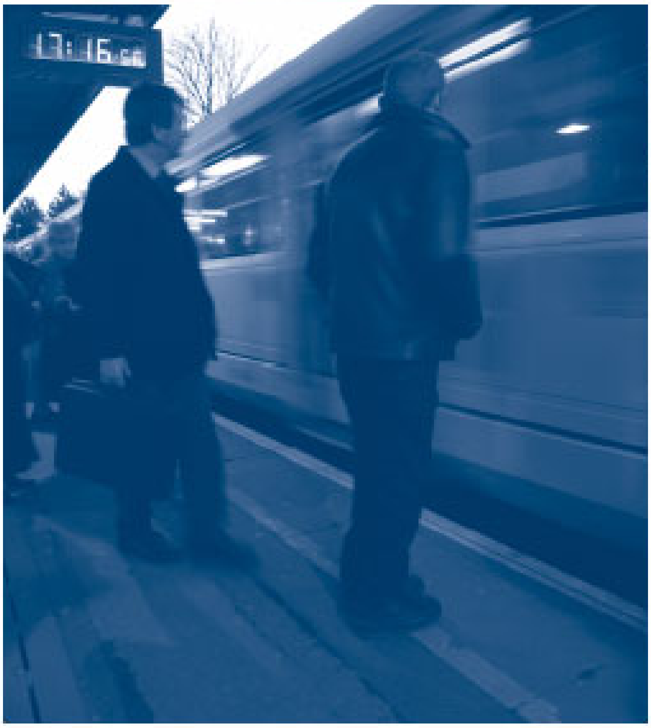
The Voice of the Passenger Railway ATOC

# Baseline energy statement – energy consumption and carbon dioxide emissions on the railway

March 2007

## Summary

This paper addresses the current carbon dioxide ($CO_2$) emissions of rail, car and domestic air travel, together with trends over the last ten years.* The paper also sets out a provisional projection of the carbon dioxide emissions from marginal additional rail travel in the future.

The report uses national statistics, combined with detailed ATOC data, to compare rail with both road and air. National statistics (DUKES) have been used for the electricity generation mix.

Our analysis indicates that, on average, passenger rail currently emits approximately half the carbon dioxide per passenger kilometre of cars and around a quarter that of domestic air. Since 1995/6, passenger rail has improved its position substantially: average emissions per passenger km falling by an estimated 22% compared to an 8% reduction from car traffic and a 5% increase from domestic air.

This analysis is based on average figures. Quite clearly, in any specific example, the occupancy of the vehicle is key. A fully-loaded car will perform well on a $CO_2$ per passenger km basis compared to the most efficient train with very 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 clarify the starting position. Further work is needed to consider the effect of practical policy options open to us to reduce emissions from transport.

Looking ahead in the short term, rail is likely to carry additional passengers with negligible carbon impact. In the longer term, it is estimated that rail can provide additional passenger capacity at a carbon intensity of about half the current figure.

On this basis, UK carbon dioxide emissions can be reduced if rail attracts a greater share of the national traffic.

Rail has an important role to play in tackling climate change but the key challenge remains the reduction of $CO_2$ emissions from cars and road freight.

In the long term, a policy aimed at sharply reducing the carbon intensity of UK electricity generation is essential if climate change objectives are to be met.

A wide range of initiatives is underway aimed at further improving energy efficiency and reducing $CO_2$ emissions per passenger km from rail. These include implementing brake regeneration (where electric trains return energy to the power supply), biofuels trials and investigating the scope for energy savings from more efficient driving techniques. Taken together these measures should have a significant impact on the railway's core energy efficiency.


*Note: This paper covers traction energy and emissions for passenger rail only. It does not cover rail freight or maintenance traffic.

## Acknowledgement

This paper has been prepared by ATOC with support from Paul Watkiss and has been reviewed by Ian M. Arbon.

Paul Watkiss is an independent policy associate and a former director of the Policy Group of AEA Technology Environment. He has extensive expertise in the areas of air quality and climate change.

