Energy and Emissions Statement - 2006/7

Rail travel sharply reducing its carbon footprint, down 5% in one year and 25% in the last ten years.

Rail travel has half the carbon footprint of car and a quarter that of domestic air measured on a per passenger kilometre basis.

October 2007

Summary

This paper updates the *Baseline Energy Statement* published in March 2007, using the latest data available to show the current carbon dioxide (CO_2) emissions of passenger rail (2006/7), and of car and domestic air travel (2005) together with trends over the last ten years. The report uses CO_2 emissions per passenger kilometre as the yardstick for comparison and trend.

On average, passenger rail currently emits approximately half the carbon dioxide per passenger kilometre of cars and a quarter that of domestic air.

On the railway the regenerative braking project and other measures were successful last year in reducing energy use for electric trains in absolute terms (down by 2.5%) whilst they carried more people (up 8%).

In the last year rail reduced overall emissions per passenger kilometre by 5% after taking into account a small increase in the carbon intensity of UK electricity generation. This brings the total reduction for the last ten years to 25% - some three times the improvement seen for the car.

In the case of car travel, in the latest year average carbon emissions per passenger kilometre fell by 1.5%, making a 9% reduction over the last 10 years. Domestic air travel has increased in carbon intensity by 11% over the decade.

This analysis is based on average figures. Quite clearly, for any specific journey, the occupancy of the vehicle is a key factor. Four people in a car will perform well on a CO_2 per passenger kilometre basis compared to the most efficient train with few people in it. Similarly the averages quoted here cover a range of traffic conditions and may well differ from those of individual operators running specific services. Nonetheless these average figures give an important indication of the difference in performance of the three modes.

Looking ahead, rail can carry some additional passengers with negligible additional carbon impact. However, as new capacity is put on to carry additional people, that extra capacity will require energy. It is estimated, very approximately, that rail can provide additional passenger capacity at a marginal carbon intensity of about half the current figure.

Energy and emissions saving measures are crucially important and train operators are committed to further improvements. Brake regeneration (where electric trains return energy to the power supply) is now active on some parts of the network, with savings of up to 20% being seen in these areas. Similarly in-service biodiesel trials have begun to assess the feasibility of more widespread use, providing it can be procured from sustainable sources at a realistic cost.

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1. Rail, car and air – overview

In aggregate, passenger rail contributes just 0.5% to total UK CO_2 emissions. This compares to 12.6% for passenger cars and 0.4% for domestic air, as shown in the table below.

Rail freight contributes a small fraction of total UK CO_2 emissions, while road freight contributes 8.2%.

Table 1. Transport and UK CO_2 emissions

Mode	$MtCO_2$ 2005	% UK emissions (by source)
Passenger cars and taxis	69.9	12.6%
Passenger rail	2.7	0.5%[*]
London Underground	0.4	0.1%[#]
Civil domestic aviation	2.5	0.4%
Buses and coaches	3.6	0.6%
Motorcycles and mopeds	0.4	0.1%
Other road emissions	0.6	0.1%
Total passenger transport	**80.1**	**14.4%**
Road freight (LGV and HGV)	45.4	8.2%
Rail freight	0.8	0.1%
Shipping (national navigation)	4.2	0.8%
Total freight transport	**50.4**	**9.1%**
Other mobile machinery	0.4	0.1%
Total transport	**130.9**	**23.6%**
Total UK	**554.2**	
International aviation	*35.0*	*6.3%*
International shipping	*5.9*	*1.1%*

Source: Transport Statistics Great Britain (updated 2006), National Atmospheric Emissions Inventory data 2006 and LUL Environment Report, 2006. Numbers are rounded in some cases.

Note: International aviation and shipping are not included in the UK National Inventory and are shown above as equivalent percentages of the national total.

In looking at how carbon intensity has changed over time the comparison between modes is calculated on the basis of CO_2 emissions per passenger kilometre. In the case of rail, the data is from ATOC and National Rail Trends, combined with Digest of UK Energy Statistics (DUKES) and DEFRA data to derive electric and diesel emissions. In the case of car and air, the data is from national statistics, principally the National Atmospheric Emissions Inventory (GB data) and Transport Statistics Great Britain.

Table 2 shows the average CO_2 emissions from rail, air and car per passenger kilometre together with the change since 1995/6. A more detailed commentary on the carbon intensity of each mode is provided further below.

Table 2. Estimates of CO_2 emissions by mode and change since 1995/6 (GB)

Mode	Emissions gCO_2/pkm (latest year available)	Emissions gCO_2/pkm (previous year)	% change on year	% change since 1995/6
Passenger rail – diesel	69	74	-6%	-22%
Passenger rail – electric	51	53	-5%	-28%
Passenger rail – overall	58	61	-5%	-25%
Car and taxi	104	106	-1.5%	-9%
Domestic air	227	214	+6%	+11%

Source: NAEI (GB data), TSGB (for car and taxi, domestic air) and National Rail Trends, NAEI, DUKES, ATOC data (rail). Figures are rounded.

Latest year 2006/7 for rail, 2005 for car/taxi and domestic air.

Rail is also important in freight movements, particularly for high volume/weight goods. Rail freight has advantages over road in terms of security, accident rates, reliability (especially over long distances)[1] and environmental performance. The relative carbon intensity of the different freight modes is shown below.

Table 3. CO_2 emissions from road and rail freight (GB)

Mode	$MtCO_2$ 2005	Total billion tonne km, 2005	Emissions gCO_2/tonne km
HGV Road freight (rigid and artic >3.5 t)	27.2	153	178
Rail freight	0.8	22	37

Source: NAEI, TSGB.

While the amount of freight transported by rail is low compared to road, the table shows that rail has a far lower carbon intensity, on average emitting some five times less CO_2 per tonne km. This confirms the very positive CO_2 advantage rail is known to have over road in the movement of goods.

2. Domestic air

Between 2004 and 2005, average emissions of CO_2 per passenger km from domestic air increased by 6%. Looking back over the last decade, while the figures vary from year to year, overall the figure has risen by 11% according to national statistics.[2]

A more detailed analysis of the underlying data shows an overall increase in seat occupancy over the past decade (from 63.3 to 68.0% for all scheduled domestic flights), although occupancy fell in 2005 (to 65%). Aircraft fuel efficiency has also improved over the same period, improving by 1 to 2 % per year.[3] However, these changes do not appear to have translated through into the overall figures. One reason could be an increase in the number of shorter city to city domestic trips than a decade ago.[4]

Looking ahead aviation emissions are predicted to grow considerably.

