in adapted petrol engines. The potential to use bioLPG as a bio alternative to LPG is therefore also currently very limited. There has been no supply in the UK to date, but there are plans to import biopropane where it is produced as a coproduct of hydrotreated vegetable oil (HVO) production. As with LPG, fuel substitution potential is limited.

224 There is significant variation in the carbon intensity of the above fuels. Although each has a lower carbon intensity than diesel, the available GHG emission savings are heavily dependent on individual vehicle technologies. Data from the Low Carbon Truck Trial (LCTT), which supported industry uptake of alternatively fuelled commercial vehicles, show that displacing diesel with natural gas does not deliver significant GHG emission savings. However the LCTT was predominantly focussed on trialling Euro V dual fuel (diesel/gas) engine technologies - and the quality of the retrofit conversions, level of integration with existing engines, and fuel substitution

ratios were variable - affecting overall emissions performance[121].

225 Results from the LCTT broadly correlate with those from the recently-published Emissions Testing of Gas-Powered Commercial Vehicles project, undertaken by the Low Carbon Vehicle Partnership (LowCVP) on behalf of DfT. This work tested a number of dedicated gas and dual fuel trucks against conventional diesel comparators. It confirmed that GHG emissions savings from existing dedicated natural gas and dual fuel trucks are limited, and indeed can be significantly higher for dual fuel trucks when methane slip is taken into account[122].

226 Encouragingly, however, the results of these studies also indicate that for the current generation of dedicated gas trucks – increased use of biomenthane could deliver a step change reduction in greenhouse gas emissions. The results of this work are discussed further throughout this chapter.

227 The gas HGV market continues to develop at pace, with a range of Euro VI products currently available and new offerings on the horizon. Further vehicle tests will be needed to measure the emissions performance of new gas commercial vehicles relative to conventional diesel drivetrains. Future policy on HGV fuels will also need to take account of the evolving evidence base in this area, including any relevant findings from DfT's ongoing transport energy work which is assessing a range of alternative energy pathways for road vehicles out to 2050.

228 In addition, the 2016 Rail Freight Strategy highlighted that there may be scope to explore lower carbon alternatives to diesel-fuelled rail freight transport, including increased use of biofuels. Further work is needed to understand the potential costs and benefits of increasing biofuel supply to this sector[123].

Existing and forthcoming legislation and targets

229 There are a number of fuel-related targets and measures, in place or on the horizon, that are expected to encourage the uptake of more sustainable fuels within the transport sector, some of which relate to the implementation of EU legislation. The Government is considering carefully all the potential implications arising from the UK’s exit of the EU. Until exit negotiations are concluded, the UK remains a full member of the EU and all the rights and obligations of EU membership remain in force. During this period the Government will continue to negotiate, implement and apply EU legislation. The outcome of these negotiations will determine what arrangements apply in relation to EU legislation in future once the UK has left the EU. Targets and measures include:

- The **Renewable Energy Directive** establishes an overall policy for the production and promotion of energy from renewable sources in the EU. It requires the EU to fulfil at least 20% of its total energy need with renewables by 2020 – to be achieved through the attainment of individual national targets (15% for the UK). All EU countries must also ensure that at least 10% of their transport fuels come from renewable sources by 2020.
- The **EU Fuel Quality Directive** requires fuel suppliers to reduce the carbon intensity of their transport fuel by 6% by 2020 compared to a 2010 baseline.

[121] https://www.gov.uk/government/publications/low-carbon-truck-and-refuelling-infrastructure-demonstration-trial-final-report
[122] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/581859/emissions-testing-of-gas-powered-commercial-vehicles.pdf
[123] https://www.gov.uk/government/publications/rail-freight-transport

- Amendments to the **General Circulation Directive** ((EU) 2015/719) on vehicle weights and dimensions must be transposed by May 2017. The new Directive allows for up to one tonne extra weight for certain alternative fuel technologies (including hydrogen, natural gas and biomethane) to account for their heavier drivetrains, when compared to conventional drivetrains. This will help prevent any loss of payload and is intended to incentivise the uptake of less polluting vehicles.
- The **EU Clean Power for Transport** (CPT) package aims to facilitate the development of a single market for alternative fuels for transport in Europe. The package includes a Directive (94/2014/EU) on the deployment of alternative fuels recharging and refuelling infrastructure. According to the Directive, which is the cornerstone of the CPT package, Member States must develop a plan (National Policy Framework) to establish a network of refuelling stations for natural gas vehicles in cities, ports and along the Trans-European-Network for Transport (TEN-T). Member States must provide refuelling points for:
  - CNG in cities/densely populated areas by 2020
  - CNG and LNG along the TEN-T core network by 2025
  - LNG in sufficient TEN-T seaports by 2025
  - LNG in sufficient TEN-T inland ports by 2030
- **EU heavy duty vehicle CO_2 regulations** (expected in 2018) will cover the monitoring and reporting of fuel consumption and CO_2 emissions from all new HGVs to inform purchasing behaviour, and potentially be used to set CO_2 emission standards in the longer term. Improved transparency of fuel consumption would allow a degree of vehicle comparability to stimulate consumer awareness and create competition among vehicle manufacturers to reduce emissions.

Existing and forthcoming measures

230 There are a number of measures already in place to support the deployment of alternative fuels within the road freight sector, which are summarised below.

Fuel duty differential for road fuel gases

231 A fuel duty differential is in place for road fuel gases, which are taxed at a lower rate than petrol and diesel. The duty differential is currently approximately 33 pence per litre, and was initially guaranteed for three years – up to and including 2015-16. The 2013 Autumn Statement extended the duty differential for road fuel gas for ten years, up to 2024, with a review in 2018.

232 While the duty differential has not to date led to a significant uptake in gas-powered HGVs, this is likely to be due to the range of barriers that need to be overcome in order for gaseous road fuels to become more widely adopted. Within the road freight sector, while fuel costs are a key consideration for fleet operators, vehicle availability, consumer acceptance and refuelling infrastructure availability may override financial decisions, so a duty differential alone is unlikely to provide sufficient incentive for uptake.

233 More recently, despite improvements in vehicle and infrastructure availability, the lack of uptake may be attributed in part to the fall in diesel price, which has increased the payback period for gas trucks and made it difficult for operators to recoup capex costs within an acceptable time frame. The Low Carbon Truck Trial for example

found an average price premium of £25,500 for the dual fuel trucks deployed through the trial, with just 21% of fleets expected to achieve financial payback within six years[124].

234 The duty differential for biodiesel was withdrawn in 2010 except for biodiesel from used cooking oil which continued to benefit until 2012. The Renewable Transport Fuel Obligation (RTFO) was introduced in 2008, and while biodiesel uptake in the transport sector has consequently increased overall, we have been informed by some stakeholders that its demand as an HGV fuel has declined. Some stakeholders have suggested that without the duty incentive biodiesel is generally more expensive to supply and purchase than fossil diesel; and when fuel costs are combined with those of converting engines to accommodate high biodiesel blends, it can be difficult for operators to make the business case for investing.

235 The differential between the main fuel duty rate and the LPG rate is set to reduce by £0.01 per litre each year to 2024. However, as the main rate of fuel duty is frozen, the LPG differential also remains frozen.

Renewable Transport Fuel Obligation (RTFO)

236 The use of sustainable biofuels in the UK is primarily encouraged through the RTFO, which aims to deliver reductions in GHG emissions from the road transport sector (and for non-road mobile machinery). The RTFO requires refiners, importers and any others who supply more than 450,000 litres of transport fuel per year to the UK market to redeem a number of Renewable Transport Fuel Certificates (RTFCs) in proportion to the volume of fossil fuel (and any unsustainable biofuel) they supply.

237 RTFCs may be bought or sold on the open market. Obligated suppliers also have the option to 'buy out' of their obligation, paying 30 pence per litre of biofuel that would otherwise have to have been supplied to meet their obligation. The scheme was amended in 2015 to increase the rewards available for those supplying bioLPG and biomethane. The GHG emission savings from biofuel reported under the scheme in 2014/15 were the equivalent of taking 1.3 million cars off the road.

238 While industry welcomes the support provided through the RTFO, they have raised concerns over the fluctuation in certificate prices and have indicated that higher, more stable rewards can be accessed through supplying biomethane for use in domestic heating under the Renewable Heat Incentive. DfT has recently consulted on proposed legislative amendments to meet our 2020 targets on renewable energy and GHG emissions. The proposals included raising the reward for advanced fuels, including biomethane and other fuels suitable for HGVs, through the creation of a ‘development fuels’ sub-target under the RTFO, to support fuels of strategic importance.

239 The Government is also proposing to set long term targets under the RTFO. With the fuels market becoming smaller over time, and as lighter vehicles are increasingly powered by electricity, it is expected that low carbon fuels will naturally start to be directed towards specific transport sectors, including HGVs.

Low Carbon Truck Trial

240 Through the Low Carbon Truck Trial (LCTT), which concluded in 2016, the Government has provided over £11m to part-fund around 370 alternatively-fuelled commercial vehicles, with most using a gas or dual fuel system (diesel and gas), plus gas refuelling sites. The trial has been successful in stimulating the gas truck and dual fuel retrofit conversion market and in delivering new and upgraded refuelling

[124] https://www.gov.uk/government/publications/low-carbon-truck-and-refuelling-infrastructure-demonstration-trial-final-report

infrastructure. However, the project was dominated by Euro V dual fuel retrofit conversions and, as noted above, the CO_2 savings delivered by some of the systems on trial were limited[125].

241 Furthermore, the LCTT identified an issue with emissions of unburned methane, known as 'methane slip', from some of the participating vehicles, particularly the retrofit dual-fuel diesel/natural gas conversions. Methane is a potent GHG, and recent work by Ricardo-AEA (now Ricardo Energy & Environment) has estimated that, for a dual fuel vehicle operating at typical substitution rates, methane slip at a level of 2% could completely negate the GHG savings available from using methane as a vehicle fuel in place of diesel[126].

242 To provide further evidence on the methane slip issue, the **HGV Emissions Testing** study has developed a protocol to measure methane and air pollutant emissions from a variety of gas and dual-fuelled (diesel/gas and diesel/LPG) HGVs against conventional diesel equivalents. As discussed above, LowCVP has used this protocol to test a representative sample of Euro V and Euro VI trucks[127].

Low Emission Freight and Logistics Trial

243 In June 2016 the OLEV and Innovate UK launched a new technology neutral demonstration trial competition to stimulate the real-world on-road demonstration of innovative 'near to market' low and zero emission vehicle technologies for vans and HGVs and new energy infrastructure (charge-points and methane fuelling depots). Twenty competition winners were announced in January and will share £20m funding to trial a range of technologies, including electric and hydrogen as well as gas. Projects also cover light-weighting, aerodynamics and innovative recharging solutions[128].

Capital support for renewable fuels

244 The Government is encouraging the development of advanced fuel technologies through a £25m Advanced Biofuel Demonstration Competition[129]. The winners were announced in September 2015, each of which are using the capital grants awarded, with significant support from private sector investment, to construct demonstration-scale advanced biofuel plants, which will produce 1m litres of waste-derived fuel by 2018.

245 Autumn Statement 2016 announced £20m to support the development of advanced renewable fuels for HGVs and aviation through the **new Advanced Renewable Fuel Demonstration Competition**. It is intended that this funding will be matched by significant private sector investment, to build demonstration-scale advanced renewable fuel plants in the UK. This will increase the production and deployment of strategically important low carbon fuels.

246 An externally produced feasibility study intended to equip DfT with the information required to design and launch the completion has now been completed, and detailed design work has begun. Launch of the competition is expected in the first half of 2017.

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125 https://www.gov.uk/government/publications/low-carbon-truck-and-refuelling-infrastructure-demonstration-trial-final-report
126 Waste and Gaseous Fuels in Transport – Final Report. Ricardo-AEA report for DfT, July 2014 - https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/336022/gasesous-fuels-report.pdf
127 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/581859/emissions-testing-of-gas-powered-commercial-vehicles.pdf
128 https://www.gov.uk/government/news/low-emmission-freight-and-logistics-trial-competition-winners-announced
129 https://www.gov.uk/government/news/winners-from-25-million-prize-to-develop-greener-fuel-technology-announced

Barriers to uptake of alternative fuels

247 As set out above, support for alternative HGV fuels is already in place. However a number of uptake barriers remain, which have been widely reported upon by industry and academic experts. There is broad consensus around the key barriers to wider deployment of alternative fuels in the road freight sector, which are summarised below.

Costs

248 For many operators, the upfront capital cost of purchasing an alternatively fuelled truck is the principal barrier to uptake. This can be a particular issue for smaller operators, who may have limited capacity to tolerate the risks inherent in investing in relatively new and unproven fuels and engine technologies.

249 In the case of gas-fuelled HGVs, the price premium is primarily driven by the current scale of gas truck production, with costs expected to decrease should gas-fuelled HGVs become more mainstream[130]. The average additional capital costs of vehicles purchased or converted in the LCTT are shown in Table 5.2 below.

Table 5.2: Low Carbon Truck Trial system costs[131]

Vehicle	Dedicated gas truck	Dual fuel truck
System cost*	£25,000 - £31,000	£15,000 - £33,000

*Additional costs of an alternatively fuelled truck, compared to a diesel truck of the same size

250 In addition to capital costs, participants in the LCTT reported increased operational costs associated with the dual fuel diesel/gas systems, with annual average maintenance cost increases of £1,110 (range £500 - £2,500). Fuel prices also impacted on the economic performance of the alternatively-fuelled trucks deployed through the LCTT. The average cost of diesel and gas over the trial period was £0.99/litre and £0.93/kg respectively. The positive cost differential between diesel and gas prices eroded slowly over the duration of the trial. During 2014 the cost of gas was on average 10% lower than diesel (per unit of fuel purchased), but by the end of the data monitoring period (January 2016) natural gas was on average 3% more expensive than diesel.

251 A further cost issue relates to the residual values for vehicles using new technologies and fuels, which are often low or unknown. The lack of a second hand market for gas trucks limits their resale value and the cost premium is unlikely to be recovered until the used vehicle market becomes familiar with, and desires, gas vehicles[132]. Dual fuel trucks are usually converted back to diesel-only operation prior to resale on the second hand commercial vehicle market. Furthermore the costs of removing a dual fuel gas system range from between £1,500 and £2,500, so that the truck can then maintain the same residual value as a diesel truck. An OEM dedicated gas truck is estimated to attract a reduction in residual value of between 30 – 50% until the infrastructure provision in the UK improves[133].

Product availability

252 A key barrier to the wider uptake of gas-fuelled commercial vehicles is the limited availability of Euro VI gas-powered HGVs. At present, a limited number of gas truck models, including those manufactured by Scania and Iveco, are available on the UK

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130 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/287528/taskforce-recommendations.pdf
131 https://www.gov.uk/government/publications/low-carbon-truck-and-refuelling-infrastructure-demonstration-trial-final-report
132 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/287528/taskforce-recommendations.pdf
133 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/581858/low-carbon-truck-trial-final-report.pdf

market and we expect a small number of additional products to become available over the coming years. Issues have also been identified around the engine efficiency of dedicated gas engines, which are currently reliant on spark ignition technology, which is inherently less efficient than compression ignition diesel engine technology. However work is underway to manufacture more powerful, fuel efficient gas-fuelled commercial vehicles, which are expected to become available to the UK market over the next few years.

Refuelling infrastructure

253 Opinion is currently divided on the need for additional gas refuelling infrastructure. Some stakeholders consulted through the Freight Carbon Review suggested that the limited availability of gas refuelling sites still poses a significant barrier for operators, while others suggested that infrastructure is now sufficient and that the primary barrier to wider gas deployment is the lack of suitable trucks available to UK operators. A 2015 Element Energy study estimated that existing infrastructure includes 25 private depot stations, with around 60% offering LNG and 17 public forecourts with a similar LNG/CNG mix[134]. The LCTT commissioned seven new and upgraded eight existing refuelling stations, leading to a significant increase in available gas refuelling infrastructure, with further stations planned throughout this year[135].

254 The costs associated with installing gas refuelling infrastructure can also be prohibitive. A 2012 study by Ricardo-AEA (now Ricardo Energy & Environment) noted that these costs ranged from £250,000 to £2m, compared to £17,000 for a standard diesel fuel tank and pump[136].

255 Some participants in the LCTT experienced delays in commissioning gas refuelling stations, which were linked to identifying appropriate sites, planning permission processes, and legal and technical issues. These delays impacted on fuel substitution rates and therefore the performance of the gas trucks. Station operators also noted that the process for approving and assessing gas station applications was not consistent between planning authorities. LCTT station providers suggested that a single set of procedures and guidance for local planning authorities would be beneficial[137].

Uncertainty over emissions performance

Methane slip

256 As noted above, methane slip from certain types of gas-powered engines has the potential to eliminate any CO_2 emission savings from using these vehicles. Methane has a global warming potential 25 times greater that CO_2[138]. Testing undertaken by consortia in the LCTT showed that unburned methane emitted from some dual fuel vehicles resulted in these trucks having greater CO_2 equivalent emissions than a standard diesel truck[139]. This issue was not highlighted as a concern for dedicated gas trucks, which allow a more complete methane burn. This finding is supported by the HGV emissions testing work undertaken by LowCVP, which found significant

[134] Transport Energy Infrastructure Roadmap to 2050: Methane Roadmap – available at: http://www.lowcvp.org.uk/projects/fuels-working-group/infrastructure-roadmap.htm
[135] https://www.gov.uk/government/publications/low-carbon-truck-and-refuelling-infrastructure-demonstration-trial-final-report
[136] Ricardo-AEA ‘Opportunities to overcome the barriers to uptake of low emission technologies for each commercial vehicle duty cycle’ -available at: http://www.lowcvp.org.uk/news,new-report-identifies-clear-opportunities-for-cutting-carbon-and-lowering-costs-from-road-freight-operations_1924.htm
[137] https://www.gov.uk/government/publications/low-carbon-truck-and-refuelling-infrastructure-demonstration-trial-final-report
[138] At the time of writing, the latest scientific evidence, described in the IPCC 5th Assessment Report (Synthesis Report, 2015) recommends a 100-year GWP of 28 for methane, but this figure has not yet been officially adopted for GHG reporting.
[139] https://www.gov.uk/government/publications/low-carbon-truck-and-refuelling-infrastructure-demonstration-trial-final-report

methane slip from both the Euro V and Euro VI dual fuel (diesel/gas) trucks that were tested, and confirmed that this is not an issue for dedicated gas trucks[140].

257 Consequently there is divided opinion regarding the potential role of natural gas in decarbonising the road freight sector. The CCC suggests that, due to the relatively small potential tailpipe CO_2 savings available from use of natural gas, and potential risks around methane slip, it is important that lower carbon options for HGVs (such as hydrogen and electricity) are fully explored rather than relying on use of natural gas and biomethane in HGVs to help meet the UK's climate change targets[141].

258 Conversely, advocates of natural gas argue that, with limited fuel-based options to decarbonise commercial vehicles through the 2020s, further exploration of natural gas as an HGV fuel is needed. Furthermore, the provision of infrastructure and incentives to increase the uptake of natural gas could pave the way for wider deployment of biomethane within the road freight sector, potentially leading to a significant reduction in GHG emissions. There is also a degree of scepticism and uncertainty among some experts surrounding the future role of hydrogen as an HGV fuel.

Nitrous Oxide

259 The results of a limited number of vehicle tests indicate that some Euro VI diesel buses equipped with Selective Catalytic Reduction (SCR) NOx after-treatment systems emit high levels of Nitrous Oxide (N_2O). This results from the reaction between the NOx produced through diesel combustion and the ammonia in the NOx catalyst, which can increase tailpipe N_2O emissions. A small amount of N_2O emitted from an SCR-equipped Euro VI diesel vehicle could lead to a substantial increase in CO_2e emissions due to the potency of N_2O, which has a global warming potential 298 times that of CO_2[142].

260 Through DfT's HGV Emissions Testing study, we have undertaken a small number of vehicle tests to better understand how this issue might manifest in HGVs. The tests found that N_2O emissions were very low for a dedicated gas vehicle and non-SCR equipped diesel vehicles, with a measurable increase in N_2O from the SCR-equipped diesel truck that was tested[143]. This is based on a very limited number of vehicle tests and the scale and prevalence of this issue therefore remains unclear - further vehicle tests may be necessary. Dedicated gas trucks do not require SCR after-treatment to meet Euro VI standards; so if diesel trucks are found to be significantly affected by this issue, the GHG benefits of gas are likely to become more favourable when compared to Euro VI diesel equivalents.

Biomethane incentives

261 There is considerable industry interest in using biomethane as an HGV fuel, due to its GHG abatement potential and sustainability benefits. However, at present a very small amount is currently supplied directly to the transport sector as there is limited availability and competition for this fuel from other parts of the economy.

262 There are a number of incentive regimes to encourage the use of renewable energy in different sectors. The Renewable Heat Incentive (RHI) provides an incentive for

[140] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/581859/emissions-testing-of-gas-powered-commercial-vehicles.pdf
[141] https://www.theccc.org.uk/wp-content/uploads/2016/06/2016-CCC-Progress-Report.pdf
[142] At the time of writing, the latest scientific evidence, described in the IPCC 5th Assessment Report (Synthesis Report, 2015) recommends a 100-year GWP of 265 for N2O and 28 for CH4, but these figures have not yet been officially adopted for reporting purposes.
[143] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/581859/emissions-testing-of-gas-powered-commercial-vehicles.pdf

biomethane (excluding biomethane from landfill) to be injected into the gas grid and used primarily for space heating, and the RTFO incentivises the supply of biomethane directly as a transport fuel. In 2015 the incentive for biomethane was increased significantly under the RTFO. The Government currently allows biomethane extracted from the gas grid and used in road transport to be eligible for RTFCs, providing that it meets the sustainability criteria. We currently have no plans to change this position and should we do so, will consult.

263 Parts of the road freight sector have previously asked the Government to further improve the incentives for biomethane as a transport fuel. DfT has recently consulted on proposals to raise the reward for certain fuels, including biomethane and other fuels suitable for HGVs, through the creation of a development fuels sub-target under the RTFO[144].

264 The Committee on Climate Change acknowledges that the use of biomethane in HGVs could offer more significant GHG savings than natural gas, but suggests that the available, although limited, resource is likely to be better used in the power and buildings sectors. It is important to note that there is likely to be continued biomethane demand from buildings and industry. Therefore, increased use of biomethane in transport would be likely to displace it from other sectors and therefore not provide a net reduction in emissions across the economy[145].

Impacts of alternative fuels on vehicle payloads

265 Any propulsion technology that increases a vehicle's weight in comparison to a conventional diesel drivetrain will reduce the maximum available vehicle payload. For smaller (3.5 to 12 tonne) vehicles and for trucking of aggregates (where payment is commonly by tonne-km) this can be particularly problematic[146]. This issue should be addressed for some vehicle categories through forthcoming amendments to the General Circulation Directive on vehicle weights and dimensions, which will allow additional weight for certain types of heavy duty vehicle using certain alternative fuels (including LNG, CNG and biomethane) to account for their heavier drivetrains.

266 In addition the Government is currently developing proposals to seek an EU derogation that would allow Category B driving licence holders to drive alternatively fuelled vehicles up to 4,250 kg GVW (the current limit is 3,500 kg). This should help achieve payload parity with conventional diesel vehicles and overcome a key barrier to the adoption of alternative fuels, which require heavier powertrains.

Next steps

267 As set out in this chapter, there are a number of alternative fuels with the potential to reduce road freight GHG and air pollutant emissions. However, the evidence base on the performance of these fuels needs further development, particularly in relation to new and emerging gas engine technologies.

268 DfT will continue to play an active role in developing the evidence base on the emissions reduction potential of alternatively-fuelled HGVs, with a focus on new and emerging Euro VI technologies. This will include supporting further vehicle tests and monitoring the results of wider work in this field.

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[144] https://www.gov.uk/government/consultations/renewable-transport-fuel-obligation-proposed-changes-for-2017
[145] CCC: https://www.theccc.org.uk/wp-content/uploads/2016/06/2016-CCC-Progress-Report.pdf
[146] Ricardo Energy & Environment 'Opportunities to overcome the barriers to uptake of low emission technologies for each commercial vehicle duty cycle' - available at: http://www.lowcvp.org.uk/news,new-report-identifies-clear-opportunities-for-cutting-carbon-and-lowering-costs-from-road-freight-operations_1924.htm

269 Future policy on HGV fuels will need to take account of the evolving evidence base, including any relevant findings from DfT's ongoing transport energy work, which is assessing a range of alternative energy pathways for road vehicles out to 2050.

270 DfT will carefully consider responses to the recent consultation on proposed legislative amendments to meet our 2020 targets on renewable energy and GHG emissions, which include proposals on raising the reward for advanced fuels suitable for HGVs, through the creation of a ‘development fuels’ sub-target under the RTFO.

271 We will also ensure that rail freight is considered as part of work to develop options for wider deployment of biofuels to decarbonise the freight sector.

272 DfT will work with Department for Business, Energy and Industrial Strategy (BEIS) and the Department for Environment, Food and Rural Affairs (Defra) to consider the supply and demand of bioenergy across sectors of the UK and the role of these fuels in meeting the UK’s climate change targets.

6. Shifting the focus to low and zero emission technologies

Key messages

- There are a range of options currently available or on the horizon to electrify commercial vehicles.
- To support the electrification of heavier vehicles, the Government has announced an extension of the OLEV Plug-in Van Grant to encompass N2 and N3 category vehicles and an increase in support of up to £20,000 for the first 200 eligible vehicle sales.
- In the longer term 'on road' charging through Direct Wireless Power Transfer or Overhead Wired Power Transfer may provide a viable option for powering heavier HGVs, particularly if battery technology suitable for heavier trucks does not materialise. The Government will continue to monitor the ongoing international trials of these technologies, which will inform future policy.
- As with cars and vans, the decarbonisation of heavier vehicles is likely to be reliant upon the development of regulations to ensure that viable alternatives to the traditional internal combustion engine are developed and deployed, without damaging competition in the market.
- The UK has actively engaged with work to develop EU heavy duty vehicle CO_2 regulations on the monitoring and reporting of fuel consumption and CO_2 emissions from all new HGVs to inform purchasing behaviour. Potentially these could be used to set CO_2 emissions standards in the longer term.
- Improved transparency on fuel consumption should allow a degree of vehicle comparability to stimulate consumer awareness and create competition among vehicle manufacturers to reduce emissions.

Introduction

273 The Freight Carbon Review has considered recent and forthcoming developments in zero emission capable commercial vehicles, and initiated discussion with the road freight sector about how the Government could support industry in progressing towards achieving a significant GHG reduction by 2050.

274 The development of zero emission capable commercial vehicles and their deployment on UK roads has not progressed at the same pace and scale as the passenger car market. Opportunities for HGV electrification, including battery electric and hydrogen fuel cell vehicles, are now emerging mainly through niche vehicle manufacturers. In the short-medium term, as has been seen within the bus market, these options could become suitable for deployment in an increasingly broad range of commercial vehicles. In the long term, it is expected that the availability of a diverse range of vehicles should lead to zero emission solutions becoming accessible to all vehicle operators.

275 This chapter explores some of the technologies that offer alternative, cleaner and more efficient ways of powering commercial vehicles and identifies a number of potential measures to enable their development, manufacture and use in the UK. It starts by summarising existing and near-term vehicle technologies, and then considers potential longer-term solutions for decarbonising road freight, before setting out the key barriers to the wider deployment of new technologies and identifying potential measures to promote uptake.

276 Encouraging vehicle manufacturers to invest in the research and development of lower carbon options, and fleet operators to switch to alternative drivetrains may require further incentives or policies to be in place, including the provision of new infrastructure. The Government can play a valuable role in enabling and maximising the opportunities for the development of these technologies in the UK through providing a supportive route to market.

277 When considering the lengthy time horizons that apply in the context of technological developments for the road freight sector, and to minimise the risk of supporting the development of technologies that may ultimately not prove viable, the Government also needs to determine which technologies might be appropriate for support, as well as how and when they should be pursued.

278 It is important to note that the term ‘emissions’ in the context of this chapter, refers to ‘Tank to Wheel’ rather than ‘Well to Wheel’ emissions. This means that the analysis presented in this chapter focuses solely on tailpipe emissions and does not take account of the full lifecycle emissions associated with the generation of hydrogen or electricity. We recognise that there is debate about the sustainability and efficiency of hydrogen and electricity generation and its deployment to vehicles.

Existing and potential vehicle technologies

279 This section explores the key existing and near-to-market zero emission capable technologies considered suitable for deployment in commercial vehicles. Drawing on the findings of DfT analysis, it considers the GHG emissions reduction potential from a range of alternative HGV drivetrains.

Vehicle Types

280 Currently, the vast majority of UK trucks are powered via a traditional internal combustion engine (ICE). A range of alternative propulsion technologies are currently available to UK fleet operators, as summarised in Table 6.1 below.

