Carbon Footprinting of Policies, Programmes and Projects

Final report to PTEG

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Executive Summary

PTEG, which represents the six English Passenger Transport Executives (PTEs), with Strathclyde Partnership for Transport (SPT) and Transport for London (TfL) as associate members, commissioned AEA to undertake this study to examine how the PTEs and SPT might carbon footprint their activities and journeys within their areas. The aim of the study was to establish a common basis for estimating the carbon emissions from the range of PTE/SPT activities and, where appropriate, the emissions saved compared with an alternative course of action. Key stages and outcomes of the study are summarised below.

Firstly, **AEA undertook a review of existing assumptions, guidelines and models** that are used to calculate the carbon footprint of public transport operations. This found that there are two types of approach: a 'top down' approach based on fuel use and a 'bottom up' approach based on vehicle km and vehicle types. The private sector tends to use a 'top down' approach primarily because they can easily access the fuel use data of their operations. The public sector uses a mixture of 'top down' and 'bottom up' approaches. There is overlap between the approaches and both are valid. Currently, the availability of data would be the most important determinant of the approach that the PTEs might take.

Secondly, **AEA and the PTEs undertook the data collection required for the carbon footprint analysis** (i.e. information on passenger km, fuel use, vehicle km and vehicle types). Gaps in the data were identified these included, for bus and train, limited information on passenger km and passenger load factors. With bus there was also limited data on fuel use. A further issue was that train data was at the aggregate rather than PTE level and assumptions therefore had to be made in order to allocate this data to the individual PTEs. Going forward, AEA recommends that a data request form (template) should be used to help facilitate data gathering; and that it may be appropriate for the PTEs to consider how changes within the current data collection process could help facilitate data collection.

Thirdly, AEA used the outcomes of the above two stages to inform **potential carbon footprint approaches for each of the modes (bus, rail, light rail).** The use of a 'top down' approach is more appropriate for light rail, while a 'bottom up' and 'top down' approach is better for bus and rail. These approaches were then used to provide information for each mode and PTE for the following metrics - **g CO_2 per vehicle km, g CO_2 per passenger km and g CO_2 per passenger journey**. The results for passenger km and passenger journey are shown in the below table. Information on vehicle km was available for bus, however since train and light rail both operate in units, aggregate rather than vehicle km information was provided for these modes. The results are single factors and are based on a weighted average for passenger journey and vehicle km, with the weighting reflecting the number of passenger journeys and vehicle km undertaken in each PTE. Passenger km data was not available and so an unweighted average (mean) was used.

Mode of transport	CO_2 per passenger km (g)	CO_2 per passenger journey (g)	CO_2 per bus vehicle/train/ light rail km(g)	Transport Direct / DEFRA figures
Bus	107.3 *118.6*	481.9 *533.4*	919.6 *1015.4*	115.8 (local bus)
Light rail	70.3	445.2	2371.2	78.0
Rail	66.4	1144.2	2870.2	60.2

For **bus two CO_2 emission figures** are provided in the above table. The first (in normal font) is based on UK Greenhouse Gas Inventory (GHGI) data on different bus emission classes, this approach was used because fuel use data from the bus operators was not available. The GHGI data, however, suggests that fuel consumption, and therefore CO_2 emissions decreases over time, and this conflicts with statements by bus operators, which suggest that the use of Euro Standard III buses results in an increase in fuel consumption, and therefore CO_2 emissions. Explanations for this include that GHGI data does not refer to Euro III with PM traps and though it involves extensive testing this is on a small number of vehicles. A sensitivity analysis which takes this difference into account was undertaken and the results are shown in *italics*.

The **outcomes of this analysis tied in well, overall, with Government (including the Transport Direct Calculator) and private sector figures.** Going forward there is the potential for PTEG to use the PTEs rail carbon figures as a basis for discussion with the Department for Transport on the Transport Direct calculator.

When looking at these figures it is important to recognise that **gaps in the data and the resulting use of assumptions impacts on the reliability of the results**. Going forward this could be improved through the provision of more consistent and more comprehensive data from the PTEs, in particular, data on passenger kilometres and passengers journeys, by vehicle type, and data on peak and off peak trips.

Single factors (based on a weighted average) are shown in the table, however, individual, PTE-specific emissions factors are also of value for benchmarking purposes and provide a greater degree of specificity.

A comparison of the carbon emissions from public and private transport was also made. However, it is important to remember that carbon emissions are not the only factor in any decision, and the contribution of public transport to wider sustainable development principles should also be considered. We, therefore, recommend that if such a comparison is undertaken it should be part of a wider appraisal.

Fourthly, **AEA considered Life Cycle carbon emissions.** The analysis suggested that the majority of the carbon generated by public transport vehicles is from their use rather than from their construction, maintenance and disposal. Furthermore, the carbon footprinting of public transport carried out by other public sector and private sector bodies does not take into account the emissions from the full life cycle instead it considers vehicle use only. For these reasons AEA suggests that either 1) the carbon footprinting figures used by PTEs should be for vehicle use only rather than the full life cycle 2) A full life cycle approach is used but the contribution from vehicle use emissions clearly stated to enable a fair comparison with other public sector and private sector bodies. AEA recommends that if the latter option is chosen this should be kept under review as carbon footprinting based on full life cycle analysis will become more common over time.

Finally, **AEA examined approaches to the Carbon Footprinting of PTE projects**. The analysis suggested that there is limited ‘off the shelf’ guidance or best practice for carbon footprinting the overall plans, policies and programmes of PTEs – in particular on the construction of the public transport infrastucture. AEA identified a number of ways in which the PTEs could contribute to this area: the use of a carbon calculator to assess the potential impact of schemes; the undertaking of real life case studies and procuring in a low carbon way – placing an onus on suppliers to provide information on their lower carbon activities.

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Introduction

PTEG, which represents the six English Passenger Transport Executives (PTEs) with Strathclyde Partnership for Transport (SPT) and Transport for London (TfL) as associate members, commissioned AEA to undertake this study to examine how the PTEs and SPT might carbon footprint their activities. The aim of the study was to establish a common basis for estimating the carbon emissions from the range of PTE/SPT activities and, where appropriate, the emissions saved compared with an alternative course of action.

Section one is a review of the existing assumptions, guidelines and models that are already used to calculate the carbon footprint of public transport operations. This was achieved using a combination of: literature reviews; analysis of carbon footprinting models/calculators; interviews with private sector stakeholders and AEA's in-house expertise.

Section two, reflects the importance of access to data in determining the carbon footprint approach to use, and is an assessment of the processes used to collect data for the project. These included: data collection within the PTEs; discussions with the operators and the outcomes of a literature review of Government and industry transport statistics.

Section three brings together sections 1 and 2 to inform the development of potential PTE approaches to carbon footprinting of public transport operations. Carbon footprint numbers are presented and recommendations made.

Section four looks at the whole life cycle emissions and considers the contribution of vehicle manufacture, disposal and emissions associated with fuel production to the total carbon footprint of public transport vehicles. How these results could be incorporated into future carbon footprinting by the PTEs is assessed, and recommendations are made.

Section five examines approaches to the Carbon Footprinting of PTE projects in particular construction. How these results could be incorporated into future carbon footprinting by the PTEs is considered and recommendations suggested.

Section six brings together the findings from the previous sections to provide recommendations and conclusions.

BACKGROUND INFORMATION

Carbon Dioxide and Carbon

Carbon dioxide (CO_2) is a greenhouse gas, which makes a substantial contribution to climate change. In quantifying the contribution that carbon dioxide makes to climate change CO_2 and carbon (C) can be used.

To convert CO_2 to C, CO_2 emissions are multiplied by the ratio of the molecular weight of C (which is 12) to the molecular weight of CO_2 (which is 44), i.e. 12/44 which is 0.27. Likewise to convert from C to CO_2 the inverse ratio is used 44/12 (which is 3.67).

In this report, CO_2 is used to quantify emissions both for simplicity and because it is the more recognised term (e.g. grams CO_2 per vehicle kilometre).

However, carbon is still used for consistency when referring, in the text, to carbon footprinting (CO_2 footprinting is not a commonly heard phrase).

Grams, Kilograms, Tonnes and Million Tonnes

In quantifying CO_2 (and C) emissions metric units of weight are used. These include: Grams (g), Kilograms (Kg), Tonnes (T) and Million tonnes (MT). These units of weight are related. For example:

1000 g = 1 Kg

1000 kg = 1 T

The units used in the following report vary according to the size of the emissions quantified.

1 Carbon footprinting of transport operations

Key findings:

A key difference between the public transport carbon footprinting methods reviewed relates to whether a '**top down'** (based on total fuel, and emission factors associated with the fuel) or a '**bottom up approach'** (based on fuel consumption per vehicle type and vehicle km driven by each type) is used. The suitability of the different methods for the PTEs will depend on the availability of this data (fuel use, fuel consumption and vehicle km). It should be noted that these methods can be complementary – one can be used as a 'check' on the other.

Public and private sector approaches, particularly the former, result in carbon figures that are highly aggregate in nature, that is they mask a wide variation in types (and therefore efficiencies) and passenger loads. This is understandable and justifiable given that these figures are used in a broad context rather than specific, 'real life' trips. It is important, therefore, that the PTEs keep this in mind when reading this report and are aware, that if the data is available, a more disaggregated approach, which is more representative of 'real life' trips, can occur.

1.1 Introduction

The aim of this study is to help establish a common basis for estimating the carbon emissions from the range of PTE/SPT activities. To achieve this we undertook a review of current approaches to the carbon footprinting of transport operations in both the public and private sector. The outcomes of this review are summarised below.

1.2 Current approaches to carbon footprinting

Prior to reviewing the literature it is important to set the different carbon footprinting approaches in the wider context of climate change, and to understand the links between the different approaches the UK Government uses.

In terms of the wider climate change policy context, the UK is a signatory to the Kyoto Protocol, which is the protocol to the United Nations Framework Convention on Climate Change and has the objective of reducing greenhouse gases that cause climate change. Under the Kyoto Protocol the UK has to submit a **UK Greenhouse Gas Inventory (GHGI**) every year. The GHGI is compiled to Inter Governmental Panel on Climate Change guidelines. The GHGI is based on the same datasets used in another Inventory - **the National Atmospheric Emissions Inventory (NAEI)**. The NAEI covers all air, not just greenhouse gas, emissions. There are direct links between the GHGI, the NAEI and the Department for the Environment, Food and Rural Affairs (DEFRA) guidelines for Greenhouse Gas (GHG) Company Reporting. With the latter being used to help companies to identify and address their emissions. The guidelines therefore include conversion factors to help companies convert existing data sources into CO_2 equivalent data. However, it should be noted that some of the transport factors have been developed especially for the guidelines for company reporting and are not used in the GHGI or in the NAEI. This is because the NAEI and GHGI report at a different level of sector detail and the latter follows internationally agreed rules for reporting emissions.

Transport Direct is a website funded by the Department for Transport (DfT) which provides travel planning information for members of the public. The site incorporates a carbon calculator which enables people to compare the carbon emissions of journeys by different modes for example car compared with bus. The metric used is 'g CO_2 per passenger kilometre' and is calculated based on NAEI and DEFRA guidelines for GHG Company Reporting.