Modal shift from air to rail for domestic and short haul European trips is a realistic way to reduce carbon emissions for many routes. Rail has cut heavily into the London-Manchester air market and similarly Eurostar has successfully gained a dominant market share (between 65 and 70%) on London-Paris and London-Brussels routes. The opening of High Speed 1 into London St Pancras in November this year will further reduce journey times and strengthen rail's competitive position.

3. Cars

Despite the increasing availability of high fuel efficiency cars, in practice these seem to have had only a small effect on emissions from the whole car fleet, which have seen only modest improvements over the past decade.

In the past decade, there has been a reduction in average CO_2 emissions from new cars in the UK fleet of around 12% and an 8% reduction in the average for all cars in the fleet.[5] While this improvement is due in part to technological advances, it is also driven by the greater share of diesel vehicles in the fleet (up 10% to 20%).[6,7]

The average number of occupants per car has fallen very slightly, from 1.6 in 1995/97 to 1.58 in 2005. Interestingly, in 2005, 61 per cent of cars on the road had only one occupant.[8]

Overall these trends, combined with other factors such as lower traffic speeds and congestion, have resulted in a reduction in CO_2/passenger km of about 9% since 1995.[9]

In the near future new EC proposals aim to mandate reductions in average emissions from new cars from the current average of approximately 160gCO_2/vehicle km to no more than 130gCO_2/vehicle km by 2012 (this is anticipated to fall to 120gCO_2/vehicle km when greater use of biofuels and other complementary efficiency measures are taken into account). Even if this target were to be achieved, with current load factors, average car emissions per passenger kilometre would, at around 75gCO_2/vehicle km, still be above the current rail average.

Looking ahead, despite attempts to improve new car efficiency, it is likely that emissions from cars will rise. Whilst much of current Government policy is aimed at improving the efficiency of new cars and reducing the carbon content of fuel (e.g. through increased use of biofuels) this seems unlikely to be enough to tackle rising demand for car travel, nor consumers' appetite for high-emitting cars. For this reason mandatory vehicle standards need to be given serious consideration.

4. Rail

The detailed position of diesel and electric rail is discussed further below.

As Table 2 indicates, passenger rail overall has reduced its emissions of CO_2 per passenger kilometre by 5% on 2005/6 and by an estimated 25% since 1995/6. This improvement has been achieved by a combination of improved energy efficiency, passenger growth and changes in the carbon intensity of the electricity generation mix.[10] Whilst the newer trains introduced onto the network in recent years do tend to use more energy, this is less than has been supposed. Further, they are equipped with a much wider range of passenger facilities and have delivered greater capacity on many routes, in turn enabling higher passenger loadings.

4.1 Rail – diesel traction

As Table 2 indicates, average carbon dioxide emissions from passenger traffic on diesel trains are estimated to be 69gCO_2/passenger km. This represents a 6% improvement on last year. Whilst diesel consumption has increased very slightly (by just under 1%), passenger kilometres travelled on diesel trains have risen by an estimated 7%.

The small increase in consumption observed is due to a combination of increased mileage and possibly some other factors, including the impact of newer, more powerful diesel rolling stock. Nonetheless the newer stock provides a much improved passenger experience which has contributed to the growth in passengers.

Looking back to 1995/6, we do not have accurate historic records of diesel consumption. However we have estimated that emissions per passenger km have fallen by 22% between 1995 and 2006/7 based on the following considerations:

- Vehicle kilometres have increased by 22%
- Passenger kilometres have increased by 57%
- Some increase in fuel consumption by the new diesel trains compared with older, lighter trains.

Taken together this has resulted in improved utilisation of existing train capacity, and commensurate improvement in carbon dioxide emissions per passenger km. Table 4 below summarises the current position and change over time.

Table 4. Diesel consumption and estimated change in CO_2 emissions

Rail - diesel	2006/7	2005/6	% change on year	Estimated % change since 1995/6
Diesel use (million litres)	463.7	459.3	+0.9%	-
Diesel vehicle km (million)	893	889	+0.4%	+22%
Thus, litres per vehicle km	0.519	0.517	+0.5%	+5% (est.)
Passenger km (billion)	17.9	16.68	+7%	+57%
Thus, loading (passenger km/vehicle km)	20.05	18.76	+7%	+29%
Thus, litres per passenger km	0.026	0.028	-6%	-22%
gCO_2 emissions per litre	2674	2674	-	-
Thus, gCO_2 per passenger km	69	74	-6%	-22%

Source: ATOC data. Numbers are rounded in some cases. Note: for the purposes of this analysis only diesel fuel consumed directly by operators has been considered – this excludes the production and distribution of such fuels and associated emissions.

4.2 Rail – electric traction

There are three factors to consider in any calculation of CO_2 emissions per passenger km from electric trains:

- Energy consumption (kWh) per vehicle km. Over the past year energy consumption in absolute terms has fallen by about 2.5%, in part reflecting the impact of energy saving initiatives being implemented by operators (e.g. regenerative braking) but also the relatively mild 2006/7 winter temperatures.[11] Whilst electric vehicle kilometres have fallen only very slightly, overall energy consumption per vehicle kilometre has fallen by approximately 2%.
- Loading – the number of passengers in a vehicle.
- Changes in the UK generation mix. Carbon intensity in 2006 is predicted to have increased due to a temporary increase in the use of coal resulting from

high gas prices (although these increases have now reversed in the first two quarters of 2007). This increase in coal use has been used to estimate the likely increase in the carbon intensity of the 2006 generation mix. Looking further back, since 1995, the carbon intensity of the UK generation mix is estimated to have fallen by 5%.

Table 5. Changes in the UK electricity generation mix since 1990 and forecast to 2020

Year	Generation mix (%)						
	Coal	Oil	Gas	Nuclear	Renewables	Other	gCO_2/kWh
1995	46	3	18	26	2	6	537
2005	34	1	37	20	5	4	487
2006	38	1	34	19	5	4	512
2020 without Energy White Paper Policy Options	29	0	49	6	12	5	454 (down 11% on 2006)
2020 with Energy White Paper Policy Options	19	0	53	7	16	5	384 (down 25% on 2006)

Source: DUKES; DTI UEP26; Energy White Paper 2007, NAEI, Defra GHG company reporting guidelines. Note: Due to rounding figures for some years may not equal 100%.

4.2.1 Overall changes in emissions from electric traction

The overall energy use and change in emissions from the electric railway are shown in the table below. In the last year, energy use has declined by 2.5%, vehicle kilometres have fallen very slightly, by 0.5%, and passenger km have increased by 8%. Finally, the carbon intensity of the UK generation mix has increased by an estimated 5%. Putting these factors together, carbon dioxide emissions per passenger km have reduced by 5%.