Table 6.1: Overview of key alternative propulsion technologies

Technology	Description
Battery electric vehicles (BEVs)	BEVs are zero tailpipe emission vehicles with an electric drivetrain that rely entirely on a battery pack for their power. Battery powered vehicles, including vans and small trucks, are already available in the UK, including the Nissan eNV200, Renault Kangoo, and Paneltex[147]. Mercedes Benz has recently announced its first fully battery electric 26t truck, which could be available to the market by the early 2020s[148]. This follows successful trials of an all-electric 12t FUSO Cantor e-cell product in Stuttgart.
Range extended battery electric vehicles	These vehicles rely on a battery as their main power source but also carry an optimised ICE or hydrogen fuel cell to recharge the battery or power their wheels on the move. These vehicles have zero tailpipe emissions when using their batteries but can produce emissions when reliant on their generator for range extension. If reliant on a hydrogen fuel cell, the vehicles emit water vapour when the fuel cell is in use. Range extended battery electric vehicles can travel greater distances between charges - often doubling the range of BEVs. However, when in range extension mode they are often not zero emission (except in hydrogen fuel cell range extended versions). Tevva Motors is currently developing a 7.5t truck with a battery as its primary power source and a 1.6l diesel engine to extend the range of the vehicle. The truck is expected on the UK market in 2018[149].
Hydrogen fuel cell	These are vehicles with an electric drivetrain powered by hydrogen. Whereas time is required to charge a battery in a full BEV (typically requiring the vehicle to be attached to a static charging system), a hydrogen fuel cell powers the drivetrain on the move and can be refilled as quickly as a conventional petrol or diesel fuel tank. In the US hydrogen fuel cell trucks are available on the market and are eligible for state grants of up to $40,000 per purchase - but there is no evidence that this type of truck is currently available for sale in the UK[150].
Hybrid electric vehicles	These feature an electric powertrain combined with an internal combustion engine (ICE), to form a hybrid drive. Energy is recovered and stored in a battery when the vehicle is braking and this can be called on to assist the ICE when moving off or accelerating, which can save fuel. These vehicles have the ability to run zero tailpipe emission miles under certain conditions (low speeds, short distances) but produce emissions when reliant on their ICE. AutoTrader reported in 2016 that manufacturers are beginning to develop plug-in hybrid trucks for the market and some vehicles are already deployed in demonstration fleets in the US[151].

[147] www.paneltex.co.uk/electric.html
[148] www.daimler.com/products/trucks/mercedes-benz/urban-etruck.html
[149] http://vanfleetworld.co.uk/first-drive-tevva-motors-75-tonne-electric-range-extender-truck/
[150] www.hydrogencarsnow.com/index.php/vision-tyrano-truck/
[151] www.autotrader.com/car-news/hybrid-trucks-on-the-way-117314

Mild hybrids	Mild hybrids can use a flywheel or other form of kinetic energy recovery system to harvest kinetic energy from the vehicle braking system to power an electric drivetrain. This additional drivetrain can assist the conventional drivetrain when the vehicle is accelerating. Vehicles using this technology do not usually carry a battery and rely on an ICE for the majority of the time. These vehicles are not zero emission but often have lower CO_2 emissions than traditional ICEs. This technology was initially developed for Formula 1 vehicles and has been used on buses for at least the last 5 years. Some manufacturers are now developing the technology, which can be retrofitted to existing trucks[152].
Other vehicle types	There are many other types of hybrid that include different combinations of dual fuelling - some of which are discussed in Chapter 5 of this report. They can include a vehicle which carries two different types of fossil fuel or vehicles with both an internal combustion engine and an electric drivetrain.

Cost effectiveness and GHG emissions reduction potential

Costs of HGVs with alternative drivetrains

281 As the market for low and zero emission HGVs is at an early stage of development, there is limited evidence on the additional costs of these vehicles when compared to current or anticipated future costs of a standard diesel ICE truck. The most comprehensive analysis of current and projected future vehicle costs that DfT is aware of was undertaken by AEA (now Ricardo Energy & Environment) for the Committee on Climate Change (CCC) in 2012[153]. This considered how the costs of different vehicle components would evolve over time and hence how whole vehicle costs might change out to 2050. The study explored different vehicle technologies including battery electric and hydrogen fuel cell vehicles. It also considered how the energy efficiency of different vehicle technologies would change over time.

282 This analysis identifies that for all possible measures to improve HGV efficiency, the development of drivetrain technology consistently has the greatest impact. It suggests that hydrogen fuel cell technology has the greatest scope for core technological advancements leading to substantial efficiency improvements, and also has the benefit of zero tailpipe emissions. By 2050, an average sized hydrogen fuelled HGV would be expected to be 2.3 times more energy efficient than an equivalent diesel vehicle. In contrast, diesel/electric hybrid HGVs are expected to be only slightly more energy efficient than conventional diesel HGVs in 2050.

283 This work estimated the cost of a small rigid battery electric vehicle at just under £100,000 in 2010, representing a cost premium of around £70,000 over a diesel ICE vehicle. This is broadly comparable with DfT estimates of the additional cost of a 5.5t battery electric vehicle of around £60,000 in 2015. AEA estimated that the cost premium would fall to around £15,500 by 2030, driven by a 65% reduction in the battery cost. In more recent analysis the CCC estimated the cost premium associated with a small battery electric truck at £19,000 in 2030[154].

[152] Source: www.torotrak.com/products-partners/products/flybrid/
[153] www.theccc.org.uk/archive/aws/ED57444%20-%20CCC%20RoadV%20Cost-Eff%20to%202050%20FINAL%2025Apr12.pdf
[154] Committee on Climate Change, Sectoral Scenarios for the fifth carbon budget, https://www.theccc.org.uk/wp-content/uploads/2015/11/Sectoral-scenarios-for-the-fifth-carbon-budget-Committee-on-Climate-Change.pdf

284 AEA also considered the potential future cost of hydrogen fuel cell technologies for different types of HGV – small rigid, large rigid, articulated and construction vehicles. Their assessment was that the very high costs associated with these drivetrains and energy storage in 2010 will fall rapidly by 2030, with the vehicle cost falling below that of a diesel ICE by 2050.

285 The trajectory for vehicle costs by technology as set out in the AEA study is shown in Figure 6.1 below. This shows projections for average capital costs between 2010 and 2050 for different low and zero emission HGV technologies. These figures are averages across the different HGV types, categorised in the report as small rigid, large rigid, articulated, and construction. Battery electric costs, however, were only estimated for small rigid vehicles.

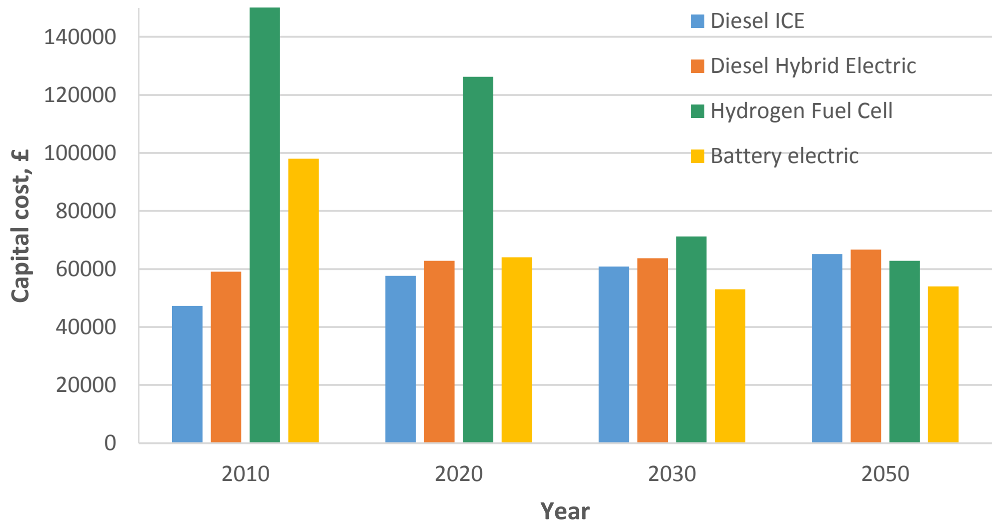

Figure 6.1: Average HGV capital costs over time by vehicle technology (£)

286 Combining the capital cost estimates with projected fuel costs and operating and maintenance costs provides an estimate of the cost premium across the whole vehicle lifetime in different years. Figure 6.2 shows the AEA assessment of how additional lifetime costs of different technologies could fall over time, with all low and zero emission technologies cheaper than the equivalent diesel ICE vehicle by 2030. However, it should be noted that there are considerable uncertainties around many of the assumptions that feed into this analysis, not only around the projected vehicle costs, costs which are drawn from a study which is now several years old, but also around future fuel prices, that could change the conclusions drawn from this analysis significantly.

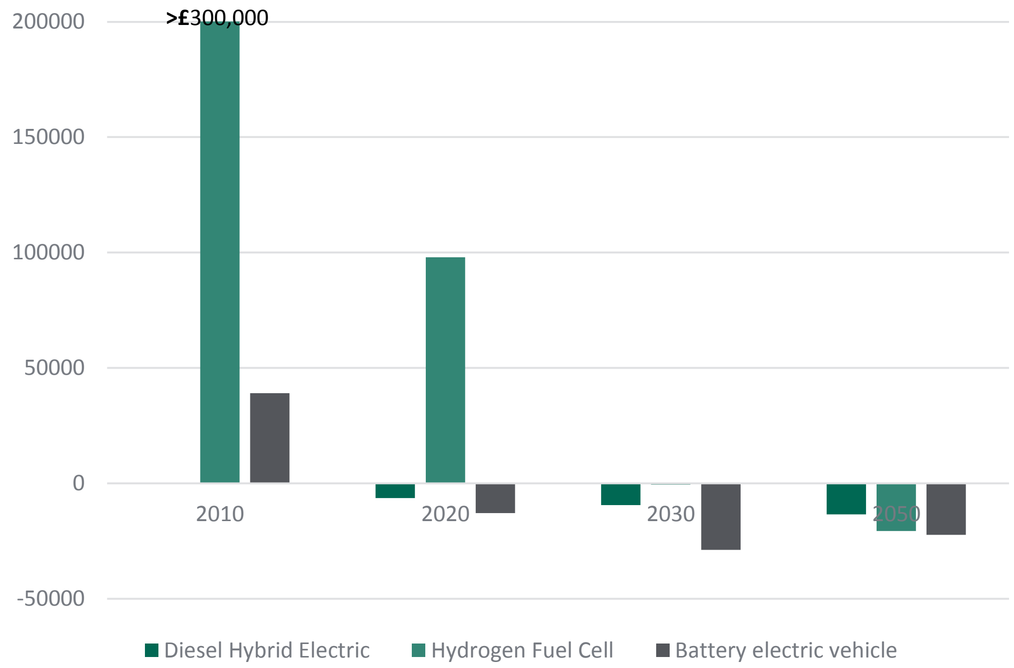

Figure 6.2: Average lifetime cost premium for low and zero emission technologies vs diesel HGV (£)

287 In addition, DfT analysis provides an indication of the current lifetime costs for a private freight operator of purchasing a 7.5t diesel/electric hybrid, or 5.5t battery electric vehicle compared to a conventional diesel powered small urban delivery HGV in 2015. The results of this analysis are very sensitive to assumptions made around the vehicle mileage, the period of first ownership and the assumed residual value of the vehicle on resale. Table 6.2 shows the lifetime cost premium associated with different vehicles under varying assumptions. The analysis focuses on vehicle technologies that are currently available on the UK market.

Table 6.2: Cost premium for different HGV technologies in 2015[155]

Technology		Period of first ownership	
		3 years	**6 years**
5.5t battery electric vehicle vs 5.5t diesel vehicle	Excluding residual value	£42000	£27000
	Including residual value	£27000	£18000
7.5t hybrid electric vehicle vs 7.5t diesel vehicle	Excluding residual value	£5000	£1000
	Including residual value	£2000	£-1000

288 This analysis suggests that even over a relatively long six year ownership period, a freight operator would face a cost premium for a small battery powered HGV of between £18,000 and £27,000 over a conventional diesel vehicle. In contrast, over the same ownership period, the hybrid HGV is expected to become cheaper than a diesel by £1,000 if the vehicle retains some residual value. This suggests that there

[155] DfT analysis based on 2015 estimates of vehicle and fuel costs.

is currently no financial motivation for a freight operator to purchase a battery electric HGV over a diesel vehicle, and a hybrid vehicle is only more cost-effective than a diesel vehicle if a certain residual value is assumed at the end of the period of first ownership.

Social cost-effectiveness of alternative technologies

289 An assessment of social cost-effectiveness also takes into account wider costs and benefits to society beyond the private costs and benefits incurred by the freight operator. The DfT analysis described above was extended to consider these wider benefits for the 5.5t battery electric vehicle and the 7.5t hybrid electric vehicle. These wider impacts include the value of the CO_2 saved and the monetised impact on air quality.

290 The results of the battery electric HGV modelling suggest that these vehicles are not currently a cost-effective way to reduce CO_2 given their upfront cost. This is compared to a carbon value for 2016 of £63/tCO_2. The analysis suggests that the higher the assumed lifetime mileage, the more cost-effective the vehicles become.

291 The small hybrid HGV is currently a more cost-effective carbon abatement measure. The vehicle’s societal cost falls below the 2016 carbon value assuming a relatively low lifetime mileage of 170,000-230,000 miles.

GHG abatement potential

292 The potential contribution of different low and zero emission technologies to reducing HGV emissions in line with the UK’s 2050 carbon target is uncertain, and will depend on the point at which different technologies are market ready, their applicability to different vehicle types and the speed of uptake. To illustrate the potential impact on emissions in the longer term, DfT has developed some illustrative analysis which shows how, in the long term, emissions might be reduced under different assumptions around technology uptake, with a focus on the potential for electric hybrid, battery electric and hydrogen fuel cell vehicles to reduce tailpipe emissions.

293 This analysis projects HGV emissions under current assumptions around future growth in HGV kilometres and future fuel efficiency improvements (i.e. a 0.5% improvement to the efficiency of new vehicles per annum), and assuming no significant take up of low or zero emission technologies. This suggests that HGV emissions could be just 3% lower in 2050 than 1990 levels if no further action is taken to improve fuel efficiency, or zero and low emission technologies are not taken up.

294 Illustrative scenarios about the uptake of other low and zero emission vehicles have then been developed which show the impacts in relation to that baseline. The scenarios are not intended to forecast uptake rates of different technologies but rather to illustrate how uptake could impact on emissions. Other scenarios could be developed which would show different impacts.

295 The analysis assumes that only HGVs <12t or municipal utility vehicles can be fully electrified[156] but that electric hybrid vehicles can be used across different sized vehicles and operational cycles. In total, the analysis assumes 100% of forecast HGV mileage is driven by battery electric or electric hybrid vehicles by 2050, equating to around a quarter of total HGV mileage being fuelled by electricity, and reducing emissions by just under 30%.

[156] This assumption draws on findings from Ricardo-AEA (2012), ‘Opportunities to overcome the barriers to uptake of low emission technologies for each commercial vehicle duty cycle’

296 Hydrogen fuel cell electric vehicles (FCEVs) are a potentially important technology, alongside battery electric vehicles, for decarbonising road transport and delivering the Government's ambition that all new cars and vans should have zero tailpipe emissions by 2040. They have strengths (e.g. rapid refuelling and long range) and disadvantages (e.g. currently higher capital and operating cost) relative to battery electric vehicles, suggesting both technologies may co-exist in the market, fulfilling different transport needs – for example FCEVs may prove a more viable option for goods vehicles and larger cars.

297 Hydrogen fuel cell technology may also have a longer term role to play in the freight sector. The CCC has identified fuel cell technology as a preferred route for difficult to decarbonise long haul HGVs. However current activity on fuel cell HGVs remains at a research and development stage, with substantial cost reduction being required before they could become commercially viable.

298 The scenario work described above also considered the impact of an illustrative level of uptake of hydrogen fuel cell HGVs on emissions. This assumed that significant uptake is delayed until 2030 and beyond, with 40% of mileage assumed to be hydrogen-fuelled by 2050 across all duty cycles. This level of uptake would contribute to GHG emission savings (from 1990 levels) of 42% in 2050. Figure 6.3 below shows the impact on emissions of the illustrative technology scenarios described.

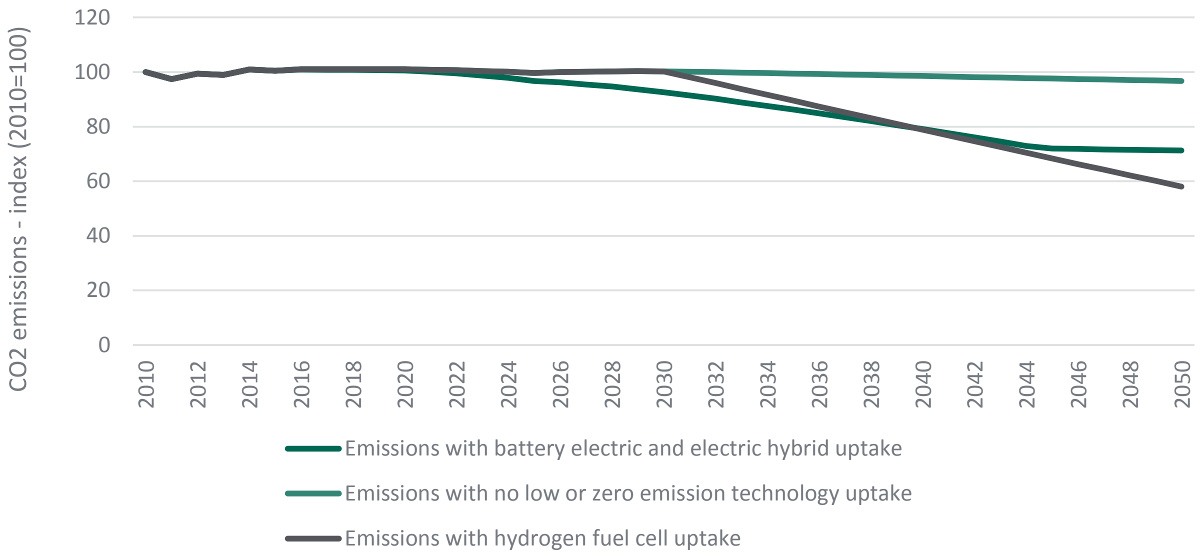

Figure 6.3: Total HGV emissions ($MtCO_2$) under different technology deployment scenarios

299 As described above, the scenarios are intended to be illustrative and each scenario is also exclusive of other fuel efficiency improvements that may be made to conventional diesel vehicles, or low and zero emission technologies which could be taken up - and hence is likely to underestimate the potential of a combination of emissions reduction solutions. However, the analysis shows that unless rapid uptake of low and zero technology vehicles is brought forward, there will also be an important role for other measures in reducing emissions across the entire fleet.

Longer term options for HGV electrification

300 The drivetrain options discussed above are likely to become viable for deployment in increasingly heavy vehicles as the technologies develop and mature, and become more cost effective over time. However, barriers to uptake are likely to remain at the heavier end of the commercial vehicle market and other options for electrification should be considered. This section considers the role of Direct Wireless Power Transfer and Overhead Wired Power Transfer in supporting the electrification of heavier trucks.

Direct Wireless Power Transfer

301 Direct Wireless Power Transfer (DWPT), also known as 'inductive charging', enables energy to be transferred from coils or plates placed beneath the surface of a road to vehicles using the road through electromagnetic induction. This technology can be used for 'static' charging where vehicles park directly above the equipment and charge while stationary, or 'dynamic' charging where vehicles drive over successive charging plates, picking up a charge on the move.

302 All vehicles are able to drive on a DWPT-equipped road surface and any electric vehicles fitted with correlating equipment can take charge from the plates or coils. A key benefit of this technology is that it enables vehicles to carry a smaller, lighter battery, thus alleviating payload penalties and increasing the feasibility of HGV electrification. The technology is depicted in Figure 6.7 below.

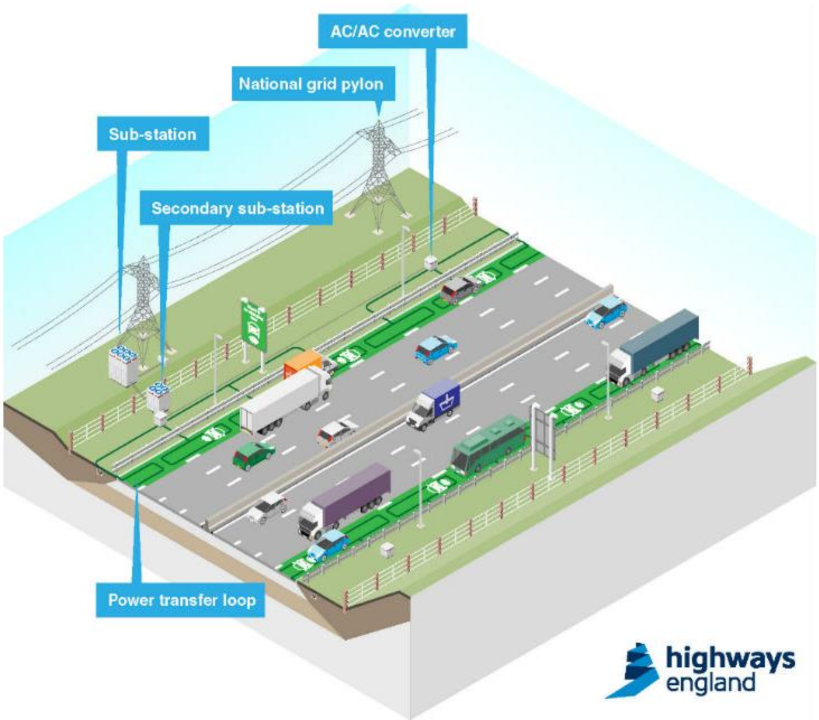

Figure 6.7: Example of Direct Wireless Power Transfer[157]

[157] https://www.gov.uk/government/news/off-road-trials-for-electric-highways-technology

303 Examples of static wireless charging already exist. The technology has been deployed in the UK on bus routes in Milton Keynes, Glasgow and London. Internationally, a small number of countries, including the Netherlands, Germany and South Korea, have also deployed trials of dynamic inductive charging systems on public bus routes.

304 In the UK, Highways England has examined the feasibility of trialling dynamic DWPT charging on the strategic road network in England. This study explored the effectiveness of a number of systems, and sought to identify the requirements for deploying such a system in the UK. It considered how the technology might be integrated into the road and its potential role in different vehicle types, and explored issues around connection to the electric grid. The study made some initial estimates of the potential costs and benefits of DWPT, concluding that it would be extremely expensive to install in the UK (between £1.7 and £5.5 million per mile), but may offer value over the longer term[158].

305 In terms of emissions reduction potential, the study modelled a representative 1 km section of motorway equipped with one DWPT lane, heading in one direction, where the proportion of DWPT vehicles was increased steadily over 20 years from 10% to 30% for light DWPT vehicles and from 5% to 75% for heavy DWPT vehicles. The analysis suggests that deployment of a DWPT system could reduce the total CO_2 emissions released by over 40%, with cumulative CO_2 savings over 20 years (taking account of CO_2 emissions from power generation) offering a monetised value of approximately £2m per km (equivalent to £1.24m per mile). Similarly, emissions of NOx and PM could be reduced by 35% and 40% respectively. It should be noted that these savings are not purely from HGVs using DWPT; a contribution from light vehicles using DWPT was also included in the model.

Overhead Wired Power Transfer

306 Overhead Wired Power Transfer (OWPT) is an alternative method for charging a vehicle's battery on the move. This system requires contact between an overhead wire and a charging point on the vehicle, for example a pantograph. Vehicles using this technology can take charge from the overhead wire while in motion and therefore carry a smaller, lighter battery compared to fully battery powered vehicles, with resultant weight and payload benefits.

307 The concept of power transfer via overhead wires and a pantograph is not new and is widely used in rail applications around the world. However, for road vehicles there are additional considerations such as how vehicles transfer onto and off the overhead wires when they move from one part of the road network to another, as well as the need to demonstrate that the technology can be safely deployed on the road. Further considerations are the visual impact of overhead wires, and the ongoing maintenance costs for the road network.

308 When running on overhead wires, OWPT-compatible trucks would have zero tailpipe emissions. Were the technology to be coupled with an ICE for use when wires were not available, GHG emissions from these trucks would be the same as similar sized ICE-powered trucks operating to the same duty cycles, when not reliant on the wires to power the drivetrain.

309 The Swedish Transport Administration has recently inaugurated a 2 km stretch of 'electric road' on the E16 highway in Sandviken. As shown in Figure 6.9 below, the test area is equipped with electric catenary lines over one of the lanes. The truck has

[158] http://assets.highways.gov.uk/specialist-information/knowledge-compendium/2014 2015/Feasibility+study+Powering+electric+vehicles+on+Englands+major+roads.pdf

a pantograph on the roof that feeds 750 VDC to the truck's hybrid electric system. The conductor can connect automatically at speeds up to 90 km/h. The agency also plans to test an alternate technology, which involves installing an electric rail on a closed road near Arlanda. These tests are ongoing and will continue until 2018.

Figure: 6.9 OWPT trial on E16 highway in Sandviken[159]

Emerging Technologies

310 This section outlines some new, potentially disruptive, technologies which could impact upon the traditional operation of the freight industry over the coming years.

Connected and Autonomous Vehicles (CAVs)

311 Manufacturers are already equipping HGVs with internet connectivity, bringing with it the potential for efficiency gains through the use of live travel data to reroute vehicles away from traffic jams and reducing vehicle downtime by using data to support the early diagnosis of potential maintenance issues.

312 Connectivity between vehicles, known as 'V2V communication', combined with increasing levels of vehicle autonomy could in future allow HGVs to move in platoons. Truck platooning is a concept whereby two or more trucks cooperate by driving with a shorter separation distance between each vehicle, using automated driver assist technologies to maintain each vehicle's speed and sometimes direction. While all the vehicles still require drivers to operate them, one of the key benefits of platoons is that they can use the slipstream of the lead HGV to minimise air friction for the following vehicles, therefore increasing their fuel efficiency and thus reducing operating costs.

313 Platoons also have the potential for safety benefits: as these technologies allow the vehicles to automatically accelerate and brake simultaneously, there would no longer be a reliance on the driver's reactions in an emergency stop, effectively removing the 'thinking' distance.

314 UK trials of platooning were announced in the Budget speech in March 2016[160] and a DfT/Highways England-funded platooning trial is scheduled to commence this year. The trial will take a staged approach, starting with off-road testing.

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[159] http://www.trafikverket.se/en/startpage/about-us/news/2016/2016-06/first-electric-road-in-sweden-inaugurated//
[160] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/508193/HMT_Budget_2016_Web_Accessible.pdf

315 Autonomous vehicles have further potential to reduce emissions by changing gear, accelerating and braking more efficiently than a human driver. For example, in-cab technologies that are already available can anticipate the road ahead through accurate mapping for gradient, road curvature and traffic conditions, and will be capable of making decisions on behalf of a driver. Decisions about when and by how much to accelerate could be 'tuned' to the vehicle's most efficient operating mode and therefore save fuel.

Delivery drones

316 Within the e-commerce industry, the potential for drones to offer a fast, convenient delivery option is increasing. Examples include Amazon Prime Air, which seeks to automate last-mile delivery of packages using small drones, able to reach a destination in 30 minutes whilst carrying a small parcel[161]. Amazon completed its first test delivery in the UK in December 2016[162]. Analysis suggests that this could be a relatively cost-effective delivery option. For example, it has been estimated that sending a 2 kg package within a 10 km radius in the US by ground transport costs Amazon $2-$8 compared with around 30 cents using a drone[163].

317 The current DfT consultation on the commercial use of small drones considers safety issues, as well as requirements for insurance, registration and guidance[164]. Additionally, DfT's Pathfinder Programme announced in 2015 that it aims to create an environment in the UK in which drones can be safely and efficiently flown beyond visual line of sight, and will consider applications to logistics and geo-mapping as part of this work. It should be noted that the energy and environmental implications of widespread use of delivery drones are not yet fully understood and will need to be assessed before long-term policy can be developed.

Barriers to uptake of ULEV HGVs

318 The technologies discussed in this chapter are potentially game changers in terms of their emission reduction capabilities. However, there are a number of barriers to wider industry adoption, including the cost of vehicles and refuelling infrastructure, limited availability of off-depot charging or refuelling infrastructure, limited vehicle options, payload penalties associated with battery weights, and risks inherent with being early adopters of new, unproven technologies.

319 The most significant barriers to uptake of zero tailpipe emission capable commercial vehicles, include:

- A lack of suitable models, particularly in the large van segment (2.5-3.5t), and above. This is reflective of the relatively weak EU CO_2 regulations currently in place for vans, and the absence of any EU CO_2 regulations for trucks. This situation has led to a lack of incentive for manufacturers to supply Ultra Low Emission Vehicles (ULEVs) to this market. There are currently no large ULEV vans or HGVs in volume production although, as outlined above, some manufacturers have plans to introduce products during the next few years.
- The lack of suitable vehicles combined with the emergent nature of the technology means that technology costs are currently high compared to

[161] https://www.pwc.pl/pl/pdf/clarity-from-above-pwc.pdf
[162] https://techcrunch.com/2016/12/14/amazons-prime-air-delivery-uk/
[163] http://www.businessinsider.com/delivery-fee-for-amazon-prime-air-2015-4?IR=T
[164] https://www.gov.uk/government/consultations/benefits-of-drones-to-the-uk-economy

conventional diesel trucks. As the technology normalises, it is expected that this barrier will erode but it is, nonetheless, very significant in the short term.