The private sector (for example **National Express**, **Go Ahead** and **Eurostar**) also undertakes its own carbon footprinting and there is extensive overlap between these approaches and those outlined above. We draw parallels between these approaches in the analysis below.

We consider the approaches used in turn for each of the modes:

- Bus
- Rail
- Light rail

First, we provide a summary of the outputs from the different approaches, then we discuss the approaches (with further information provided in Appendices one - three) and where relevant draw comparisons between the approaches. In compiling this review we drew on Government and private sector sources. In assessing Government literature we benefited from AEA's work in developing the NAEI, DEFRA GHG conversion factors for company reporting and our involvement in Transport Direct. Assessing the private sector carbon footprinting techniques involved a review of public transport operator websites and relevant company literature.

A wider search of transport journals (through the Science Direct website), information from the research councils and an internet search also took place.

1.3 Bus

This review considers seven carbon footprinting approaches:

- Government (public sector):
    - National Atmospheric Emissions Inventory
    - DEFRA guidelines for GHG Company Reporting (both the 2007 and 2008 versions)
    - Transport Direct Carbon Calculator
    - DfT New Approach to Appraisal

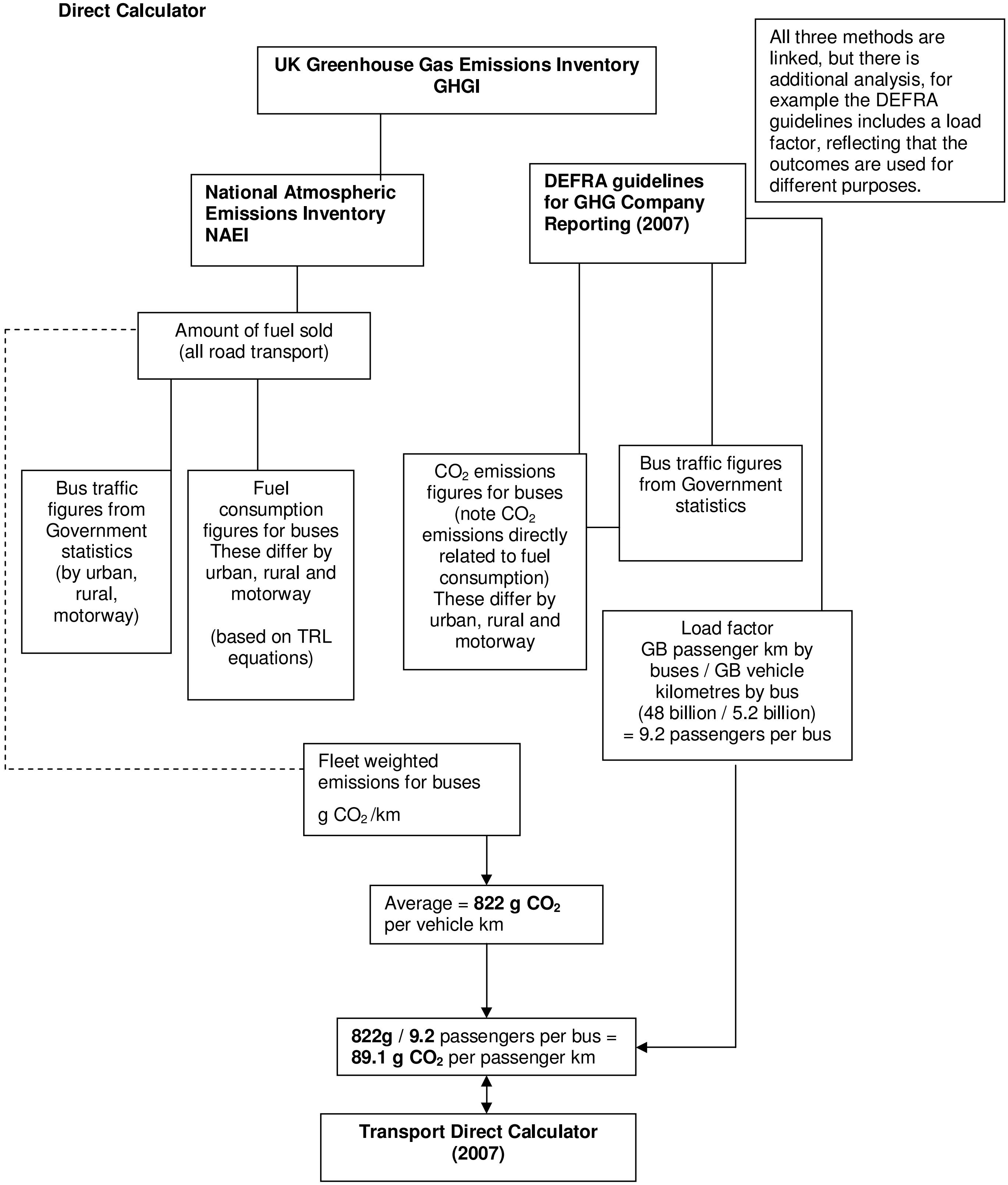
- Private Sector:
    - Go Ahead
    - National Express
    - First Group

To help set the scene outcomes from the different carbon footprinting approaches are set out below in Table 1.1. Furthermore, the links between the first three approaches are set out in Figure 1-1, it is clear that the information from the NAEI is used to inform the UK GHGI, and there are links between the NAEI and DEFRA guidelines for GHG Company Reporting (2007 version). The former provides information on emissions per vehicle km and the latter uses this figure along an average load factor to calculate emissions per passenger km (which, in a guidelines approach, is a more useful metric).

Table 1.1 Outcomes from the different bus carbon footprint approaches

Approach	Outcome
NAEI	822 g CO_2 per vehicle km
DEFRA guidelines for GHG Company Reporting (conversion factors used) (2007; 2008)	Bus 89.1 g CO_2 per passenger km (2007 figures) Local bus 115.8 g CO_2 per passenger km (2008 figures) London bus 81.8 g CO_2 per passenger km (2008 figures) Average bus 107.3 g CO_2 per passenger km (2008 figures)
Transport Direct Carbon Calculator	89.1 g CO_2 per passenger km (2007) 107. 3 g CO2 per passenger km (2008)
DfT New Approach to Appraisal	None
Go Ahead	490 g CO_2 per passenger journey
National Express	99 g CO_2 per passenger km
First Group	665 g CO_2 per passenger journey (also references DEFRA guidelines for GHG)

Figure 1-1 Links between NAEI, DEFRA Company Reporting Guidelines and the Transport Direct Calculator



Government approaches (NAEI, Defra Company Reporting Guidelines and the Transport Direct Calculator)

Detailed information on the above approaches (including data tables) is provided in Appendix one. Key information includes data on g CO_2 per bus vehicle km under different driving conditions (shown in Table 1.2) and the percentage split between different the driving conditions (shown in Table 1.3).

Table 1.2 CO_2 Emissions from different bus emission classes (from the UK GHG Inventory)

CO_2 /km (g)	Urban	Rural – single carriageway	Rural – dual carriageway	Motorway
Pre – 1998	1254	561	683	718
Pre- Euro I	1212	547	669	704
Euro I	1003	613	656	669
Euro II	905	600	640	654
Euro III	905	600	640	654
Euro IV	878	582	620	635
Euro V	851	564	601	615

Please note that the UK GHGI data suggests that fuel consumption, and therefore CO_2 emissions, decreases over time. This conflicts with statements by the bus operators[1], which suggest that the use of Euro Standard III buses results in an increase in fuel consumption, and therefore CO_2 emissions. This issue is considered further in Chapter 3.

Table 1.3 Split of Journey types

Road type	Urban	Rural – single carriageway	Rural – dual carriageway	Motorway
Percentage of bus vehicle km	62%	23%	6%	9%

Combining Table 1.2 and Table 1.3 with the proportion of the different bus vehicle km undertaken by the different Euro standard vehicles results in a fleet average of 822 g CO_2 per km (shown in Table 1.4).

Table 1.4 Proportion of bus vehicle km travelled by buses meeting the different Euro Standards (2007)*

	Average for all journeys (g CO_2/km)	Proportion of bus vehicle km (%)
Pre-1988	1011	4
Pre-Euro I	980	6
Euro I	862	9
Euro II	796	38
Euro III	796	43
Euro IV	772	0
Euro V	748	0
Fleet average	**822**	**100**

**Please note that this is from the 2007 report - increased levels of Euro IV and Euro V will be reflected in later versions*

DEFRA guidelines for GHG Company Reporting (2007)

The 2007 DEFRA guidelines for GHG Company Reporting (emission factors for bus) used data from Transport Statistics Great Britain on passenger km by buses (i.e. 48 million) and vehicle km by bus (5.2 billion) to calculate an average load factor of 9.2 per bus. Dividing the 822 g CO_2/ km figure by the 9.2 results in an average of 89.1 g CO_2 per passenger km used in the guidelines.

[1] http://www.firstgroup.com/corporate/csr/climate_change_strategy/ukbus_division_strategy.php
Comments on a decrease in fuel efficiency over the Euro Standards were also made by the PTEs.

DEFRA guidelines for GHG Company Reporting (2008)

For the 2008 guidelines new emission factors were developed based on information provided on major bus operator websites/environmental reports (e.g. fuel consumption/emission factors, fuel consumption and passenger km). Emission factors for buses (London and local) were calculated based on data from Transport for London (TfL), National Express, Go-Ahead, Arriva, Stagecoach and First Group.

A total average was estimated based on relative market share according to figures from 'Bus Industry Monitor 2006'[2]. These are shown below in Table 1.5.

Table 1.5 Market share of local bus services by different operators

Bus operator	Percentage
Transport for London	0.90%
Management	2.50%
Municipals	5.60%
National Express	5.90%
Go-Ahead	9.80%
Overseas	11.80%
Stagecoach	14.00%
Arriva	14.50%
Independents	14.50%
First Group	20.60%

Source: Bus Industry Monitor 2006 TAS. Provided on the Stagecoach website at: *http://www.stagecoachgroup.com/scg/about/keyfacts/*

Emission factors for coach services were based on figures from National Express, who provide the majority of scheduled coach services in the UK.

The new average emission factors for different bus service types are summarised in Table 1.6, together with indicative figures from DfT statistics on average bus occupancy levels.

Table 1.6 Average emission factors for different bus types

Bus type	Occupancy	CO_2 per passenger km (g)
Coach	17.1	29.0
Average coach and bus	12.3	68.6
London bus	13.5	81.8
Average bus	9.7	107.3
Local bus	8.9	115.8

The difference in the results in the 2007 and 2008 emission factors relates to two main factors the first is the assumptions around CO_2 emissions associated with vehicle use, the second is with regard to load factors. The 2007 emission factors are based on the extensive testing of limited sample of buses while the 2008 data is based on bus operator data. This issue is discussed further in section three where the 2007 approach is used (reflecting data availability from the PTEs) but a sensitivity analysis to reflect some of the issues addressed in the 2008 approach is undertaken. A higher load factor is used for the 2008 emission factor reflecting the latest data supplied by the DfT.

[2] available on Stagecoach's website.