Looking further back, CO_2 emissions per passenger km from electric trains have improved by 28% since 1995/6. Trains are more efficient, passenger loadings have increased and there have been improvements in the electricity generation mix.

Table 6. Electricity consumption and change in CO_2 emissions

Rail - Electric	2006/7	2005/6	% change on year	% change since 1995/6
Electricity consumed (GWh)	2,820	2,892	-2.5%	+16%
Electric vehicle km (million)	1,444	1,451	-0.5%	+23%
Thus, kWh per vehicle km	1.95	1.99	-2%	-6%
Electric passenger km (billion)	28.93	26.86	+8%	+55%
Thus, loading (passenger km/vehicle km)	20.04	18.51	+8%	+26%
Thus, kWh per passenger km	0.098	0.108	-9%	-25%
gCO_2 per kWh	512	487	+5%	-5%
Thus, gCO_2 per passenger km	51	53	-5%	-28%

Source: ATOC data. Numbers are rounded in some cases.

These emissions figures are based on the average UK electricity generation mix. The actual picture for electric rail is very much better than the table above would suggest since operators source electricity from British Energy whose carbon intensity of supply is much lower than that of the average generation mix – around $100gCO_2/kWh$, about a fifth of the UK average – largely due to the high proportion of nuclear generation (approximately 87%) in the total.

5. The Future – Rail

In this section we consider the likely changes to the carbon intensity of rail as a consequence of carrying additional traffic.

5.1 Electric rail

As has already been noted, the future carbon performance of electric rail is fundamentally related to improvements in energy efficiency, passenger loadings and the carbon intensity of UK power generation. The latter factor is particularly important; as the carbon intensity of power generation falls so too does that of electric rail. This improvement is in addition to any technical and operational improvements implemented by operators e.g. regenerative braking.

5.1.2 The UK electricity generation mix

The forecast carbon emissions from UK electricity generation are taken from the recent Government White Paper on Energy (DTI, 2007). They are summarised in Table 5 above and show a reduction of 25% by 2020. This forecast assumes that certain key policy measures, set out in the document, are adopted. If they are not adopted, the forecast reduction is only 11%.

The key policy measures referred to in the White Paper on Energy are to:

- Encourage renewables through strengthening the delivery of the Renewables Obligation, improve the planning and consenting process for on and offshore renewables and improve grid connections for on and offshore renewables;

- Move towards commercial scale carbon capture and storage and;
- Consult on the potential for new nuclear power.

As rail is a growing industry absolute reductions in carbon emissions will be difficult to achieve unless the main sources of its energy become themselves less carbon intensive. This means, crucially, that the carbon intensity of UK electricity generation must be sharply reduced. The policy measures outlined above therefore need to be adopted as urgent matters.

5.1.3 Improving the efficiency of electric rail

The industry is actively pursuing further energy savings from electric traction through the roll-out of regenerative braking (all AC fleets with the technical capability to regenerate are now in operation; work to enable regenerative braking on the DC network is underway), trials of on-train energy metering to manage energy consumption and training drivers in more energy efficient driving techniques. In sum these measures should improve the energy efficiency of electric rail in the medium term.

Looking further ahead the industry is also considering trialling hybrid trains and assessing the longer-term role that hydrogen fuel cells could play. The Government is setting challenging requirements for train mass and flexibility of fuel source as part of the Intercity Express Project in the anticipation that the cost of installing future new technologies such as fuel cells (if they become viable) will be minimised.[12]

5.2 Diesel rail

The industry is also pursuing a range of initiatives designed to reduce the carbon intensity of diesel operation including:

- Biodiesel. Overseen by a cross-industry Biodiesel Working Group, an in-service trial of biodiesel on Virgin Cross Country is currently underway, supported by test-bed trials of additional engine types. The object is to understand the operational impact of biodiesel such that, providing robust sustainability criteria are met, it can be used more widely across the railway.
- Re-engining of High Speed Trains (HSTs). An ongoing programme of re-engining will see the existing fleet of HSTs substantially overhauled, reducing fuel consumption by as much as 15%.[13]
- Other measures such as selected engine running where appropriate and reduced engine idling (whereby engines are automatically shut down after a pre-determined period e.g. in stations). Both should further reduce CO_2 emissions from diesel operation.

Taken together, these activities will have a useful impact on the future level of carbon emissions from diesel traction.

5.3 Future emissions on a per passenger km basis

In the immediate short term, marginal additional rail traffic will have a negligible carbon impact. Over the next five or so years, additional traffic can be carried on the rail network with only a small penalty in terms of carbon dioxide emissions.[14]

Looking further ahead the railway is likely to be called on to carry significantly more traffic and it is interesting to consider how this might be done.

Future growth in traffic will be carried by a combination of:

- Increased load factors - which will have negligible carbon impact.
- Higher capacity trains – adding rolling stock to an existing train might be expected to have a lower carbon impact compared to running additional trains at higher frequency.[15]
- Additional trains – where the overall energy efficiency of new trains could be significantly improved due to a combination of operational measures and technical and design improvements.[16]

On this basis we estimate, very approximately, that rail can provide additional passenger capacity at a marginal carbon intensity of about half the current figure.

[Notes to text are located at the end of this report.]

APPENDIX A

Notes on data sources

1. Carbon dioxide emissions from diesel trains have been calculated from ATOC fuel use data using the appropriate emissions factor from the Defra Greenhouse Gas Company Reporting Guidelines.

2. Carbon dioxide emissions from electric trains have been calculated from ATOC data on train electricity consumption (adjusted for losses in the high voltage national grid and losses in the rail electricity distribution network). Information on the emissions from major power stations has been taken from the NAEI and combined with information on electricity generated from major power stations and renewable generators from the Digest of UK Energy Statistics (DUKES).

3. Carbon dioxide emissions for car and taxi and domestic air travel have been taken from the National Atmospheric Emissions Inventory (NAEI), collated by Netcen for Defra and published in the National Greenhouse Gas Inventory reports. To match the passenger statistics from Transport Statistics Great Britain (TSGB) the inventory data output for Great Britain has been used.

4. Data on passenger km is taken from Department for Transport figures published in TSGB. Note TSGB does not give values for car and taxi billion passenger km but the value can be derived from the average occupancy rates quoted (1.64 for cars and taxis). For rail passenger km data contained in National Rail Trends combined with ATOC data has been used for the calculation of rail diesel and electric values, with the split between electric and rail passenger km provided by ATOC.

APPENDIX B

Notes to tables

Table 1.