- The lack of charging infrastructure suitably located for use by large commercial vehicles means hauliers cannot reliably purchase electricity ‘on the go’ as their drivers move around the UK. While some hauliers can install their own infrastructure locally and operate ‘back to base’ routes, this is not suitable for all types of duty cycle and is a particular issue for hauliers operating long haul delivery cycles. The capacity of the electricity supply into some business premises can limit the number of vehicles that can be charged simultaneously and connection costs for very high powered charging infrastructure can entail significant upgrade costs for businesses.
- Refuelling infrastructure availability is a key potential barrier to roll out of FCEVs. Without a reasonable refuelling offer no vehicles can be deployed - and without a reasonable number of vehicles in operation, investment in refuelling infrastructure does not offer a commercial return. The joint Government-industry UK H2 Mobility programme examined the hydrogen for transport opportunity in the UK and developed a hydrogen roadmap. This identified that an initial network of 65 refuelling stations would be sufficient to provide coverage for national roll-out of vehicles. It also conducted analysis showing that investment in stations prior to the late 2020s would not offer a commercial return[165].
- Fleet customer attitudes can further inhibit the uptake of electric and hydrogen commercial vehicles. Fleet purchases typically involve multiple decision-makers, who can be unaware of or reticent about ULEV options.
- Technologies such as wired or wireless power transfer for HGVs, and other emerging and as yet unproven technologies, face significant barriers in order to get to the testing phase in the UK. The Government will monitor the progress of international trials so that informed decisions can be made in future. Very significant barriers will include proving that the technology works and is appropriate for the UK, the cost of infrastructure installation and maintenance, and establishing viable business models for financing and operating. It will also be important to consider how the infrastructure can be installed on a busy network, bearing in mind that it is not a ‘drop in’ solution and that we do not yet have comprehensive evidence on its impacts.

Existing and forthcoming measures

Incentivising the uptake of new and cleaner vehicles via Clean Air Zones

320 Defra has recently consulted on a national framework which will provide a consistent approach to the implementation of Clean Air Zones[166]. The draft framework sets out how Clean Air Zones can enable local authorities to coordinate measures to support improvements in air quality and health, local growth and ambition, and accelerate the transition to cleaner vehicles.

321 Clean Air Zones will see the most polluting vehicles, such as old buses, taxis, coaches and HGVs, discouraged from entering the Zone through charges. They will reduce pollution in urban centres and encourage the replacement of old, polluting vehicles with modern, cleaner vehicles.

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[165] http://www.ukh2mobility.co.uk/wp-content/uploads/2013/08/UKH2-Mobility-Phase-1-Results-April-2013.pdf
[166] https://consult.defra.gov.uk/airquality/implementation-of-cazs/

322 While these plans are being put in place primarily to improve air quality and reduce nitrogen dioxide emissions it is expected that they will also have an impact on other emissions, including CO_2, as some businesses opt to switch to zero emission vehicles.

323 The draft framework includes a number of suggestions for how local authorities might reduce emissions from freight and encourage cleaner vehicles to be used for deliveries in a Clean Air Zone. For example, it suggests that where compatible with other requirements such as noise and safety, local authorities could consider giving other exemptions to vehicles operating on electric power within a zone, such as allowing night-time delivery or delivery access to pedestrian areas[167].

324 The National Planning Policy Framework encourages sustainable transport solutions that support reductions in GHG emissions, and for the incorporation in developments of facilities for plug-in charging and other ultra-low emission vehicles. We will consider the scope for further action to support zero emission vehicles through the planning system.

Ultra Low Emission Zones

325 The Mayor of London has recently consulted on proposals for the implementation of the Emissions Surcharge (more commonly known as the 'T-Charge') in 2017, for the older, more polluting vehicles driving into and within central London, and ideas for improving the Ultra Low Emission Zone (ULEZ). These include:

- Bringing forward the introduction of the ULEZ to 2019, instead of 2020.
- Extending the ULEZ from Central London to London-wide for heavy vehicles (HGVs, buses and coaches), as early as 2019, but possibly later.
- Extending the ULEZ from Central London up to the North and South Circular roads for all vehicles (i.e. those hat will be subject to the ULEZ in central London due to start in September 2020) as early as 2019, but possibly later[168].

Transport for London's LoCITY programme

326 LoCITY is a structured collaborative programme that brings together the full range of stakeholders needed to stimulate the uptake of alternatively fuelled commercial vehicles[169].

327 The programme is increasing the supply and uptake of alternatively fuelled commercial vehicles and associated infrastructure through technical research, industry working groups and a targeted fleet advice programme. In addition, new procurement standards are being developed to help encourage fleets to invest in this technology.

328 The programme is also engaging, supporting and preparing freight and fleet operators for the implementation of the forthcoming Ultra Low Emission Zone in London.

EU regulation for reducing fuel consumption and CO_2 emissions from heavy duty vehicles

329 Unlike cars and vans, heavy-duty vehicles (HDVs – trucks, buses and coaches) are not yet within scope of European CO_2 emissions legislation. In 2015 the European Commission proposed legislation that will introduce a simulation methodology to

[167] https://consult.defra.gov.uk/airquality/implementation-of-cazs/
[168] https://consultations.tfl.gov.uk/environment/air-quality-consultation-phase-2/?cid=airquality-consultation
[169] https://locity.org.uk/programme-overview/

calculate fuel consumption and CO_2 emissions from new trucks and buses.

330 The proposed Regulation is based on CO_2 simulation, using a model known as VECTO (Vehicle Energy Consumption calculation TOol)[170]. Manufacturers will be required to run VECTO for every individual vehicle manufactured over one of five standard mission profiles (long haul, regional delivery, urban delivery, municipal utility, construction) designed to represent typical operations. The modelled results will be used by the European Commission (EC) to monitor HDV CO_2 emissions from 2018 and a separate regulation will require their publication for consumer information.

331 The EC expects that improved transparency of CO_2 emissions will allow a degree of vehicle comparability by freight operators and so stimulate consumer awareness, leading to the production and purchase of more energy efficient trucks and buses. Once legislation is in place on measuring and reporting, there is likely to be a desire to set mandatory limits on average CO_2 emissions from newly-registered HGVs, as is already in place for cars and vans.

332 It is difficult to estimate what impact such regulation would have on the industry, without fully understanding the baseline situation. As mentioned above, there are already targets in place for new car CO_2 emissions with penalty payments in place for manufacturers that fail to meet the target levels. Since monitoring started under current legislation in 2010, emissions have decreased by 20g CO_2/km (15%)[171]. This suggests that, if implemented correctly, regulation has the potential to have a very positive impact on CO_2 emissions from the HGV sector.

333 As a further step, in July 2016 the EC published a communication titled 'A European Strategy for Low-Emission Mobility' which confirmed the acceleration of efforts to develop new regulatory measures limiting CO_2 emissions from heavy duty vehicles, noting that other parts of the world (US, China, Japan and Canada) have already introduced standards and that the EU will be at risk of a market disadvantage[172].

334 While information is not yet available on the likely level of ambition in the forthcoming legislation, the EC has suggested that targets could be expected in the 2020-2025 timeframe. It is likely that, similar to cars and vans, these targets will apply to vehicle manufacturers and impact purchasers of new vehicles. Fuel efficiency improvements can reduce operational costs, though payback periods for the additional technology investments remain key.

335 The reporting and monitoring requirements are likely to make it easier for buyers of vehicles to assess whether the vehicle they are buying meets their needs and offers CO_2 savings. The regulations on emissions are likely to mean that vehicle manufacturers increase levels of investment in research and development to ensure their trucks meet the EU standards and that more fuel efficient trucks are available to the purchaser.

336 The Government is considering carefully all the potential implications arising from the UK's exit of the EU. Until we leave, EU law will continue to apply to the UK alongside national rules. We will need to consider the implications of the regulations described above for UK industry and ensure that appropriate safeguards are put in place to encourage and maintain innovation in our HGV market. This should have a positive

[170] VECTO uses measured vehicle component performance as input, i.e. engine fuelling map, transmission efficiency map, axle performance, tyre rolling resistance, aerodynamic resistance and (default characteristics for) auxiliaries. Each of these 'components' will be type approved to generate input data for the model. The vehicle manufacturer's process for generating CO_2 figures using the model will also be type approved.

[171] http://ec.europa.eu/clima/news/articles/news_2016041401_en.htm

[172] http://europa.eu/rapid/press-release_MEMO-16-2497_en.htm

impact on the efficiency, competitiveness of the sector, while reducing air pollution and GHG emissions from road freight.

Extension of the Plug-in Van Grant

337 The share of vans in the domestic transport mix is increasing, with the growth rate of new van sales over the past five years more than double that of cars. In 2015, ULEVs accounted for only 0.27% of new van sales (1,009 vehicles), compared to 1.09% of new car sales.

338 The Plug-in Van Grant (PIVG) was introduced by OLEV in 2012, modelled closely on the Plug-in Car Grant (PICG). To support the electrification of increasingly heavy vehicles, the Government has recently announced an extension of the PIVG to encompass N2 and N3 category vehicles and an increase in support of up to £20,000 for the first 200 eligible vehicle sales[173].

Government Buying Standards

339 The Government has the ability to require minimum standards from those offering services through setting and imposing sustainability criteria in relation to major purchases or contracts for key infrastructure. This in turn can demonstrate best practice for companies wishing to bid for future contracts or major Government infrastructure projects.

340 By requiring companies bidding for these contracts to demonstrate that they meet minimum environmental standards from vehicles used in the delivery of freight or on site, Government contracts can encourage manufacturers to create products that meet these standards.

Hydrogen for Transport Advancement

341 The Government's Hydrogen for Transport Advancement Programme is supporting the deployment of hydrogen refuelling sites by providing capital funding for early refuelling stations. £5m has been allocated to build or upgrade 12 stations to support the launch of FCEVs by vehicle manufacturers. This has helped to secure the UK as one of five global launch markets for FCEVs. The early nature of the market means that vehicle costs are still high, due in part to very low production volumes. Therefore the Government is providing £2m to support early deployment of vehicles in public and private sector fleets[174].

Modern Transport Bill

342 OLEV is working across Government to position the UK at the forefront of ULEV development, manufacture and use, including through providing targeted funding for the rapidly expanding infrastructure that supports ever increasing numbers of plug-in and hydrogen FCEVs. Across the UK there are now more than 11,000 chargepoints, including the largest network of rapid chargers in Europe and a growing number of publicly accessible hydrogen refuelling stations.

343 The Government has recently consulted on a number of measures that, as part of the Modern Transport Bill, would support the roll-out and use of recharging and refuelling infrastructure for ULEVs, including battery and hydrogen FCEVs, and maximise their benefits. The proposed measures address three challenges for the growing ULEV sector: the consumer experience of using the infrastructure, the interaction of the charging infrastructure with the electricity system, and the future provision of

[173] https://www.gov.uk/government/publications/plug-in-van-grant-extension-to-larger-vans/plug-in-van-grant-extension-to-larger-vans
[174] https://www.gov.uk/government/news/government-launches-2-million-competition-to-promote-roll-out-of-hydrogen-fuelled-fleet-vehicles

infrastructure[175].

Next steps

344 The Freight Carbon Review has considered recent and forthcoming developments in zero emission capable commercial vehicles that could support the road freight sector in progressing towards achieving significant a GHG reduction by 2050. However, we recognise that there is considerable uncertainty regarding both the mix of technologies that will be available by 2050 and the extent to which emerging technologies such as hydrogen fuel cell will penetrate the HGV market.

345 The Government will continue to encourage the development of low and zero emission vehicle technologies for heavier trucks, including through OLEV's research and development support programme.

346 We will monitor the results of the Low Emission Freight and Logistics Trial, which is funding 20 projects to demonstrate new technologies and to encourage the widespread introduction of low and zero emission vehicles to UK fleets.

347 We will monitor the progress of international trials of DWPT and OWPT so that informed decisions can be made on the potential for further trials on logistics vehicles in the UK in future.

348 In addition we will continue to take forward proposals that are being developed to allow Category B driving licence holders to drive alternatively-fuelled vans up to 4,250 kg to account for their heavier drivetrains, thereby addressing the payload penalty issues associated with battery propulsion. We plan to consult on these proposals later this year.

349 Opportunities to encourage the use of low emission vehicles may emerge from the development and roll-out of Clean Air Zones. We will work with Defra and the local authorities involved in establishing these Zones to consider the use of incentives, such as allowing night-time delivery or delivery access to pedestrian areas, to encourage hauliers to use cleaner vehicles.

[175] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/562370/ulev-modern-tranport-bill-consultation.pdf

7. Conclusions

Actions and next steps

350 The Freight Carbon Review has considered a range of existing and newly-commissioned evidence as well as stakeholder views to develop an overview of the key opportunities for and barriers to reducing GHG emissions from the road freight sector, identify key evidence gaps, and propose a number of potential options for reducing emissions. The Government is committed to supporting industry in implementing cost-effective GHG emissions reduction measures.

351 In support of this we have recently announced an extension of the OLEV Plug-in Van Grant to encompass heavier vehicles of category N2 and N3 and an increase in support of up to £20,000 for the first 200 eligible vehicle sales, £20m grant support for industry-led trials of alternative propulsion technologies for commercial vehicles, £20m funding for an Advanced Renewable Fuel Demonstration Competition, and an HGV accreditation scheme to assess the fuel and GHG emissions savings from a range of aftermarket technologies.

352 However, we recognise that further measures will be needed to deliver a significant emissions reduction from the road freight sector in line with national climate change targets. Government will consider the scope for developing additional measures as part of the process to develop the Emissions Reduction Plan. In addition, we will take forward the measures outlined below.

Support for efficient driving and in-cab technologies

- We will work with the Energy Saving Trust to pilot an HGV fleet review scheme, to advise SME fleet operators on reducing fuel consumption and costs, with the aim of delivering GHG savings and developing a case for future support. Evidence collected from the evaluation of this trial will inform future policy.

Fleet design

- We will continue to work with the Low Carbon Vehicle Partnership and industry to support the roll-out of the HGV technology accreditation scheme, and consider options for increasing industry uptake.
- We will work with the Freight Transport Association to support and encourage wider uptake of the Logistics Carbon Reduction Scheme, particularly among smaller operators.

Reducing road miles

- We will consider the scope for further modal shift from road to rail, through further work to assess the costs and benefits of opportunities identified in the Rail Freight Strategy.
- We will take forward work over the next year to extend the Longer Semi-Trailer Trial, in collaboration with industry. Operators will be invited to bid for a share of

the additional allocation in the coming months, and details on how to apply will be available in due course.

- We will consider the scope for developing further measures to support wider industry collaboration and address barriers within the road freight sector.

Alternative fuels

- We have recently consulted on biofuels policy, including on measures to increase renewable fuel supply across the road transport sector and to support advanced fuels suitable for freight under the Renewable Transport Fuel Obligation. We will consider the responses and set out our next steps for biofuels policy later this year.
- We will engage with industry as we transpose amendments to the General Circulation Directive by May 2017, including the adoption into UK law of measures to allow operators of alternatively-fuelled HGVs up to an extra tonne in weight to account for the heavier drivetrains.
- We will continue to gather and monitor evidence on the environmental and economic performance of alternatively-fuelled commercial vehicles.
- We will engage industry with the development of our £20m Advanced Renewable Fuel Demonstration Competition.

Shifting the focus to low and zero emission technologies

- We are developing proposals that would allow Category B driving licence holders to operate alternatively-fuelled vans up to 4,250 kg to account for their heavier drivetrains, and plan to consult on these proposals later this year.
- OLEV will continue to encourage the development of low and zero emission vehicle technologies for heavier trucks through its research and development support programme.
- We will work with Defra and the local authorities involved in establishing Clean Air Zones to consider the use of incentives to encourage hauliers to use cleaner, quieter vehicles.

353 We will work closely with the road freight industry, as well other Government departments and the devolved administrations, to take forward these actions. We recognise that further work is needed and will build on the findings of this Review to identify and assess additional freight decarbonisation measures. Our goal is to ensure that future work in this area is supportive of the road freight industry, and that we encourage its development in a way that is compatible with reducing emissions from the sector.

Appendix A: Glossary

Term	Definition
Biomethane	Biomethane is methane gas of biogenic, rather than fossil, origin.
Committee on Climate Change (CCC)	An independent, statutory body established under the Climate Change Act 2008. The CCC advises the UK Government and Devolved Administrations on emissions targets and report to Parliament on progress made in reducing greenhouse gas emissions and preparing for climate change.
Compressed Natural Gas (CNG)	Methane gas that is stored on a vehicle in high-pressure tanks at around 200 to 250 bar.
Dual fuel	A vehicle that operates on a mixture of two different fuels (e.g. diesel and gas).
Duty cycle	Heavy commercial vehicles are used in a very wide range of operations with very variable mission profiles, known as duty cycles.
Fatty-acid-methyl-ester (FAME)	A nearly wholly renewable transport fuel, in that it is derived from around 90% biomass and around 10% methanol from fossil fuel.
Gross Vehicle Weight (GVW)	The weight of a vehicle or trailer including the maximum load that can be carried safely when it's being used on the road.
Heavy Goods Vehicle (HGV)	A commercial vehicle over 3.5 tonnes GVW.
Liquefied Natural Gas (LNG)	Natural gas that is converted to a liquid by cooling it to -162 degrees centigrade
Liquefied Petroleum Gas (LPG)	LPG is a mixture of liquefied propane and butane which is produced both from oil and gas extraction, and also as a by-product of fossil fuel refining.
N2 category vehicles	Vehicles designed and constructed for the carriage of goods and having a maximum mass exceeding 3.5 tonnes but not exceeding 12 tonnes.
N3 category vehicles	Vehicles designed and constructed for the carriage of goods and having a maximum mass exceeding 12 tonnes.
Natural gas	Natural gas consists mainly of methane along with smaller quantities of other hydrocarbons.
Oxides of Nitrogen (NOx)	Nitrogen dioxide is a brown gas, with the chemical formula NO_2. It is chemically related to nitric oxide (nitrogen monoxide), a colourless gas with the chemical formula NO. Together, NO and NO_2 are known as NOx.
Tonne Kilometre	A metric of the amount of freight moved, taking into account weight and distance travelled.

Appendix B: HGV technology survey

Overview

In 2015, DfT undertook a HGV Technology Survey with the objective of improving the evidence base on the current levels of uptake of fuel efficient technologies amongst HGV operators. DfT sent a short survey to a sample of 1,000 HGV owners, selected from respondents to the annual Continuing Survey of Road Goods Transport (CSRGT). Around 700 responses were received, covering a representative sample of the entire HGV fleet.

The survey covered 17 technologies, as shown in Table A1, which can be grouped into three categories: ‘aerodynamics’, ‘tyres’ and ‘other’.

Table A1: Technologies included in HGV technology survey

Aerodynamics	Tyres	Other
Cab roof air deflector	Low rolling resistance tyres	Automated Manual Transmission
Body skirts	Automatic tyre inflation	Voluntary speed limiter
Cab collar	Tyre pressure monitoring system	Voluntary rev limiter
Full gap fairings		Predictive cruise control
Teardrop-shaped trailer		Electronic driver performance monitoring
Trailer rear end (taper/boat-trail)		Telematics to optimise vehicle routing
Spray reduction mud flaps		Technology to reduce engine idling

Survey results

The survey collected data on technology uptake levels. It also provided insight regarding the number of HGVs operated by each participating company, as well as the duty cycles operated, and truck ownership arrangements. This has allowed DfT to analyse patterns of technology uptake within specific segments of the industry, as well as across the road freight industry as a whole.

Duty Cycle

Figure A1 below shows there is a significant variation in duty cycle depending on how many HGVs an individual company operates. The survey found that construction accounted for 36% of vehicles held by operators of 1-4 HGVs, whereas it made up only 6% of vehicles for companies operating 150+ vehicles. This needs to be taken into account in the analysis of overall uptake because construction vehicles are less likely than vehicles operating to other duty cycles to have efficient technologies fitted due to their unique shape and operation pattern. Indeed the survey results show that uptake across all efficient technologies was lowest for vehicles operating to municipal and construction duty cycles. This is due to the shape and size requirements for these vehicles which means that many technologies, particularly those designed to improve vehicle aerodynamics, are unsuited to these HGVs.

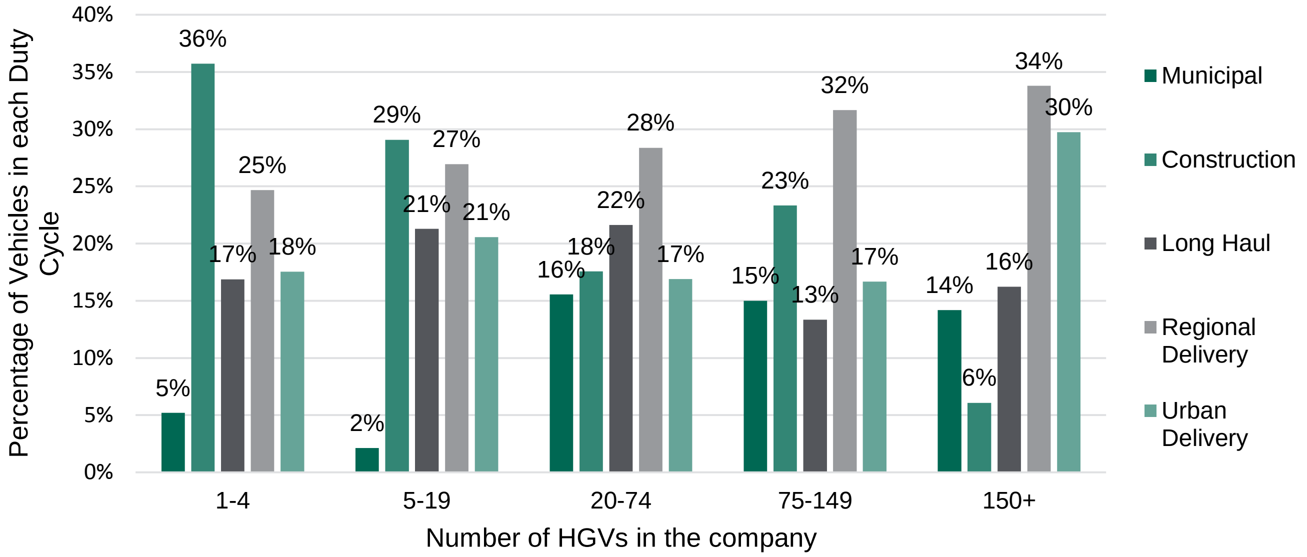


Figure A1: Duty cycles amongst survey participants

Ownership arrangement

As shown in Figure A2 below, the ownership arrangement differed substantially depending on the number of HGVs operated by individual companies. For companies with 1-4 HGVs, 25% of vehicles were new and 70% of vehicles were second hand owned. However for companies that owned over 150 vehicles, the percentage of new and second hand owned vehicles changed to 61% and 3%respectively. This is an important distinction as new HGVs are more fuel efficient and are likely to have some carbon saving technologies already fitted, whereas older vehicles are likely to be less efficient. The results of this survey therefore indicate that the least efficient vehicles are owned by smaller firms.

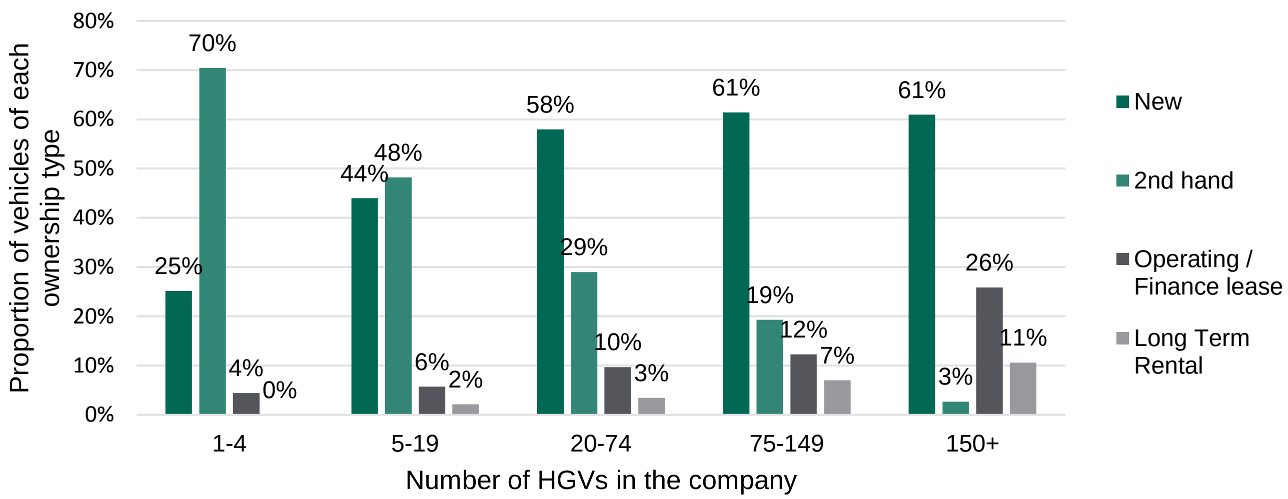


Figure A2: Ownership arrangement by number of HGVs owned

Technology uptake

Table A2 below shows the uptake of technologies across all survey respondents. Spray reduction mud flaps were found to be the most commonly fitted of the technologies listed, with more than 70% of respondents stating that they were installed on their vehicle. However, it is possible that some respondents may not have made the distinction between standard spray reduction mud flaps and those brands specifically marketed as providing fuel cost savings when responding to the survey, and incorrectly identified themselves as using this technology. We would however expect spray reduction mud flaps to be one of the more popular technologies given their low cost and relatively short payback period.

Automatic tyre inflation was the least popular of the technologies listed, installed by only 1% of survey respondents. This result is understandable given the limited market availability and relatively high upfront costs associated with automatic tyre inflation systems.

Table A2: Technology uptake rates amongst survey participants

Technology	Uptake amongst survey respondents
Spray reduction mud flaps	74.3%
Voluntary speed limiter	57.8%
Cab roof air deflector	51.8%
Automated Manual Transmission	48.6%
Telematics to optimise vehicle routing	41.1%
Electronic driver performance monitoring	34.6%
Technology to reduce engine idling	33.1%
Low rolling resistance tyres	25.3%
Cab collar	24.9%
Predictive cruise control	24.7%
Body skirts	16.4%
Voluntary rev limiter	16.3%
Full gap fairings	16.0%
Tyre pressure monitoring system	11.1%
Trailer rear end (taper/boat-tail)	2.3%
Teardrop-shaped trailer	1.3%
Automatic tyre inflation	1%

Figure A3 presents shows technology uptake according to operator size. These results suggest that operators with a larger fleet have generally higher technology uptake rates than operators with smaller fleets. 90% of vehicles in companies owning 75-149 HGVs have spray reduction mud flaps installed. This compares to a 60% uptake rate amongst companies owning 1-4 HGVs.

The differences between uptake in larger and smaller operators are much less pronounced for the less popular technologies. For example, around 25% of respondents stated that they had predictive cruise control installed and this result did not vary according to fleet size. A similar result was seen for other less popular technologies such as voluntary rev limiters and tyre pressure monitoring systems.

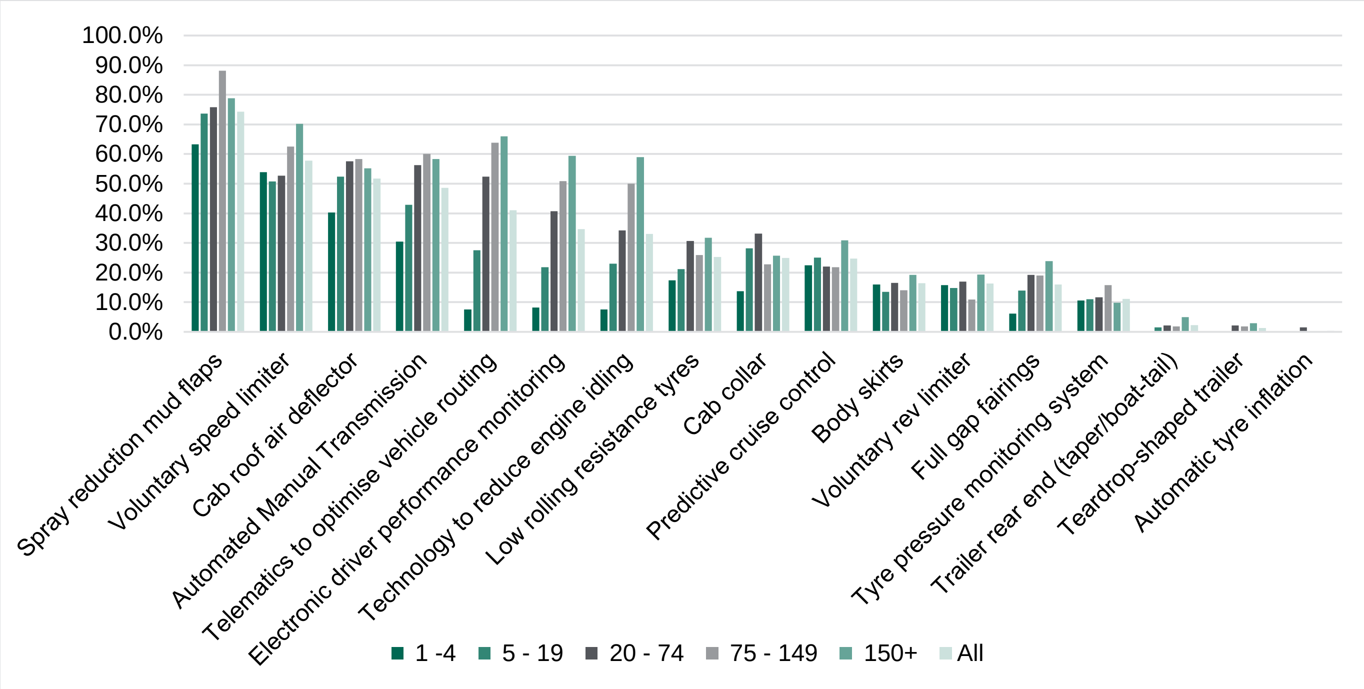


Figure A3: Technology uptake by operator size

The above analysis suggests that larger operators are more likely to have purchased their HGVs as new rather than second hand. However, even when new HGVs are removed from the survey data, and we focus solely on second hand owned vehicles, there is still a pattern of larger operators having relatively high uptake rates across all the technologies.