DfT's New Approach to Appraisal

The New Approach to Appraisal[3] is an analysis tool "which appraises the economic, environmental and social impacts of all transport proposals that require DfT funding or approval".

For road vehicles, the following steps apply for the calculation of carbon emissions:

1. **Calculation of Fuel Consumption:**

- Fuel consumption in litres per kilometre based on average speed in km per hour and parameters (supplied by the DfT and provided in Appendix one)

2. **Calculation of Carbon Emission Levels for each year:**

- Fuel consumption can be converted into carbon emissions by multiplying fuel consumption by the grams of carbon released from burning one litre (g carbon/l) of petrol or diesel (conversion factor supplied by the DfT and provided in Appendix one - for example in 2007 one litre of diesel fuel releases 2631 g CO_2)

3. **Calculation of the change between the two scenarios for each over a 60-year appraisal period**

4. **Estimation of the Social Cost of Carbon (SCC)**

The approach therefore requires information on **speed levels** of different buses.

Private Sector approaches

National Express

National Express employed the Edinburgh Centre for Carbon Management (ECCM) to undertake their Carbon Footprint analysis. ECCM use the World Business Council for Sustainable Development's (WBCSD) and the World Resource Institute's (WRI) Greenhouse Gas Protocol Initiative accounting procedure.

The assessment methodology follows a similar approach to that used in the NAEI and DEFRA guidelines for GHG Company Reporting in that:

- Carbon emission sources are identified (in this case transport emissions)
- A calculation approach is chosen (recognising that when direct monitoring is not available accurate, emission data can be calculated from fuel use data).
- Data is collected and emission factors chosen.
- Calculation tools are applied (companies may substitute their own GHG calculation methods provided they are more accurate than or at least consistent with the GHG protocol corporate standard approaches).

It should be noted that analysis of the calculation tools[4] suggests that each litre of diesel fuel would produce 2746 g CO_2, which is slightly higher than the DfT emission factors of 2631 g CO_2 per litre.

First Group

First Group also employed ECCM who used the WBCSD's and the WRI's Greenhouse Gas Protocol Initiative accounting procedure. DEFRA guidelines for GHG Company Reporting and work by AEA were also referenced in their company reports.

[3] DfT (2008) Webag http://www.webtag.org.uk/
[4] The Greenhouse Gas Protocol Initiative http://www.ghgprotocol.org/calculation-tools/all-tools - The CO_2 Emissions from Transport and Mobile sources.

Go Ahead

Go Ahead (in their company reports) provide data on fuel use, CO_2 emissions from bus use and total passenger journeys:

- CO_2 from bus use is 268,823 tonnes
- Passenger journeys are 548 million

The 490 g CO_2 per passenger journey figure is based on dividing the CO_2 from bus use figure by the number of passenger journeys.

In terms of calculating the CO_2 emissions from bus use figure it is not clear what assumptions have been made. Data on fuel use is provided (109.8 million litres). However, applying standard emission factors to this for example the DfT's 2631 g CO_2 per litre results in a slightly higher figure of 288,786 tonnes.

Conclusions

The literature review suggests that the key difference between the bus carbon footprinting methods relates to whether a **'top down' (total fuel)** or a **'bottom up' approach (based on fuel consumption per bus type and vehicle km**) is used. The appropriateness of the different methods for the PTEs' carbon footprinting will depend on the availability of this data (fuel use, fuel consumption and vehicle km), which is discussed in sections two and three. Recommendations on ways forward for the PTEs are therefore made at the end of section three. It should also be recognised, however, that these need not be separate approaches. For example data on total fuel use (where available) can be used as a check on approaches that use fuel consumption and vehicle km (as in the NAEI and Defra Company Reporting Guidelines).

The WBCSD and WRI Greenhouse Gas Protocol accounting procedure follows a similar approach to the NAEI emissions Inventory and the DEFRA guidelines for GHG Company Reporting and is both a 'top down' and 'bottom up' method. Though slightly different emission factors are used the difference is not significant enough to be considered an issue. The similarities between these approaches will bring benefits with regard to transferability of the methods.

1.4 Rail

This review considers nine carbon footprinting approaches:

- Government (public sector):
    - National Atmospheric Emissions Inventory
    - DEFRA guidelines for GHG Company Reporting (both the 2007 and 2008 versions)
    - Transport Direct Carbon Calculator
    - DfT New Approach to Appraisal
    - DfT Network Modelling Framework Rail environmental model

- Private Sector:
    - Go Ahead
    - National Express
    - Eurostar
    - Virgin

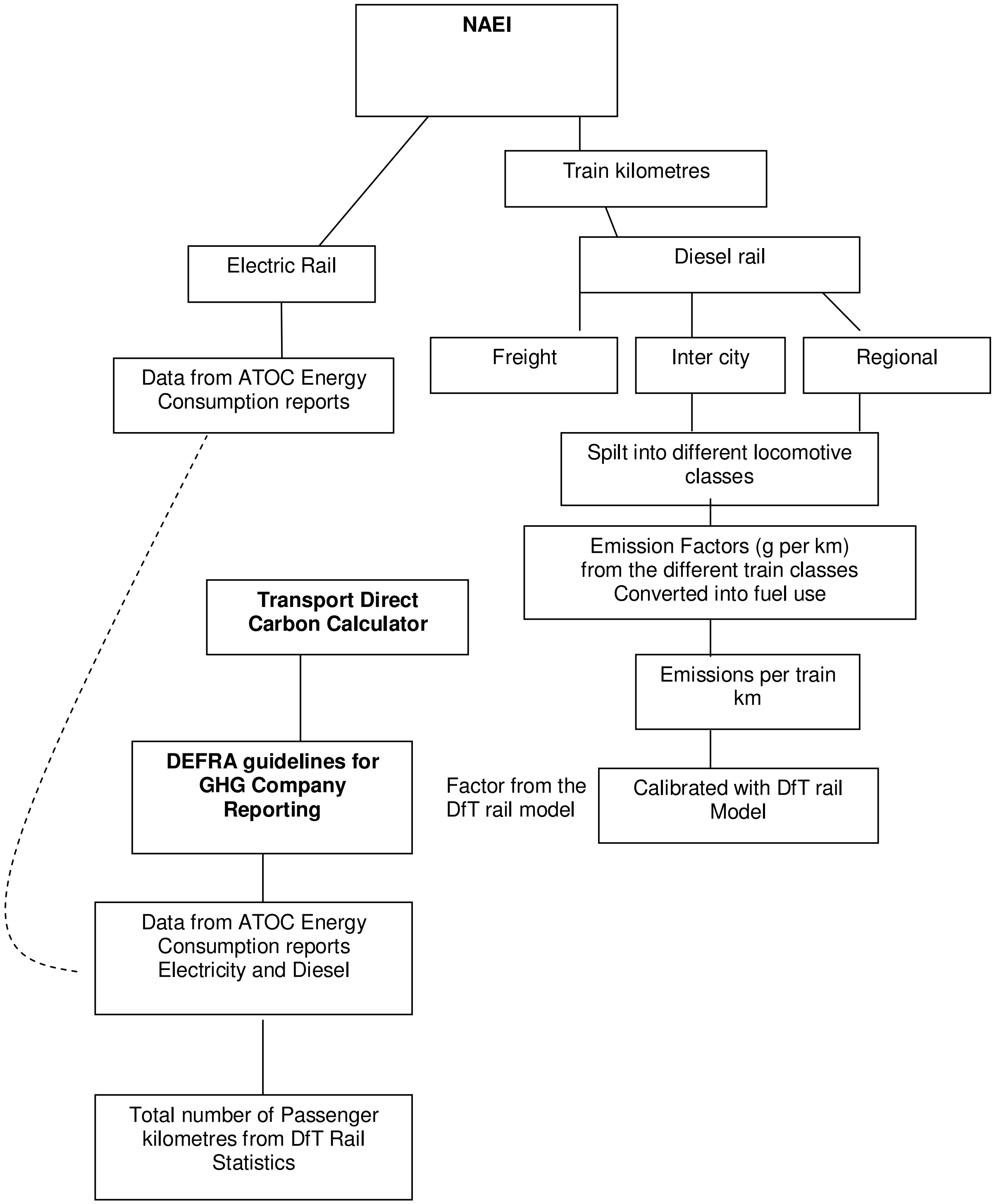
To help set the scene, outcomes from the different approaches are set out below in Table 1.7 Links between the Government's approaches are shown in Figure 1-2. Here, data from the ATOC energy consumption reports is used in the NAEI and DEFRA guidelines for GHG company reporting for electric, and electric and diesel rail respectively. For diesel rail, the NAEI uses rail km travelled and gas oil consumption by the railway sector and this is calibrated with the DfT rail model. While the DEFRA guidelines for GHG company reporting emission factors are used in the Transport Direct Calculator.

Table 1.7 Outcomes from the different rail carbon footprinting approaches

Approach	Outcomes
NAEI	Emissions from electric trains are reported under Public Electricity section of the inventory (most of the electricity used by the railways for electric traction is supplied from the public distribution system) Diesel trains Intercity 8873 g CO_2 per vehicle km Regional 657 g CO_2 per vehicle km
DEFRA guidelines for GHG Company Reporting (2007; 2008)	60.2 g CO_2 per passenger km in 2007 Remains the same in 2008
Transport Direct Carbon Calculator	60.2 g CO_2 per passenger km
DfT New Approach to Appraisal	Recommends the use of the Rail Emission Model[5] There are links with the NAEI
DfT Network Modelling Framework Environmental Model	CO_2 per route
Go Ahead	1240 g CO_2 per passenger journey
National Express	52 g CO_2 per passenger km
Eurostar	Varies depending on assumptions – UK section in the region of 40 – 60 CO_2 g per passenger km
Virgin	Pendolino = 27.2 g CO_2 per passenger km Voyager = 74.1 g CO_2 per passenger km

[5] http://www.dft.gov.uk/pgr/rail/researchtech/research/railemissionmodel

Figure 1-2 Links between different rail carbon footprinting approaches



NAEI

The NAEI considers electric and diesel rail separately. For electric trains a 'top down' approach is used and emissions are based on fuel consumption data from the Department for Business, Enterprise and Regulatory Reform (BERR).

For diesel trains, emissions are split into three categories: freight, intercity and regional.

Carbon dioxide emissions are calculated using fuel based emission factors and fuel consumption data. The fuel consumption is distributed according to:

- Rail km data taken from the National Rail Trends Yearbook (2007)[6] for the three categories
- Assumed mix of locomotives for each category (based on data from the Association of Train Operating Companies (ATOC))
- Fuel consumption factors for different types of locomotive

Fuel consumption factors for the different types of locomotive are based on analysis by AEA for the Strategic Rail Authority to develop a Rail Emission model[7] and includes work undertaken by the London Research Centre. Information on these factors is provided in Appendix two.

The DEFRA guidelines for GHG Company Reporting and Transport Direct Carbon Calculator

The DEFRA guidelines for GHG Company Reporting conversion factors for rail are based on data from ATOC Energy Consumption reports for electricity and diesel. This data is commercially sensitive and we are unable to provide it here. This is converted into g CO_2 and divided by the total number of passenger km (43,211 million in 2005/2006) from DfT rail statistics[8]. This results in an average 60.2 g CO_2 emission per passenger km figure.