1. Passenger rail emissions are National Rail only. Estimated using ATOC data and including emissions from electricity generation. This value cannot be compared with the estimate in TSGB or the NAEI, which only reports diesel rail (i.e. which excludes emissions from electric traction from passenger rail and LUL).
2. LUL emissions estimated using published LUL data.
3. Rail freight emissions from NAEI data.
4. Values for total transport emissions differ slightly from TSGB Table 3.1. which quotes 129 $MtCO_2$ from transport, equivalent to 23.3%. The numbers here are higher as electricity use for national rail and LUL transport is also allocated for the purposes of a comparison across modes.
5. Figures for international aviation and international shipping are shown as percentage equivalent of total UK emissions only and are not included in the reported UK National Inventory. The 6.3% quoted for international aviation represents emissions associated with fuel usage from international aviation bunkers within the UK. This method only accounts for emissions from international flights leaving the UK. Furthermore these values only account for the CO_2 from aircraft, they do not account for other potential climate effects from aviation emissions at altitude.

Table 2.

1. Latest year available refers to 2006/7 for rail, 2005 for car/taxi and domestic air and previous year refers to 2005/6 for rail, 2004 for car/taxi and domestic air. For comparisons over the past decade, 1995/6 is used for rail, 1995 for car/taxi and domestic air.
2. The 2006 emissions value for electric rail has been calculated using a provisional estimate of CO_2 from the 2006 UK generation mix based on DTI March 2007 Energy trends (see also notes to Table 5). The carbon intensity for 2006 is around 5% higher than 2005 due to the increased coal use due to higher gas prices.
3. National Rail Trends and ATOC passenger km data has been used for the calculation of rail diesel and electric values, with the split between electric and diesel passenger km based on vehicle km operated.
4. The value for rail (overall) is very close to the value in the recent Defra GHG company reporting guidance (http://www.defra.gov.uk/environment/business/envrp/pdf/conversion-factors.pdf), which gives a value of 60gCO_2/pkm for rail. The minor difference is due to the updated information used here.
5. The 2005 value for cars and taxis can be compared to the Defra GHG company reporting guidance transport methodology paper on passenger transport emissions factors (see: http://www.defra.gov.uk/environment/business/envrp/pdf/passenger-transport.pdf). This provides an average value for the UK car fleet of 180 gCO_2/vehicle km. Using an average occupancy of 1.64 for cars and taxis (TSGB, 2006) this gives a value of 110 gCO_2/pass km, which is very slightly higher than the GB value given in the table. However, the Defra GHG company reporting guidance also recommends an uplift of 15% (agreed with DfT) to take into account further real-world driving effects. This increases the average car value in the GHG guidance to 208 gCO_2/vehicle km (127 gCO_2/pass km). Using this uplift would increase the car value in the table. However, following discussion with the NAEI team, we do not believe it appropriate to include the uplift here as the NAEI numbers above are based on a bottom-up method that is reconciled with total fuel sale statistics. Note that should the uplift be subsequently included in the NAEI it would increase the car CO_2 values shown by 15%.
6. The 2005 value for domestic aviation is higher than the illustrative values in the Defra GHG company reporting guidance which quotes a value of 158 gCO_2/pass.km which, with the standard distance uplift factor of 109% applied, is 172 gCO_2/pass.km. This is largely because the Defra guidance gives a value for a London-Scotland trip (463km), which is one of the longer domestic flights. Shorter flights have higher gCO_2/pass.km values, because of influence of the landing and take off emissions on the overall journey total.

Table 4.

1. There have been some minor revisions to the data from 2005/6 however these do not affect overall carbon intensity.
2. Emission factor for gas oil taken from DEFRA GHG company reporting guidelines (2007).
3. New diesel trains are assumed to use more diesel than the old trains they replace, but only part of the fleet has been renewed. Overall the effect is assumed to be an increase in diesel use per vehicle km of approximately 5%.

Table 5.

1. 'Other' includes imports, pumped storage.
2. Values for carbon intensity based on major power producers and excluding imports/pumped storage. Values exclude transmission losses (which are incorporated in later emissions calculations). Values are consistent with the new Defra GHG company reporting guidance, which gives a value for 2005 of

527gCO_2/kWh (http://www.defra.gov.uk/environment/business/envrp/pdf/conversion-factors.pdf), which is equivalent to the value shown after the Defra value is adjusted for transmission losses (at 7.5%).

3. The 2005 value is minor revision from the value presented in the previous version of the ATOC Baseline Energy Statement due to revisions in the final UK energy statistics (the previous value for 2005 was 489gCO_2/kWh).
4. The 2006 value for carbon intensity is based on the generation mix in 2006 (DUKES, 2007), and provisional estimates published by DTI in the March 2007 of Energy Trends. This indicates that CO_2 emissions from power generation increased by 4.75% between 2005 and 2006 http://www.berr.gov.uk/files/file38674.pdf) to 49 MtC and leads to the value of 512 gCO_2/kWh. This increase was due to higher coal use during 2006.

Table 6.

1. There have been some minor revisions to the data from 2005/6 however these do not affect the overall figures for carbon intensity.
2. The aggregate electricity consumption numbers include rail distribution losses but exclude losses in the national transmission system (see note 4 below).
3. The figure for carbon intensity of 512gCO_2/kWh is a provisional estimate for 2006. See notes to Table 5 above.
4. In converting kWh into carbon emissions (gCO_2/pkm) values are adjusted include losses in the high voltage national grid (estimated at 1.5% in DUKES) to match power station emissions to electricity supplied to the rail network.

APPENDIX C

Passenger cars and taxis

Fuel consumption

Data on car fuel consumption is collated by DfT, published in TSGB. Table 3.4 of TSGB below shows that overall fuel consumption is fairly similar to 1995/7 levels – for 'all cars (miles per gallon)' there has been a small increase in fuel efficiency in the overall fleet from 32 to 33 miles per gallon over the period 1995 to 2005.

3.4 Average fuel consumption by age and type of vehicle and type of fuel: 1995/1997 to 2005

a) Passenger cars[1]						Miles per gallon/litres per 100 km
	1995/1997	1998/2000	2002	2003	2004	2005
Petrol cars						
Up to 2 years	32	30	31	31	32	32
Over 2 to 6 years	31	30	31	31	31	31
Over 6 to 10 years	30	30	31	31	30	30
Over 10 years	29	28	28	29	29	30
All petrol cars	31	30	30	30	30	31
Diesel cars [2]						
Up to 2 years	43	35	40	40	41	40
Over 2 years	44	39	38	38	39	38
All diesel cars	44	38	39	39	40	39
Company cars [2]	34	30	35	34	36	36
Private cars	32	31	31	32	32	32
All cars (miles/gallon)	32	31	32	32	32	33
All cars (litres/100 km)	8.8	9.1	8.9	8.9	8.8	8.7

b) HGVs						Miles per gallon
	1996	1999	2002	2003	2004	2005
Rigid vehicles	8.2	8.3	8.1	7.8	8.3	8.3
Articulated vehicles	7.3	7.7	7.6	7.5	7.9	8.1

1 All figures are based on weighted data and therefore differ from previously published figures which were based on unweighted data.
2 These estimates have a large sampling error because of the smaller sample sizes involved.