In order to further understand how uptake differs between larger and smaller operators we have extracted data from the above graph to focus on vehicles undertaking long haul and regional delivery cycles. We would expect technology uptake to be relatively high across both these duty cycles as there are increased fuel saving benefits when travelling long distances. However Figure A4 below shows there is a consistent pattern of smaller operators, particularly those operating 1-4 HGVs, having relatively low technology uptake rates. This can be seen particularly clearly for electronic driver performance monitoring systems and technology to reduce engine idling, where uptake is around 60% lower than for larger operators.

There is a significant difference in uptake of electronic driver performance monitoring, telematics and technology to reduce engine idling between larger and smaller operators. The results also show a higher uptake of predictive cruise control among smaller firms compared to larger firms, albeit a small difference.

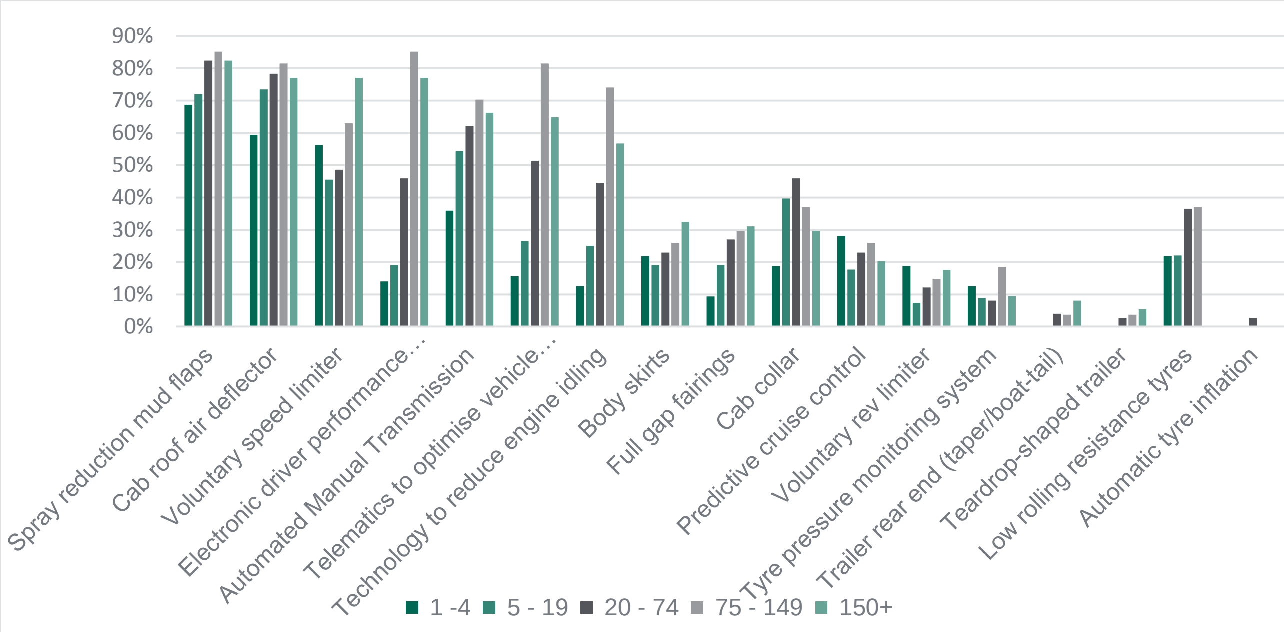
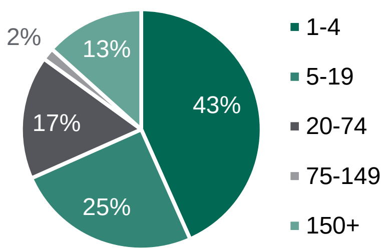
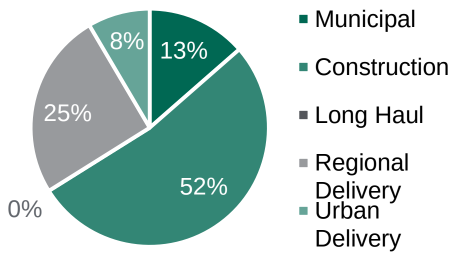


Figure A4: Percentage uptake of technologies by operator size (long haul and regional delivery cycles only)

60 respondents (9%) had none of the listed technologies installed. The make-up of these respondents in terms of ownership arrangement, size and duty cycle can be found in Figure A5. As expected, the majority were construction vehicles. Furthermore, 43% of the respondents with no technologies installed were small operators with 1-4 HGVs. DfT has contacted a number of these respondents to understand their decision making processes and the key barriers preventing wider uptake. Respondents commented that the key barriers to uptake were cost of the technologies and a need for clear evidence of the benefits from authoritative sources.





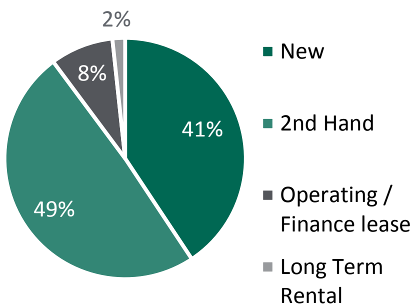


Figure A5: Technology uptake by size of operator (left), duty cycle (right), and ownership arrangment (centre)

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The sustainability of UK Aviation:

Trends in the mitigation of noise and emissions

Peter Hind and RDC Aviation Ltd
March 2016

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Independent Transport Commission
70 Cowcross Street
London
EC1M 6EJ

Tel No: **0207 253 5510**
www.theitc.org.uk

Registered Charity No. 1080134

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March 2016

Foreword from the ITC Chairman

The ITC has demonstrated through several research reports the importance of good international aviation connectivity for Britain, and the particular benefits of hosting a top, globally-connected, hub airport. We have therefore encouraged the Government to act swiftly and implement the Airports Commission's recommendations to allow the delivery of new aviation infrastructure.

That the Government has not yet done so is due to concerns about the environmental impacts of aviation, particularly in three areas: noise, carbon emissions, and local air quality. The Government announced in December 2015 that it would be conducting further work on noise and local air quality, as well as addressing sustainability concerns that have arisen over airport expansion, before it takes a decision on airport expansion. The ITC agrees that these are crucial issues. We have commissioned this report to explore the trajectory of improvements in aviation sustainability and to reach an assessment on whether these will continue.

This report, by aviation sustainability experts at RDC Aviation, has examined a wide range of sources relating to the noise, carbon emissions and pollutants that arise from aviation operations in the UK. The report indicates that technological and other improvements are available to mitigate any increases in noise, CO_2 and oxides of Nitrogen (NOx) emissions arising from airport expansion. Progress in these areas has been rapid over the past 30 years and the evidence suggests that improvements are likely to continue.

The researchers analysed NOx emissions and concluded that the contribution of these pollutants to poor air quality, even in the vicinity of airports, is caused principally by surface transport. The issue clearly needs to be tackled irrespective of airport expansion, and the report suggests tools exist to enable this to happen.

Aircraft noise is the other major local sustainability issue. The report points to the very significant progress in reducing noise impacts over the past 30 years and evidence that progress will continue. While clearly the measured noise impact is greater in areas of denser population, it is difficult for us to evaluate that impact when aircraft and significant other ambient noise exists. Noise could be reduced if the airport approach paths were managed with that objective, rather than, as for the rest of the flight, fuel economy.

Carbon emissions, meanwhile, are also likely to continue to reduce through progress in aircraft efficiency and operations. This is a global issue where unilateral action alone is insufficient. Significantly, the research suggests that, as well as its economic benefits, the 'hub' operational model produces up to 24% less carbon per passenger than the same connectivity provided through point-to-point services.

Finally, the report recognises that technology alone is not enough. It flags the need to build public confidence and trust, for example through a regulator with independence and powers to monitor and control sensitive issues such as noise.

The report concludes that although these environmental challenges are important and difficult, they are not insuperable. If tackled vigorously and transparently, it is possible for the UK to drive down the environmental costs of aviation while realising the great connectivity benefits that an expanded hub can provide. The challenge now is to move forward and actually deliver!

Dr Stephen Hickey
Chairman of the Aviation working group
Independent Transport Commission

The sustainability of UK Aviation:
Trends in the mitigation of noise and emissions

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Executive Summary

This study forms part of a series of papers that the ITC is commissioning on UK aviation strategy and how to meet our international connectivity needs. It has been produced following the studies undertaken by the Airports Commission into Airport capacity and the subsequent decision by the Government to undertake more research into the environmental effects before deciding on where to build the new capacity.

The aviation industry has come a long way in efficiency and sustainability through improvements in operations and technology since jet engines first soared over UK skies. However, as the industry continues to grow it will face a number of key challenges if it is to do so without adverse impacts on the environment and local communities. We see three core areas in which the industry must continue to improve: noise, local air quality and CO_2 emissions. Our analysis suggests that, over the coming decades, it is foreseeable that a range of solutions will enable forecasts of future growth to be delivered within acceptable environmental boundaries, even without step-changes in technology.

At a global level, we consider the most important of these to be the reduction in emissions of the greenhouse gases that contribute to climate change, but this is also the most difficult to reconcile since it will require global standards and international cooperation to achieve a workable solution without market distortion. Still, with progress being made by the United Nation's International Civil Aviation Organisation (ICAO), this is not an impossible problem to solve, and we suggest that even without mass-uptake in biofuels there are opportunities to mitigate and reduce the contribution of CO_2 from air transport. Market-based mechanisms such as carbon trading coupled with continued advances in airframe technology and operating procedure improvements can all contribute to reducing fuel burn and CO_2 emissions. Our work suggests that the hub-and-spoke model is the more efficient method of transporting passengers and freight across a wide range of routes – through the use of larger, more efficient aircraft – when it comes to CO_2, although the model concentrates noise at the hub location.

At a local level, the more apparent issues are those of noise and local air quality. Our research shows that whilst these pose significant challenges within the UK, neither are insurmountable. Aircraft noise has been falling year-by-year with new technology improvements and is substantially lower than 30 years ago, while improvements in the technology behind aircraft navigation will offer much improved opportunities for noise respite. Our findings show a 'technology implementation gap' from the late-1980s to very recent times, with almost no completely new airframe development, other than the Boeing 777 in 1995, until the Airbus A380 in 2005. Consequently much of today's fleet, particularly in the long-haul segment, is operating legacy equipment with airframes and engines designed in the 1980s and 90s. The very recent introduction of aircraft built on new technology, the Boeing 787 (commercial launch, 2012) and Airbus A350 (2015), will deliver quantifiable improvements in noise and are expected to quickly proliferate the global fleet, replacing the old equipment. Short-term fixes such as sharing standard operating procedures between airlines can play a part in ensuring avoidable noise, such as that caused by the drag from landing gear, can be minimised across all operators using a particular airport.

Local air quality remains an important issue, particularly in the communities immediately around any airport. Whilst the Airports Commission was unable to confirm that some of the expansion proposals would not breach EU limits, the most significant observation here is that Oxides of Nitrogen (NOx) output is a product of the whole transport spectrum and not primarily aviation. Road transport accounts for just under one third of NOx emissions in the UK[1], with the proportion increasing in areas of intense vehicle concentration such as the M25 and M4 road network around Heathrow, which carries over 300,000 vehicle journeys per day[2]. Road travel has seen significant reductions in NOx and other harmful gases in recent years, and unlike aviation it has the opportunity to embrace green propulsion within the next decade or two, meaning that in the long term, even with growth in aircraft movements, there is opportunity to improve air quality around our airports. That is not to dismiss the need to reduce airport-based NOx emissions, which are mostly generated by aircraft taxiing and running the Auxiliary Power Unit (APU) while stationary. Moving to biofuel powered Ground Power Units (GPUs) or clean Fixed Electrical Ground Power (FEGP) with single-engine taxi, provide immediate alternatives to current procedures and will reduce NOx output.

For these local issues it is especially important to engage with the communities, so that they can understand and influence the way the airports operate and what is being done to reduce the impact on noise and emissions. These include consultation on and full disclosure of long-term proposals for flight paths and periods of respite; legally binding targets; and the creation of tools to aid in monitoring aircraft, such as the WebTrak tool in use at Helsinki airport.

Policy at a UK and international level can also provide a focus on bringing forward solutions. Government mandates to use alternative fuels can bring forward investment in such technology; the ICAO noise chapters provide a mechanism for airports to penalise noisy aircraft and for governments to ban them from airspace. We note that there is sometimes a trade-off between environmental objectives where, for example, a more noise efficient route may be less CO_2 efficient. Development of a flight-level environmental scoring metric which balances noise around airports with CO_2 for other phases of flight, similar to the NATS 3Di measure, could be used to highlight which airlines operate with environmental sensitivity rather than just in the most fuel efficient way. Mandated use of some flight paths could be considered to offset the flexibility airlines have in their daily flight planning, coupled with a coherent strategy on noise from government, mandating how to use flight paths to limit the impact on communities. We support the creation of an independent noise authority with powers to research and recommend best practise, monitor performance and fine operators for breaching agreed targets. Likewise, existing and planned market-based mechanisms should be adapted to recognise that different objectives apply for flight phases close to airports.

By UK standards the London airports have high levels of access by public transport, but these remain behind the global leaders. In order for any new capacity to be delivered sustainably, it needs to be developed in the context of the wider transport network and not as a standalone project. This means, as far as possible, closer integration with the rail network to provide easy dispersion of traffic not just to London but the rest of the South East, Midlands and West.

1 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/486085/Emissions_of_air_pollutants_statistical_release_2015_-_Final__2_.pdf

2 Department for Transport – Annual road traffic census counts

1. Introduction

1.1 This paper has been commissioned by the Independent Transport Commission (ITC), Britain's leading research charity focused on transport, land-use and planning issues, and written by the independent consultancy firm RDC Aviation Ltd. (RDC).

1.2 Previous studies by the ITC have concluded that the hub model is the optimal choice for improving the UK's long-haul connectivity and therefore the prospects for the UK as an international economy. In order to meet future demand projections, it has been identified that a hub with a minimum of three runways would be required.

1.3 The ITC analysis has been published following the recommendations of the government-appointed Airports Commission and the UK government's subsequent response. The Commission investigated the options available to the South East UK's airport capacity problem, concluding that a hub model must be pursued and that the optimal location for additional capacity is at London's Heathrow Airport. The UK government has requested more work be undertaken to understand the environmental costs of the proposals. The aim of this ITC paper is not to compare the proposals, but to investigate the overall sustainability of UK aviation in this context.

Airports Commission Findings and Government Response

1.4 The conclusions of the Airports Commission highlighted that although additional capacity is urgently needed, it must be delivered using a "balanced approach" that ensures the long-term sustainability of the project.

1.5 This report builds on and supplements the previous publications of both the ITC and the Airports Commission by assessing the capability of UK aviation to develop sustainably in the medium to long-term future. In this report, sustainability is viewed as meeting the demand for air travel whilst not increasing, and where possible decreasing, the social and environmental impacts of its operation, both in terms of local impacts (air quality and noise) and global impacts (specifically climate change).

1.6 The Airports Commission concluded that sustainability is highly important for the delivery of much needed capacity to London's airports but that it is also achievable. Of the schemes that were considered, the Commission concluded that a second runway at Gatwick would have the least impact in terms of noise, air quality and CO_2. We also note that the sustainability of a scheme is a factor of the type of setting/locality that each occupies, and that decision makers will need to look at the core areas of noise, air quality and carbon, alongside the broader environmental, social and economic sustainability aspects of a major infrastructure scheme such as airport capacity expansion. However, it was also concluded that the impacts were not significant enough to outweigh the economic argument in favour of Heathrow, and therefore overall the Commission recommended a third runway to be built at Heathrow.

1.7 There are challenges in unravelling the incremental noise attributable to aircraft flying over West London and there is scope for substantial additional research in this area. Present policy is based around concentrating noise, which produces greater periods of exposure for fewer people. Understanding whether this approach is preferable to dispersing noise around a wider population base but for shorter periods should be a core aim. Both Heathrow runway proposals offer different solutions in this respect, with Heathrow Hub giving potential to move the whole noise envelope approximately two-miles west when capacity allows, whilst the Heathrow scheme offers options for more respite periods. Both schemes enable alternation of the runways being used for landing and take-off to some extent, and thereby provide scope for extended periods of respite for residents. The Commission believe that this, along with improving technology and the use of displaced thresholds, will significantly reduce the noise impact on the community after the construction of a new runway.

1.8 In terms of emissions, the Airports Commission could not be certain that some EU limits on air quality would not be breached with expansion of Heathrow, but requested more work be undertaken before setting concrete conclusions on this and acknowledged that the mitigation measures put forward were credible. The forecasts suggested all expansion schemes are likely to increase CO_2 emissions by varying extents, although this could be mitigated to an extent by carbon trading and/or carbon capping.

1.9 The UK government's response to this, published in December 2015, declares that while it is agreed that more capacity is needed, more research into the environmental effects of the proposals needs to be undertaken to ensure that the decision creates a sustainable future for UK aviation. The Secretary of State for Transport, The Rt Hon Patrick McLoughlin said: *"The case for aviation expansion is clear – but it's vitally important we get the decision right so that it will benefit generations to come. We will undertake more work on environmental impacts, including air quality, noise and carbon."*

UK's Commitments on Climate Change

1.10 The UK has been one of the leaders worldwide in addressing the climate change problem. It was a signatory on the Kyoto Protocol, which committed the UK to reducing greenhouse gas emissions to 12.5% below 1990 levels by 2012 – a task which was successfully accomplished, with emissions actually falling to 27% below 1990 levels in 2011 (Committee on Climate Change). However, the UK remains committed to reducing emissions further, and the 2008 climate change act has set the target of reducing greenhouse gas emissions to 80% below 1990 levels by 2050. Furthermore, as a part of the European Union the UK has agreed to several more specific measures for tackling climate change, these include the emissions trading scheme and a commitment for the transport sector to use 15% renewable fuels by 2020.

1.11 There have been a number of practical difficulties in placing aviation within these targets in the past, as the multi-national nature of the industry makes it difficult to assign responsibility for emissions. Indeed at the latest meeting of the United Nations Framework Convention on Climate Change (COP21) aviation, along with maritime, was not specifically covered by the milestone agreement. However, it is clearly important aviation is included in these targets as soon as possible and rightly held accountable for its environmental impacts.

2. Sustainability and Air Transport – A Background

2.1 Air transport's impact on climate change through CO_2 emissions has been well documented in the mainstream media. It is the industry's largest pollutant and has been shown to have a direct effect on climate change. It is formed by the combustion of fuel in aircraft engines and therefore is a direct linear function of fuel burn, which means that airlines have a significant incentive to reduce their CO_2 emissions indirectly by reducing their fuel costs, which can account for up to 40% of operating cost on some routes. Therefore whilst CO_2 emissions remain a long-term challenge for the industry, it is an issue that can be tackled through technological developments and market forces.

Industry Position

2.2 The aviation industry has been developing its environmental agenda for many years and although growth in air transport has meant an increase in total emissions and frequency of noise at many airports, at an individual flight level aircraft are now more fuel efficient and quieter than ever before. Efforts were focused more on noise reduction in the early years of the jet engine, while the last two-decades have seen fuel burn and emissions output become of equal importance. Sustainability is now recognised as being critical to future expansion rather than simply an aspiration.

2.3 The International Air Transport Association's (IATA) goal for aviation emissions over the next 35 years is for the industry to reduce its carbon footprint to half that of a baseline year (2005). It has developed a four-pillar strategy to achieve this, focusing on technology, operations, infrastructure and carbon trading as the key levers of improvement. The core ambition is for airlines to increase fuel efficiency at a rate of 1.5% per annum to 2020; carbon neutral growth after 2020; and by 2050 to have achieved a reduction of 50% in CO_2 emissions against the 2005 baseline. For this to be achievable at a global level, within the backdrop of growing demand for air travel, each of the four-pillars will need to deliver potential savings unless there is a step-change in technology.

2.4 Our analysis shows that long-term fuel efficiency of 1.6% should be achieved simply through the proliferation of new aircraft replacing old and that a range of other measures can deliver additional fuel savings at a flight-level. The industry is already participating in various market-based mechanisms (MBMs) – intra-European flights have been included in the Europe's Emissions Trading Scheme since 2012, meaning emissions are monitored, reported and accounted for along with the other industries within the scheme.

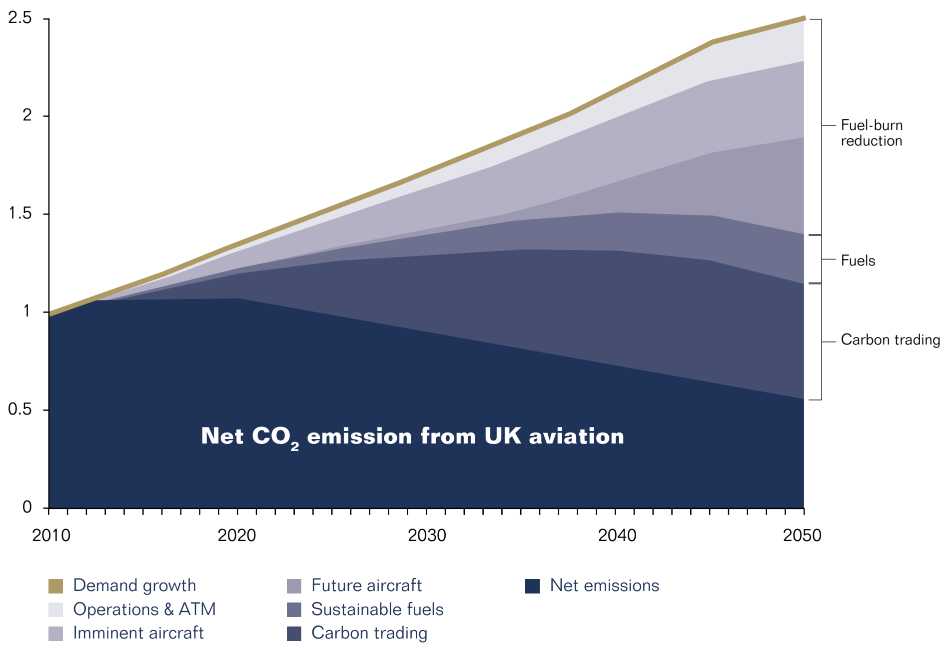
2.5 Although the recent UNFCCC COP21 meeting concluded with the adoption of the Paris Agreement, it lacked any specific reference to international aviation. The UN agency responsible for aviation, ICAO, has committed to the implementation of a MBM solution covering international aviation from 2020 and will be discussing high level resolution text in May 2016, ahead of presenting recommendations at its 39th Assembly later in the year.

2.6 Alongside IATA and ICAO sit a number of other groups looking into the long term sustainability options for air transport, notably Sustainable Aviation; Air Transport Action Group (ATAG); and the US-led Commercial Aviation Alternative Fuels Initiative (CAAFI). What is unusual about these groups, compared to other industries, is they pull together the spectrum of industry participants rather than acting as a lobby group representing the views of one side of the industry. Sustainable Aviation, for example, counts airlines, airports, airframe and engine manufacturers and air navigation service providers amongst its members. This collaborative approach ensures expert input and common understanding can be used to develop workable solutions.

Emissions Roadmap

2.7 Looking at how the UK can meet its emissions objectives, the roadmap developed by Sustainable Aviation shows the effect of various improvements in fuel burn on UK emissions to 2050. By carefully considering the relative potential of improvements from operations, new aircraft, sustainable fuels and carbon trading, Sustainable Aviation predicts that with contributions from all these areas, UK aviation can accommodate significant growth to 2050 without substantially increasing its contribution to CO_2 levels.

Figure 1: Sustainable Aviation Carbon Roadmap

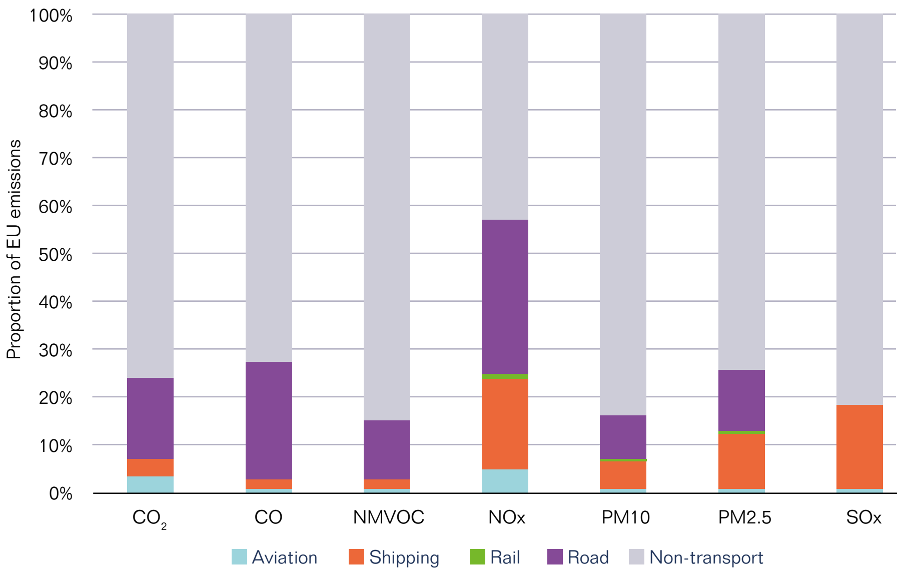


Source: Sustainable Aviation CO_2 Roadmap

Local Air Quality

2.8 Whilst CO_2 is the greatest contributor towards the global climate change problem, at a local level several emissions are known to be contributors to local air quality problems, which recently have been highlighted in a number of challenges against expanding London's airport capacity. In urban areas road traffic is the dominant source of pollutants affecting local air quality. Figure 2 shows how aviation's contribution to these harmful emissions compares with both other transport modes and the EU as a whole.

Figure 2: EU Emissions by Transport Mode



Key to Abbreviations: CO_2 = Carbon Dioxide; CO = Carbon Monoxide; NMVOC = Non-methane volatile organic compounds; NOx = nitrogen oxides; PM10 = Particulate matter 10 microns or lower; PM2.5 = Particulate matter 2.5 microns or lower; SOx = sulphur oxides.

Source: European Environment Agency (EEA)

2.9 Although various emissions are created in flight, aviation only generates a significant contribution to overall emissions in the cases of CO_2 and NOx. Unlike CO_2, the production of NOx is not directly linked to fuel burn, and therefore there has been a strong push from industry to regulate and minimise NOx production, particularly in new aircraft. Above about 200m aircraft do not make a significant contribution to local air quality.[3] The largest source of NOx at airports is usually not the aircraft but the surface access routes; however road travel in particular is also making strong progress in reducing NOx emissions (see chapter 6) and therefore the impact of NOx at airports is expected to decrease over time.

3 Rogers, H.L., Lee, D.S., Raper, D.W., de, F., Forster, P.M., Wilson, C.W., Newton, P.J., 2002. The impacts of aviation on the atmosphere. The Aeronautical Journal. 106, 521–546. Copy available at http://uk-air.defra.gov.uk/assets/documents/ozone-uv/aviation_impacts.pdf

Noise

2.10 Noise from aviation and its supporting operations is a key issue at airports across the world. It is frequently perceived as a nuisance and detriment to quality of life, and can be a significant barrier to the growth of an airport and its related aviation facilities. This problem is greatest in the evening, night and early morning when people are more likely to be at home and it can have a serious impact on sleep patterns and the quality of life of local residents. This is a problem that airlines and airports are actively engaged in rectifying, as limits on night flying ("curfews") can harm an airline's profitability for overnight freight and long flights that must arrive/depart at inconvenient times in order to comply with curfews. However, as discussed in the ITC's previous work, we do not believe a UK hub needs 24 hour operations to be effective.

2.11 The most direct cause of noise from aircraft is from the combustion of fuel in engines. This is typically louder on take-off but is also significant on approach when aircraft are in line with the runway for several miles before touchdown. It generally peaks on touch-down as reverse thrusters are deployed to bring the aircraft to a safe and swift stop.

2.12 Noise improvements from technology have typically come from engines, but as these have become significantly quieter, other aspects of the aircraft are increasingly being studied for their own noise improvements. This particularly considers the frame of the aircraft itself, and the noises that are created as high-speed air rushes across it. Noise can also be made by the turbulence created by hot air from the engines mixing with cold surrounding air – a particular solution to this problem can be seen on the serrated edges of the nacelles on the Rolls Royce Trent 1000 and General Electric GEnx engines that power the Boeing 787 Dreamliner (below).

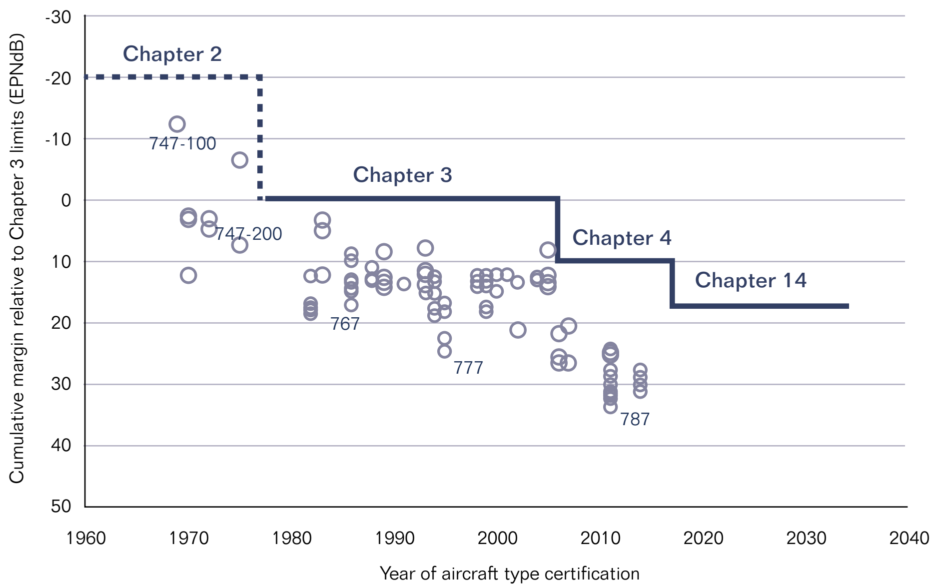
Figure 3: Rolls Royce Trent 1000

Source: Wikimedia Commons

2.13 Noise problems from aviation are not limited to aircraft operations. Airports, as the focal point for transport interchanges, generate additional noise from airport-based vehicle operations as well as surface access traffic using the local road and rail infrastructure.