The Transport Direct Carbon Calculator is based on the approach taken by DEFRA's guidelines for GHG Company Reporting, so has a factor of 60.2 g CO_2 per passenger km.

DfT Network Modelling Framework Environmental Model

The Network Modelling Framework (NMF) Environmental Model was developed by AEA to assess the most significant environmental impacts and the environmental damage costs associated with all rail services included in the DfT's new NMF. Such a model was required primarily to support the High Level Output Specification (HLOS) process, which has been used to set out what the Government would like the rail industry to achieve over 2009-2014 time period. Essentially, the model is a tool that allows DfT to assess the environmental impacts and damage costs associated with future timetable scenarios and railway policy decisions.

In order to develop both the emissions model (and the associated noise model), a significant amount of detailed railway and environmental data was required. The data included the following:

- **Rolling stock data** – including train configurations, power output data for each rolling stock class and train configuration, and emission factor data.
- **Timetable data** – Timetables from the NMF for 2005 and 2009 were used to develop the emissions and noise models.
- **Energy consumption data** – Annual energy consumption data for both diesel and electric passenger services, disaggregated by train operating company, were obtained from ATOC.
- **Geographical co-ordinate data for the Strategic Rail Network** – Detailed co-ordinate data for each route link (Strategic Route Section) were obtained from the Network Modelling Framework.

[6] National Rail Trends Yearbook http://www.rail-reg.gov.uk/upload/pdf/330-rev4.pdf

[7] AEA for the Strategic Rail Authority (2001) Rail Emission Model
http://www.dft.gov.uk/pgr/rail/researchtech/research/railemissionmodel

[8] Department for Transport - DfT (2007b). *Transport Statistics Bulletin – Public Transport Statistics Bulletin GB: 2007 Edition*. [online]. Available at: http://www.dft.gov.uk/162259/162469/221412/221535/224237/271898/publictransportstatistics07.pdf

The model calculates energy consumption and energy output data for each train service and uses these parameters in conjunction with rolling stock emission factor data, power station emission factor data, and data on the carbon and sulphur content of gas oil and diesel fuel in order to estimate emissions of CO_2 (and air pollutants). This calculation included the following stages:

- The diesel consumption and electricity consumption data generated by the model are normalised by calibrating the model outputs against actual rolling stock energy consumption data for each train operating company published by ATOC; hence the emissions estimates produced by the model for each train service are validated and corrected using real-world data.
- Estimates of **CO_2 emissions from diesel trains** are calculated in the model using the normalised diesel consumption data calculated for each train. CO_2 emissions from diesel trains are directly proportional to fuel consumption.
- For **electric trains**, the model quantifies annual emissions using electricity consumption data in conjunction with national average power station emission factor data. Current power station emission factors are based on data published by BERR.

Parallels between this approach, the NAEI and DEFRA Company Reporting Guidelines can be drawn - for example the use of rolling stock data and energy consumption data from ATOC. The development of the model and the use of additional data, for example timetable information, enables more detailed outcomes to be produced. The model is effectively a ‘bottom up’ approach which is verified and calibrated with ‘top down’ data.

Go-Ahead

Go-Ahead take a ‘top down’ approach[9], the majority of their rail fleet runs on electricity and electricity consumed for traction is reported as a key indicator of environmental performance. Go-Ahead highlight that the amount of electricity consumed by each train operating company is calculated by Network Rail by apportioning a share of total consumption within large areas of the network based on a range of factors such as the numbers of trains operated, the type of journeys and the number of journeys made.

Eurostar

AEA have worked with Eurostar to calculate the carbon footprint of their trains. All Eurostar trains are powered by electricity, so a ‘top down’ approach was used based on two parameters – the energy consumption of the train and the emissions from the electricity generated to power the train. Assessments were provided using both the average UK electricity mix as well as the emissions data from Eurostar’s specific electricity provider (when in the UK) as they had lower CO_2 emissions per unit of electricity supplied.

The study used route specific load factors to assess the emissions per passenger carried and the emissions per passenger km. It also considered how these emissions might change in the future with the new high-speed Eurostar service (CTRL2), and the future electricity generation mix. Journey delays were not taken into account.

National Express

National Express uses the WBCSD’s and WRI’s Greenhouse Gas Protocol Initiative Corporate GHG accounting for calculating rail (as well as bus) emissions. The GHG accounting worksheets reference UK and US Government data (including DEFRA figures from 1999). In the analysis for rail, DEFRA guidelines for GHG Company Reporting conversion factors have been used.

[9] The Go-Ahead Group Plc Environmental and Social Reporting (2006) http://www.go-ahead.com/content/doc/cms/CSR%20Web%20Text%200506%20(7).pdf

Virgin

Virgin provides information on both its West Coast (Pendolino) and CrossCountry (Voyager) journeys. ECCM carried out the analysis and the results are shown below in Table 1.8 and Table 1.9. A 'top down' approach (based on energy use) is used. Conversion factors from DEFRA (2005) are used rather than the latest information, reflecting when the calculations took place.

Table 1.8 Calculation of Emissions for Pendolino

Energy consumption of a Class 390 Virgin Pendolino service traveling between London Euston and Manchester Piccadilly	4200 kWh
Distance London Euston to Manchester Piccadilly	265.5km
Energy consumption per train kilometre	14.17 kWh/km (derived from above)
Seats per train	439
Load factor for Virgin Intercity West Coast trains	0.51
Average number of passengers per train	224 (derived from above)
Energy consumption per passenger	0.06 kWh / pass km
CO_2 emissions for electricity	0.43 kg/ kWh (DEFRA, 2005)
Conversion miles to km	1.609
CO_2 emissions per passenger kilometre	0.0272 kg CO_2/ pass km (derived from above)
CO_2 emissions per passenger mile	0.0438 kg CO_2 / pass km (derived from above)

Table 1.9 Calculation of Emissions for Voyager

Fuel consumption for the Voyager fleet year 2005/2006	99 million litres gas oil
Total fleet km, year 2005/2006	30.1 million
Fuel consumption for the Voyager fleet year 2005/2006	3.3 litres/km (derived from above)
Average number of seats per train	217
Load factor of Virgin CrossCountry trains	0.55
Average number of passengers per train	119 (derived from above)
Fuel consumption per passenger	0.028 litres
CO_2 emissions for gas oil	2.69 kg / litre (DEFRA, 2005)
Conversion miles to km	1.609
CO_2 emissions per passenger kilometre	0.0741 kg CO_2 / pass km (derived from above)
CO_2 emissions per passenger mile	0.1192 kg CO_2 /pass km (derived from above

Conclusions

A key difference between the rail carbon footprinting methods relates to whether diesel or electric rail is used. **Electric rail** emissions are calculated in a **'top down'** way based on energy used. For **diesel rail** emissions a **mixture of approaches are used** – **'top down'** based on energy use and **'bottom up'** in terms of train vehicle km and emissions associated with different vehicle classes. The appropriateness of the different methods for the PTEs carbon footprinting will depend on the availability of this data (fuel use, fuel consumption and vehicle km), which is discussed in sections two and three. Recommendations on ways forward for the PTEs are therefore made at the end of section three. It should also be recognised, however, that the two methods need not be used in isolation; one set of results could be used as a check on the other.

The similarities between the NAEI, DEFRA guidelines for GHG Company Reporting and the Greenhouse Gas Protocol Accounting Procedure bring benefits in terms of the transferability of methods.

1.5 Light Rail

Table 1.10 Outcomes from the different bus carbon footprint approaches

Approach	Outcome
NAEI	Emissions from light rail are reported under Public Electricity
DEFRA guidelines for GHG Company Reporting (2007; 2008)	78 g CO_2 per passenger km (2008 figures) 65 g CO_2 per passenger km (2007 figures)

NAEI

Light rail is powered by electricity and therefore like heavy rail a 'top down' approach is used and emissions are based on fuel consumption data from BERR.

DEFRA guidelines for GHG Company Reporting

In 2007, the light rail factors were based on an average of factors for the Docklands LightRail (DLR) service, the Manchester Metrolink and the Croydon Tramlink. In 2008, the figures were based on the same light rail systems as 2007 with the addition of Tyne and Wear Metro. The factors for these light rail systems were based on annual electricity consumption and passenger km data provided by the network operators and the CO_2 emission factor for electricity generation on the national grid from the UK Greenhouse Gas Inventory.

Conclusions

A '**top down'** approach based on electricity consumption is likely to be the most appropriate method of carbon footprinting light rail. However, as with bus and rail it is more appropriate to make recommendations at the end of section three.

2 Data Collection

Key findings:

This review of the data collection process results in a number of recommendations, including:

- a data request form (template) should be used to help facilitate data gathering
- it may be appropriate for the PTEs to consider how changes within the current data collection process could help facilitate data collection.

These recommendations must be seen in conjunction with the outcomes of Section three, in particular the role of more detailed data in facilitating the development of 'real life' carbon footprints.

The carbon footprinting method used by the PTEs will depend on the availability of different data, and data collection was therefore an important part of the project. A threefold approach was used:

- The PTEs
- Public transport operators
- Government transport statistics

2.1 PTEs

From the outset of the project a representative from each PTE was in charge of data collection. This was beneficial to AEA in terms of monitoring the data collection process.

The PTEs collected the data:

- Internally - through PTE data collection contacts and annual reports (where available); and
- Externally - through bus and rail operator contacts

AEA supplied the PTEs with a data request for the following information:

- Vehicle km:
    - Weekday and weekend
    - Morning peak (8am to 9am), total for the day
- Patronage:
    - Number of passengers, weekday and weekend (with information on route if possible)
- Passenger km:
    - Weekday and weekend (with information on route if possible)
- Fuel use:
    - Type of fuel and amount of fuel used by bus route number
- Vehicle types by Euro standard

Information on the split between rural and urban journeys was also requested.

The request was detailed to try and elicit as much information as possible to enable the testing of the different carbon footprinting approaches. For example, information on vehicle km and vehicle types would allow the development of a 'bottom up' approach, while information on fuel use would allow a 'top down' approach. Information on patronage and passenger km would enable CO_2 per passenger journey and per passenger km to be calculated respectively.

The number of passenger journeys and passenger km undertaken varies by time of day and day of the week. In order to attempt to elicit the scale of this change, morning and evening peak information was requested.

Where appropriate, reassurance that the data would be treated as confidential was provided.

Towards the end of the project AEA asked (via telephone) each PTE representative to comment on the data collection process. Key issues identified included the time taken for the data to be collected, with the process taking between 2 to 3 months. Accessing the data was not always straightforward: the PTE representative had to identify the person in charge of data collection, contact them (and wait if they were on leave/ absent due to ill health) and follow up if the data was not forthcoming. One recommendation was that in terms of future carbon footprinting, the length of time that data collection may take should be incorporated into any planning. It was suggested in helping facilitate access to the data, a short note or template (similar to the one used in project) would be useful. The PTE representatives also mentioned that the project made them aware that there was less data available than they had anticipated and that this was something they may address in the future. It should be noted that some of the PTEs produced annual reports and this was a useful source of data.