Cars: 020 7944 3097
HGVs: 020 7944 4261
Sources - Passenger cars: National Travel Survey
HGVs: Survey of Road Goods Transport

Source: DfT, TSGB 2006.

Fuel efficiency translates directly into CO_2 emissions. There have been improvements in car fuel efficiency, and reductions in CO_2, for new cars (of the same type) in recent years, though in looking at the overall picture, it is necessary to take account of the efficiency of new vehicles and the total fleet.

ACEA (the European Automobile Manufacturers' Association) cites that in the past decade, ACEA members have reduced CO_2 emissions for new vehicles in Europe by over 13%.[17,18] In the UK, the SMMT (Society of Motor Manufacturers and Traders) reports that average new car emissions have fallen from 190 gCO_2/km in 1997 to 169 gCO_2/km in 2005 (an 11% reduction) and 167 in gCO_2/km in 2006 (a 12% reduction)[19,20]

However, the falls in the overall average car are less (because of time taken for fleet turnover) – and are estimated by the SMMT to have fallen from 196 g/km in 1997 to 181g/km in 2006, an 8% reduction.[21]

Vehicle trends

There have been a number of trends on vehicle types over the past decade. The proportion of diesel fuel cars has increased significantly over the last decade, rising from 10% to over 20% of all cars licensed as shown below. This has been important in the improvement in fuel efficiency as diesel cars are typically 5-20 per cent lower CO_2 emitting than a petrol equivalent model.[22]

Table 1.3 Cars licensed: by ownership and propulsion type: 1996-2006

Thousands

		of which	of which						
Year	All Cars	Company	Petrol	Diesel	Other[1]	Per cent company	Per cent petrol	Per cent diesel	Per cent other
1996	22,238	2,283	20,052	2,182	4	10.3	*90.2*	*9.8*	*0.0*
1997	22,832	2,392	20,385	2,441	6	10.5	*89.3*	*10.7*	*0.0*
1998	23,293	2,424	20,591	2,693	10	10.4	*88.4*	*11.6*	*0.0*
1999	23,975	2,387	21,031	2,930	14	10.0	*87.7*	*12.2*	*0.1*
2000	24,406	2,519	21,233	3,153	20	10.3	*87.0*	*12.9*	*0.1*
2001	25,126	2,442	21,641	3,460	25	9.7	*86.1*	*13.8*	*0.1*
2002	25,782	2,320	21,839	3,912	30	9.0	*84.7*	*15.2*	*0.1*
2003	26,240	2,212	21,805	4,400	35	8.4	*83.1*	*16.8*	*0.1*
2004	27,028	2,293	21,977	5,011	41	8.5	*81.3*	*18.5*	*0.2*
2005	27,520	2,434	21,876	5,596	48	8.8	*79.5*	*20.3*	*0.2*
2006	27,830	2,410	21,635	6,135	60	8.7	*77.7*	*22.0*	*0.2*

1 Other propulsion types are electricity; steam; gas; petrol/gas; gas/bi-fuel; hybrid electric and gas diesel

Source: DfT, Vehicle Licensing Statistics 2006.

There has also been a rise in the number of vehicles with larger engine sizes, shown in the table below. Whilst this must be viewed in light of the increases in overall registrations, the much faster relative growth in >2l cars is evident up until recent years. However, more recently there have also been greater relative increases in more fuel efficient small car (supermini) markets.

Table 1.4 Cars licensed: by engine capacity: 1996-2006

Petrol Cars — Thousands

Year	Over:		700 cc	1,000 cc	1,200 cc	1,500 cc	1,800 cc	2,000 cc	2,500 cc	3,000 cc		All Petrol
	Not over:	700 cc	1,000 cc	1,200 cc	1,500 cc	1,800 cc	2,000 cc	2,500 cc	3,000 cc		Unknown	Cars
1996		44	1,770	2,464	5,573	5,862	2,878	626	483	349	1	20,052
1997		39	1,653	2,466	5,692	5,964	3,028	668	494	380	1	20,385
1998		32	1,544	2,405	5,767	6,070	3,142	714	502	412	1	20,591
1999		21	1,514	2,378	5,847	6,245	3,286	772	519	449	1	21,031
2000		22	1,492	2,329	5,904	6,342	3,346	807	523	468	1	21,233
2001		26	1,444	2,342	6,020	6,513	3,385	880	537	495	1	21,641
2002		31	1,389	2,351	6,046	6,660	3,361	939	542	520	1	21,839
2003		40	1,309	2,322	6,037	6,737	3,285	973	550	552	-	21,805
2004		50	1,267	2,306	6,109	6,877	3,215	995	566	590	-	21,977
2005		55	1,218	2,226	6,131	6,958	3,115	994	565	615	-	21,876
2006		59	1,195	2,112	6,145	6,952	2,989	981	565	636	-	21,635

Diesel Cars — Thousands

Year	Over:		700 cc	1,000 cc	1,200 cc	1,500 cc	1,800 cc	2,000 cc	2,500 cc	3,000 cc		All Diesel
	Not over:	700 cc	1,000 cc	1,200 cc	1,500 cc	1,800 cc	2,000 cc	2,500 cc	3,000 cc		Unknown	Cars
1996		1	3	2	92	941	782	262	71	27	-	2,182
1997		1	3	2	93	997	931	298	86	30	-	2,441
1998		1	2	1	92	1,028	1,100	331	105	32	-	2,693
1999		-	2	-	91	1,045	1,267	367	123	34	-	2,930
2000		1	2	-	91	1,053	1,429	397	140	40	-	3,153
2001		1	2	-	97	1,043	1,662	442	162	50	-	3,460
2002		2	1	-	136	1,027	1,983	511	195	57	-	3,912
2003		2	1	-	193	990	2,297	599	247	70	-	4,400
2004		2	1	-	272	978	2,662	701	312	83	-	5,011
2005		2	1	-	339	964	3,014	793	392	90	-	5,596
2006		2	1	-	412	961	3,292	891	483	93	-	6,135

Source: DfT, Vehicle Licensing Statistics 2006.