2.14 Noise can be regulated in a number of ways. On an industry-wide scale, the International Civil Aviation Organisation (ICAO) provides a pre-emptive regulation measure through the categorisation of aircraft into noise “chapters”. Airports and authorities can then place limits on noise by chapter of aircraft, either through a total ban, time restrictions or quota limits. There is therefore an incentive for manufacturers to reduce noise output from their aircraft in order to fit into the more flexible of these noise chapters. Chapter 2 aircraft have been completely banned from flying in European airspace since 2002, and chapter 3 will be expected to follow in due course. This measure effectively performs as a ‘one way valve’, as aircraft are only allowed to become quieter and never noisier. This also leads to improved technology, both for new aircraft and for the retrofitting of older aircraft with quieter or cleaner equipment such as hush-kits. The noise chapters have been displayed in figure 4 with wide-body aircraft plotted, showing the progression of chapter 4 and beyond compared to a baseline of chapter 3.

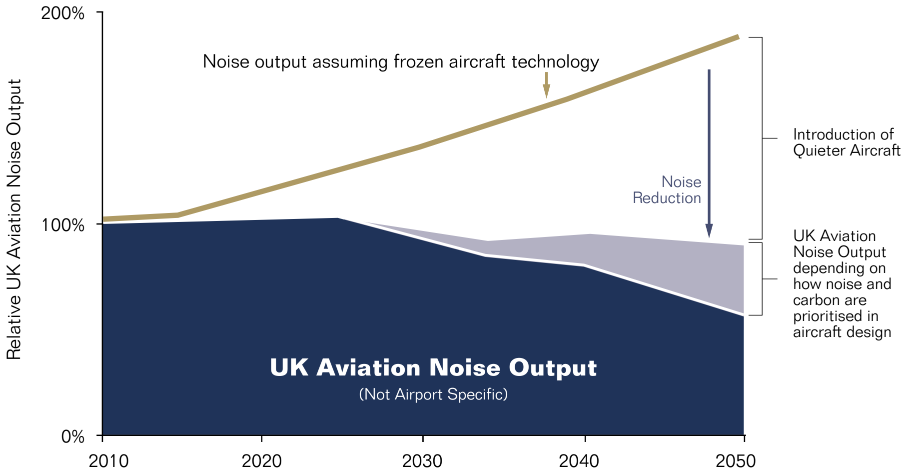
Figure 4 - ICAO noise chapter performance of wide-body aircraft since 1960



Source: EASA European Aviation Environmental Report

2.15 The noise roadmap compiled by Sustainable Aviation produced the diagram below as a sign of how the industry is expected to develop to 2050 assuming a strong level of growth. The most significant reductions are seen to come from improvements in technology and the implementation of the best technology that is available today, keeping overall noise output below 2010 levels even with significant traffic growth. This roadmap does not include other potential reductions in noise such as from operational and behavioural changes that are described later in this paper.

Figure 5: Sustainable Aviation Noise Roadmap



Source: Sustainable Aviation Noise Roadmap

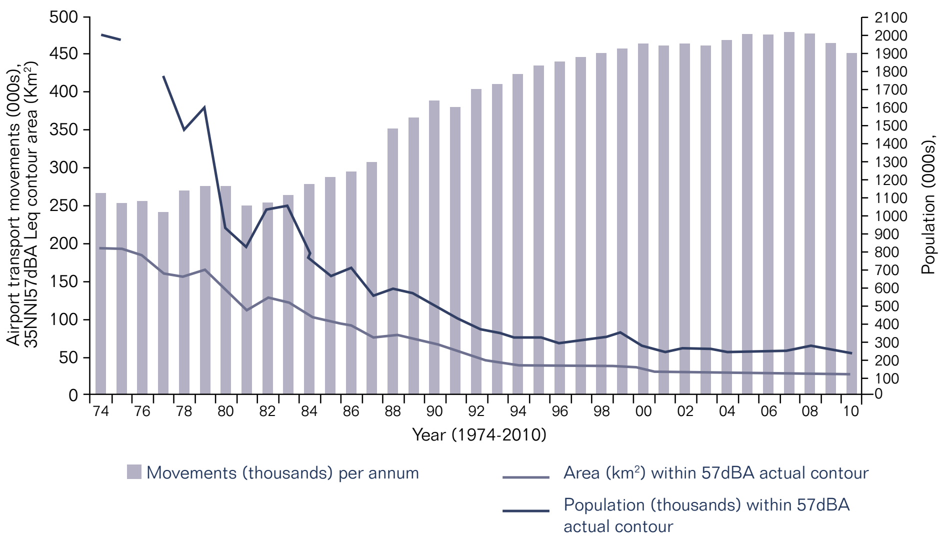
2.16 Unfortunately, the solutions to the aviation industry's problems of noise and emissions are not always mutually compatible. Some solutions to one problem may come at the cost of another. This is highlighted by Sustainable Aviation as a potential area for noise improvement depending on where priorities are placed. Perhaps the clearest trade-off is in the design of airport flight-paths – for many local communities, re-routed flightpaths may be desired to avoid densely populated areas; however by flying indirectly more fuel will be burnt and therefore the impact from CO_2 and other gases on the global climate change problem will be greater. Other examples of these trade-offs exist in aircraft technology, where a noise reducing design on the fuselage may be aerodynamically less efficient, and a more fuel (and therefore carbon) efficient engine design, such as open rotor, may prove to be noisier than the jet engines they replace. Sustainability can only be achieved where these various demands are carefully evaluated and balanced alongside economic impacts to develop the optimal approach.

Noise Progress

2.17 Noise measurement and reporting is a complex area and whilst we know that aircraft are becoming quieter, and will continue to do so, understanding the impact on communities is challenging. The tolerance of resident groups affected by noise will differ based on a range of individual factors, as will the willingness of others to consider changes to flight-paths that might bring new areas into the noise envelope. One solution is to provide a long-term noise roadmap for the UKs major airports that considers how growth forecasts would be accommodated in a re-optimised UK airspace using next-generation navigation methods and working with communities to implement a binding agreement. An independent noise authority along the lines of that recommended by the Airports Commission should be a priority in ensuring any targets are implemented and adhered to.

2.18 The noise improvements that have been made in the last half decade have been recorded by some airports and show progress has been made through the continued reduction in aircraft noise. The diagram below shows how the population within the 57dBA noise contour around Heathrow has decreased at a greater rate than the increase in movements from air transport.

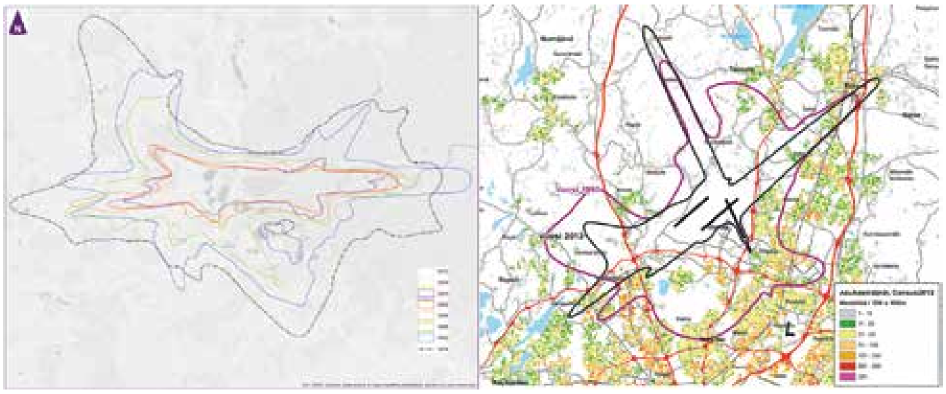
Figure 6: Land Area and Population Within the 57dBA Noise Contour



Source: Heathrow Airport Ltd.

2.19 The impact of quieter aircraft can be illustrated from the noise maps of Heathrow and Helsinki airports, which are shown in Figure 7. Both charts show the size of the noise envelope over time and suggest that a combination of engine/airframe improvements and changes to navigation patterns can dramatically alter the shape of noise nuisance.

Figure 7: Shrinking Airport Noise Contours: Heathrow, 1974-2012 (left) and Helsinki, 1990-2013 (right)



Source: Heathrow Airport Ltd, Helsinki Airport[4].

2.20 There is, of course, a limit to the progress that can be made in aircraft noise and ultimately the area beneath the final flight path, in which the aircraft is configured for landing and in line with the runway, will inevitably be the most affected by noise. That said, there remain ways to mitigate this by use of displaced thresholds or, in the case of the Heathrow Hub proposal, using the western runway for landing, in which case the noise contour could move 3km west at certain times of the day. Many of the Airports Commission proposals also promote the use of runway alternation, where runways used for arrivals or departures are changed predictably across the day to offer periods of respite. This is something that can only be offered when spare capacity is available.

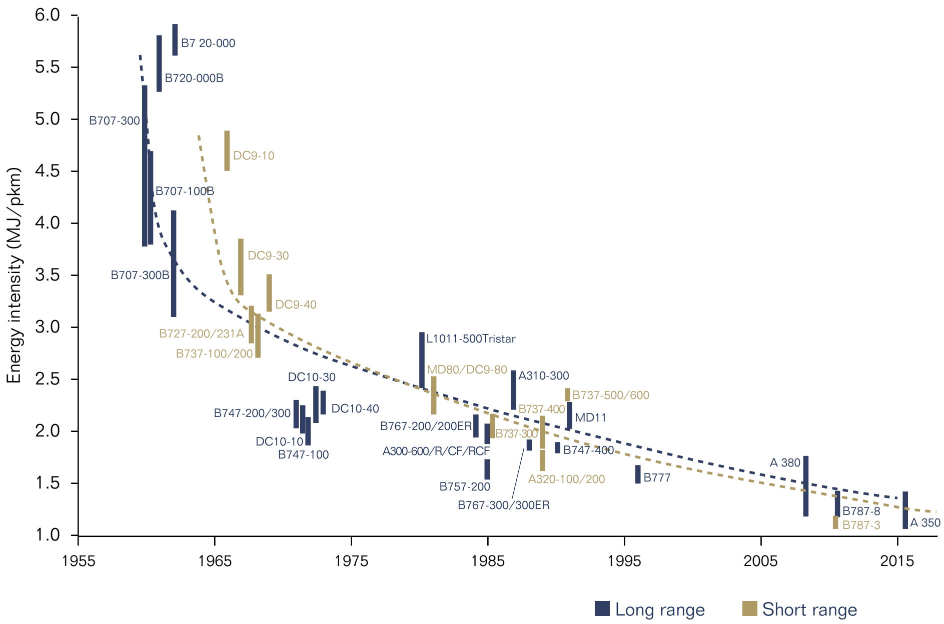
4 http://vuosikertomus.finavia.fi/en/2014/responsibility/responsibility-information/environmental-information/aircraft-noise-control/

3. Aircraft Design

3.1 Improvement in the efficiency of technology is frequently cited as the main source of improvements in sustainability for the industry. The Committee for Climate Change (CCC) 2008 report into aviation and climate change predicted a 0.8% increase in fuel efficiency per annum as a result of these improvements, increasing to 1.5% with funding support for these new developments. This figure sits below our estimate of 1.6% before new developments.

3.2 The improvements in technology can be easily demonstrated by the diagram below, produced by the International Energy Agency (IEA). Whilst it is immediately apparent that the greatest increases in efficiency were made in the early years of the jet age, the industry is continuing on a steep path of improvement. There was also a significant gap in the development of new technology between 1998 and 2008, other than the Boeing 777. Most of the aircraft in operation today are still of the pre-1998 generation but this is likely to rapidly swing towards the newer generation over the next few years, bringing with it substantial improvements in emissions and noise.

Figure 8: Aircraft Efficiency Gains since 1955



Source: IEA, 2009

3.3 Engines have understandably been the focus of most of the technological improvements for aviation in recent years, as they are responsible for both the greatest noise output and the vast majority of emissions outputs. The technology has taken great leaps since the beginning of the "jet age" in the 1950s. The most visual difference is the switch from turbojet engines (known for their "cigar" shape) to the more modern and efficient turbofans.

3.4 Turbofans have been incrementally improved by increases in the bypass ratio – that is, the ratio of the amount of air that passes through the fan but not the engine core to the amount of air that passes through the core itself. In practice this leads to larger, stubbier engines and increased fuel efficiency.

3.5 Further improvements in turbofan performance are expected to arrive in the next generation of aircraft. One variety of improvement is known as a "geared" turbofan, which uses a series of gears to operate various compressor stages at different speeds. This is more efficient, providing greater thrust per unit of energy burned, and the reduction of the fan-tip speed below the speed of sound creates considerably less noise. Pratt and Whitney claim that their PW1000G geared turbofan engine will burn 16% less fuel than the current equivalent engines and reduce noise footprints by up to 75%.

3.6 A turboprop is an alternative engine that is often preferred by regional and some low cost airlines. These engines provide a fuel efficiency benefit over turbofans that leads to lower emissions and lower operating costs. However, as well as being significantly noisier than turbojets, most turboprops lack the speed to be able to compete over longer distances.

3.7 A study by Aviation Economics and Loughborough University[5] found that the narrow-body category of aircraft (formed mainly of variants of the Boeing 737 and Airbus A320 families) has become very efficient, able to offer a fuel burn of around 200g per seat per minute in the approach phase of flight, and there is a vast gap between these aircraft and the smaller wide-body aircraft in terms of efficiency.

3.8 At the opposite end of the spectrum, "jumbo" sized aircraft are also becoming significantly more efficient. These were highlighted by the older 747-400 (530g of CO_2 per seat per minute) and its cutting-edge replacement Airbus A380 (320g of CO_2 per seat per minute), showing the vast improvements that have been made in technology in the 29 years between the aircraft developments.

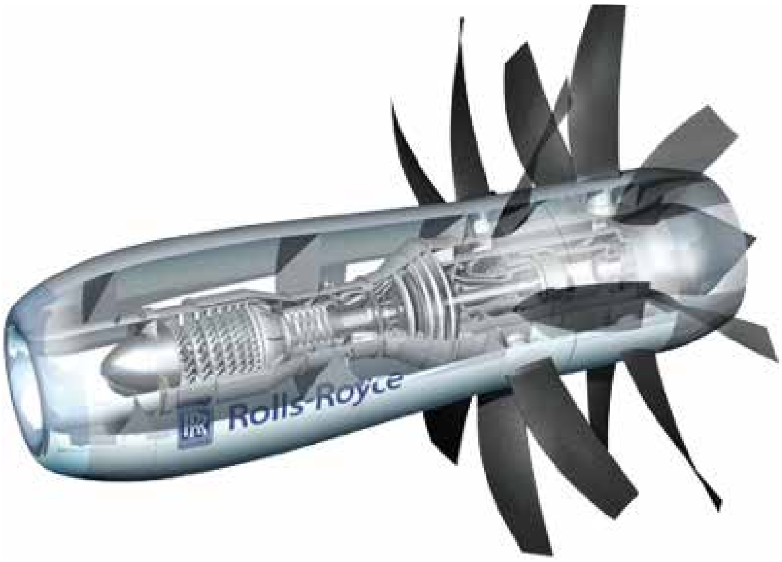
3.9 Whilst engine technology has improved substantially over previous decades, there remain a large number of opportunities for further improvement. In the short-term, increases of the propulsive efficiency through higher bypass engines may still yield the greatest improvements, however more radical engine designs may be needed in the mid to long term.

5 Irvine, Budd, Ison & Kitching (2015) "The environmental effects of peak hour air traffic congestion: the case of London Heathrow Airport"

Open Rotor

3.10 Open rotor engines are one particular design that the aviation industry has highlighted for future potential. These utilise many of the fuel efficiency gains of a turboprop engine whilst still maintaining the long distance speed that can be achieved with a turbofan. By increasing the fuel efficiency, emissions will be kept to a minimum. General Electric estimates that the first generation of open rotor aircraft could burn 15% less fuel than the current series of 737 aircraft. One potential issue with the open rotor design that will need to be resolved is that it would be expected to be noisier than an equivalent turbofan engine. Passengers have also been found to be sceptical to the use of propeller-based engines (viewed as old and less safe) and so the issue of passenger acceptance must also be addressed.

Figure 9: Open Rotor Engine



Source: Rolls Royce

3.11 In the very long-term, the aviation industry must look to switch to a green propulsion option. The technology is currently not advanced enough to power a large airliner, however a number of milestones have been made with much smaller aircraft which demonstrate the feasibility of the technology. More information on these can be found in Chapter 7.

Wing

3.12 The wing of an aircraft is one of the most critical aspects in determining the efficiency of the airframe and how much noise it may generate in flight. An interesting case study in the improvements made in wing technology can be seen from Boeing's 737 family of aircraft. These aircraft have been manufactured since the 1960s and have undergone several significant redesigns in that time. From the 737 'Classic' series to the 737 'Next Generation' series (introduced in 1998), the wing span was increased significantly (by around 20%) to increase fuel efficiency and general performance. Blended winglets offer a 3.5% saving on fuel for an average length trip by the aircraft, while the newer split-scimitar winglets offer a further 1.6% fuel saving.

Figure 10: Split Scimitar Winglets

Source: Wikimedia Commons

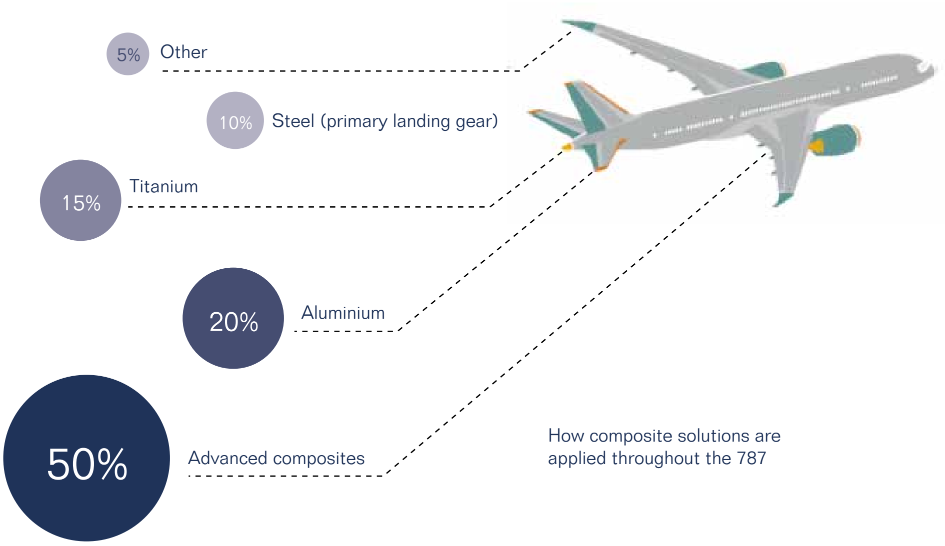
3.13 The Airbus A320 is one of the most popular airliners flying today but has gained a reputation among residents under the flightpaths of some airports for its distinctive "whining" sound. This is caused by air rushing over circular openings on the underside of the wing, creating an effect similar to that of blowing over the top of a bottle. Airlines and airports have identified this and a solution has been created, reducing the noise impact by around 6dB. New aircraft now come with this update fitted and older aircraft are in the process of being retrofitted.

3.14 In the long-term, efficiency of wing designs is likely to be improved by the use of laminar flow control – this means controlling the air flowing over the top of the wing and avoiding it becoming "turbulent" until as far back along the wing as possible. Estimates suggest this could save 4-5% in fuel burn (Airbus).

Airframe

3.15 The latest generation of new aircraft, the Airbus A350 and Boeing 787, are the first aircraft to be developed primarily with composite materials rather than aluminium or other metals. There are currently 375 of these types flying, representing just 24% of the total order-book to date. Both aircraft feature over 50% composite materials. For the Boeing 787 this represents a 20% weight reduction over a conventional aluminium design. The effect of this is that less thrust is required to propel the aircraft, and therefore not only is fuel efficiency dramatically increased but noise from the aircraft is lower.

Figure 11: Airframe Composition – Boeing 787

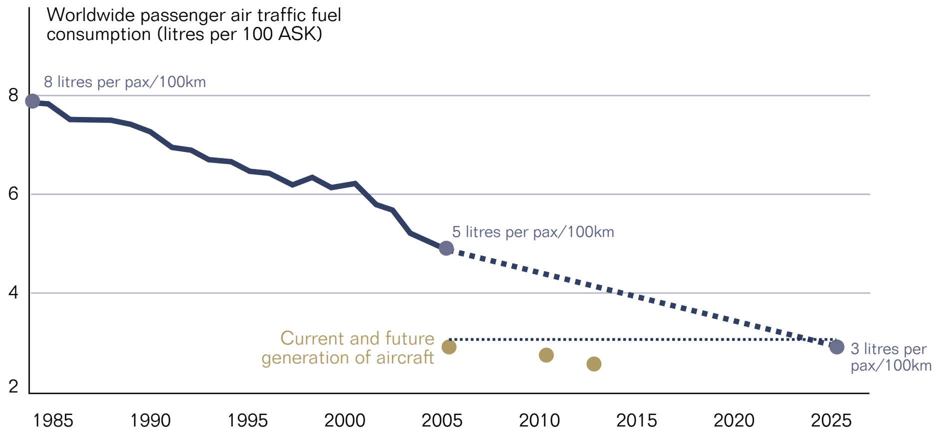


Source: Boeing

Fuel Efficiency over Time

3.16 Fuel efficiency of aviation has developed continually since the 1960s. Studies undertaken by the International Council on Clean Transportation (ICCT)[6] found that the gains were particularly large in the 60s and 70s, and though efficiency gains have slowed since 1990, they are estimated to be less than 50% of 1960 levels. A further study has been made by the International Coordinating Council of Aerospace Industries Associations (ICCAIA) using a metric of fuel burn per person per 100km. This interpretation suggests that fuel efficiency gains have continued since 2000, perhaps driven by a greater focus on improving load factors, which would not be accounted for in the ICCT model.

Figure 12: Fuel Efficiency and Forecast v Today



Source: ICAO and ICCAIA

3.17 This diagram also displays the current fuel efficiency of the latest cutting edge aircraft (shown in gold). These aircraft currently burn around 60% of the overall industry average fuel consumption. The forecast here then makes the reasonable assumption that the industry average will reach this level by around 2025.

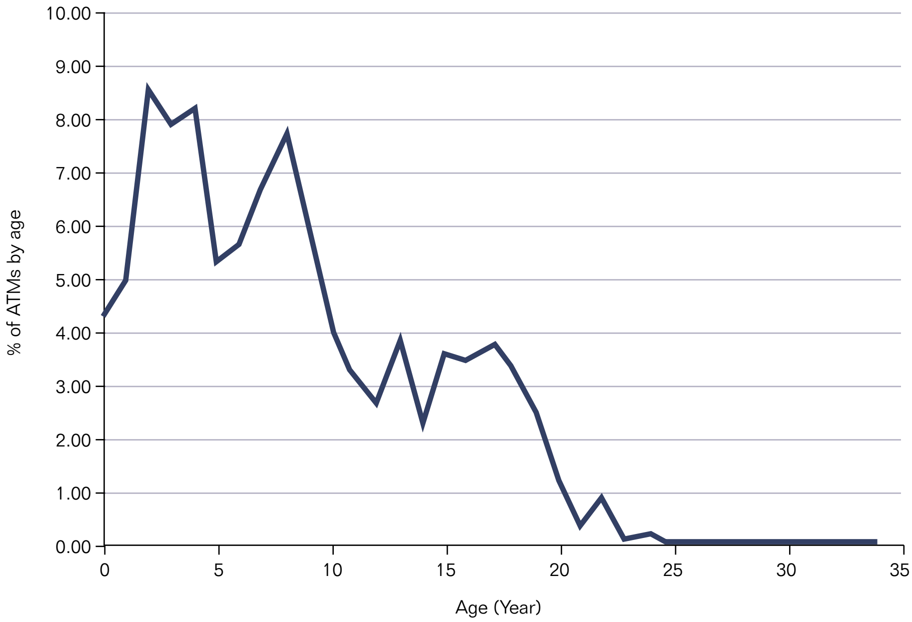
6 ICCT report – "Fuel efficiency trends for new commercial jet aircraft:1960 to 2014"

Speed of Technology Implementation/Aircraft Life Cycles

3.18 It stands to reason that the improvements in aircraft technology are limited in their impact by the speed at which they are taken up by the airlines. For all airlines, aircraft are a substantial investment leased or depreciated over long periods, and the economics of retiring old aircraft early to move to more efficient new airframes does not add up – the additional cost to change outweighs the savings. The balance sheet life of aircraft, and the cost element factored into airfares, is generally based on the life-cycle cost over 10 to 20 years. Furthermore, as the returns on operating new aircraft are long-term, a smaller or newer airline may look to purchase second-hand aircraft rather than the latest model (low cost airlines are the exception to this – see chapter 3). This means that it can take a very long time for a new and more efficient aircraft to completely replace the older, less efficient fleet.

3.19 Shown below is a diagram from a study undertaken by consultants Ecometrics Research and Consulting (EMRC) and the AEA Technology (AEA) for the Department for Transport (DfT) on the sustainability opportunities in aviation. It showed the age of the UK fleet in 2007, demonstrating that the vast majority of the fleet at that stage was young (under 10 years old). However, there are several important aspects that this does not show. Firstly, by operating on a "per ATM" basis, the greatest emphasis is wrongly placed on short-haul flights, when research has shown the majority of emissions are burned on long-haul. Secondly, the study focuses only on UK airlines, ignoring the fact that foreign airlines flying to the UK are equally responsible for UK emissions. Finally, it is important to look at the age of the technology, rather than the age of the airframe itself, as this is a far bigger factor in emissions and noise output.

Figure 13: UK Fleet, Average Age

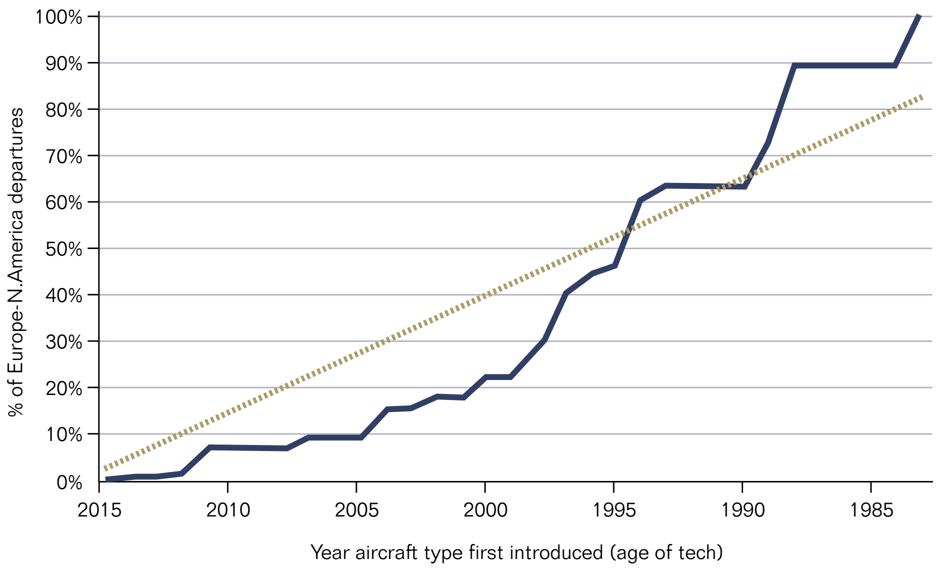


Source: EMRC/AEA (for DfT)

Case Study – Trans Atlantic Market

3.20 The figure below shows the technology age of aircraft operating in the transatlantic market (age based on date of first commercial flight for type). The transatlantic market has been chosen as it mostly negates the issue of varying distances affecting the "per ATM" metric and the North Atlantic crossing is operated by a reasonable selection of common aircraft with clearly defined aircraft models – the short-haul market view is clouded by dozens of smaller improvements over time to a small number of very popular models. The chart is slightly skewed by the presence of the 747-400, which was exceptionally popular in the 1990s/early 2000s and is soon approaching its retirement age, however the clear trend can be seen. The rate of technology uptake is around 2.5% per year, such that over 50% of the technology in operation is under 20 years old; however, the trend from the last 10 years has seen a very poor uptake of new technology, partly due to the lack of new technology to acquire.