The outcomes of the PTE data collection process are presented and considered in detail in Section three on data analysis. The scope and extent of the data collected varied between the PTEs and the mode of transport: for bus and rail there was limited information available on fuel use, patronage and passenger km and these are therefore areas where stronger data is required in the future.

2.2 Public Transport Operators

At the start of the project the five largest public transport operators (Stagecoach, Go Ahead, Arriva, National Express and First Group) were contacted by PTEG. Background information to the project was provided and this was accompanied by a detailed data request (which had been produced by AEA and TTR). The public transport operators' response to the data request was limited. As a result, telephone conversations and meetings instigated by AEA followed the request. It became clear that the public transport operators receive data requests continually but do not have the staff resources to respond to these requests. Hence the lack of a positive response to the PTEG request is due to wider issues. The conversations helped make it clear that there was interest in the project, particularly when the operators could see how outcomes could link into analysis they had undertaken. There were also useful discussions around the use of the different metrics, with Go Ahead making it clear that limited data on passenger km resulted in the use of 'g CO_2 per passenger journey' rather than 'g CO_2 per passenger km' metric.

AEA also undertook a literature review on existing data provided by the Public Transport Operators in their company reports[10]. This included from:

- Stagecoach Group Plc:
    - Total passenger mileage information

- Go-Ahead Group Plc:
    - Bus passenger vehicle km (regional data)
    - Rail passenger journeys (regional data)

2.3 Government Transport Statistics

AEA also undertook a review of Government (i.e. DfT) transport statistics[10]. This included:

- DfT (2007) Regional Transport Statistics:
    - Bus vehicle km

[10] AEA (2008) Review of UK Bus and Rail statistics report to PTEG February 2008

- DfT (2007) Transport Statistics Bulletin – Public Transport Statistics Bulletin:
    - Bus passenger journeys
    - Rail passenger km
    - Rail passenger journeys

Data from the above is used in the following section in comparison with the data supplied by the PTEs and background data.

Recommendations

The data collection process enabled a number of recommendations to be developed:

- For data collection for future carbon footprinting activities there should be a named representative within the PTEs responsible for data collection.

- The length of time of data collection could take (up to three months) should be reflected in any project planning.

- A data request form (template) should be used to help facilitate data gathering. An example is provided in Appendix four.

- It may be appropriate for the PTEs to consider how changes within the current data collection process within the PTEs could facilitate easier data collection. For example, key information could be stored on a central pteg intranet.

- Annual reports could be one means of facilitating data collection.

- It may be appropriate for relationships with public transport operators to be developed further. This could be particularly useful with regard to accessing fuel use data and rail data.

- Government Transport Statistics provided a useful crosscheck and source of additional information.

3 Data analysis

Key findings:

- Overall, the carbon footprinting figures generated by PTE data are consistent with public and private sector figures.
- There is validity in having weighted average cross-PTE figures for bus, rail and light rail.
- The weighted average cross-PTE figures for bus and light rail are relatively consistent with Transport Direct.
- The weighted average cross-PTE figures for rail are relatively consistent with Transport Direct. In the future, Transport Direct may be developed to reflect regional and intercity rail travel and the PTE figure could be used to help with the former.
- The use of individual figures for PTES also has validity for benchmarking.
- The carbon footprinting figures, particularly bus and rail, involved a number of assumptions and aggregations.
- The reliability of the carbon figures could be improved through the provision of more consistent and more comprehensive data from the PTES, in particular, data on passenger kilometres and passengers journeys, by vehicle type, and data on peak and off peak trips.
- In a comparison of public and private transport modes the report finds that rail and most light rail systems outperform the car. However the smallest and most fuel-efficient cars can outperform the bus. However, it is important that comparisons with the car are viewed in a wider context.
- It is recommended that these figures are reviewed on a bi-annual basis to reflect the greater availability of consistent data for example on passenger kilometres and passenger journeys and changes in vehicle fleets.

3.1 Introduction

For each of the modes (bus, rail and light rail), the outcomes of the data collection process are discussed below. A carbon footprint approach is suggested and then analysis to produce results for all metrics (g CO_2 per vehicle kilometre; g CO_2 per passenger journey; g CO_2 per passenger km[11]) is undertaken.

3.2 Bus

Bus information was available on the following parameters:

- Vehicle types by Euro standard were available from all PTES, note this had to be inferred for Centro.
- Vehicle km (with information on vehicle km by route available from WYPTE and SYPTE).
- Patronage – information on the total number of passengers was available for all PTEs (detailed information was available from WYPTE and SYPTE)
- Passenger km (available for approximately half the PTEs) detailed information available from SYPTE).
- Fuel use:
    - Type and amount of fuel used by buses – only Centro (total fuel use) provided this information (which was from their annual report). BERR is the source of this fuel use number and this discussed in the Top down section on fuel use.
- Rural/urban journey split – this varied amongst the PTEs with some able to provide a stronger steer than others.

[11] in line with the outcomes of the discussion at the PTEG meeting (27th May).

The limited information on fuel use supplied by the PTEs meant that a 'top down' approach (as in the NAEI or Greenhouse Gas Protocol accounting procedures) as the primary carbon footprinting approach was not feasible. However, data used by BERR could be, and was, used as a secondary check.

Data was, however, available on vehicle types, split by Euro standard and vehicle km, and therefore a 'bottom up' approach in line with the DEFRA guidelines for GHG Company Reporting (2007) could be used to calculate the CO_2 emissions associated with bus use. Data on patronage and passenger km was also available which meant that g CO_2 per passenger journey and g CO_2 per passenger km could also be calculated. Below we go through each of these metrics in turn and then undertake a sensitivity analysis with regard to assumptions on Euro Standards, consider the potential for variation by time of day, day of week and different routes and then use BERR data in a top down approach.

Bottom up - CO_2 emissions associated with vehicle use

The analysis for CO_2 emissions associated with bus vehicle use is shown in Appendix five. The results are shown below in Table 3.1.

Table 3.1 Fleet Average Emissions

	Fleet Average g CO_2/km
Centro	900.6
GMPTE	926.3
Merseytravel	907.0
Nexus	946.4
SPT	900.3
SYPTE	935.6
WYPTE	942.0

Discussion
As can be seen, fleet average emissions are relatively similar across the PTEs (only a 6% difference between the highest and lowest fleet average emission factors) and are slightly higher than the UK average of 822g CO_2 per kilometre (DEFRA guidelines for GHG Company Reporting 2007). It should be noted that the UK average figure takes into account London, which has newer, lower emitting buses. There is also the potential that the PTEs' numbers overestimate the amount of urban driving (which has higher levels of CO_2 emissions associated with it). The PTEs reported that data collection on the split between urban and rural was difficult (with issues over classification raised).

We note that there are sensitivities around the use of this approach and undertake an analysis to reflect this later in this section.

Bottom up - bus vehicle km and total CO_2 emissions

The PTEs were also able to provide data on bus vehicle km and this is shown below (Table 3.2). As a check, numbers from DfT Statistics are provided in brackets and the numbers are similar. With WYPTE, information on the total number of passenger journeys was not available, and so DfT data was used.

This information is combined with the fleet average information (Table 3.1) to provide total CO_2 emissions, using the following equation:

$$\text{Number of bus vehicle km} \times \text{Fleet Average Emissions} = \text{Total } CO_2 \text{ Emissions}$$

Table 3.2 Total CO_2 emissions (tonnes)

	Number of bus vehicle km (million)	Total CO_2 emissions (thousand tonnes)
Centro	139.3 (128)	125.4
GMPTE	114 (129)	105.7
Merseytravel	73.4 (77)	66.5
Nexus	77.3 (75)	73.1
SPT	155 (Total for Scotland 377)	139.5
SYPTE	70.1 (71)	65.6
WYPTE	(104)	98.0

Bottom up - CO_2 emissions per passenger journey

To calculate g CO_2 per passenger journey, total CO_2 emissions are divided by passenger journeys. Data on the number of passenger journeys from the PTEs is provided in Table 3.3. As a check DfT Statistics numbers are provided in brackets and these numbers are similar. For the WYPTE, information on the total number of passenger journeys was not available, so DfT data was used.

Table 3.3 CO_2 per passenger journey

	Number of passenger journeys (million)	CO_2 per passenger journey (g)
Centro	310.4 (317)	404.1
GMPTE	223 (217)	473.9
Merseytravel	153.8 (150)	432.8
Nexus	130.0 (124)	562.4
SPT	221	631.4

	(Total for Scotland 482)	
SYPTE	113.4 (116)	578.5
WYPTE	(185)	529.51

Discussion
Larger differences between the PTEs were noted for the g CO_2 per passenger journey metric (404.09 to 631.44g). It should be noted that Go Ahead and First Group suggest 490 and 665 g respectively and that this lower end figure (the 490g) is higher than the Centro, GMPTE and Merseytravel figures. However, care should be taken because of the impact of assumptions with regard to the rural urban split for example with Merseytravel, the use of average Euro standard information for Centro and most importantly because of the differences in bus operators data and that used in Table 3.1 (Appendix five), particularly with regard to the treatment of the different Euro Standards. We undertake an analysis to reflect this later in this section.

Bottom up - CO_2 emissions per passenger km

To calculate g CO_2 per passenger km, the fleet average (Table 3.1) is divided by the load factor. The load factor can be calculated through the total number of passenger km being divided by the total number of vehicle km and outcomes are shown in Table 3.4 For the PTEs where information on passenger km was not available, an average (8.6) was used.

Table 3.4 CO_2 per passenger km

	Passenger km (million)	Load factor (passenger km / vehicle km)	CO_2 per passenger km (g) (fleet average / load factor*)
Centro			104.7
GMPTE		Provided an average of 9	102.9
Merseytravel	600.2	8.2	110.8
Nexus	654.0	8.5	111.8
SPT			104.7
SYPTE	613.8	8.8	106.8
WYPTE			109.5

* (average used where load factor data not provided)

Discussion
CO_2 emissions per passenger km (in the range 102.9 to 111.8 g) are slightly lower than the local bus information provided in DEFRA guidelines for GHG Company Reporting 2008 (115.8 g). The sensitivity analysis in the next section helps explain this difference. It should be noted that care should be taken when comparing the PTEs because of the use of an average load factor for some of the PTEs.

Bottom up – sensitivity analysis around Euro Standards

The UK GHGI data suggests that fuel consumption, and therefore CO_2 emissions, decreases over time. This conflicts with statements by the bus operators[12], which suggest that the use of Euro Standard III buses results in an increase in fuel consumption, and therefore CO_2 emissions. There are two explanations for this difference. First, the bus operators may use PM traps. The UK GHGI data does not refer to Euro III with PM traps, and if it did a decrease in fuel efficiency would have been assumed[13]. Second, the UK GHGI data is based on test cycle measurements, which are limited to extensive tests, but only done on a very small sample of vehicles. In comparison, fuel consumption data from operators is based on a much larger sample of vehicles, but limited to an overall average, without the information that test cycle data gives on how fuel consumption changes with cycle. The approach by bus operators could therefore be considered as more representative.