Car occupancy trends

The National Travel Survey (DfT) collates data on occupancy levels for cars over time. This data shows very slightly decreasing occupancy levels over the last decade. This has contributed to vehicle kilometres increasing more than passenger kilometres over the same period, and reflects smaller average size of households and increasing car ownership.

Table 6.2 Car occupancy: 1995/1997 to 2005

Number/percentage/thousands

	Vehicle occupancy		Status of people in car				
	Average occupancy	Single occupancy rate	Driver alone	Driver with passenger(s)	Passenger	Total	Unweighted sample size ('000 stages)
1995/1997	1.60	*60*	*38*	*25*	*36*	*100*	285
1998/2000	1.58	*61*	*39*	*25*	*36*	*100*	271
2002	1.59	*61*	*39*	*25*	*36*	*100*	213
2003	1.58	*61*	*39*	*25*	*35*	*100*	236
2004	1.57	*61*	*39*	*25*	*35*	*100*	233
2005	1.58	*61*	*39*	*25*	*35*	*100*	245

Source: DfT, NTS 2006.

Recent car emissions trends

The data on road transport kilometres from TSGB can be combined with carbon emissions data from NAEI (for GB only) to derive the carbon intensity over time for cars and taxis. This is summarised below. The top table shows the trend in CO_2 per vehicle km, and the bottom the trend in CO_2 per passenger km:

CO_2 per passenger km for car and taxi travel over time

Year	1995	1998	1999	2000	2001	2002	2003	2004	2005
$ktCO_2$	67221	69376	70533	70159	69583	70525	68798	68825	67724
Billion vehicle km	351.1	370.6	377.4	376.8	382.8	392.9	393.1	398.1	397.2
gCO_2/vehicle km	191.5	187.2	186.9	186.2	181.8	179.5	175.0	172.9	170.5

Year	1995	1998	1999	2000	2001	2002	2003	2004	2005
$ktCO_2$	67221	69376	70533	70159	69583	70525	68798	68825	67724
Billion pass km*	588	611.6	618.7	616.7	628.8	649.7	646.2	652.6	651.1
gCO_2/pass km	**114.3**	**113.4**	**114.0**	**113.8**	**110.7**	**108.5**	**106.5**	**105.5**	**104.0**

Source: NAEI, 2006; TSGB, 2006, NTS, 2006. Billion passenger km vehicle estimates are based on vehicle km and weighted occupancy values. Data on billion passenger km has been provided by DfT, who have provided data on billion passenger km back to 1998 (based on the new weighted occupancy analysis method). This indicates an average occupancy of around 1.64 (consistent with TSGB). Note, however, that the National Travel Survey quotes a lower occupancy rate for cars (only) of 1.58 for 2005 (Table 6.2 above).

APPENDIX D

Domestic aviation

Domestic air trends

Data has been collated for domestic air, using NAEI sources for carbon emissions from domestic aviation (GB) and TSGB passenger km data. The NAEI methodology was updated in 2006-7 and this new method has been used to estimate current and historic emissions – this leads to changes in the values to those reported in the previous ATOC energy statement.[23] The data shows an 11% increase in carbon intensity per passenger km since 1995. However, there is high year to year variability in the data and the statistics for 2005 are affected by the downturn presumably arising from the 2005 London bombings. Using 2004 as a more typical year, the statistics show a 5% increase in carbon intensity since 1995.

CO_2 per passenger km for domestic air over time

Year	1995	1998	1999	2000	2001	2002	2003	2004	2005
ktCO_2	1204	1504	1670	1807	1884	1884	1927	2101	2246
Billion pass km	5.9	7	7.3	7.6	7.7	8.5	9.1	9.8	9.9
gCO_2/pass km	**204.0**	**214.9**	**228.8**	**237.7**	**244.6**	**221.6**	**211.8**	**214.4**	**226.8**

Source: NAEI, 2006; TSGB, 2006.

Occupancy trends for domestic air

There has been an increase in seat occupancy over the past decade in domestic air transport (from 63.3 to 68.0% for all scheduled domestic flights), though there was a drop in passenger seat occupancy in 2005.

Year	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Scheduled	63.3	64.0	64.1	62.0	60.6	64.2	61.8	66.0	70.5	68.0	65.3
Non-scheduled	69.0	68.1	68.9	69.2	66.4	62.2	62.3	60.6	66.0	61.8	37.9
Total	63.4	64.0	64.2	62.1	60.7	64.9	61.8	65.9	70.4	67.9	65.0

Source: TSGB, 2006.

Fuel efficiency trends for domestic air

Aircraft fuel efficiency has also improved over recent periods, improving by 1 to 2% per year.[24]

As discussed in the future trends section, these improvements are likely to continue with the introduction of newer aircraft into the fleet, and the retirement of older aircraft. Note however that aircraft have long lifetimes, and so it will take considerable time for the most modern aircraft to completely replace the existing fleet. This is important as the current EU fleet is young (and so future improvements will take time to penetrate). While there will be continued efficiency gains, the estimated improvements vary. The aviation and global warming report (2003) examined the potential for fuel efficiency gains and found most studies estimating improvements of generally around 1 % per year (though sometimes these refer to new future aircraft and sometimes for the current fleet).[25] These improvements are unlikely to stop the overall growth in aviation CO_2 emissions overall, due to the predicted increases in demand.

Overall trends for domestic air

Despite the improvements in load factor and fuel efficiency, the values above show this has not translated through to a reduction in carbon intensity per passenger trip over time. It is possible that for domestic flights this is due to the increase in the number of shorter city to city domestic trips than a decade ago. These shorter trips have a higher carbon intensity due to the greater relative impact of the landing and take-off cycle on overall per passenger km emissions.[26]

The data may also be influenced by punctuality and delays. TSGB statistics shows the punctuality at United Kingdom Airports falling: the percentage of scheduled flights on time (within 15 minutes) was 79% in 1995, but only 73% in 2005. Journey delays also have a role: for aircraft, route delays in flight (e.g. holding patterns for congestion) significantly increase fuel consumption and CO_2 emissions because of the need to continue using fuel.