Ian M. Arbon is an independent management and engineering consultant and is Chairman of the IMechE Energy, Environment and Sustainability Group.

## Rail, car and air – overview

In aggregate, passenger rail contributes just 0.5% to total UK $CO_2$ emissions. This compares to 12.8% for passenger cars and 0.4% for domestic air. International air, much larger than domestic air, is not included in the national figures but is shown in Table 1 below for information as an equivalent percentage share of the national total.

**Table 1. Percentage of UK carbon dioxide emissions by mode**

| Mode | Percentage of UK emissions (by source) | Total billion pass km, billion tonne km |
|---|---|---|
| Passenger cars and taxis | 12.8% | 652.8 bn p km |
| Passenger rail | 0.5%* | 41.8 bn p km |
| London Underground | 0.07%# | 7.6 bn p km |
| Domestic aviation | 0.4% | 9.8 bn p km |
| *International aviation*[1,2] | *6% (see notes)* | - |
| Buses and coaches | 0.6% | 48 bn p km |
| Motorcycles and mopeds | 0.1% | 6 bn p km |
| **Total passenger transport** | **14.5%** | **766 bn p km****** |
| Road freight (LGV and HGV) | 7.9% | 163 bn t km |
| Rail freight | 0.2%## | 21 bn t km |
| Shipping | 0.7% | 59 bn t km |
| **Total freight transport** | **8.8%** | **243 bn t km****** |

Source: Transport Statistics Great Britain based on National Atmospheric Emissions Inventory data 2004. Numbers are rounded in some cases.
* National Rail only. Estimated using ATOC data and including emissions from electricity generation.
** Figures exclude passenger km travelled on some metro and light rail systems, bicycles, light vans and goods moved via pipeline.
# Estimated using published LU data.
## Estimated from NAEI data.

[1] Percentage equivalent of total UK emissions only. Note: international aviation is not included in the reported UK National Inventory. The 6% quoted above 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.
[2] In a broader context emissions from international aviation are currently estimated to contribute approximately 2% of global $CO_2$ emissions however this share is projected to rise to 5% by 2050 (see for example: http://www.mmu.ac.uk/news/news_item.php?id=461)

Although not considered further in this report, the figures for freight transport are also significant – in particular the large proportion of road freight emissions in the total.

As to carbon intensity, a comparison has been made of average $CO_2$ emissions from rail, air and car on a per passenger kilometre basis. The trend since 1995/6 has also been assessed. Table 2 below summarises the position:

**Table 2. Estimates of carbon dioxide emissions by mode and change since 1995/6**

| Mode | Emissions $gCO_2$/pkm* | Percentage change since 1995/6 |
|---|---|---|
| Passenger rail – diesel | 74 | -16% |
| Passenger rail – electric | 54 | -26% |
| Passenger rail – overall | 61 | -22% |
| Car and taxi | 106 | -8% |
| Domestic air | 231 | +5% |

Source: NAEI, TSGB (for car and taxi, domestic air) and National Rail Trends, NAEI, DUKES, ATOC data (rail)[3]

* 2005/6 figures for rail, 2004 figures for car/air (latest available).

## Domestic air

In the last decade, carbon dioxide emissions per passenger km from domestic air travel appear to have increased by 5% according to national statistics.[4] Although planes are now more fuel efficient it is possible that these improvements may have been offset by an increase in short domestic journeys which have higher $CO_2$ /passenger km due to the larger relative impact of the fuel intensive take off and landing cycle.

In the short term at least, modal shift to rail (or other low carbon modes), where practicable, is a realistic way to reduce carbon emissions from such journeys. Indeed rail has cut heavily into the London-Manchester air market in recent years and since 2004 rail has increased market share on the route from one third to almost two thirds.