It should be noted that new emission factors for bus (and other vehicles) developed by TRL, have been consulted on by the DfT, and are in the process of being finalised. The emission factors take into account the latest available vehicle emission test data from the DfT's emissions testing programme and other EU projects. These factors will in time be adopted for the NAEI and GHGI. The TRL data provides factors for 3 different sizes of buses and 2 for coaches. They show how fuel consumption varies with size of bus and also by Euro class up to Euro VI. These indicate that at urban speeds the fuel consumption factors for a given size of bus is virtually the same for Euro I to Euro III, but could be a little higher for Euro III, and then decreases (i.e. improves below Euro II levels) for Euro IV. We recommend that the PTEs monitor the outcomes of this consultation.

It is important to consider the impacts of the above on the earlier results. As an illustration we therefore modelled a scenario where there was no improvement between Euro I and Euro II and a 5% increase in fuel use and therefore CO_2 emissions for Euro III. The results are shown in Table 3.5.

Table 3.5 Fleet average assuming no improvement between Euro I and Euro II and 5% increase in fuel use (and therefore CO_2 emissions) for Euro III

	Improvement between Euro I and III Fleet Average g CO_2/km	No improvement between Euro I and II and 5% increase in fuel use for Euro III Fleet Average g CO_2 / km	Difference in emissions (%)
Centro	900.6	1008.8	12.0%
GMPTE	926.3	1025.8	10.7%
Merseytravel	907.0	1002.0	10.5%
Nexus	946.4	1047.4	10.7%
SPT	900.3	985.5	9.5%
SYPTE	935.6	1035.1	10.6%
WYPTE	942.0	1029.7	9.3%

[12] http://www.firstgroup.com/corporate/csr/climate_change_strategy/ukbus_division_strategy.php
Comments on a decrease in fuel efficiency over the Euro Standards were also made by the PTEs.

[13] Tim Murrells AEA NAEI expert (2008) personal communication

Table 3.6 CO_2 per passenger km assuming no improvement between Euro I and Euro II and 5% increase in fuel use (and therefore CO_2 emissions) for Euro III

	No improvement between Euro I and II and 5% increase in fuel use for Euro III Fleet Average g CO_2 / km	CO_2 per passenger journey (g)	CO_2 per passenger km (g)
Centro	1008.8	452.7	117.3
GMPTE	1025.8	524.4	114.0
Merseytravel	1002.0	478.2	122.5
Nexus	1047.4	622.8	123.7
SPT	985.5	691.2	114.6
SYPTE	1035.1	639.9	118.2
WYPTE	1029.7	578.9	119.7

Discussion
It is clear, that assuming there was no improvement in fuel use (and therefore CO_2 emissions) between Euro I and Euro II and a 5% increase in fuel use (and therefore CO_2 emissions) for Euro III, there would be an increase in the fleet average emissions, and correspondingly the other metrics. Information on the impact on g CO_2 per passenger journey and km is shown in Table 3.6. This is important in terms of the overall carbon footprint of the PTEs, and means that the for passenger journeys the range suggested by the bus operators (490 g to 665 g) and for passenger km the local bus emission factor (115.8 g) (DEFRA guidelines for GHG Company Reporting 2008) is more closely reflected.

In terms of future PTE updates of bus carbon footprints, UK GHGI data can still be used since it will be adjusted to take account of TRL findings.

Bottom up - variation by time of day, day of week and by different routes

Data on patronage by time of day was provided by SYPTE, GMPTE and WYPTE. There were differences in the forms in which the data was supplied. The SYPTE data was supplied on a route basis for patronage, passenger km and vehicle km route basis. Passenger load factors based on passenger km / vehicle km are shown below in Table 3.7.

Table 3.7 Passenger load factors SYPTE (passenger km/ vehicle)

	Am Peak	Monday to Friday	Saturday	Sunday
Passenger load factor	10.5	9.0	8.7	5.9

GMPTE also supplied load factor data and this is shown below in Table 3.8.

Table 3.8 Passenger load factors data from GMPTE

	Average passenger load
Route 135 Bury Manchester	27
All QBC[14]	18
QBC excluding route 135	15
General Network	9

[14] Quality Bus Corridors

WYPTE figures differed in that they were based on the number of passengers by surveyed buses. Data was provided by time of day and day of week and is shown below in Table 3.9.

Table 3.9 Average load factors data from WYPTE (survey data)

	Average load (based on survey data)
M-F am peak	33
M-F All timeslots	30
Sat	25
Sun	20
Whole week	28

Discussion
Passenger load factors, as expected are highest for am peak and lowest on Sundays. The difference in approach (i.e. passenger km/ vehicle km which was used by SYPTE versus number of passengers / surveyed buses which was used by WYPTE) makes a significant difference to the load factors. The latter is a 'snapshot' in time approach, and it would be interesting to obtain further information about the buses surveyed (for example the route stage). Whilst the former is more comprehensive in that it takes into account the empty running of buses. Data from GMPTE also suggests that there can be large variations by route. It is clear therefore that there is are significant differences in load factor, this adds to the caution discussed earlier in the report with regard to the aggregated figures not being representative of a 'real life' journey. There is also a further issue in the need for a more detailed load factor data from all of the PTEs and this is clearly an area where further data collection is required.

Top down – 'fuel use' data

BERR provide information on road transport 'fuel consumption' estimates by Government Office region and Local Authority[15]. Total fuel use by bus and coach is included in these estimates and is provided in Table 3.10. These estimates are based on CO_2 emission data from NAEI, road traffic consumption factors and traffic flow data from the DfT, therefore although the fuel use estimate is 'top down' the data that informs it is bottom up.

The fuel use covers all bus and coach services (this includes local and non-local services)[16]. Data from the DfT[17] suggests that local bus vehicle km are 2663 billion a year and total bus and coach vehicle km are 5453 billion a year, i.e. local bus vehicle km are approximately 49% of total bus and coach vehicle km. This figure is then applied to the total figure to calculate the fuel use by local services, and converted to CO_2. The results are shown in Table 3.10. For comparison data from Table 3.2 is also included.

Table 3.10 Bus Fuel use by PTE

	Total bus and coach fuel (000 tonnes of fuel) (local and non-local services)	Fuel Use (000 tonnes of fuel) (local services)	CO_2 local services using BERR data 000 tonnes ('top down' approach)	CO_2 local services using PTE supplied data Table 3.2 ('bottom up' approach)	Difference between 'top down' and 'bottom up' approach
Centro	78	38.2	120.9	125.4	-4.5 (-4%)
GMPTE	72	35.3	111.6	105.7	6.0 (5%)

[15] DBERR (2006) Road Transport Energy Consumption at Regional and Local Authority Level http://www.BERR.gov.uk/energy/statistics/regional/road-transport/page36199.html
[16] Non-local services include long distance coach, private hire, school contract and work excursions
[17] Department for Transport (2007) Transport Statistics Great Britain

Merseytravel	41	20.1	63.6	66.6	-3.0 (-5%)
Nexus	45	22.1	69.8	73.1	-3.3 (-5%)
SPT	76	37.2	117.8	139.6	-21.7 (-18%)
SYPTE	41	20.1	63.5	66.6	- 3.0 (5%)
WYPTE	56	27.4	86.8	98.0	-11.1 (-13%)

NB: Slight differences in totals will be due to rounding

Discussion

Overall there is a reasonably good fit between the CO_2 emissions from the 'top down' and 'bottom up' approaches. This fit is to a certain extent to be expected because the NAEI is adjusted to fuel use data, and because the 'top down' fuel use is based on 'bottom up' data. The largest difference is 18% for SPT and this may reflect assumptions with regard to rural / urban split.

Conclusion and recommendations

The data analysis for bus transport allowed a number of conclusions and recommendations to be made.

In terms of approaches to carbon footprinting for bus services we recommend a 'bottom' up approach because data for this (vehicle emission standards and vehicle km) was available whilst data for a 'top down' approach (fuel use data from bus operators specific to the PTEs) was not. However, this could change in the future if bus operator fuel use data becomes available.

In terms of overall outcomes the results tie in reasonably well with UK Government (public) and private sector CO_2 emission figures for bus transport (g per vehicle km, passenger journey and passenger km). The g per passenger km figure (when the sensitivity analysis on Euro Standards is included) is in line with the DEFRA guidelines for GHG company reporting figure for local bus (115.8 g per vehicle km). As shown below in Table 3.11.

Table 3.11 Bus carbon footprint data (*figures in italics include the sensitivity analysis on Euro Standards)*

Bus	CO_2 (g) per passenger journey	CO_2 (g) per passenger km	CO_2 (g) per vehicle km
Centro	404.1 *452.7*	104.7 *117.3*	900.6 *1008.8*
GMPTE	473.9 *524.4*	102.9 *114*	926.3 *1025.8*
Merseytravel	432.8 *487.2*	110.8 *122.5*	907 *1002*
Nexus	562.4 *622.8*	111.8 *123.7*	946.4 *1047.4*
SPT	631.4 *691.2*	104.7 *114.6*	900.3 *985.5*
SYPTE	578.5 *639.9*	106.8 *118.2*	935.6 *1035.1*
WYPTE	529.5 *578.9*	109.5 *119.7*	942 *1029.7*
Average	516.1 *569.7*	107.3[18] *118.6*	922.6 *1019.2*
Weighted average	481.9		919.2

[18] Absence of passenger km data meant that weighted average CO_2 per passenger km data was not possible. However, weighting the figures using data on passenger journey and vehicle km resulted in numbers which were consistent with the average, 106.8 and 106.7 g CO_2 respectively.

	533.4		*1015.4*
DEFRA guidelines for GHG company reporting Guidelines figures (2008)		81.8 London 107.3 average 115.8 Local	

Going forward, a single common PTEG figure has validity in relation to entities like Transport Direct, since it enables a comparison to be made with single figures for London and the country as a whole. However it is important to bear in mind that a single figure is derived from a series of assumptions and aggregations and that the carbon footprints of individual bus journeys within different PTEs will be subject to considerable variation.

Figures for individual PTEs are also of value for benchmarking purposes and provide a greater degree of specificity. Again, sensitivities with assumptions, especially with regard to the urban/rural split would need to be considered and care is required if these individual values are used to compare the PTEs. Here, relevant differences between the PTEs, for example in their degree of urbanisation and levels of congestion would need to be taken into consideration. Overall then, there is the potential for the use, in different contexts, of both PTE-specific and an aggregated PTEG figure.

There are several areas where data collection, and therefore the derived carbon footprint figures, could be improved. These areas include: fuel use data from the bus operators; passenger km data and load factors by route, time of day and day of week. Fuel use data from the bus operators could perhaps be obtained through on-going discussions between the PTEs and operators. Passenger km data was available from three of the PTEs (Merseytravel, Nexus and SYPTE) and these PTEs could share information on approaches used to collect this data with the other PTEs. Detailed passenger km data (and vehicle km data) for example by route, time of day and day of week would also help improve the load factor data. Alternatively, load factor data could be obtained through the use of surveys. This could be discussed at future PTEG meetings and agreed in advance of updates to the analysis.

It is recommended that the carbon emission factors are updated every two years, and that this time period will be sufficient for the data collection to be improved and not be onerous on the PTEs[19].