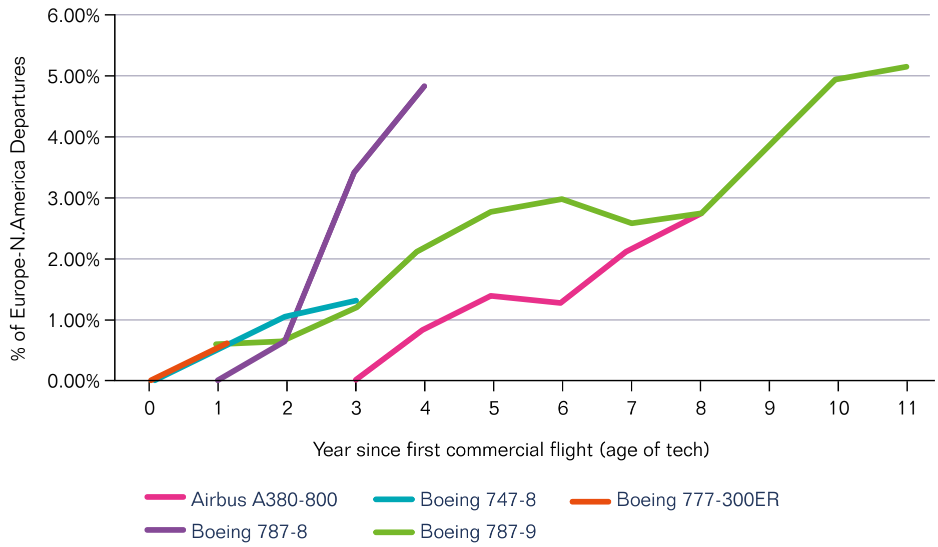
Figure 14: Europe to North America Proportion of Flights in 2015 by Technology Age



Source: Capstats.com

3.21 To understand this situation further, the trend for five of the most popular recent aircraft models has been plotted on Figure 15 opposite. The oldest model of the chart, the 777-300ER is essentially an update of a slightly earlier model with improved range and performance. The steady rate of growth for this aircraft is therefore as would be expected. It is the last of the previous generation of wide-body aircraft, and the remaining four represent the latest generation. The Airbus A380 has been slow to enter the North Atlantic, not appearing in schedules until 2012, but has since developed strongly as British Airways, Air France and Lufthansa have taken more deliveries of the type. The newer aircraft types entering service since 2011 display a greater promise for the uptake of new technology. The 787-8 in particular has already reached levels comparable with the 777-300ER despite being in commercial service for only four years. This therefore suggests that the apparent slowdown in technology uptake observed in the previous chart is more representative of a brief gap in technology generations and that the latest technology should be invested in coming years at least at the rate of 2.5% per year.

Figure 15: Uptake of New Technology, Trans-Atlantic Market



Source: Capstats.com

3.22 The rate of technology uptake is critical to the sustainability of the aviation industry. Although to a certain extent the industry is able to address this itself thanks to the cost savings made from operating new aircraft, the prohibitive cost of these new airframes remains a significant problem, especially when older models are available for a mere fraction of the price, and the benefits of retiring an old airframe (i.e. scrap value) are also low. Furthermore, in times of low fuel prices, the incentive to fly more efficient equipment is reduced. Changes to the regulations regarding the operating lives of aircraft could provide a benefit to sustainability, however it is important that any national or EU-wide regulations encourage new aircraft investment, rather than simply punish operators of older aircraft, and that regulation is universal to avoid harming British or European airlines at the extent of international competitors.

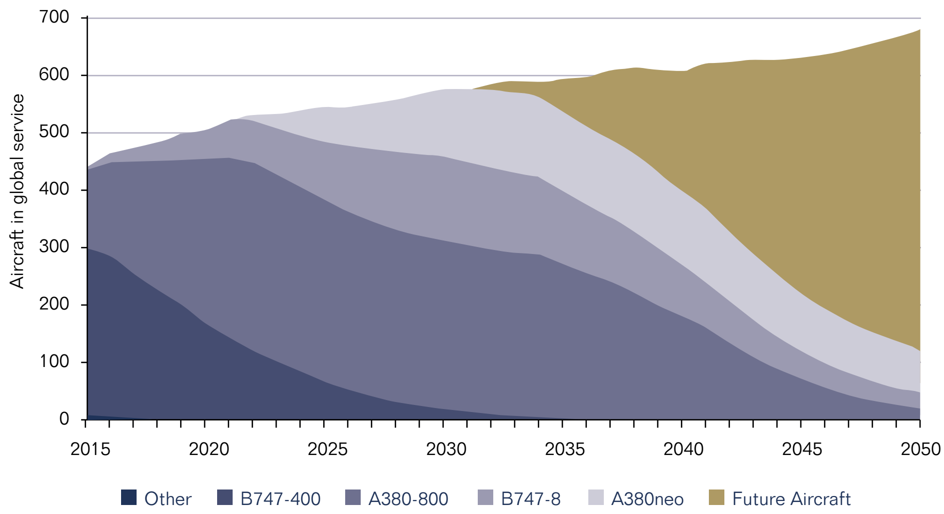
3.23 We have produced an estimate of the global fleet to 2050 using known production rates of new aircraft and estimated retirement rates of current aircraft based on their age. Airbus and Boeing both publish forecasts against which we compared our own, although the manufacturer's forecasts both stop at 2034, which is when many analysts expect the next generation of aircraft to begin operations. In the forecasts presented here, an assumed "future aircraft" of unknown technology and manufacturer is presented to show how great of an impact this will have by 2050.

3.24 "Jumbo" sized aircraft (definition here being an aircraft featuring multiple floors and with four engines) is a small and unpredictable market, a characteristic well represented by the varying opinions of the two manufacturers, with Airbus forecasting significant demand for new aircraft in the next 20 years and Boeing forecasting a modest decrease in overall number of aircraft over the same period. Whilst it is too early to confirm which of these forecasts will be correct, orders for the two types in this category, the A380 and 747-8 have been infrequent as airlines are showing a preference for the slightly smaller, twin-engine aircraft such as the 777 and A350.

3.25 The Boeing 747-400 is still the dominant workhorse, comprising 66% of the global jumbo fleet; however it is in the process of retirement, with the second largest UK operator of the type, Virgin Atlantic, having made its final 747 flight in early 2016. The two replacements, Boeing's 747-8 and Airbus' A380-800 are selling modestly and production looks set to continue only until around 2022. Other than Dubai-based Emirates, which has 77, only 102 A380s are in operation to date. Airbus has suggested an upgraded A380neo design which could take over the production line for potentially around 10 years, but would be unlikely to out-sell its predecessor unless substantial efficiency gains are made.

3.26 This means that between 2030 and 2040 the industry will be looking for a new aircraft to fill this size market. Radical technologies such as blended wing bodies could give this market a renaissance if the efficiency gains are there, but if they are not the industry would likely shift its focus back to smaller aircraft. Therefore this particular area of the aviation market has to be viewed with great uncertainty beyond 2040, and consequently our forecast for this sector of the market is relatively conservative.

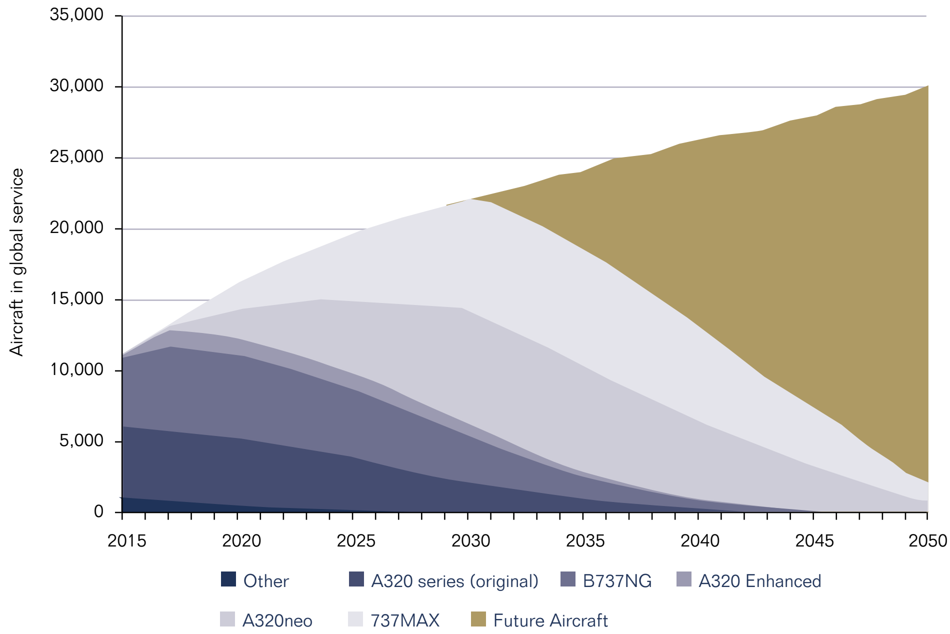
Figure 16: Future Shape of Jumbo Fleet



Source: RDC analysis

3.27 The narrow-body sector has seen the highest growth rates over previous decades, and all forecasts suggest that will continue. Currently Airbus's A320 and Boeing's 737 types dominate the market, with roughly 50% each. Both programmes have recently reached the end of their production cycle and will be replaced with the A320neo and 737MAX respectively – accounting for 50% of airframes by around 2026. It is expected that these two product lines will carry on the dominant position of their predecessors and potentially outsell them. Based on previous product cycles it seems likely that a replacement for, or the next upgrade of these would enter the market in the early 2030s, and account for 50% of the fleet by around 2040. In both instances the speed of aircraft turnover in the narrow-body market means the new generation reaches this 50% point within 10 years of entering service.

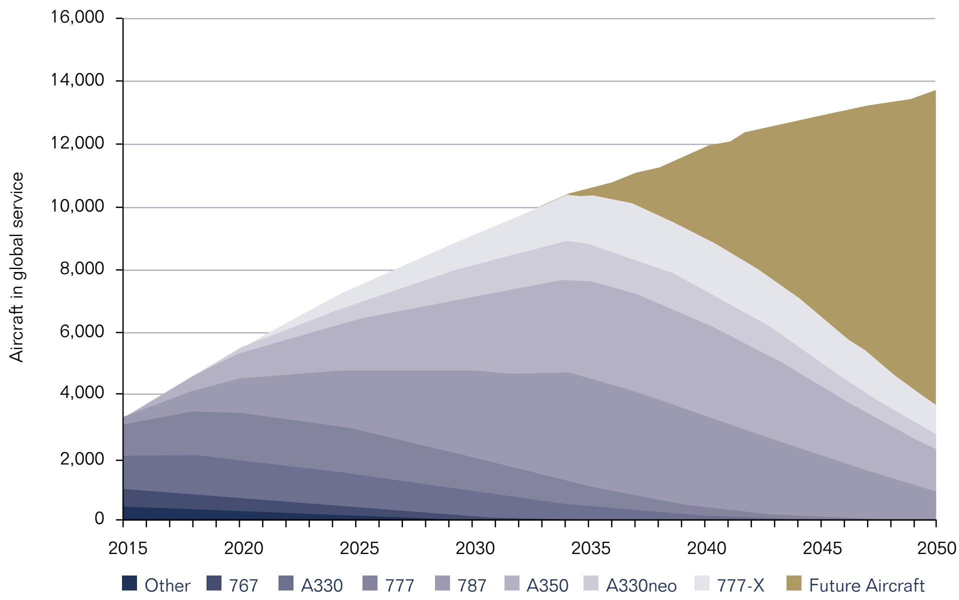
Figure 17: Future Shape of Narrow-body Fleet



Source: RDC analysis

3.28 In the widebody market, the situation is a little more complex. A number of different aircraft models exist from each of the two major manufacturers, filling a variety of roles and needs, primarily on the long-haul market. The most popular aircraft from each manufacturer in 2015 are the A330 and 777, together accounting for around 61% of the total wide-body fleet. Both models are being substantially upgraded, to the A330neo and 777x respectively, which should see at least a decade of successful production. The greater change in this sector will be from the entirely new-build 787 and A350.

Figure 18: Future Shape of Widebody Fleet

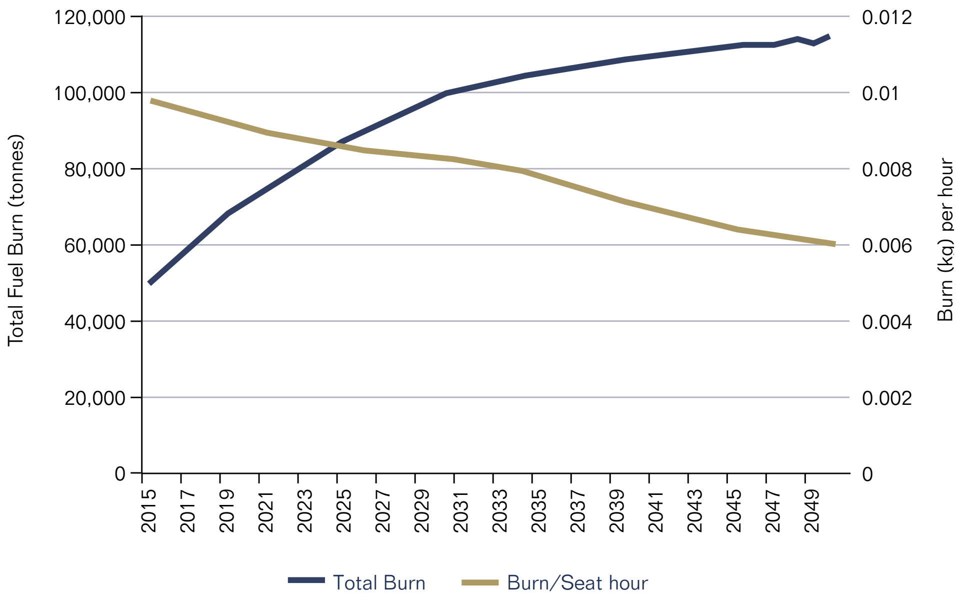


Source: RDC analysis

3.29 These technology cycle forecasts have been compiled together with RDC data on fuel consumption to provide a forecast of fuel consumption up to 2050. It must be stressed that while the near-term forecasts are very stable, beyond 2030 (when as-yet-unplanned aircraft enter service) it is difficult to predict with absolute certainty how the industry will perform. This forecast is deliberately conservative due to the magnitude of these unknowns, however the opportunity for large-scale reductions with the introduction of new technology is vast and should not be understated. In all segments, we expect the majority of aircraft flying in 2045 to be types that are not currently on the drawing board.

3.30 The forecast suggests that the rate of fuel burn improvements by implementation of technology should be fairly constant at around 1.6% per year, meaning that 45% less fuel would be burnt per seat hour by 2050. Whilst this is a substantial rate of consistent improvement, when put in the context of rising demand for aviation, particularly from developing countries, the total fuel burn from global aviation would still be expected to increase at a rate of around 2.5% per year. However, this model does not consider the effects from other changes and improvements, such as operational efficiencies and alternative fuels. These matters will be addressed in the following sections.

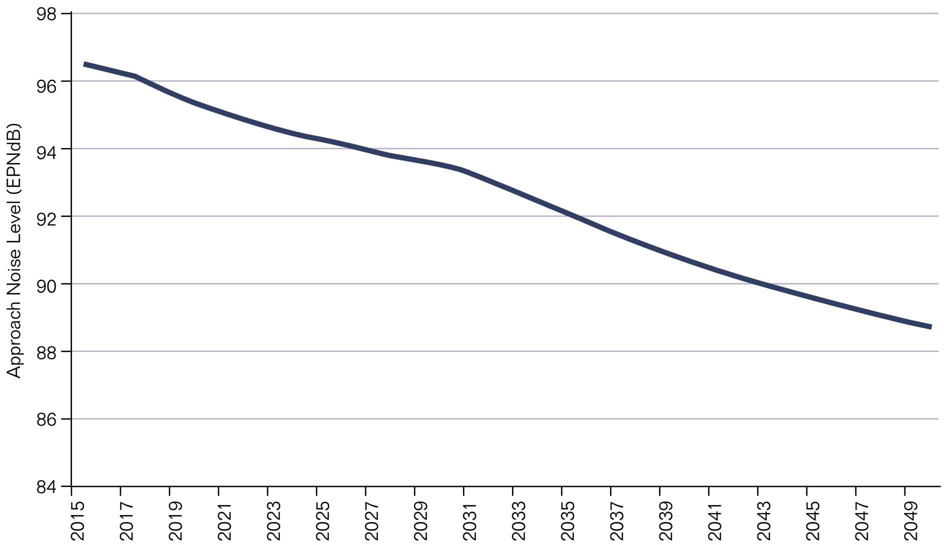
Figure 19: Global Industry Fuel Burn Forecast (tech improvements only)



Source: RDC analysis

3.31 A similar forecast can be made for noise, which is shown in figure 20 below. This has been calculated using noise data from EASA (European Aviation Safety Agency) for current aircraft, supplemented by industry predictions for new aircraft types and extrapolating trends for aircraft as-yet unplanned. This forecast shows that the current generation of aircraft will reduce the average approach noise by around 5dB by 2035. The technology that will come on line after that could take the reduction as far as 8dB below current levels by 2050.

Figure 20: Future Noise Forecast for Aircraft >100 seats



Situation	Sound Pressure Level (LpA) dB(A)
Threshold of pain	130
Threshold of discomfort	120
Chainsaw at 1m	110
Disco, 1m from speaker	100
Diesel truck pass-by, 10m	90
Kerbside of busy road, 5m	80
Vacuum cleaner, 1m	70
Conversational speech, 1m	60
Quiet office	50
Room in a quiet, suburban area	40
Quiet library	30
Background in TV studio	20
Rustling leaves in the distance	0
Hearing threshold	0

Source: EASAS, Airports Commission

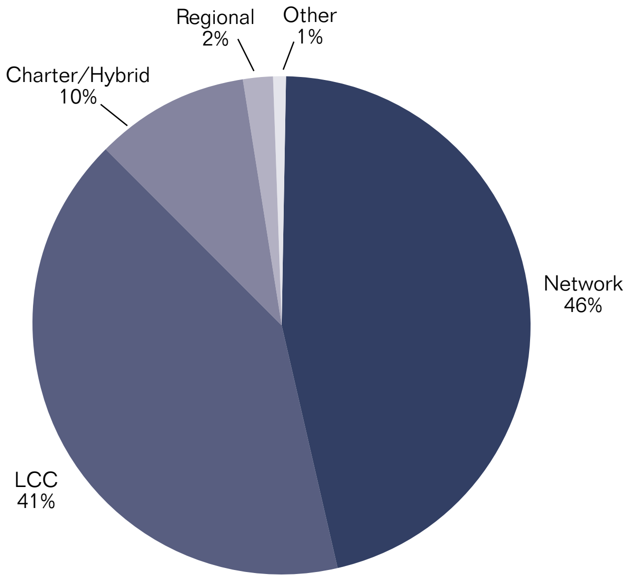
3.32 The Effective Perceived Noise (EPNdB) metric is used in aviation to measure the "annoyance" of aircraft noise on local residents. It takes a weighted average of the aircraft noise on both approach and departure, to provide a comparable figure of annoyance. Aircraft currently in operation average around 96.5EPNdB (a scale based on taking averages of several readings of both arrival and departure), which is above the noise of a diesel truck at 10m, on the Airports Commission scale.

3.33 These forecasts for fuel-burn and noise are able to provide an indication of the type and performance of aircraft that may be operating at around the time that new capacity is built at either Heathrow or Gatwick airports. Our analysis shows the average aircraft will burn 15% less fuel (and therefore CO_2) by 2030 and be around 4dB quieter, with trends set to continue long after this date. These improvements could potentially be fast-tracked and increased with the use of policy measures to incentivise the renewal of UK and European fleets.

4. Airline Business Models – Environmental or Economic Sustainability

4.1 The shape of the airline industry has changed substantially over the last two decades. From the widespread implementation of low cost business models in Europe and Asia to the rapid rise of "super-hubs" in the Middle East, all of these changes are having an effect on the industry's sustainability in one form or another, and this is the subject that will be addressed in this chapter.

Figure 21: Composition of Current UK Market



Source: Capstats.com

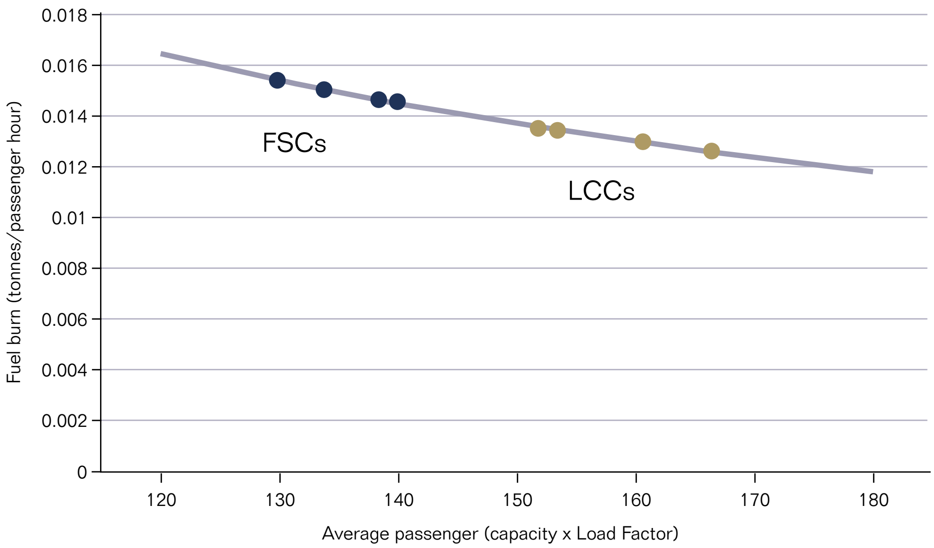
Low Cost Carriers

4.2 Perhaps the biggest change the airline industry has seen in recent years (especially in Europe) has been the rise of the low cost carriers (LCCs). These airlines established themselves in the late 90s and early 2000's thanks mainly to widespread liberalisation of the laws surrounding international air traffic and therefore the removal of considerable barriers to entry, creating the possibility for new airlines to challenge longstanding monopolies and oligopolies.

4.3 One of the key aspects of these business models is a highly efficient system of yield management, ensuring almost all the seats on board the aircraft are sold. This, combined with operating higher density seat configurations, means that LCCs will fly many more passengers than a traditional carrier using the same type of aircraft. Therefore this makes them more fuel efficient on a per passenger basis.

4.4 The effect of this can be seen in the figure 22 opposite. The fuel burn per passenger hour has been calculated for a Boeing 737-800 with various levels of passengers on board and a selection of LCCs and network carriers have been plotted according to their seat capacity and average load factor. This shows that the LCCs are burning around 2kg less fuel for every passenger hour, equivalent to a saving of around 13% in CO_2 per passenger.

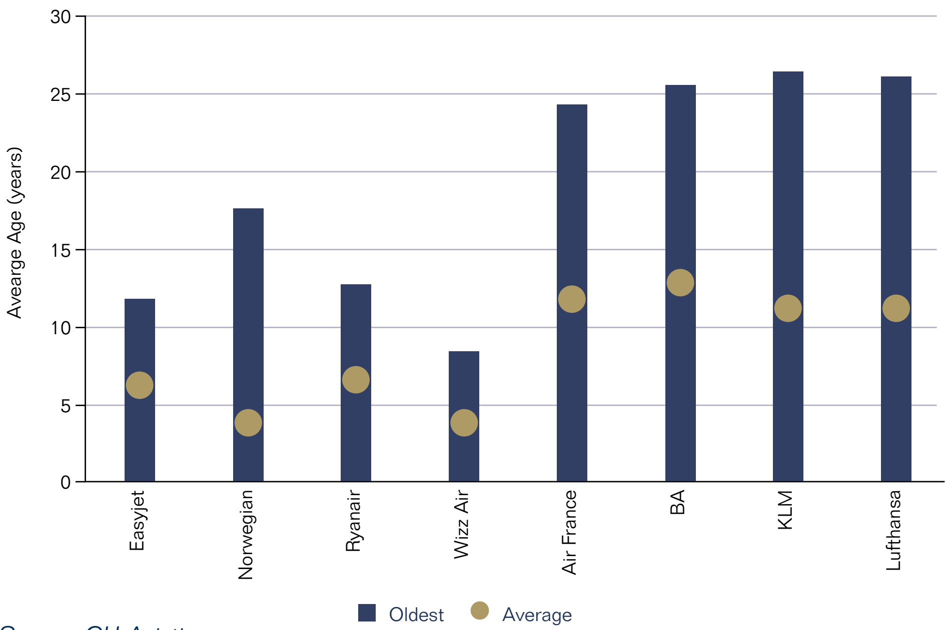
Figure 22: Average Fuel Burn by Airline Type



Source: RDC Apex. Airlines: Ryanair, Norwegian, Pegasus, Transavia, KLM, Qantas, Turkish and SAS.

4.5 A further consideration that can be made in favour of LCCs is that they generally operate a much younger fleet than their competitors. This is not a universal rule, as the "original" LCC, Texas' Southwest Airlines operates several aircraft that are over 25 years old; however for more modern LCCs in Europe and Asia, a constant stream of new aircraft deliveries and the phasing out of aircraft after just six or seven years is commonplace.

Figure 23: Average Fleet Ages for LCCs and Network Carriers



Source: CH-Aviation

4.6 The Figure 23 on the previous page shows a visualisation of this phenomenon, with four of the largest LCCs in Europe compared with four of the largest traditional network carriers. As well as being on average five to six years older, the aircraft life cycle in a network carrier appears to be over twenty years, while for an LCC it is no more than twelve. This means in practice an LCC is more likely to implement the latest environmentally sustainable aircraft sooner (see chapter 2), and dispose of outdated equipment earlier by shortening its life cycle through more intensive utilisation. However, these aircraft will probably be sold on to another airline, rather than scrapped, so that they could theoretically still be operating for many more years, although their high utilisation rates under LCC usage may make them less economical to operate and maintain at that age.

4.7 While LCCs can be more efficient on a per passenger basis than more traditional business models, when looking at the wider environmental context, the situation is more complex. There is a case to suggest that the entrance of an LCC into a market stimulates new demand rather than simply replace the demand served by less efficient airlines and whilst high asset utilisation shortens the aircraft life-cycle, it is simply producing a life-time of emissions over a shorter period of time. In the wider context it could be suggested that LCCs have created a net increase in emissions over what would otherwise have been generated by the more expensive business models.

Network Carriers

4.8 Despite the rise in LCCs, the majority of the world's air traffic is still carried by network carriers. Traditionally these airlines were supported by and/or represented their national governments and identity, but are increasingly becoming more independent, privatised and international. Ultimately, complete relaxation of foreign ownership restrictions is one way the industry can cut out 'vanity capacity' and exercise true free-market discipline.

4.9 A key differentiator is that a network carrier aims to provide a level of service for its passengers that goes above and beyond simply "flying from A to B", consequently they often have several classes of carriage, with varying levels of service and associated cost. In broad terms, network carriers can be seen as the opposite of LCCs. They operate longer flights using larger aircraft (with the exception of regional hub feed) and often at a lower density seat configuration. As demonstrated in the LCC section, their fleets tend to be older, although this may be just as much to do with long-term fleet investment (and therefore not "asset-squeezing" their aircraft) as it is to do with greater focus on cost efficiency by LCCs

4.10 One particular aspect of network operations that is important in sustainability terms is the use of hubs. These hubs allow fast and smooth connections to be made between flights, vastly increasing the number of possible city pairs that the airline can offer. This in turn makes the flights more profitable and therefore a greater number of cities can be successfully linked to the hub. This is an ideal situation for the city in which the hub is based, since it opens up more connections around the world, however it does also have some sustainability impacts.

4.11 Compared to a simple point-to-point model of airline operations (either from network carriers or LCCs), a hub can be expected to increase the number of flights – and connectivity – in the region which means at a local level may lead to greater noise and emissions. Extreme examples can be seen around the world in places such as Amsterdam and Dubai, where the level of aeronautical activity is exceedingly high compared to the demand for travel to and from the city itself. Hubs are most sustainable where there is strong local demand in place, such as New York, Shanghai or London. This is because the extra demand created is less likely to require new flights, and more likely to require a transition to larger (more efficient) aircraft on existing flights.

4.12 The beneficial effect on sustainability of operating a hub can be demonstrated with a simple model. Using London as a central hub, 10 popular short-haul cities and 10 popular North American cities have been modelled for operation with and without the hub.

4.13 In the *without hub scenario*, it is assumed that a point-to-point network serves all combinations of airports with the smallest modern wide-body aircraft available (in this instance, the state of the art Boeing 787-8) at a 75% load factor on a single daily frequency. In a real life situation, some routes (such as Paris-New York) could be operated at a good level of service without the need for an intermediary hub; and the reverse is also true that there will be some city pairs that cannot justify a long-haul service at all, but the combined demand would be enough to justify a link with a hub.

Figure 24: Network Map - Direct Services

RDC analysis

4.14 The hub scenario then assumes that all passengers re-route via the London hub. The passenger numbers are divided by the capacity of a sensible aircraft for the route to give a 5x daily 777-300ER service on the North American sectors and a 10x daily Airbus A320 service on the European sectors. The short-haul frequency may appear excessive, but in reality these flights would be spread among more regional airports within the catchment, rather than 10x daily at one central hub.

Figure 25: Network Map - Hub Services

RDC analysis

4.15 The net effect has been to reduce the number of daily long haul flights from 100 to 50. Economies of scale are gained by the use of larger aircraft and therefore the emissions on the long haul flights are considerably lower. The short haul flights are performed on efficient aircraft designed to move large numbers of people at minimal cost/maximum efficiency. By offering a greater daily frequency, the hub service can safely compete with the point-to-point services while offering considerably improved connectivity for its home market.

Table 1: Simplified Hub Model Outcome

	City Pairs	Short-haul Flights	Long-haul Flights	Short-haul Seats	Long-haul Seats	kT of CO_2	CO_2/Seat (Tonnes)
Point-to-Point	100	0	100	0	21,400	12.84	0.60
Hub	100	100	50	17,200	23,450	11.36	0.48

RDC analysis

4.16 This example has been built to show only the effect of carrying the same number of passengers between the same cities using two different airline models. Extrapolated over a wider air transport system, such as that to and from Europe, the environmental efficiency benefits are magnified whilst delivering a substantial connectivity improvement to the country hosting the hub.