In respect of international aviation, not shown in Table 2, aggregate carbon dioxide emissions have grown very substantially, by approximately 74% since 1995 whilst passenger km flown have risen by 55%.[5] Indeed the additional climate change impact of non-$CO_2$ aviation emissions, particularly from high altitude international jet flights, has been estimated to be two to three times that of the $CO_2$ emissions alone. This is due to the fact that aviation emissions are deposited higher up in the atmosphere.[6]

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[3] Note: Detailed 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 (where approximately 62% of vehicle km operated are electric, 38% diesel).
[4] NAEI, TSGB. See Appendix for more detail.
[5] Netcen/Defra, TSGB. See also footnote 1 regarding emissions from international aviation.
[6] See IPCC *Aviation and the Global Atmosphere* (1999) and RCEP *The Environmental Effects of Civil Aircraft in Flight* (2002). Note that the extent of this impact is dependent upon altitude. The additional climate change effect of emissions from relatively low altitude domestic flights will differ compared with emissions from high altitude intercontinental flights where much of the emissions are deposited in the upper atmosphere.

## Car

The position with regard to car traffic is interesting. High fuel efficiency cars are now available, but in practice these seem to have had little effect on total emissions. National statistics show that fuel consumption of UK cars has improved but only from 32mpg to 33mpg over the last decade.[7]

Growth in the number of diesel cars, combined with a slightly reduced average occupancy, and possibly some other factors, appears to have resulted in an overall reduction in $CO_2$/passenger km of about 8%.[8,9]

Looking ahead, car manufacturers face continuing demands to improve energy efficiency. A combination of legislation – particularly the potential introduction of engine standards – taxation and consumer pressure is driving the search for further efficiencies through research into cleaner fuels and advanced technologies such as hybrids and hydrogen fuel cells. However whilst the latter will reduce local emissions significantly the question of how to produce hydrogen 'cleanly' remains unresolved.

In the short to medium term, a reduction in the carbon intensity of car use could be achieved but only if there is a major shift towards high fuel efficiency cars, possibly driven by strong legislative requirements.

The recently announced EU policy direction on $CO_2$ emissions from cars is important here. New proposals aim to reduce average emissions from new cars from the current average of approximately 160g$CO_2$/vehicle km to no more than 130g$CO_2$/vehicle km by 2012 (this figure is anticipated to fall to 120g$CO_2$/vehicle km when greater use of biofuels and other efficiency measures are taken into account). This broadly reconciles to Table 2 when car occupancy is taken into account. With an average occupancy of about 1.6, current car emissions average out at approximately 106 g$CO_2$/passenger km according to Government data. If the entire car fleet were to achieve the 120 g$CO_2$/vehicle km standard – in itself very desirable – average emissions per passenger km might fall to, say 80g$CO_2$/passenger km (assuming car occupancy continues to fall slightly). This would still be above current average rail emissions.

## Rail

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

As Table 2 indicates, overall passenger rail has reduced its emissions of $CO_2$ per passenger km by an estimated 22% since 1995/6, over twice the improvement in car emissions. A significant proportion of this rail improvement has been achieved by passenger growth and changes in the carbon intensity of the electricity generation mix as indicated by national statistics.[10] Indeed whilst the newer trains do tend to use more energy they are equipped with a much wider range of passenger facilities and have delivered greater capacity on many routes. This has, in turn, helped to encourage higher passenger loadings.

A range of solutions aimed at improving the energy efficiency of the railway are under active consideration including technical solutions aimed at achieving optimum train mass and operational changes including energy efficient driving and matching stock to demand. Furthermore the rail industry, like the automotive sector, is also exploring the potential of new and emerging technologies, including hybrid drives and hydrogen fuel cells (although as with cars there remains the issue of precisely how hydrogen is produced). In the long term these advances may help significantly improve the environmental performance of rail.

[7] TSGB.
[8] TSGB.
[9] Diesel cars have lower emissions per km. The proportion of diesel fuel used by cars has doubled between 1995 and 2004 (TSGB).
[10] See Table 4.

## Rail – diesel traction

As Table 2 indicates, average carbon dioxide emissions from passenger traffic on diesel trains are estimated to be 74g$CO_2$/passenger km, based on diesel consumption and passenger kilometres on diesel trains.