APPENDIX E

UK electricity generation

The future generation mix in the UK, and the carbon emissions from this mix, were set out in the recent Government Energy White Paper (DTI, 2007) and the underlying energy projections.[27] The future predictions vary with assumptions about fossil fuel prices, the EU ETS and carbon prices, and the effectiveness of policy measures (including those in the White Paper). The future generation mix (from the White Paper) is shown below. Three alternative projections are given for both future years, based on a low, central and high policy case (reflecting the uptake of policies outlined in the White Paper), each with a different generation mix (see table below). Only the high case includes consideration of new nuclear power stations, but varying degrees of coal with carbon capture and storage (CCS) are included across all three cases, as are increases in renewables.[28]

Projections of the future UK electricity generation mix and carbon intensity

Year	Generation mix (%)							Carbon intensity gCO_2/kWh
	Coal	Oil	Gas	Nuclear	Renewable	Import	Storage	
2005	34	1	37	20	5	3	1	487
2010 (baseline)	33	1	35	19	8	3	1	473
2010 (+ policy)								
Low policy	31	1	38	19	8	3	1	466
Central policy	31	1	36	19	9	3	1	462
High policy	32	1	34	19	10	3	1	458
2020 (baseline)	29	0	49	6	12	4	1	454
2020 (+ policy)								
Low policy	18	0	59	7	12	4	1	393
Central policy	19	0	53	7	16	4	1	384
High policy	22	0	44	9	19	5	1	362

Source: Energy White Paper DTI, 2007. Note: carbon intensity based on major power producers and excludes imports and storage.

Under all policy scenarios the carbon intensity of the power sector falls by varying degrees:

- In the baseline (without future policy), the carbon intensity falls by 3% between 2005 and 2010 and by 7% between 2005 and 2020.
- With the policies included in the White Paper, the carbon intensity of electricity generation falls by 5% by 2010 compared to 2005 (central estimate), with a range of 4% to 6% (low to high estimate).
- With the policies included in the White Paper, the carbon intensity of electricity generation falls by 21% by 2020, compared to 2005 (central estimate), with a range of 19% to 26% (low to high estimates).

What is interesting is that a significant part of the reduction in carbon intensity between 2005 and 2020, under all scenarios, is due to increased use of gas at the expense of coal and nuclear. Whilst there are some increases in renewables, these are really only marked in the central and high policy scenarios to 2020.

APPENDIX F

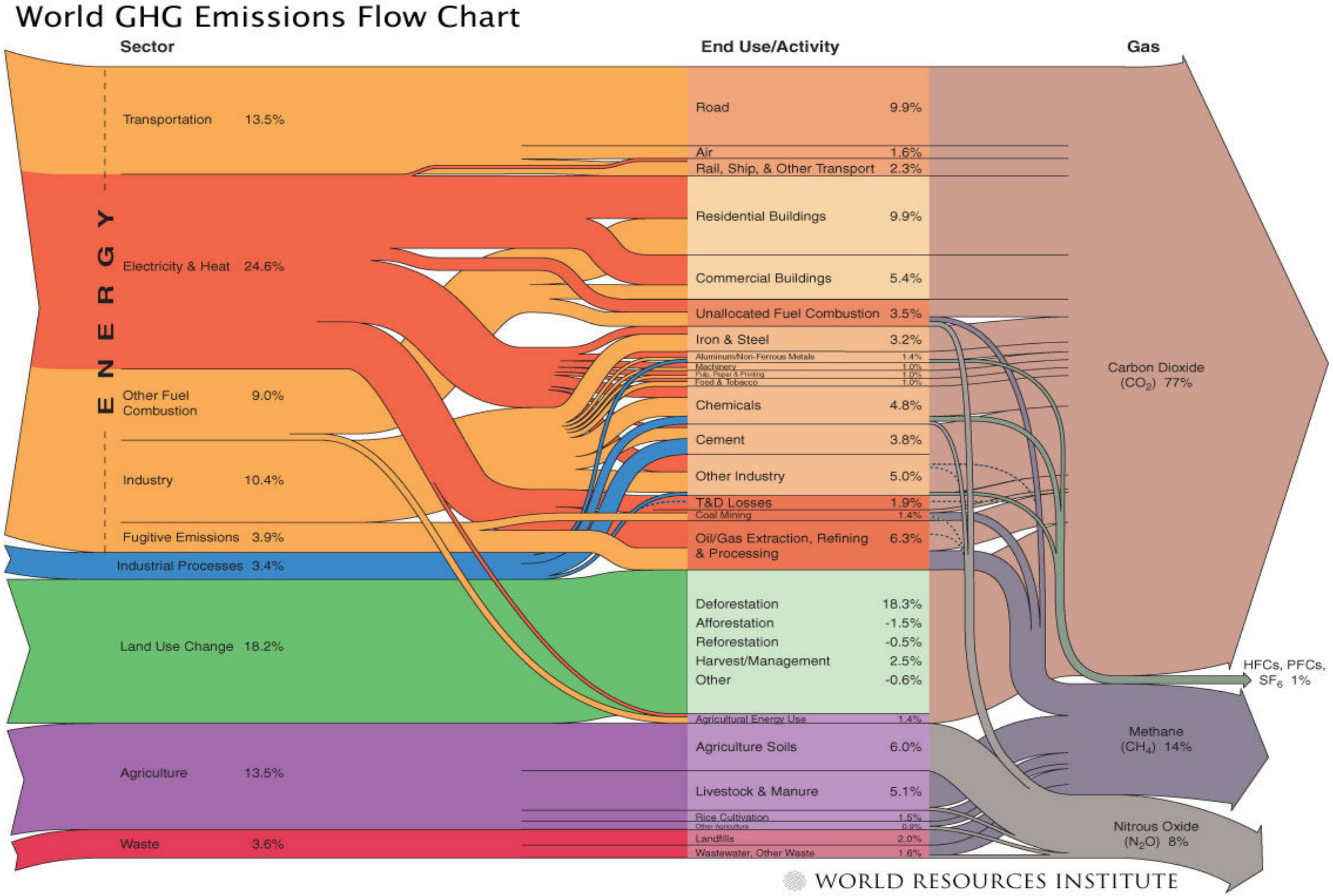
The wider context

It is particularly useful to understand the wider context in which the emissions from transport and rail in particular must be tackled.

The Stern Review on the Economics of Climate Change[29], particularly in Chapter 7 and related appendices, contains considerable information about the nature of global greenhouse gases (GHG). Although reference is best made to the report itself, one of the most useful diagrams from the report has been extracted and is reproduced further below.

While discussion of emissions often focuses on the immediate cause the graphic identifies the relationship with the end user since it is this that drives demand.

This illustrates that a quarter of global greenhouse gases come from power and heat generation, most of which is consumed by commercial and residential buildings. A further 18% of emissions come from changes in land use, predominantly deforestation. Agriculture and industry (encompassing manufacturing, construction and industrial processes) make up around 14% each, as does transport, of which emissions from road transport comprise some three quarters of the total.



Source: World Resources Institute, Climate Analysis Indicators Tool http://cait.wri.org. (Reproduced in the Stern Review on the Economics of Climate Change).