[19] Outcomes of the PTEG meeting 18th September

3.3 Rail

Overall, data on rail was more difficult to obtain than data on bus and light rail, with limited information available directly from the PTEs. However, information was provided from PTEG contacts at Northern Rail. This data included:

- Fuel use (diesel) by depot (and estimates of fuel split by train class)
- Total electricity use (kWh) by train class
- Rail km by train class
- Patronage by route

As the data was not available at the regional (PTE) level, AEA therefore had to interpret and match it to the PTEs. It should be noted that rail covers 'local' trains, which serve the areas of the region and those that pass through the regions (intercity trains). Discussions at PTEG meetings, suggested that the focus should be on former and this is reflected in the analysis.

A summary of data supplied by the different PTEs and the relevance of Northern Rail data to the PTEs is provided below in Table 3.12.

Table 3.12 Rail data supplied by the PTEs

<table>
<tr><td>Centro</td><td colspan="2">London Midland information
Rail and vehicle mileage
Guidance on split between electric and diesel

Rail passenger counts by period (West Midlands)
Rail passenger counts by year (West Midlands)</td></tr>
<tr><td>GMPTE</td><td colspan="2">Information on routes, number of passengers and vehicle types</td></tr>
<tr><td>Merseytravel</td><td>Northern Rail data relevant</td><td>Data on rail passenger km and rail passenger journeys</td></tr>
<tr><td>Nexus</td><td colspan="2">None available – Northern Rail data relevant</td></tr>
<tr><td>SPT</td><td colspan="2">Information on rolling stock type
Passenger journeys
Passenger km
Loaded train km</td></tr>
<tr><td>SYPTE</td><td colspan="2">None available – Northern Rail data relevant</td></tr>
<tr><td>WYPTE</td><td colspan="2">None available – Northern Rail data relevant</td></tr>
</table>

Below we go through each of the metrics: g CO_2 per vehicle kilometre, g CO_2 per passenger km and g CO_2 per passenger journey. Firstly, GMPTE, Merseytravel, Nexus and WYPTE (Northern Rail data) were considered, then SPT and finally Centro.

3.3.1 GMPTE, Merseytravel, Nexus and WYPTE (Northern Rail data)

CO_2 emissions per vehicle km

Total CO_2 emissions were calculated per train class and this used along with the number of vehicle km to calculate g CO_2 per vehicle km. The analysis is shown in Appendix six and the results in Table 3.13 and Table 3.14.

Table 3.13 CO_2 emissions per train km (diesel)

Train class	CO_2 per train km (g)	SRA data (train formation)
142	2154	
144	2748	2 PC + 0TC* = 1862 3 PC + 0TC* = 2606
150	2153	3 PC + 0TC* = 3202
153	1412	1415
155	2122	
156	1979	2 PC + 0TC* 2234 3 PC + 0TC* 2904
158	1979	2 PC + 0TC* 2793 3 PC + 0TC* 3273

* PC = Power Car TC = Trailer car

Table 3.14 CO_2 emissions per train km (electric)

Train class	kWh per train km	CO_2 per train km (g)	SRA data kWh per train km
321	6.9	3716	Class 321/322 (1 PC + 3TC) 5.9
323	6.1	3260	6.6
333	11.6	6213	3 car 14.4 4 car 15.0

Discussion
The g CO_2 per train km are within the regional / intercity diesel range used by the NAEI and while the numbers do not match those used by the SRA they are a reasonable fit. Northern Rail also provides *estimates* of fuel use by train class; more robust information may alter the g CO_2 per train km.

It is essential to note that the diesel and electric train vehicles are of different types - the diesel classes are Pacers/Sprinters, which are very light weight vehicles, they are therefore at the very fuel efficient end of the diesel train spectrum, the electric vehicles, on the other hand, are 'heavier' vehicles. Furthermore, the train formation (number of vehicles) can vary between diesel and electric trains, with electric trains potentially having one more vehicle and this will clearly impact on the CO_2 emissions per train km. A straightforward comparison between the diesel and electric vehicles used in the PTEs is therefore not appropriate.

CO_2 emissions per passenger journey

Northern Rail supplied data on passenger boardings for each service description route (for example Leeds to Manchester Victoria) for the period October 2007 to January 2008. AEA allocated the passenger boardings to each of the PTEs[20] and factored the boardings up to account for the remainder of the 2007-2008 period. The results are summarised in Table 3.14[21]. To calculate the g CO_2 per passenger journey the tonnes of CO_2 associated with the depots were initially used. However, some of the depots (particularly Heaton which is located with Tyne and Wear) serve a far wider area than the PTE, which significantly distorted the numbers.

Table 3.14 Passenger Boardings by PTE

PTE	Number of passenger boardings (millions)
GMPTE	26.7
Merseytravel	6.3
Nexus	1.9
SYPTE	6.5
WYPTE	19.8

A different method was therefore used whereby each of the train classes and train km was allocated to the PTEs. This allocation was based on data from the DfT NMF Environmental Model on train classes associated with the different service descriptions serving the PTEs. This is shown in Table 3.15 and Table 3.16. Detailed information is provided in Appendix six. CO_2 emissions were then allocated to each of the PTEs according to the train km for each train class (detailed information is shown in Appendix six). The outcomes of the analysis - total emissions for each of the PTEs and per passenger journey are shown in Table 3.17. Please note that for a more accurate g CO_2 per passenger journey figure the number of passenger journeys per train class should be considered. However, patronage data was by service description rather than train class and so this analysis could not be undertaken, as a result these figures should be treated with caution.

Table 3.15 Percentage allocation for each of the PTEs (diesel trains)

Train Class	Train km	GMPTE	Mersey travel	Nexus	SYPTE	WYPTE	Other
142	10580211	33%	14%	4%	6%	12%	32%
144	3573440	1%	0%	0%	26%	45%	29%
150	6516224	35%	16%	0%	6%	11%	31%
153	2483021	0%	0%	1%	23%	13%	63%
155	1156646	50%	0%	0%	0%	50%	0%
156	8151104	15%	5%	4%	12%	14%	50%
158	8858470	8%	11%	0%	9%	10%	61%

Table 3.16 Percentage allocation for each of the PTEs (electric trains)

Train Class	Train km	GMPTE	Mersey travel	Nexus	SYPTE	WYPTE	Other
321	582566	0%	0%	0%	32%	66%	2%
323	2673216	54%	0%	0%	0%	0%	46%
333	2858086	0%	0%	0%	0%	74%	26%

[20] where there were two PTEs or one PTE and one non PTE area referenced, the boardings where split 50:50
[21] the passenger journeys for Merseytravel are much lower than those in the data supplied by Merseytravel for Northern rail, this may be due to differences in allocation of passengers, but AEA will speak with Merseytravel to clarify this.

Table 3.17 Total emissions per PTE and CO_2 per passenger journey

	GMPTE	Mersey travel	Nexus	SYPTE	WYPTE
Total CO_2 emissions Tonnes	22166	8242	1612	9693	29075
Number of passenger journeys Million	26.7	6.3	1.9	6.5	19.8
CO_2 per passenger journey	830.8	1316.7	839.4	1493.6	1470.8

Discussion
The numbers are consistent (overall) with Go-Ahead numbers of 1240 g CO_2 per passenger journey. The use of the diesel train class 144 in the SYPTE and WYPTE region and the electric train 333 in the WYPTE region, both of which have 'high' CO_2 emissions per train km, will have an impact on emissions for these PTEs. However, it is also important to note that for a more accurate g CO_2 per passenger journey figure the number of passenger journeys per train class was required, this data was not available and therefore these figures should be treated with some caution.

CO_2 emissions per passenger km

CO_2 emissions per passenger km (shown in Table 3.18 and Table 3.19) were calculated by dividing the emissions per vehicle km by an average load factor of 37.5 passengers. This load factor was calculated by dividing Northern Rail passenger km (1766 million[22]) by total vehicle km (47 million). This approach was used because data on average load for train class type was not available. However, to reflect that the electric train classes were highly likely to have a higher load factor[23] a sensitivity test was also undertaken. Here, we assumed an average load factor of 70 passengers per electric train and 32 passengers per diesel train. The results are shown in Table 3.20 and 3.21. It is clear that assumptions on load factors make a significant difference to the CO_2 per passenger km figure.

Table 3.18 CO_2 per passenger km (diesel trains)

Train class	CO_2 per train km (g)	CO_2 per passenger km (g)
142	2154	57.4
144	2748	73.3
150	2153	57.4
153	1412	37.7
155	2122	56.6
156	1979	52.8
158	1979	52.8

Table 3.19 CO_2 per passenger km (electric trains)

Train class	CO_2 per train km (g)	CO_2 per passenger km (g)
321	3716	99.1
323	3260	86.9
333	6213	165.7

[22] TAS (2007) Rail Industry Monitor – The Market for Rail Services.
[23] For example the number of seats on an electric train is typically higher than on a diesel train reflecting that greater number of passengers will be catered for.

Table 3.20 CO_2 per passenger km (diesel trains) – sensitivity analysis

Train class	CO_2 per train km (g)	CO_2 per passenger km (g)
142	2154	67.3
144	2748	85.9
150	2153	67.3
153	1412	44.1
155	2122	66.3
156	1979	61.8
158	1979	61.8

Table 3.21 CO_2 per passenger km (electric trains) – sensitivity analysis

Train class	CO_2 per train km (g)	CO_2 per passenger km (g)
321	3716	53.1
323	3260	46.6
333	6213	88.8

CO_2 emissions per passenger km for the PTEs were then calculated by taking the vehicle km distance into account. Percentages (based on distance travelled) for each train class for each PTE are shown in Table 3.22. These percentages were then applied to the g CO_2 per passenger km in Table 3.18 and Table 3.19 and the results are shown in Table 3.23. Again a sensitivity analysis was undertaken using a higher load factor for electric and a lower load factor for diesel trains and the results are shown in Table 3.24.

Table 3.22 Train class split between PTEs

Train Class	GMPTE	Mersey Travel	Nexus	SYPTE	WYPTE
142	36%	37%	50%	14%	14%
144	0%	0%	0%	21%	18%
150	23%	27%	3%	9%	8%
153	0%	0%	2%	13%	4%
155	6%	0%	0%	0%	6%
156	13%	10%	46%	21%	13%
158	7%	25%	0%	19%	10%
321	0%	0%	0%	4%	4%
323	15%	0%	0%	0%	0%
333	0%	0%	0%	0%	23%
Total	100%	100%	100%	100%	100%

Table 3.23 CO_2 per passenger km

	GMPTE	Merseytravel	Nexus	SYPTE	WYPTE
CO_2 per passenger km (g)	60.9	55.8	54.9	58.1	85.2

Table 3.24 CO_2 per passenger km – sensitivity analysis

	GMPTE	Merseytravel	Nexus	SYPTE	WYPTE
CO_2 per passenger km (g)	63.0	64.7	65.0	66.1	72.8

Discussion
The g CO_2 per passenger km figures correspond well with those used in the DEFRA guidelines for GHG Company Reporting (60.2 g CO2 per passenger km). The use of different load factors makes a significant difference to the CO_2 emission per passenger km for each of the PTEs.