Over the last ten years to 2005/6 this has fallen by an estimated 16%, based on the following factors:

- Vehicle km have increased by 22%
- Passenger km have increased by 46%

Taken together these indicate a significant increase in passenger loadings, through improved utilisation of existing train capacity, and commensurate improvement in carbon dioxide emissions per passenger km. Table 3 below summarises the current position and change over time.

**Table 3. Diesel consumption and estimated change in $CO_2$ emissions since 1995/6**

| **2005/6 – Diesel** | |
|---|---|
| Diesel use – litres[11] | 459.3 million |
| Diesel vehicle km | 895 million |
| **Thus**, litres per vehicle km | 0.51 |
| Diesel passenger km | 16.64 billion |
| Litres per passenger km | 0.0276 |
| $CO_2$ emissions per litre | 2695g* |
| **Thus**, $CO_2$ per passenger km | 74g |
| | |
| **Change since 1995/6** | |
| Increase in passenger km | +46% |
| Increase in vehicle km | +22% |
| Reduction in $CO_2$ per passenger km | -16% |

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

* Based on the standard specification for rail diesel fuel.

## 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 last 10 years to 2005/6, electric energy consumption has increased by about 20% while vehicle km operated by electric rolling stock have increased by about 25%. There has therefore been a net reduction in kWh/vehicle km of about 4%.

[11] Based on fuel supplied to train operators.

- Load factor. The number of passengers in a train significantly influences energy consumption and emissions per passenger km.
- Changes in the UK generation mix. For the purposes of this analysis we have used the average carbon intensity for UK electric generation. The carbon intensity of the UK generation mix has fallen by about 11% in the last 10 years (see Table 4 below).

**Table 4. Change in UK electricity generation mix since 1990**

| | Generation mix (%) | | | | | | Carbon intensity ($gCO_2/kWh$)** |
|---|---|---|---|---|---|---|---|
| Year | Coal/oil | Oil | Gas | Nuclear | Renewable | Other* | |
| 1990 | 68 | 5 | 0 | 20 | 2 | 5 | 718 |
| 1995 | 46 | 3 | 18 | 26 | 2 | 6 | 551 |
| 1997 | 34 | 2 | 30 | 27 | 2 | 5 | 480 |
| 2000 | 32 | 1 | 37 | 23 | 3 | 5 | 472 |
| 2005 | 34 | 1 | 37 | 20 | 5 | 4 | 489 |

Source: DUKES; DTI UEP26; NAEI. Note: Due to rounding figures for some years may not equal 100%.

* Includes imports, pumped storage.

** Note: values for carbon intensity based on major power producers and exclude imports. Values quoted are higher in carbon intensity than quoted in Table 5C of DUKES.

It is clear from Table 4 that the carbon intensity does not decrease linearly over the period 1990-2005, so care must be exercised over which year is used for comparison purposes. As a general statement, power generation from fossil fuels has increased since 1997, while that from non-fossil fuels has decreased.

Nonetheless looking ahead electric trains have the potential to be fully powered by electricity from renewable sources, thereby providing a carbon neutral form of transport.

Table 5 below summarises the changes in energy consumption of electric trains over the past decade:

**Table 5. Energy consumption and percentage change since 1995/6 for electric trains**

| Year | Consumption (GWh) | Electric vehicle km | kWh/ vehicle km | Electric passenger km | kWh/ passenger km |
|---|---|---|---|---|---|
| | | Million | | Billion | |
| | | | | | |
| 95/96 | 2,430.0 | 1, 173 | 2.07 | 18.69 | 0.13 |
| 05/06 | 2,911.8 | 1, 463 | 1.99 | 27.02 | 0.108 |
| % change since 1995/6 | +20% | +25% | -4% | +45% | -17% |

Source: ATOC data. Numbers are rounded in some cases.
Note: these values take losses in the rail electric distribution system into account.