End Notes

[1] Although cost of transport plays an important role in mode choice, there are other factors that contribute to the process of decision-making including location decisions, choice of suppliers, method of production, inventory control requirements, production process, etc. (see SRA, 2004 http://www.dft.gov.uk/pgr/freight/railfreight/fms/freightmarketstudiesgeneralf3207).

[2] NAEI, TSGB. See Appendix D for more detail. The change from 1995 to 2005 shows an 11% increase in carbon intensity per passenger km, however there is high year to year variability in the data and the statistics for 2005 are affected by the downturn presumably arising from the 2005 London bombings. Using 2004 as a more typical year, the statistics show a 5% increase in carbon intensity since 1995.

[3] Figures from the airline industry indicate that over the past 30 years, aircraft fuel efficiency per passenger-km has improved by about 50% and that in the decade 1993–2004 fuel efficiency improved by 16% or 1.6% per annum (see BALPA, 2007). Note however that this is not fast enough to outpace the growth of the industry, and so total domestic emissions have risen significantly over this period (and have approximately doubled over the last decade).

[4] As regards international aviation, where flights are often at high altitude, the additional climate change impact of non-CO_2 emissions is also important. This radiative forcing impact has been estimated to be two to three times that of the CO_2 emissions alone – see IPCC *Aviation and the Global Atmosphere* (1999), RCEP *The Environmental Effects of Civil Aircraft in Flight* (2002) and the *Stern Review on the Economics of Climate Change* (2006). Note that the precise extent of this impact is dependent upon altitude.

[5] In the UK, the SMMT report that the average new car emissions in 2005 were 169 gCO_2/km and in 2006 167 gCO_2/km, compared to 190gCO_2/km in 1997. By comparison the emissions from the overall average car are estimated by SMMT to have fallen from 196 gCO_2/km in 1997 to 181 gCO_2/km in 2006. See:
http://smmtlib.findlay.co.uk/articles/sharedfolder/Publications/CO2%20report3.pdf

[6] As an example, the current Defra GHG reporting guidelines report that a mid-sized diesel car (1.7 to 2l) in the fleet has emissions of 164 gCO_2/km, compared to a mid-sized petrol car (1.4 to 2l) of 188 gCO_2/km (without real world uplift).

[7] DfT Vehicle Licensing Statistics 2006. SB (07) 19. Transport Statistics Bulletin.

[8] DfT Transport Trends(2006 edition).

[9] TSGB, NAEI GB data.

[10] DUKES, DTI 2006. See also Table 5.

[11] This would reduce on-train heating requirements for example. Note that relatively milder winter temperatures do not translate into energy savings from diesel operation in the same way that they do for electric. This is because a significant proportion of the on-train heating requirement for diesel operation uses waste heat from the engine.

[12] See: http://www.dft.gov.uk/162259/165234/203030/iepsummaryoverviewpdf

[13] See for example: http://www.firstgroup.com/corpfirst/assets/downloads/csr/FirstClimateChange.pdf

[14] Clearly there may be instances in which a fully loaded car may perform well in emissions per passenger km terms compared to a lightly loaded train on a particular journey. Nonetheless, in such circumstances, if those travelling decide to make the journey on an existing rail service instead they could be said to have a negligible additional emissions impact.

[15] For example due to the reduced weight and aerodynamic drag impact of placing additional trailer vehicles into an existing train consist. Work commissioned by ATOC is currently underway to assess the precise energy impact of train lengthening.

[16] See for example *Improving the efficiency of traction energy use*, Interfleet Technology. Available at: http://www.rssb.co.uk

[17] http://www.acea.be/files/CO2_Leaflet.pdf

[18] In 2004, average specific emissions of ACEA's new car fleet registered in the EU was 161 g CO_2/km. This compares to 1995 when emissions were 185gCO_2/km – a 13% reduction http://ec.europa.eu/environment/co2/pdf/sec_2006_1078.pdf

[19] http://smmtlib.findlay.co.uk/articles/sharedfolder/Publications/7th%20Sustainability%20report.pdf

[20] http://smmtlib.findlay.co.uk/articles/sharedfolder/Publications/CO2%20report3.pdf

[21] The SMMT data is based on emissions from new vehicles registered between 1997 and 2005 (around 70% of total registrations).

[22] The SMMT report above states that 'A key reason for the improved average new car CO_2 performance has been the dieselisation of the fleet.'

[23] The NEAI method previously used and reported in the previous energy statement overestimated fuel use and emissions from domestic aircraft. The new method estimates emissions from the number of aircraft movements broken down by aircraft type at each UK airport (http://www.airquality.co.uk/archive/reports/cat07/0704261626_ukghgi-90-05_annexes_final.pdf). The values include both LTO and cruise emissions. A flight is domestic if the initial point on the service is a domestic and the final point is a domestic airport.

[24] Figures from the airline industry indicate that over the past 30 years, aircraft fuel efficiency per passenger-km has improved by about 50% and that in the decade 1993–2004 fuel efficiency improved by 16% or 1.6% per annum (see BALPA, 2007).

[25] The IPCC has projected a 20% increase in fuel efficiency between 1997 and 2015; equivalent to a 1% per year improvement in fuel efficiency. IATA has adopted fuel efficiency targets towards fuel efficiency improvements of 26% between 1990 and 2012 (again approximately 1% per year). OXERA, in their report Financial Impact of Emissions Trading on Intra-EU Aviation, October 2003, assume fuel efficiency savings of 1% per annum to 2030. An earlier study by Arthur D Little into the Potential Impact of Changes in Technology on the Development of Air Transport in the UK forecasts a 2% per annum improvement to 2030.

[26] Though shorter trips often use turbo props or regional jets which may be more fuel efficient per passenger km, see BALPA.

[27] Annex B. Summary of Updated Energy and Carbon Emissions Projections. *Meeting the Energy Challenge. A White Paper on Energy*. May 2007. CM 7124. Department of Trade and Industry. More detailed information taken from Updated Energy and Carbon Emissions Projections, DTI White Paper website.

[28] The Government is consulting on the option of new nuclear power stations. Because this issue is subject to consultation, the model only builds new nuclear power stations in the high case, for illustrative purposes. In all the three policy cases, some of the coal generation in 2020 is from CCS demonstration power stations – ranging between 3TWh in the low policy case to 13TWh in the high policy case. The impact of the carbon price on the generation fuel mix is more significant by 2020, through its impact on the relative costs of generation and demand, favouring gas and nuclear generation at the expense of coal. (DTI, 2007).

[29] See: http://www.hm-treasury.gov.uk/independent_reviews/stern_review_economics_climate_change/stern_review_report.cfm