4.17 Using fuel burn data from RDCApex.com, the overall reduction in CO_2 produced is 12%, based on a very efficient aircraft on the without hub model and a moderately efficient aircraft flying the with hub model. This is without considering that the hub services could accommodate additional local traffic or use a more efficient large aircraft. For a city such as London, the non-hub traffic could account for as much as 50%, further increasing the economies of scale and reducing the overall CO_2 produced compared with a pure point-to-point model – potentially by as much as 24%. This analysis suggests that a hub model produces less CO_2 on both a per-passenger and overall CO_2 burn basis, while increasing connectivity for the hub airport.

4.18 The downside of this approach is that the hub airport becomes the focal point for all flights and therefore accrues the noise and local air quality issues surrounding a larger airport. It also means the host-country counts all carbon emissions on its national inventory.

Charter

4.19 This business model has been popular with many independent carriers (i.e. not state owned or influenced) since the 1960s. Its core market is leisure, and particularly the transportation of passengers to and from holiday destinations. As such, the model is designed for maximum flexibility – the route network changes and adapts through the season and capacity is leased in and out as required. As most of the passengers are low yielding, a lot of the principles of the low cost airlines such as high-density seat configurations were first used and advanced by these charter airlines. However, low cost airlines have found that their own models are just as efficient at serving these markets, and the influence of their competition has driven the charter market down to an exceedingly small scale. These days the main charter carriers (in the UK: Monarch, Thomson, Thomas Cook and Jet2) operate hybrid models that have more in common with LCCs. Though they and some of the smaller airlines may still operate ad-hoc charter work, the proportion of traffic of which this accounts for is now very slim.

Regional Services

4.20 The regional sector of aviation consumes a lot less fuel, and therefore is much less of an issue for emissions, as the aircraft are significantly smaller and the distances travelled are relatively short. They are also quieter, being smaller and requiring less thrust. The 1990s and early 2000s saw the rise in popularity of regional jets, at the expense of turboprops. Overall this would have a negative impact for the sustainability of air transport as these regional jets are comparatively inefficient on a per-passenger basis. However the most recent capacity data suggests that this trend has flat-lined as fuel prices have become more volatile and turboprops more economically viable. The trend was also less applicable to the UK market, where rail travel is a viable substitute on many short distance routes, and other routes to Europe have a large enough demand to support larger aircraft.

Freight

4.21 The transportation of freight is a part of the industry that has always been considered integral to its function. However recently this side of business is becoming increasingly polarised. LCCs, in an effort to reduce turnaround times and reliance on external suppliers, rarely accept freight on their flights, and with their fast increasing share of the market, this means the choices for transporting freight by scheduled air services are becoming few and far between.

4.22 At the other end of the spectrum, the industry has seen a large rise in the use of freight forwarding conglomerates, such as DHL, UPS and FedEx. These companies have globe-spanning networks with dozens of local bases and regional subsidiaries.

They provide a seamless service from pick-up to delivery which is highly attractive to their customers. The air network forms the link between major hubs of these freight forwarders, sometimes using other airlines' aircraft (such as Aerologic for DHL) or increasingly using their own fleet of aircraft – most importantly these aircraft are dedicated freighters, which do not and cannot carry revenue passengers on the same flight.

4.23 Traditionally, freight has been carried in the bellies of large passenger aircraft, particularly those operating in and out of hub airports (as these offer opportunities for onward connections and therefore economies of scale). This is a highly efficient means of transporting freight, as it is on-board flights that are already carrying revenue passengers and therefore the marginal cost of transporting the freight is extremely low. The use of dedicated freighters is not necessarily inefficient in itself if the loads are high for both the outbound and return legs (demand for freight can often be mono-directional), however these aircraft are usually either conversions of older passenger aircraft or the last aircraft from a given aircraft production line. This means that the rates of technology implementation for dedicated freighter airlines are among the lowest in the industry. Popular aircraft types for these airlines continue to include the McDonnell Douglas DC-10 (first flight 1970) and Airbus A300 (1974). Furthermore, dedicated freighter aircraft frequently operate at unsociable hours, due to the desire to guarantee overnight deliveries and the availability of cheap slots – this can be a primary cause of noise complaints for local residents, especially at airports without night curfews.

4.24 Sustainability for air freight is most likely to be achieved through the use of existing passenger airline hub networks supplemented by large-scale freight aggregators with dedicated aircraft fleets linking logistics hubs. This will minimise the need for extra flights, ensure economies of scale from larger aircraft, and utilise the most modern and efficient technologies available.

Conclusions and Future Direction

4.25 Overall it is clear that the way in which the aviation industry develops with respect to the various business models will have a significant impact on its sustainability. The rise of low cost airlines can be seen as a net benefit in this respect, transforming short-haul travel into an efficient and fuel-lean means of connecting across relatively short distances and making flying more affordable. However, the long-haul market will continue to be orientated towards service levels as well as cost, requires the aggregation of freight alongside passengers, and therefore is unlikely to be as successful for low cost airlines in the future. With this in mind the industry needs to focus on finding an efficient means of connecting thousands of possible city-pairs across the world with the smallest amount of infrastructure, and the solutions to this are hubs. Hubs provide the economies of scale from a wide selection of possible routes, combined with the movement of high volume freight through belly-hold space, which can reduce emissions of CO_2 and other harmful gases by at least 12% even in a simplified 20-city model.

5. Operations

5.1 The air transport system is already relatively efficient (in terms of fuel burn and therefore emissions as well as noise) as it exists in a situation where mostly-private companies are motivated to operate at maximum efficiency to minimise costs, particularly with regards to fuel burn as this is frequently the airline's most significant cost. However there are some bottle-necks in the system caused by regulation or congestion which may provide opportunities or further improvements in the coming years.

Taxiing and Ground Delays

5.2 With a finite amount of runway capacity, peak times can cause a build-up of delays at many airports. The effect that this has on the local environment in terms of noise and emissions is almost totally dependent on how the airport and airline choose to handle the situation.

5.3 The Aircraft on Ground Reduction (AGR) Programme developed by Sustainable Aviation found that at Heathrow airport, emissions from ground aircraft accounted for 30% of CO_2 emissions (not including emissions created in the "en-route" phase of flight), and is therefore an identifiable area for future improvement.

5.4 Taxiing is a relatively inefficient process, as it uses the aircraft's engines, designed to propel the aircraft to over 600mph, at speeds closer to 20-30mph. There are a number of initiatives both proposed and in use around the world that aim to reduce the fuel burn during taxiing, thereby reducing noise and emissions on the ground. The simplest of these initiatives is single-engine taxiing, where one engine is not started until as late as possible (around 2-5 minutes before departure). A study by Deonadan and Balakrishnan of MIT[7] found that at busy US airports such as New York JFK, NOx emissions from taxiing could be reduced by as much as 40% by employing this method.

5.5 Alternatively, aircraft can be towed to the runway by a tug or similar vehicle, and the same study found that this could reduce the CO_2 emissions from taxiing by around 70%. However it also noted that the use of these vehicles could also increase NOx by around 60% depending on the age and type used. There is potential in the future for aircraft tugs to be electrically powered, and therefore effectively eliminate emissions; however, these are not widely used and the appetite for universal uptake is dependent on the airport handling agents.

5.6 A perfectly managed situation would see an aircraft never leave the gate until it was able to taxi to an available runway without delay. This way the aircraft would not have to start up its engines or APU (a small engine usually located in the tail of the aircraft that powers the aircraft while on the ground) and instead could rely on the GPU or FEGP[8] until the exact moment it is required. The GPU is both quieter and less pollutant than the aircraft's on-board power systems. However this procedure requires a high level of coordination between the airport and airlines, and for airports

7 Deonadan and Balakrishnan (2010) "Evaluation of Strategies for Reducing Taxi-out Emissions at Airports"

8 Ground Power Unit and Fixed Electical Ground Power

such as Heathrow and Gatwick, could be a very inefficient way to make the most of its scarce gate and runway capacity. Deonadan and Balakrishnan found that using this system of "advanced queue management" taxi emissions could be reduced by around 50%. However, this system would not be practical in a situation of very limited runway capacity, as the act of maximising the limited available capacity would require aircraft to queue at the entrance to the runway.

5.7 Sustainable Aviation estimate that around 50% of the emissions from APUs can be cut through increased use of GPUs and other systems, and a 0.6% reduction in UK aviation's overall CO_2 emissions. A study at Zurich airport found that the NOx reduction from use of GPUs would be around 4.3% per flight.

Delays from Airborne Holding

5.8 While delays on the ground may be costly, aircraft naturally burn more fuel in the air, and so delays that occur to aircraft awaiting a slot to land can be far more devastating to both the airline and the local environment. A study by researchers from Aviation Economics and Loughborough University (2015) found that an aircraft in a holding pattern burns around 1kg of CO_2 per seat per minute (varying greatly depending on the aircraft used).

5.9 The researchers also discovered that the particular situation at London Heathrow leads to a 0.6% increase in the overall fuel and CO_2 burn of all flights arriving at the airport. There may also be an added impact of noise, since each arrival spends an average of 4-5 minutes extra holding at a height of between 8,000 and 12,000ft over mostly built-up areas. However, the noise impact of aircraft at this altitude has not been quantified.

5.10 The paper finds that these delay impacts are all directly the result of poor access to runway capacity, since an airport system with appropriate runway capacity would not have the need for holding patterns or long ground waiting times. It concludes that expansion of capacity should not always be viewed as a net cost to the surrounding environment, as it has benefits from reducing delays.

Single European Skies and Global Navigation

5.11 The "invisible infrastructure" that makes up the airways crossing our skies has remained largely unchanged for several decades. This means that many flights are directed on paths that are not as direct as they could be, leading to unnecessary fuel burn and emissions. The industry is working on a solution known as Performance Based Navigation (PBN) that would allow flights to travel on more direct flightpaths without the risk of collision. This system requires the cooperation of nations controlling the airspace, so is likely to be gradually implemented rather than a sudden 'big bang'. PBN is expected to be operating in Europe in the early 2020s.

5.12 NATS, the UK's primary air traffic service provider, monitors every flight that travels through UK airspace and gives it a *3D inefficiency* (3Di) score. This considers the difference between the track travelled by the aircraft and the optimal track to reduce fuel burn and emissions. NATS has several targets written into its UK license to improve the average 3Di score of aircraft under its control.

5.13 One critical issue to consider in the choice of flightpaths is that it is often not possible to reconcile both reducing emissions and reducing noise impacts at the same time. For example under a PBN system, all departures to the Middle East and Asia (usually large aircraft heavily laden with passengers, freight and fuel) would fly an almost identical departure track – concentrating the impacts on particular communities and not offering respite. However, fanning or splitting departures to offer respite causes longer routings which burn more fuel and emissions. Handling these separate issues is one of the challenges that needs the combined effort of regulators, airlines, airports, navigation service providers and local communities to resolve.

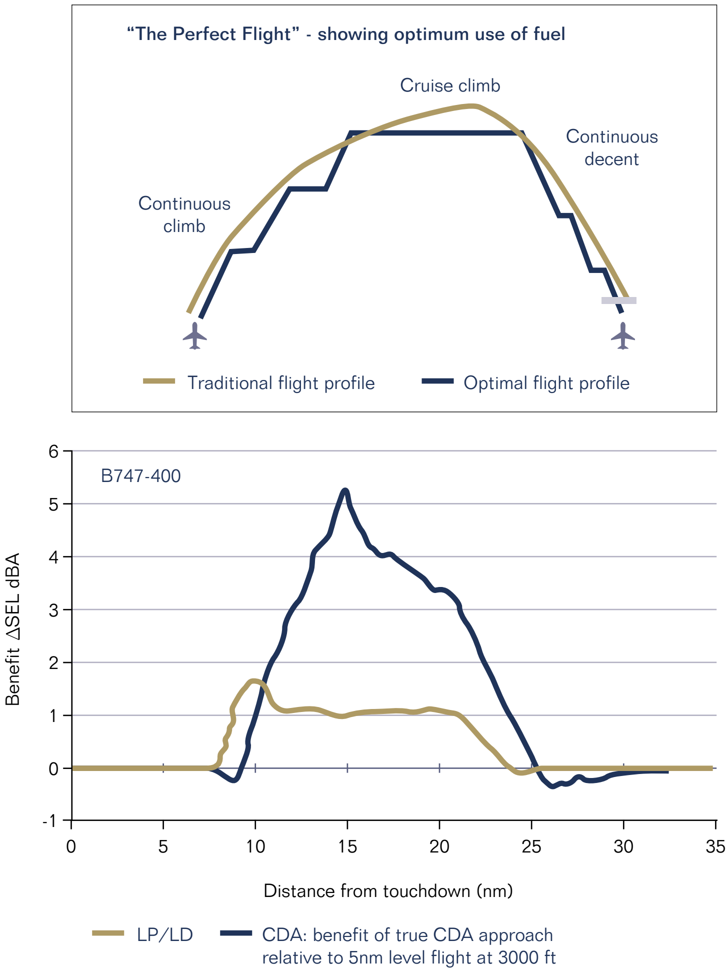
5.14 One of the largest sources of noise complaints from aviation is on the approach phase of flight. Although quieter than the departure phase, the approach offers less flexibility in planning because aircraft have to be approaching in line with the runway from around 10 miles out, whereas on departure can be vectored out to different departure paths comparatively quickly. This is a particular problem for Heathrow where the runways are East-West aligned such that aircraft approach over West and Central London when the wind is in the prevailing Westerly direction. This accounts for about 70% of Heathrow's flights.

5.15 There are a number of potential ways in which the operation of airport approaches can be optimised to reduce the impact on local residents. One of the most beneficial and simple to operate is referred to as "low power, low drag", or LP/LD approaches. This means reducing thrust to a low level early in the approach and maintaining this until landing, whilst also operating in a "clean" configuration with minimal application of flaps and no landing gear deployed for as long as safely possible. Pilots that are familiar with the airport are likely to fly in a style similar to this, however unfamiliar pilots may be anxious to complete their pre-landing checklists and establish the landing configuration as soon as possible. Establishing an airport-wide practice for LP/LD would provide benefits in these instances of around 1-2dB for most of the approach (see figure 26). Indeed, simply sharing best practice from each airlines' standard operating procedures at an airport can bring substantial benefits in noise above local communities.

5.16 Greater gains can be made with the use of continuous descent approaches (CDA). These are performed by aircraft flying a single constant descent from its cruising altitude, as opposed to the more common stepped approach. This means the aircraft can stay at a lower, quieter thrust level for longer on the approach, without the short bursts of increased thrust seen on stepped approaches. The difficulties in implementation of this system are that it often requires airspace to be redesigned, high levels of coordination to ensure aircraft begin their descent at the correct distance from the airport and sufficient capacity to not delay aircraft in holding stacks. However when this is correctly performed the expected benefits can be as high as a 5dB reduction in noise for residents under the approach path, as well as associated emissions benefits from reduced thrust.

5.17 The figure below from the DfT's code of practice for arrivals shows the relative benefits of the two systems. Continuous descent approaches provide the greatest benefit, but this can be complimented with LP/LD operations for optimal noise reduction.

Figure 26: NATS Optimal Flight Profile and Continuous Descent Profile



Source: NATS

Comparative Benefits of LP/LD and CDA Approaches

5.18 Continuous Descent Approaches fit into NATS' "perfect flight" initiative (shown above). Sustainable Aviation forecasts that improvements from this and other navigational techniques can lead to a 6.5% decrease in CO_2 emissions, while analysis by IEA indicated that a CDA could save between 5% and 11% of fuel on the final 300km of a flight.

5.19 For some aircraft operations, the impact of aircraft noise can be further mitigated through the use of displaced thresholds. These change the position of touchdown for aircraft to further down the runway, thereby increasing the relative height at which the aircraft pass overhead local communities, and limiting the lowest part of the approach to within the airport perimeter. In order to perform these operations, the aircraft must have a sufficient length of runway to land with no safety implications. A 1 nautical mile displaced threshold can mean aircraft are 300ft higher when flying over local communities. In Heathrow Airport's submission to the Airports Commission, it claimed that it could operate one or more runways like this with a three-runway configuration, alternating usage to give residents periods of respite – an activity which Heathrow has calculated to provide a net benefit in terms of reduced sleep disturbance and annoyance over the current operations at a two-runway Heathrow. A study by Jacobs UK Ltd. on behalf of the Airports Commission found that the use of displaced thresholds on Heathrow's runways would reduce the population within the 90dB SEL noise contour by around 78% (although it must be noted that not all flights could perform this operation). Some of the schemes analysed by the Airports Commission promoted the use of displaced thresholds. Of particular note is the Heathrow Hub scheme, which involved extending the Northern runway out to the West. This would mean that at off-peak times (such as the first arrivals of the morning) aircraft could land further down the runway and that the last 2 nautical miles of flight would be over the airport site itself.

Table 2: Summary of Potential Improvements

	CO_2 benefit (global)	NOx benefit (local)	Flightpath noise benefit	Notes
APU reduction	0.6%	4.3%	-	
Single-engine taxi	0.5%	10%	-	Using SA estimate of 30% CO_2 emissions from ground
Advanced Queue Management	2.0%	20%	-	
No Holding	0.6%	2.5%	-	Some noise benefit under holding patterns
Performance Based Navigation	1.7%	-	-	
LP/LD Approach	0.3%	-	1db	
Continuous Descent Approach	0.5%	-	4db	
Displaced Thresholds	-	-	4db	300ft higher but not for all aircraft
Estimated Total*	6.20%	36.8%	6-9db	

Using various sources supplemented with RDC data and assumptions.

*Assumes that all measures are independent and not currently being employed.

5.20 The table above shows a summary of the methods described in this chapter and the gains that could hypothetically be made with all measures in place. It should be noted that some of these measures may already be partially in place or not fully realisable in combination with other measures, but that with the use of as many of these measures as is realistically possible, the impacts from aviation could still be reduced substantially. The opportunities for the greatest environmental benefits from operational changes are for local air quality and noise. CO_2 remains a global issue that needs to be dealt with in all phases of flight.

6. Policy and Implementation Options

Surface Access

6.1 When considering the sustainability of aviation, it is important consider it as part of a wider transport network, creating demand for traffic on modes such as road and rail, and it exists in a system in which much of the traffic bypasses the airport as if it were not there.

6.2 A Heathrow Airport study of its surrounding area found that NOx emissions from aviation were only 13%, while other airport impacts including surface access accounted for a further 10% (19% and 28% respectively on the airport site itself). Measurements taken at nearby Hillingdon and Hayes were found to be higher than at the airport or its immediate surroundings and in excess of legal limits despite the airport and its associated impacts only accounting for 6% of these emissions at Hayes. The road network around Heathrow includes the UKs busiest stretch of motorway – the M25 between J13 and 14, which combined with the M4 carries over 350,000 vehicles per day[9], while the airport handles around 1,300 flights per day, forecast to peak at 2,000 with a new runway.

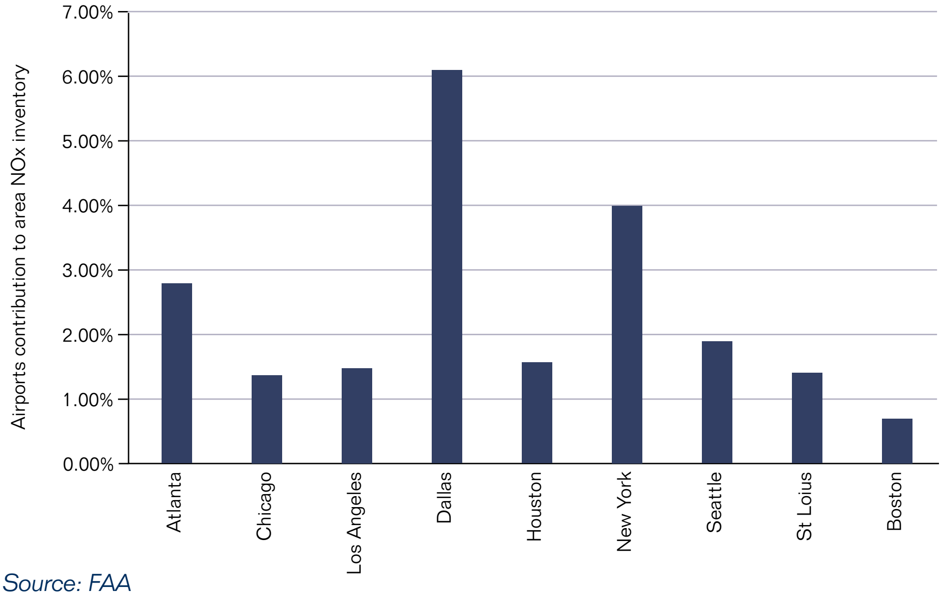
6.3 An academic study by Farias and ApSimon[10] reinforces this assertion, as they found that the impact from traffic on local emissions was found to be significantly larger than that from aircraft. This evidence shows that while aviation can have an impact on local air quality, it is often polluting indirectly through other modes – and in some cases the other modes are far greater sources of emissions, regardless of airport traffic. Therefore it is important to consider both the effect of an airport on other modes and also its impacts in context with these other modes.

6.4 Similar analysis by the USA's FAA can be seen in the Figure 27 opposite. This study features 9 cities with at least one airport in the top 20 in the country. The airports' contribution to the area NOx inventories vary from 0.7% to 6.1%, with the greatest contributor being Dallas which has two very large urban-located airports and is obviously an extreme case.

9 Department for Transport – Annual road traffic census counts

10 Farias and ApSimon (2004), "Relative contributions from traffic and aircraft NOx emissions to exposure in West London", Envrionmental Modelling Software 21

Figure 27: Airport Contribution to Local NOx at Selected US Airports



Source: FAA

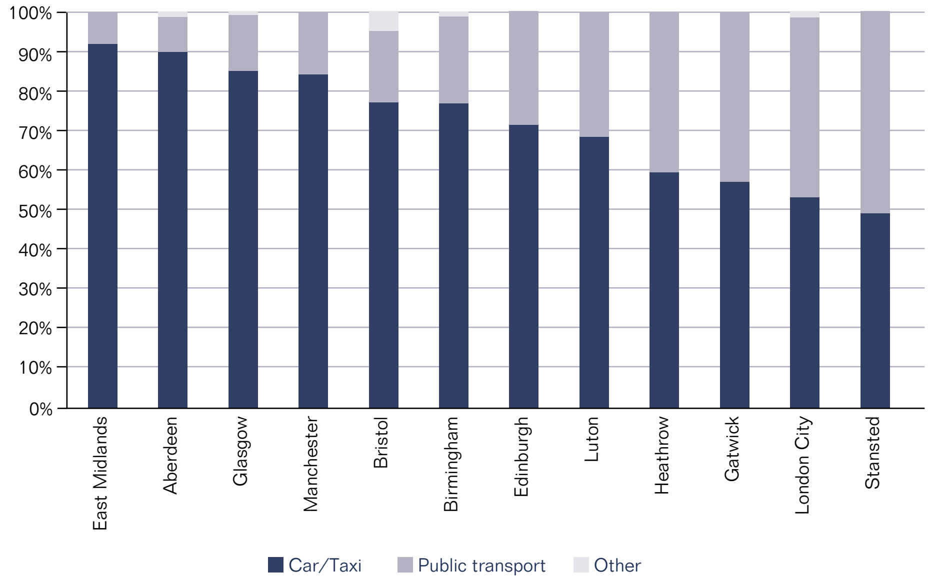
6.5 Road vehicles have seen substantial improvements in emissions such as NOx and PM10 since the introduction of catalytic converters in the 1990s, however their overall emissions represent the greatest challenge to the wider transport network and were still recording year-on-year increases until the economic recession of 2008 caused reductions in road traffic.

6.6 The automotive sector already has a mandated quota of biodiesel in circulation, and is able to embrace electric and electric-hybrid powered vehicles in a way that aviation cannot until battery technology vastly improves. The Department for Transport have taken this improvement in automotive technology into account in their road emissions forecasts, estimating that NOx will fall by 62% and CO_2 by 15% from 2015 to 2040.

6.7 As aviation is a part of this collective system, improvements in emissions from road vehicles and a continuing shift away from private cars use for staff and passengers will see benefits flow through to the areas around our airports, resulting in lower levels of particulate and NOx emissions within those areas.

6.8 Surface access to UK airports is currently made predominantly by road, though it varies greatly depending on the airport (e.g. public transport share at London City is 46% but at East Midlands is 7%). However the UK government is supporting the creation and improvement of alternative modes, such as Crossrail to Heathrow and improving capacity on the line to Gatwick Airport. The diagram 28 overleaf shows the public transport mode share of the top 12 UK airports. As a general rule, larger airports can support greater infrastructure investments and therefore have a larger share of public transport usage. The two notable exceptions to this are London City, which is small but has a high public transport share, and Manchester, which is large but with a much lower public transport share.

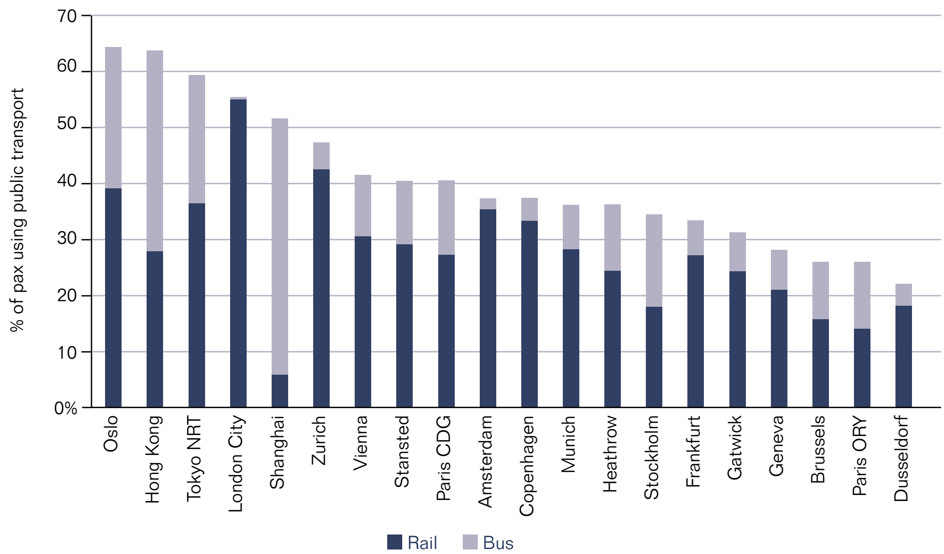
Figure 28: UK Airport Modal Split



Source: CAA (2011)

6.9 The chart below shows how four of London's airports perform among a worldwide selection in terms of public transport usage. The data shows that the London airports have a reasonable share of public transport (approx 30-40%) but there remains room for improvement compared to leading-class airports such as Oslo and some of the largest Asian airports.

Figure 29: Modal Splits at a Selection of Large Airports

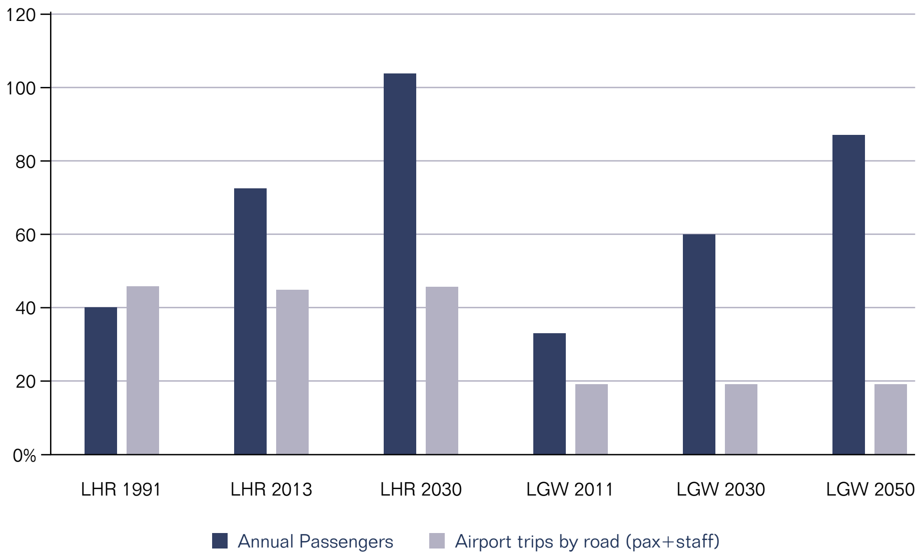


Source: FAA NB. The FAA definition of public transport (bus and rail only) is slightly less comprehensive than that used by the CAA in Figure 28 above.

6.10 Emissions from surface access are primarily from road travel and can be reduced through increased use of public transport and other less-pollutant means. In order to ensure that this happens, new airport capacity should be delivered as part of a wider integrated intermodal transport plan. The relative geographic and temporal proximities of any Heathrow expansion and High Speed 2 plans have made them obvious candidates for being integrated together (and it is disappointing that they have not been) but the approach should be wider than that and consider modes of transport from all directions. The proposals for Southern and Western rail access to Heathrow are steps in the right direction.[11]

6.11 The assumption is often made that airports increasing in size will increase the amount of road traffic, however where investment in infrastructure is made to meet the demand, then this effect can actually be reversed. Heathrow Airport presents a key case study of this phenomenon, with road trips not increasing between 1991 and 2013, despite an increase in passengers of 80% over the same period. This has been due to investment in public transport such as the Heathrow Express alongside improvements to the Piccadilly line as well as Heathrow's comprehensive commuter programme to reduce travel to work by car.

Figure 30: Surface Transport Mix – Heathrow and Gatwick Forecasts from Airports Commission Submissions



Source: Heathrow Airport and Gatwick Airport

6.12 Gatwick Airport's own forecast of surface access usage paints a very similar picture of substantial growth not leading to an increase in car usage, and its position on the London to Brighton rail line is core to this.