For 2005/6, energy consumed (kWh/passenger km) was 0.108 as shown in Table 5. Converting this into $gCO_2$/pass km using the appropriate emissions factor we get:

0.108 kWh/passenger km = 54 $gCO_2$/passenger km[12]

From this we can see that $CO_2$ emissions per passenger km from electric trains have improved by 26% since 1995/6:

**Table 6. Summary of electricity consumption and $CO_2$ emissions: change since 1995/6**

| **Rail - Electric** | **Percentage change since 1995/6** |
|---|---|
| Increased GWh | +20% |
| Increased vehicle km | +25% |
| **Thus**, net change per vehicle km | -4% |
| Change in passenger loadings | +16% |
| **Thus**, kWh/passenger km | -17% |
| Change in carbon intensity of UK generation mix | -11%[13] |
| **Thus**, reduction in $CO_2$ per passenger km | -26% |

## The future

In this section we consider the likely future carbon intensity of rail, car and domestic air as modes for carrying additional traffic.

In the immediate short term, marginal rail traffic will have virtually zero carbon impact. Over the next five or even ten years, additional traffic can be carried on the rail network with a small increase in carbon dioxide emissions.[14]

Looking to the longer term, if current growth patterns continue, additional carrying capacity will be needed on a significant scale; in this context rail is likely to be able to carry passengers at about half its current carbon intensity. This predicted growth in traffic will be carried by a combination of:

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[12] kWh converted into carbon emissions at the rate of 489 $gCO_2$ per kWh, where 489 is 133.3 (gC/kWh), multiplied by 44/12 to derive $CO_2$ emissions per passenger km. Note: the 489 $gCO_2$/KWh figure is higher than that quoted in DUKES (124 gC/KWh, equivalent to 455 $gCO_2$/kWh) since the latter is considered to be an underestimate. To derive the final figure for $gCO_2$/pass km this value is adjusted to 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.

[13] Note that comparison with 1997 figures would give a significantly different result from those for 1995, see Table 4 above.

[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. Equally, in such circumstances, if those travelling decide to make the journey by rail instead they could be said to have a negligible additional emissions impact.

- Increased load factors - say 30% of additional traffic - which will have negligible carbon impact

- Higher capacity trains - say 50% of additional traffic – adding rolling stock to an existing train might be expected to have a carbon impact of about 60% of the un-lengthened train[15]

- Additional trains - say 20% of additional traffic – where the overall energy efficiency of new trains could be as much as 25% below that of existing stock due to a combination of operational measures and technical and design improvements.[16]

On this basis we can estimate the likely $CO_2$ emissions from additional long term traffic growth as follows:

$$(0.3 * 0) + 0.5 * 0.6 * 61 + 0.2 * 0.75 * 61 = 27.5$$

This shows that the marginal additional traffic would emit around half (27.5 $gCO_2$/passenger km) the current level of $CO_2$ per passenger km. [17]

Assuming no increase in passenger occupancy, additional car traffic will tend to have the same carbon impact as the then average for the car. However, this average is anticipated to reduce from the present level with new technology and changing car buying behaviour.

Regarding domestic air travel, the scope for carrying additional traffic at a much reduced carbon intensity is much more limited.

Notwithstanding the likely improvements in car and aviation fields, the relative advantage of rail is likely to increase further.

## Modal shift

In light of the above analysis, overall UK carbon dioxide emissions can be reduced if rail attracts a greater share of the national traffic.

## Conclusion

This analysis indicates that passenger rail has significantly lower carbon dioxide emissions per passenger km than car or domestic air. In addition rail has reduced $CO_2$ emissions per passenger km by 22% over the past decade, over twice as much as car, while domestic air has increased in carbon intensity.

A modal shift from car and/or air to rail can reduce UK carbon dioxide emissions.

Nonetheless the industry cannot afford to be complacent and operators are committed to further improvements in energy efficiency. A range of initiatives, coordinated by ATOC, is in hand to achieve this including:

- a rolling programme to implement brake regeneration, in partnership with Network Rail. This is ongoing and is already is use on a number of train services

- biofuels trials to assess the feasibility of wider use

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[15] For example due to the reduced weight and aerodynamic drag impact of placing additional trailer vehicles into an existing train consist.

[16] *Improving the efficiency of traction energy use*, Interfleet Technology.

[17] Where carbon dioxide emissions from the railway overall are 61$gCO_2$/passenger km.

- improved energy measurement to enable operators to better manage electricity consumption
- promotion of energy efficient driving techniques, supported by the use of driver simulators, to deliver energy savings.

Looking to the longer term operators are closely involved in work to optimise the weight and energy consumption of new trains as well as research into future technologies, including hybrids and fuel cells.

In addition Government is considering the potential for including surface transport, along with aviation, in the EU Emissions Trading Scheme (EU ETS). Whilst this may provide a cost effective means of reducing transport emissions it is important to ensure that the full implications of including rail in such a scheme are assessed and understood before moving forward.

In this context the key policy questions for Government are how best to support the industry's programme to deliver further improvements and, more widely, how to harness rail's relative environmental advantage to deliver on its commitment to reduce carbon dioxide emissions by 20% below 1990 levels by 2010 and by 60% by 2050.

# 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 National Atmospheric Emissions Inventory (NAEI).

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, 2006).

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 in 2004). The value derived has been checked with DfT for confirmation.

   For rail detailed 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

## Supporting analysis – cars and taxis, domestic air

**Paul Watkiss**

This section provides further background regarding carbon emissions from cars and taxis and domestic air.

### Car Trends

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

The National Travel Survey (DfT) collates data on occupancy levels for cars over time:

**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).

This data shows 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.

These data sources can be combined with carbon emissions data from NAEI (GB) to derive the trend in carbon intensity over time for cars and taxis. This is summarised below:

| **Year** | **1995** | **1998** | **1999** | **2000** | **2001** | **2002** | **2003** | **2004** |
|---|---|---|---|---|---|---|---|---|
| **kt$CO_2$** | 67438 | 69602 | 70766 | 70392 | 69819 | 70704 | 68982 | 68980 |
| **Bpkm*** | 585.6 | 612.7 | 624.0 | 623.0 | 632.8 | 650.7 | 647.8 | 652.8 |
| **g$CO_2$/pkm** | 115 | 114 | 113 | 113 | 110 | 109 | 106 | 106 |

Source: NAEI, 2006; TSGB, 2006, NTS, 2006.

*Billion passenger km vehicle estimates are based on vehicle km and weighted occupancy values. Note: TSGB 2006 states that in 2004, the occupancy rates were 1.64 for cars and taxis and this has been used to derive billion passenger km from vehicle km. The value has also been checked with DfT who have cited a value of 652 bpkm (based on the new weighted occupancy analysis method). Note, however, that the National Travel Survey quotes a rate for cars (only) of 1.57 for 2004 (Table 6.2 above).

This shows a slight improvement over time (8%). This reflects improvements in fuel efficiency of new cars, but includes the reductions in occupancy levels. However, the data is also influenced by the growing number of diesel cars in the fleet, which have improved fuel efficiency (and lower emissions per km). The proportion of diesel fuel used for cars (TSGB table 3.1) shows over a 2 fold increase from 1995 to 2004 in diesel fuel use for cars and taxis.

### Domestic Air Trends

Data has been collated for domestic air, using NAEI sources for carbon emissions (GB) and TSGB passenger km data. This shows a 5% increase in carbon intensity over the decade.

**$CO_2$ per passenger km for Domestic Air over time**

| | $CO_2$ (kilotonnes) | Billion passenger km | $gCO_2$/ passenger km |
|---|---|---|---|
| **Domestic air (1995)** | 1,301 | 5.9 | 221 |
| **Domestic air (2004)** | 2,260 | 9.8 | 231 |

Source: NAEI, 2006; TSGB, 2006.