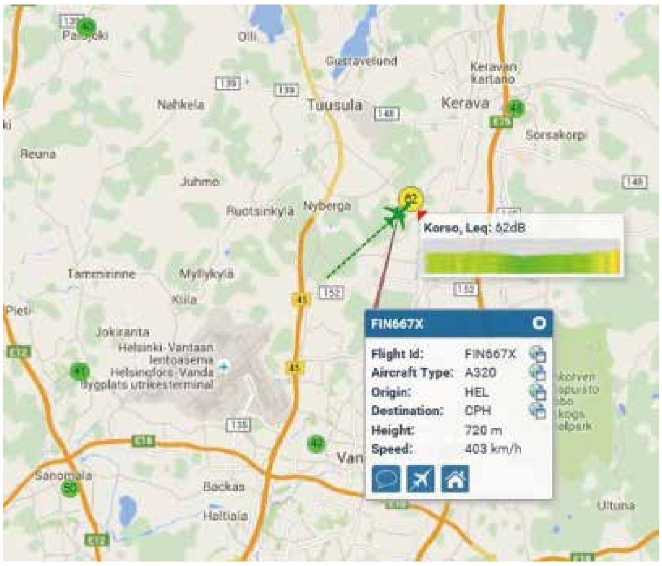
11 http://your.heathrow.com/takingbritainfurther/wp-content/uploads/2014/09/Transport-Fact-Sheet_FINAL2.pdf

Community Engagement

6.13 Emissions and noise impacts go far beyond simple numbers and charts in their effect on local residents. Commercial airports in the UK are already engaging with their local community to ensure that information is available on noise, how it might affect them and what is being done about it to improve the situation for the future. Many airports currently offer grants for additional noise insulation to local communities, understanding that it is important that they engage in this way to improve the understanding of the airport and wider aviation industry.

6.14 The UK's national air traffic service provider, NATS, engages with the communities whenever changes are made to airspace or flightpaths. It has found that proposed changes are often met with a cautious response. For instance the aim of a flightpath change might be to provide periods of respite to those most overflown, but if it brings new households under the flightpaths then there will be a negative reaction from these residents, even though as a whole the community might be better off. However, through this process of engagement, it has been able to conclude that predictable periods of respite are critical to enable those affected to plan their activities around known 'quiet' periods.

Figure 31: Helsinki Airport WebTrak



Helsinki Airport WebTrak

6.15 Finland is a global leader in dealing with the environmental impact of Vantaa airport in Helsinki, which handles around 80% of the country's flights and 99% of long-haul services. Through a range of local and national environmental policies, Vantaa Airport is able to meet the objectives of providing greater connectivity for Finland within its goal to minimise impact on the environment.

6.16 The air transport landscape in Finland is more joined-up than other parts of Europe with one entity, Finavia, operating the airports and navigation services for the country. This provides the opportunity for a joined-up national policy and implementation framework. As part of its noise commitment around Vantaa, the airport publishes flight tracking and noise monitoring in real time, enabling communities to monitor the performance of particular airlines, aircraft and routings at a number of points around the airport. Heathrow uses a similar system but with less transparency. Until recently, data were delayed by 24 hours before being shown, and the system currently has no real time noise monitoring, but is being enhanced with new noise monitoring terminals being added that will bring the ability to conduct self-service analysis.

6.17 We believe the industry in the UK can go further, however there is an important trade-off to be made. Systems employed by NATS and other organisations in the past have looked to optimise flight paths to reduce fuel burn and CO_2 production, but this can be vastly different from the optimal flightpath for reducing noise impacts. RDC proposes that a system similar to NATS "3Di" (see section 5) could be introduced in the UK, whereby airlines are monitored and scored for their fuel and CO_2 efficiency during the cruise phase (above a height of around 10,000ft) but on approach and landing at UK airports they are monitored and scored by their noise impact. The noise impact would be a combination of the intensity of the sound measured from ground stations and the population size that is affected by it. Airlines would then be incentivised to fly noise-friendlier approach paths and controllers incentivised to facilitate them. The key to making this system work would be making it publicly available and usable, similar to the WebTrak system at Helsinki Airport, allowing residents to see how current flights are performing as well as being able to access historical data showing which flights consistently perform poorly.

Policy Measures

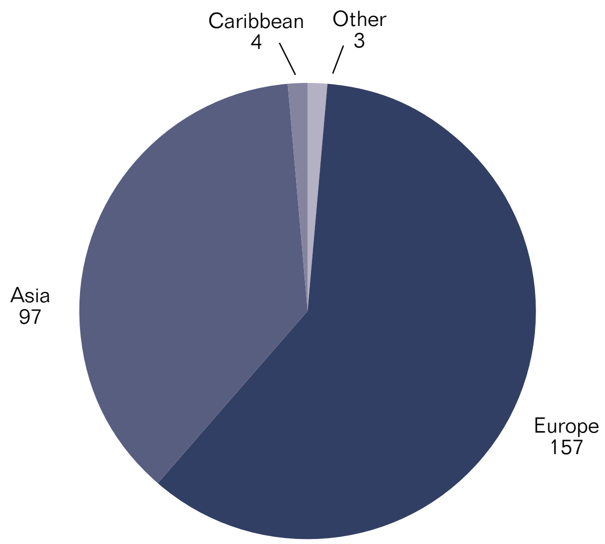
6.18 There are a number of ways an airport can look to reduce emissions from the operation of its own facilities and by encouraging users to reduce their own. Airports Council International (ACI) in Europe has produced a carbon accreditation scheme which offers a roadmap for airports to become carbon neutral from their own operations. So called "kiss and fly" visits, where a person is dropped off or picked up by a relative (creating double the necessary car trips), are particularly undesirable and airports can introduce charges for drop-offs to limit these and encourage passengers to use alternative modes of transport. A large number of trips to airports are made by staff, so most major airports have schemes in place to reduce these, including staff shuttle buses and incentive schemes to use public transport.

6.19 At a government policy level, the UK Air Passenger Duty (APD) is charged to departing passengers at UK airports. Depending on the distance and the class of travel, this is charged at between £13 and £142 per passenger, and is one of the most expensive taxes of its type worldwide. It has in the past been referred to as an environmental or "green" tax, however it has no clear direct link to reducing emissions other than discouraging low-income travel and potentially has the effect of shifting inbound tourism to neighbouring countries such as France, Germany and Ireland where air passenger taxes are either significantly lower or non-existent.

Ireland, Netherlands and Belgium are examples of countries that have successfully abolished their tax and benefited as a result. Any economic policy measure to reduce emissions must be significantly more direct (i.e. charged on a per emission or fuel burn basis) and applied as universally as possible to avoid harmful market distortion. Revenues gained through such measures or, indeed, incremental revenues from APD, could be hypothecated for use in supporting communities around the airport or wider environmental measures.

6.20 Around the world, Europe is leading the way in terms of establishing noise and environment-related charges on airlines. 60% of all airports with such charging structures are in Europe, whereas there are none in North America. At an airport level, industry has taken to incentivising quieter and less polluting travel through the use of differentiated charging structures, with the number of airports using these systems increasing over recent years. These charges typically take the form of either a noise charge or a NOx charge, as these are the impacts that are most relevant to the airport and its local community.

Figure 32: Airports with Environmental Charge Elements Split by Continent



Source: Airportcharges.com

6.21 Within Europe, the UK is one of the front-runners in implementing environmental charges. The nine largest airports all have noise charges, and three of those also charge for NOx.

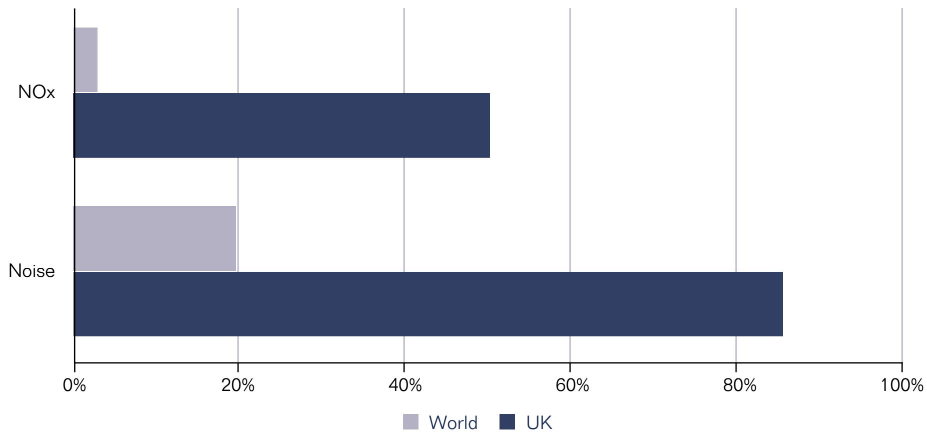
Table 3: UK Airports with Environmental Charging Elements

Airport	Noise charges	Nox charges
London - Heathrow Airport	Yes	Yes
London - Gatwick Airport	Yes	Yes
Manchester International Airport	Yes	
London - Stansted Airport	Yes	
London - Luton Airport	Yes	Yes
Edinburgh Airport	Yes	
Birmingham International Airport	Yes	
Glasgow International Airport	Yes	
Bristol Airport	Yes	
London City Airport		
Newcastle Airport		
Liverpool John Lennon Airport		
Belfast International Airport		
East Midlands Airport	Yes	
Aberdeen Airport	Yes	
Leeds/Bradford Airport		
Belfast City Airport		
Southampton Airport	Yes	
Jersey Airport		
Guernsey Airport		

Source: airportcharges.com and RDC analysis. Note that London City and Belfast City airports have local planning agreements that restrict movements

6.22 Although there remain a number of airports in the UK without environmental charges, the high coverage of the largest airports means that 86% of the UK departing seats are covered by noise charges and 51% by NOx charges.

Figure 33: Proportion of UK Airport seats Covered by Environment Charges



Source: Airportcharges.com

Noise Management

6.23 Before construction of any new capacity at either Heathrow or Gatwick, the government should introduce new noise abatement policies, limits or quotas to ensure that the capacity is delivered whilst limiting the impact on local residents. It could also mandate the use of certain routing pathways to ensure airline flight plans are optimised for the needs of communities rather than to simply reduce fuel burn. However on their own, bilateral actions by government or the airport operators may be treated with extreme scepticism by those living under flight paths. Building the trust of communities is a vital part of the planning and delivery process, with community participation essential to delivering effective noise management. The chances of meaningful engagement with community groups will be greatly improved if there are independent redress and control measures that oversee all short and long term agreements, with direct powers of intervention for breach of agreed limits.

6.24 For this reason we support the creation of an independent regulator responsible for highly sensitive issues such as noise. Ideally this body would have a wider ranging remit than simply flight-path noise and would objectively consider how best to manage noise from aircraft and other forms of transport around the airport in conjunction with those most affected. An authority independent from government and the other aviation regulatory bodies would be able to advise on a range of critical issues, from the location of monitoring stations to consulting on proposed solutions and advising government on best practise.

6.25 With the Airports Commission having published a revised set of long-term growth projections for the UK, a noise authority should look to create a long-term noise road-map that links current and future flight paths to demand projections, showing how noise is expected to develop in terms of intensity and frequency. It would be in a position to work with local stakeholders and NATS on developing a range of environmentally optimised approach and departure paths that balance reducing fuel burn with carbon emissions and minimising local noise.

6.26 Planning permission, or even the airport operating licence, should include new regulatory limits or noise quotas, backed up with ongoing publication of results by airline, aircraft type and route across a range of monitoring stations. Add to this real-time noise monitoring and a noise authority with the power to approve, suspend or fine operators for failure to use agreed flight paths or hit targets for aircraft operations, it should be possible to gain the trust of local communities.

6.27 It is increasingly common for such restrictions to be included in the planning permission at major airports across Europe, and there are a number of key examples to learn from:

- Frankfurt – In 2011 the airport opened its fourth runway, which came with a ban on night flights – a total ban for 6 hours during the night, and a tight restriction on the number of flights in the borderline times.
- Berlin Brandenburg – Marketed as a new airport but essentially a major expansion of the current Schönefeld Airport, including the construction of a second runway. Flights will be banned between midnight and 5am, with "strict quota limitations" from 10pm and between 5-6am.
- Amsterdam Schiphol – Constructed sixth runway in 2003. Night operating procedures were tightened to include shoulder periods of one runway used for arrivals and one runway for departures.

7. Radical Technologies

7.1 So far we have looked at the efficiencies that should be achievable within the aviation sector through the implementation of 'known' or relatively low-risk technologies. These tend to be improvements in equipment, techniques or procedures that are either in use today or that are very likely to be introduced before 2030.

7.2 Looking beyond the 2030 time period, which is the point beyond which we expect the current and planned global fleet starting to be replaced by aircraft that are yet-to-be developed, there are likely to be further enhancements across the environmental spectrum that could have a material impact on CO_2 emissions, NOx and noise. However the levels of uncertainty are such that they should be considered as 'unknown' in the context of a study such as this. Nonetheless, there is scope for radical future technologies to make a step-change in emissions and/or noise from aircraft.

Biofuels

7.3 At present biofuels (also known as Sustainable Aviation Fuels) are seen as an important part of the long-term sustainability solution for aviation. Depending on the projections, anywhere between 5% and 20% of future emission savings could come about from use of biofuels as a replacement for the jet kerosene that is currently used to power the global fleet.

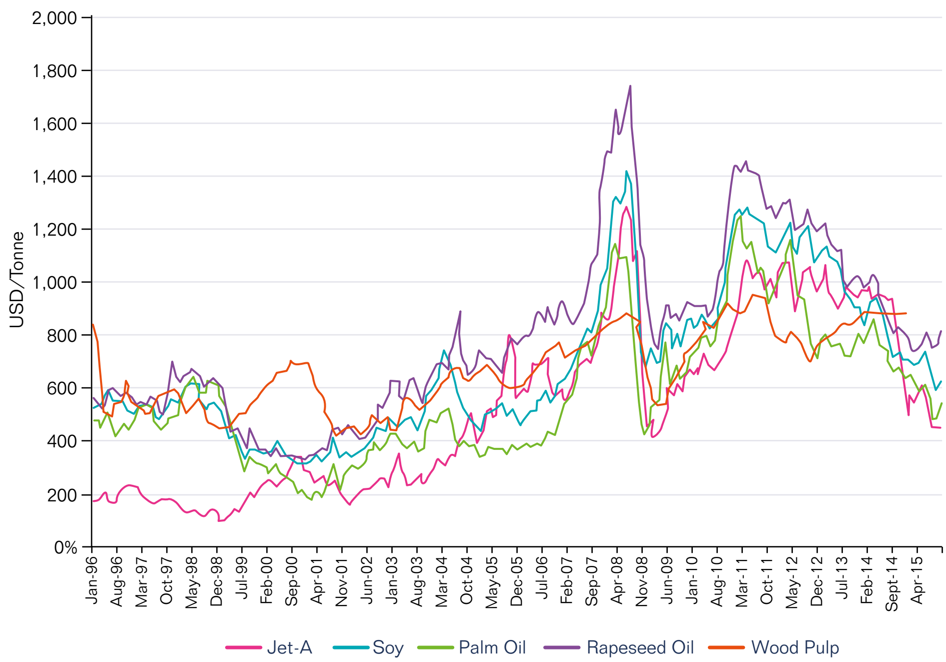
7.4 For production, distribution and logistical reasons, biofuels must be compatible with conventional jet fuel so that aircraft can be flown safely irrespective of the type of fuel available at an airport, which means any alternative fuel must have 'drop-in' properties whereby it can be mixed with regular fuel and behave in the same way. Unlike road transport, for which there are relatively few risks in achieving a stable mix of bio- and regular fuels, replicating the properties of jet kerosene comes with significant challenges. Any 'drop-in' fuel must share similar properties to that with which it is being mixed, including having the same freeze- and flash-points; density and energy content; and being able to share the same on-site infrastructure in order to propel an aircraft safely through the extreme range of operational conditions, be that at high altitude over the Polar Regions or taking-off at sea level in the desert.

7.5 Given the potential value of achieving a breakthrough in developing sustainable biofuels it is no surprise that there are a considerable number of processes, techniques and fuel sources under investigation. In the US alone, an estimated 2,700 biofuel patents have been issued since 2002 and there are now several alternative fuels that have been certified for use and tested in real-life flight conditions. In its 2014 report into alternative fuels, IATA details 3 already-approved pathways to producing biofuels and highlights 21 agreements between airlines and producers to develop and test these alternative fuels. Over the last decade, in excess of 1,500 flights have been undertaken using a blend of regular and biofuel and the world's largest airlines – who are also the heaviest consumers of jet fuel – have conducted test flights using mixes of up to 50% biofuel developed using various techniques and fuel sources. To date, there have been a range of raw materials used to synthesise aviation fuel, including agricultural waste, used cooking oil, various plant and switchgrass sources such as jatropha and camelina, and fermented hydro-processed sugar.

7.6 However, although it is now proven that aircraft can be safely powered by various mixes and types of biofuel there is yet to be clarity over how to achieve future large-scale production at commercially viable prices. There are a number of reasons behind this. Firstly, crop-based biofuels must come from sustainable sources, meaning they cannot be derived from food-crops, nor can they compete with land or other resources, such as water, that could be used to grow such crops. Second, fuel sources must be able to generate a predictable and stable yield, which is not the case with some of the plants used to date. Finally, production and retail costs must be similar to the cost of the fuel they are replacing, or at least the cost of the fuel plus any environmental mitigation costs such as associated carbon trading or emissions charges.

7.7 Looking at the cost of a sample of raw materials that could be used to produce bio-jet, including soy and palm oil or wood-pulp, we can see that the commodity cost-per-tonne tracks a similar line to that of jet fuel over a 20-year period. In this example, the chart compares the cost of raw materials for the crop-based commodities versus refined jet fuel. In the case of rapeseed oil, about 2.5 tonnes is required to produce one tonne of biofuel[12], making the rapeseed around three-times more expensive per tonne than jet fuel – before production costs are factored.

Figure 34: Cost per Tonne of Jet Fuel and Selected Biomass Raw Materials



Source: US EIA, Index Mundi, RDC

12 European Biomass Industry Association

7.8 The second major challenge for crop-based biofuels is the land-mass required for large scale production. Using a simplistic illustration, UK airlines consume an estimated 8m tonnes of fuel per year. A mid-yield biofuel crop such as rapeseed has a yield of around 1,000 litres of fuel per hectare, which equates to over 9m hectares of land required to generate enough fuel to power the UK airline fleet for a year – an equivalent land mass to Portugal.

7.9 Other resources such as municipal or agricultural waste, or used cooking oil, offer 'win-win' potential as source materials for biofuel but are difficult to aggregate and transfer to production sites in large volumes without adding carbon.

7.10 In a recent MIT study into the use of advanced biofuels in aviation[13], Winchester et al conclude that there are significant challenges to scaling-up production of biofuels for commercial use in aviation, which include *"high production costs and lack of integration of aviation biofuels into regulatory frameworks, limits in scale-up due to feedstock availability, environmental and socio-economic consequences of large-scale land-use change and competition with food and feed needs, water consumption associated with biomass cultivation and time required for scaling up biomass cultivation and conversion facilities."*

7.11 Biofuels have a role in the mitigation of carbon emissions and are part of a range of measures that we believe can help the wider transportation industry reduce its environmental impacts. However, given the challenges currently facing large-scale production, they are unlikely to produce a step-change in emission levels for any mode of transport, and in terms of air transport it is safer to assume that for the next two-decades there will be a slow and steady introduction of such fuels in modest quantities rather than a radical shift.

Other Alternative Power Sources

7.12 As with road, rail and other transport, the long-term future for the propulsion of air transport is likely to be with electrical power. Unfortunately for an aircraft the technology required to make this feasible needs to be considerably more advanced than other modes, as the power output is high and the distances between possible opportunities for charging are huge.

7.13 Airbus is one of several manufacturers to carry out research into this field. In 2015 they successfully flew the Airbus "e-fan" for the first time – a twin seat electrically powered aircraft aimed at the flight training market.

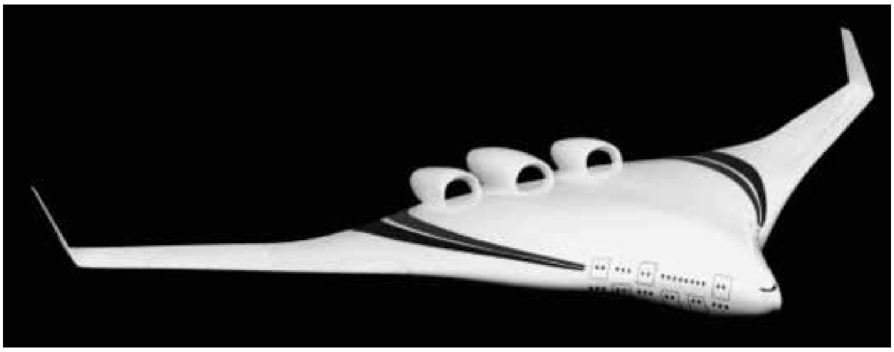
7.14 Airbus has also developed a concept, known as the "e-thrust", which would essentially be a hybrid-powered aircraft for commercial use. One jet turbofan engine would charge a battery, which provides the power to six large fans. This would increase the effective bypass ratio and significantly increase the efficiency of the aircraft. However the technology required is currently well beyond that of the e-fan, as each of the e-thrust's engines are required to deliver 670kW of power, while the entire e-fan aircraft runs off just 60kW of power.

13 Niven Winchester et al, The Impact of Advanced Biofuels on Aviation Emissions and Operations in the US, Feb 2015

Non-powerplant Changes

7.15 A number of opportunities exist for commercial aircraft design to develop away from what has become "the norm" in aircraft design. One idea that has been discussed on a number of occasions – albeit often as too radical – is known as the blended wing body, and an even more radical change is known as the flying wing.

Figure 35: Concept of a Blended Wing Body Airliner



Source: Wikimedia Commons

7.16 Both designs are significantly more fuel efficient and quieter than traditional commercial aircraft designs, although estimates vary greatly. The greatest challenges in their implementation will be a redesign of existing infrastructure (as the designs require long wingspans/shorter fuselages) and acceptance from passengers of the new configurations, such as less windows.

Summary

7.17 With some of these technology options, key challenges including financial viability of research and development may not be resolved from the private sector alone. As we have seen very recently, projects that appeared commercially attractive with oil at $150/barrel no longer appear viable when it falls below $50/barrel. Low oil prices in the short term affects the development of long-term market-based environmental solutions, including the UN's Clean Development Mechanism which underpins global carbon trading, that are currently struggling to attract investment while oil remains cheap. Governments have a role to play here in supporting R&D or requiring its own departments to use or develop clean technologies that will filter through into the commercial world over time.

7.18 The military plays a part here, particularly in terms of aviation. The US Department of Defence has mandated itself to reduce reliance on fossil fuels, targeting 50% from renewable sources by 2020. The US Air Force alone uses an estimated 2.4 billion gallons of jet fuel annually, and its investment in support of the US biofuel industry to generate over 1bn gallons of biofuel for its consumption can only bring forward production solutions. The same goes for airframe technology, where radical designs may be tested and developed for military use many years before entering commercial service.

7.19 We conclude that the aircraft of the future is likely to be very different to that of today, but is unlikely to be taking to the skies any time before the mid-2030s at the earliest, and more likely post-2040. Until then, working on incremental efficiency gains and a combination of policy intervention, development of international standards and research pathways coupled with market forces, will drive change at a sufficient rate to ensure radical technologies are not essential to enable short-term growth.

8 Conclusions

8.1 The UK aviation industry clearly has to show responsibility for its environmental and social impacts. For many years the wider industry has avoided CO_2 targets, and this is something that must be rectified swiftly in order to bring the global industry into line and make it as answerable as other sectors. However, in the UK this process is already underway, and EU regulations have made possible the stringent measurement of NOx and other gases which can harm air quality around the airport perimeter. The outcomes of the UK's Airports Commission have shown that there is an urgent need to build more airport capacity, but this cannot come at the detriment of sustainability.

8.2 Local air quality is a problem that is rightly high on the public agenda but it is difficult to unravel the full impact of aircraft from NOx emissions from the wider transport network, of which London is the worst performing capital city in Europe[14]. Firstly, the impact is limited to the immediate surroundings of the airport itself, as emissions from altitude are sufficiently dispersed so as not to be a problem for residents on the ground. The impacts from aircraft themselves are relatively modest, with research suggesting airport vehicles and surface access add an equivalent amount. Surface access is difficult to split out from with non-airport traffic – for instance at the air quality monitoring stations around Heathrow, the highest NOx emissions are seen at areas where less than 5% of the NOx comes from airport traffic. Where emissions such as NOx are a problem, there are a number of opportunities for reducing these impacts with more efficient airport operations – and new technology will have an impact as well. With surface access forming a substantial portion of these emissions, the continuous improvement in automotive technology should significantly reduce the impact from the airport, for instance the DfT forecast a 62% reduction in NOx from road vehicles by 2040.

8.3 From a noise perspective the industry has been driving gains since the height of the jet-age in the 1960s and 70s, however it is apparent that residents local to airports are still affected by noise nuisance. We consider the means to address this are three-fold. Firstly, continued technology improvement through new aircraft and retro-fitting upgrades to older aircraft – we forecast that the average aircraft will be at least 9dB quieter by 2050, without any radical new technology. Secondly, the tweaking of airport operations to minimise noise to local communities, such as the use of continuous descent approaches and displaced runway thresholds, could save up to 9dB. Use of PBN in conjunction with a legally binding flight paths with guaranteed periods respite can offset the impact of continual and concentrated noise. Airports need to continue and further develop engagement with their local communities in order to disseminate information and increase awareness of the airports operation, providing the knowledge and prior warning of flightpath usage that should make living under a flightpath a less stressful experience, with guaranteed periods of respite wherever possible. This should be enhanced by giving communities access to an independent arbiter in the form of a noise authority with powers to monitor and report on performance against agreed limits and penalise where necessary.

14 Clean Air in London - http://cleanair.london/sources/guide-to-sources-london-has-the-highest-levels-of-nitrogen-dioxide-of-any-capital-city-in-europe/

8.4 CO_2 is a global issue that must be tackled with global measures. The fuel efficiency of new technology will see the industry becoming more fuel efficient by around 1.6% per year, however this will almost certainly be outstripped by increasing demand from developing economies. Carbon trading and greater multinational coordination are the potential long-term solutions to this, along with a continued drive to deliver improving technology. In the meantime, the UK should avoid attempting to address its own problem with unilateral action. By stifling the country's air transport industry, the UK would only succeed in pushing its portion of emissions to other countries, in what is undoubtedly a global problem, whilst allowing delays and severe inefficiencies to become commonplace. Furthermore, the evidence laid out in this report suggests that the hub model is a more efficient means of transporting passengers over long distances than the point-to-point alternative, and therefore capping airport growth as an environmental measure is likely to be flawed if it inhibits a hub model from functioning effectively.

8.5 Sustainability is undoubtedly one of the greatest challenges facing the aviation industry in the 21st Century, and we have explored various impacts and mitigation measures available. Aviation can meet almost all of its targets for sustainability by following the current trend, helped by pragmatic engagement with communities and some regulatory intervention. Noise and local air quality impacts have been improving greatly as new technology becomes greener and more efficient. CO_2 is also falling on a per passenger basis, however high rates of growth in developing regions of the world are likely to lead to an overall increase in CO_2 without further action. The aviation industry requires greater coordination on a global scale in order to contain this problem, including encouraging greater streamlining through the use of hubs and a global approach to carbon trading and other measures.

Notes

Author Profile

Peter Hind is Managing Director of RDC Aviation and has over 20 years' experience in the aviation sector, including senior roles in the strategy and network planning team at bmi. He has also authored the ITC's reports on 'The Optimal Size of a UK Hub Airport' and 'Delivering improved airport capacity' which were submitted to the Airports Commission. Peter also teaches Sustainable aviation on the Air Transport Management MSc at City University.

The Brief

This Report was commissioned by the Independent Transport Commission (ITC) to review and assess advancements in the sustainability of air travel over recent decades, as well as to determine whether or not progress can be expected to continue. The report is intended to give an independent assessment of how technology and operations have contributed towards improving the sustainability of air travel, particularly in the areas of emissions and noise, and seeks to determine the scale of progress made so far and whether or not this is likely to continue over the next 30-50 years.

Disclaimer

Any statements made in the Report that are not historical fact are based on data and information provided by others. RDC has not verified the accuracy of any such data and information unless otherwise specified. Any conclusions, recommendations, forecasts, projections or estimates contained within the Report constitute forward-looking statements that, by their very nature, involve risks and uncertainties that are beyond our control. No allowance has been made for changes in government policy or regulation; economic performance; price; taxation; company failure; strategic change; ownership change; business failure; or other external factors that could cause actual results to differ materially from those shown in the Report. RDC specifically does not guarantee or warrant any estimate, forecast or projected outcome contained in this Report.

The information contained in the Report was produced between October 2015 and January 2016 and is based on the conditions encountered and information available at that time.

RDC Aviation
The Hub
40 Friar Lane
Nottingham NG1 6DQ

t: +44 (0) 115 852 3043
f: +44 (0) 115 924 0361
www.rdcaviation.com
info@rdcaviation.com

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For further information and electronic copies please visit:

www.theitc.org.uk

or write to:

The Independent Transport Commission

70 Cowcross Street

London

EC1M 6EJ

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Independent Transport Commission
70 Cowcross Street
London
EC1M 6EJ

Tel No: **0207 253 5510**
www.theitc.org.uk

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