There have been improvements in aircraft fuel efficiency over the past decade and a very slight increase in seat occupancy (from 63.3 to 65.3%). However it is possible that the apparent increase in carbon intensity is due to an increase in the number of shorter city to city domestic trips (which have higher carbon intensity due to the greater relative impact of the landing and take-off cycle)

## APPENDIX C

### 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 recent Stern Review on the Economics of Climate Change[18], particularly in Chapter 7 and related appendices, contains considerable information about 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 sources often focuses on the immediate cause, the graphic also identifies the relationship with the end-user – shown in the centre column. It is the end user activity that drives demand.

**Current and projected emissions sources by sector**[19]

**Power**
A quarter of all global greenhouse-gas emissions come from the generation of power and heat, which is mostly used in domestic and commercial buildings, and by industry. This was the fastest growing source of emissions worldwide between 1990 and 2002, growing at a rate of 2.2% per year; developing-country emissions grew most rapidly, with emissions from Asia (including China and India), the Middle East and the transition economies doubling between 1990 and 2000.

This sector also includes emissions arising from petroleum refineries, gas works and coal mines in the transformation of fossil fuel into a form that can be used in transport, industry and buildings. Emissions from this source are likely to increase over four-fold between now and 2050 because of increased synfuel production from gas and coal, according to the IEA. Total power-sector emissions are likely to rise more than three-fold over this period.

**Land use**
Changes in land use account for 18% of global emissions. This is driven almost entirely by emissions from deforestation. Deforestation is highly concentrated in a few countries. Currently around 30% of land-use emissions are from Indonesia and a further 20% from Brazil. Land-use emissions are projected to fall by 2050, because it is assumed that countries stop deforestation after 85% of forest has been cleared.

**Agriculture**
Non-$CO_2$ emissions from agriculture amount to 14% of total GHG emissions. Of this, fertiliser use and livestock each account for one third of emissions; other sources include rice and manure management. Over half of these emissions are from developing countries. Agricultural practices such as the manner of tillage are also responsible for releasing stores of $CO_2$ from the soil, although there are no global estimates of this effect.

Agriculture is also indirectly responsible for emissions from land-use change (agriculture is a key driver of deforestation), industry (in the production of fertiliser), and transport (in the movement of goods).

[18] See: http://www.hm-treasury.gov.uk/independent_reviews/stern_review_economics_climate_change/stern_review_report.cfm
[19] The following text is reproduced from the Stern Review, Chapter 7, pp171-172.

Increasing demand for agricultural products, due to rising population and incomes per head, is expected to lead to continued rises in emissions from this source.

Total non-$CO_2$ emissions are expected to double in the period to 2050.

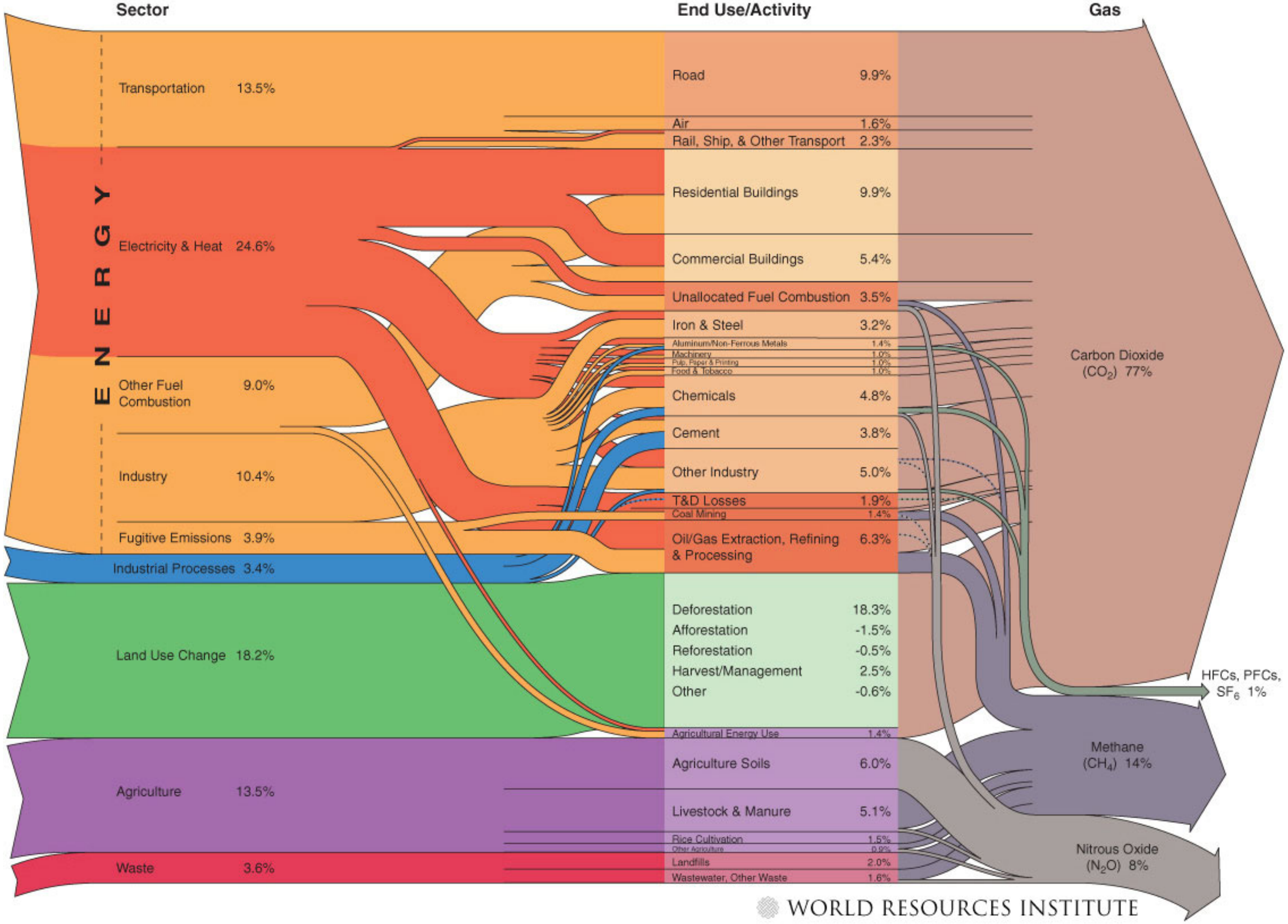
**Transport**
Transport accounts for 14% of global greenhouse-gas emissions, making it the third largest source of emissions jointly with agriculture and industry. Three-quarters of these emissions are from road transport, while aviation accounts for around one eighth and rail and shipping make up the remainder. Total $CO_2$ emissions from transport are expected to more than double in the period to 2050, making it the second-fastest growing sector after power.

$CO_2$ emissions from aviation are expected to grow by over three-fold in the period to 2050, making it among the fastest growing sectors. After taking account of the additional global warming effects of aviation emissions aviation is expected to account for 5% of the total warming effect (radiative forcing) in 2050.

**Industry**
Industry accounts for 14% of total direct emissions of GHG (of which 10% are $CO_2$ emissions from combustion of fossil fuels in manufacturing and construction and 3% are $CO_2$ and non-$CO_2$ emissions from industrial processes such as production of cement and chemicals).

**Buildings**
A further 8% of emissions are accounted for by direct combustion of fossil fuels and biomass in commercial and residential buildings, mostly for heating and cooking.
The contribution of the buildings and industry sectors to climate change are greater than these figures suggest, because they are also consumers of the electricity and heat produced by the power sector (as shown in Figure B below). Direct emissions from both industry and buildings are both expected to increase by around two thirds between 2000 and 2050 under business as usual conditions.

## World GHG Emissions Flow Chart




Source: World Resources Institute, Climate Analysis Indicators Tool (CAIT). See: http://cait.wri.org