3.3.2 SPT

SPT provided AEA with information on:

- Train class (rolling stock type)
- Passenger journeys
- Passenger km
- Loaded train km

This information was used below to calculate CO_2 emissions per vehicle km, passenger km and passenger journey.

CO_2 emissions per train km

The SPT data on train class that was used alongside relevant emission factors is provided in Appendix six. In taking forward calculations, given the split between the lower and higher emitting train classes, an average of 3500 g CO_2 per km was used.

SPT provided information on the number of train km previously supported by the Passenger Transport Executive – 15.6 million loaded train km. Applying the above average of 3500 g CO_2 per train km then this is equal to 54,565 tonnes of CO_2.

CO_2 per passenger journey

SPT provided information on the number of passenger journeys previously supported by the Passenger Transport Executive - 52.1 million journeys per year (2006/2007). Dividing the above 54,565 CO_2 tonnes figure by this number of passenger journeys results in an average of 1047.3g CO_2 per passenger journey. Note that passengers travelling on train services which used 'lower carbon' train classes would have lower carbon emissions associated with their journey.

CO_2 per passenger km

SPT provided information on the number of passenger km previously supported by the Passenger Transport Executive – 863 million passenger km per year (2006/2007). Dividing the above 54,565 CO_2 tonnes figure by the number of passenger km results in an average of 62.2 g CO_2 per passenger km. Note that this figure will vary depending on the train class the passengers travel in.

Discussion
The above emission figures for passenger journey and passenger km tie in reasonably well with the Go Ahead figure of 1240 g CO_2 per passenger journey and the DEFRA guidelines for GHG Company Reporting figure of 60.2 g CO_2 per passenger km.

3.3.3 Centro

Centro provided AEA with information for London Midland (for the Centro area) on rail and vehicle km and guidance on the split between electric and diesel vehicles. Centro also provided AEA with information on rail passenger counts by period (West Midlands) and rail passengers counts by year (West Midlands).

CO_2 emissions per train km

There was a total of 6.2 million train km travelled in the Centro area in 2007/2008. The proportion by diesel trains is 45%, and the proportion by electric trains is 55%.

Therefore there are 2.8 million km by diesel train and 3.4 million km by electric train.

Diesel trains used in the Centro area include the 150/0, 150/1 and 150/2 train classes. Emission factors for the 150 class are 1) 2153 g CO_2 per train vehicle km based on data from this project and 2) 3202 g CO_2 per train vehicle km based on SRA[47] data.

Multiplying the 2.8 million km for diesel train with the different emission factors there would be 1) 6006 tonnes CO_2 using the emission factors from this project (Table 3.13 -2153 g) and 2) 8931 tonnes of CO_2 from diesel using the SRA emission factors (3202 g).

Electric trains used in the Centro area include the 321/4 and 323 train classes. Based on data from this project (Table 3.13) emission factors for the 321 class are 3716g CO_2 per train vehicle km and for the 323 class are 3260g CO_2 per train vehicle km. Based on SRA data[47] emission factors for the 323 are 5639 g CO_2 per train kilometre.

Assuming that electric trains are a 50% split between 321 and 323 classes, and using data from this project (the 3716 g and the 3260 g mentioned above) and the 3.4 million km figure for electric trains results in a total of 11,890 tonnes of CO2.

The total emissions from diesel and electric trains (using emission factors from this project) would be 6006 (diesel) + 11,890 (electric) = 17,896 tonnes of CO_2.

This results in an average 17,896 million g CO_2 / 6.2 million km = 2887.2 g CO_2 per km

Assuming that electric trains are a 50% split between 321 and 323 train classes and using data from this project for the 321 train class (3716 g) from this project plus SRA data[47] for the 323 train class (3260 g), and the 3.4 million km figure for electric trains results in a total of 15,945 tonnes of CO_2.

The total emissions from diesel and electric trains (using emission factors from this project and SRA emission factors[47]) would be:

8931 (diesel) + 15945 (electric) = 24,876 tonnes of CO_2

This results in an average 24,876 million g CO_2 / 6.2 km = 4013.0 g CO_2 per vehicle km

CO_2 emissions per passenger journey

There are 21.4 million passenger journeys per annum[24].

Dividing the above 17,896 tonnes of CO_2 by the number of passenger journeys (21.4 million) results in an average of 834.6 g CO_2 per passenger journey.

Dividing the above 24,876 tonnes of CO_2 by the number of passenger journeys (21.4 million) results in an average of 1160.1 g CO_2 per passenger journey.

CO_2 per emissions passenger km

Data on the number of passenger km travelled (in the Centro area) was unavailable from Centro. CO_2 emissions per passenger km can be calculated by dividing the emissions per train vehicle km by an average load factor (with the average load factor calculated by dividing passenger km by total vehicle km). However, using London Midland passenger km and vehicle km data is not appropriate since it produces an average load for all destinations rather than just those relevant to Centro. In particular,

[24] Note that this is for a year for the period March 2007 to March 2008. In comparison, the train km data was for December 2006 to December 2007. However, potential differences were not significant and therefore these datasets were used.

the inclusion of intercity services will distort the figure. We, therefore, used an average regional train load factor of 49.8[25]. The results are shown below.

Using 2887.0 g CO_2 per train km / 49.8 = 58.0 g CO_2 per passenger km

Using 4013.0 g CO_2 per train km / 49.8 = 80.6 g CO_2 per passenger km

Discussion
The above emission figures for passenger journey and passenger km tie in reasonably well with the Go Ahead figure of 1240 g CO_2 per passenger journey and the DEFRA guidelines for GHG Company Reporting figure of 60.2 g CO_2 per passenger km.

3.3.4 Merseyrail Electrics

Merseyrail Electrics provided AEA with information for on rail vehicle km, patronage, passenger km and fuel use

CO_2 emissions per train km

A total of 5.9 million train km (a mixture of train class 508 and train class 507) were undertaken by Merseyrail Electrics in 2008. Fuel use was 57.02 million kWh. Using DEFRA guidelines for GHG Company Reporting (2008) figure of 0.537 kg of CO_2 per kWh then this results in a total of 30, 620 tonnes of CO_2. Dividing this total CO_2 figure by the number of train km results in an average of 5149 g CO_2 per train km.

CO_2 emissions per passenger journey

There are 30.83 million passenger journeys in 2008. Dividing the above 30,620 tonnes of CO_2 by this figure results in an average of 993.22 g CO_2 per passenger journey.

CO_2 per emissions passenger km

There are 3607million passenger km in 2008. Dividing the above 30,620 tonnes of CO_2 by this figure results in an average of 84.90 g of CO_2 per passenger km.

Conclusions and recommendations

The most appropriate future approach to carbon footprinting will depend on the availability of data. If ‘top down’ data is available (diesel fuel use and electricity use) which is allocated to the PTEs we suggest that this is used. However, this may need to be complemented by a ‘bottom up’ approach, in which the allocation of the train vehicle km is allocated respectively, as has been the approach in this analysis.

In terms of overall outcomes the figures tie in, on the whole, reasonably well with UK government (public) and private sector CO_2 emission figures for rail transport (especially passenger journey and passenger km). The Transport Direct Calculator (60.2 g CO_2 per passenger km) is consistent with the carbon footprint figures derived from PTE data – 66.4 g CO_2 per passenger km.

Going forward, a single common PTEG figure has validity in relation to entities like Transport Direct, However it is important to bear in mind that a single figure is derived from a series of assumptions and aggregations and that the carbon footprints of individual bus journeys within different PTEs will be subject to considerable variation. Different assumptions can result in significant changes to the resulting carbon footprinting figures as the sensitivity tests around peak hour loadings demonstrates.

[25] Based on regional average train load data (weighted to train km travelled) - TAS (2007) Rail Industry Monitor – The Market for Rail Services

Table 3.25 Rail carbon footprint data

Train	CO_2 (g) per passenger journey	CO_2 (g) per passenger km	CO_2 (g) per train km
GMPTE	830.8	60.9	2271
Merseyrail	1316.7	55.8	1693.6
Nexus	839.4	54.9	2082.1
SYPTE	1495.6	58.1	2159.9
WYPTE	1470.8	85.2	3222.7
SPT	1047.3	62.2	3500
CENTRO	1160	69.3	2887.2
Merseyrail electrics	993.2	84.9	5149
Average	1144.2	66.4[26]	2870.7
Weighted average	1093.00		3067.7
DEFRA guidelines for GHG company reporting figures (2008)		60.2	

Improved data on load factors (passenger km) and passenger journeys per train class would help reduce the number of assumptions involved. As would further information on train class split between the PTEs. Data improvement plans by the rail industry will also help. These plans include the introduction of metering on diesel and electric trains, while this is primarily being introduced for other reasons[27], it will help improve energy data and CO_2 information for the different train classes. This metering will be introduced on new vehicles and retrofitted on existing vehicles. AEA suggest that the PTEs discuss with the operators their plans for metering and future access to the energy data. The rail industry is also working with the Committee on Climate Change on the setting and achieving of carbon emission reduction targets for the sector, which will bring future benefits in efficiency improvements. Future scenarios[28] for the rail sector have also been developed which consider different options for carbon management.

In the future, the DEFRA guidelines for GHG company reporting (which informs the Transport Direct figures) may split rail into the following sectors: regional, intercity, London and the South East, electric and diesel. Going forward there is the potential for the PTEG data to be used in developing the latter figures.

The rail emission factors should be updated every two years, this would not be too onerous on the PTEs and would enable time for improvements in data collection[19].

3.4 Light Rail

Light rail was, because of direct access by the PTEs to relevant data, the easiest mode to analyse. Furthermore, DfT also provides relevant information on passenger km, passenger journeys and loaded light rail km in Transport Statistics Great Britain[29].

The same approach as set out in the DEFRA guidelines for GHG Company Reporting was used, with total kWh being converted into CO_2 emissions and then divided by passenger km / passenger journeys and vehicle km as appropriate. Therefore:

kWh x (Emission Factor for electricity use) = Total CO_2 emissions (kg)

[26] Absence of passenger km data meant that weighted averageCO_2 per passenger km data was not possible. However, weighting the figures using data on passenger journey and vehicle km resulted in numbers which were consistent with the average, 69.40 and 67.81 g CO_2 respectively.
[27] for diesel it will minimise fuel losses through optimum maintenance, for electric it will improve data on the current allocation of electricity use by the different train operating companies
[28] Rail Safety and Standards Board Foresight Studies in Sustainable Development http://www.rssb.co.uk/pdf/reports/research/T713_rpt_final_scenarios.pdf

Total CO_2 emissions / passenger km = g CO_2 per passenger km

Total CO_2 emissions / passenger journey = g CO_2 per passenger journey

Total CO_2 emissions / light rail km = g CO_2 per light rail km

Total CO_2 emissions / loaded light rail km = g CO_2 per loaded light rail km

The results are shown in Table 3.26. Where data, for example on passenger km, was not available from the PTEs data from DfT Transport Statistics Great Britain was used for the relevant year (and this is shown in brackets in the table).

Table 3.26 Total CO_2 Emissions and g CO_2 per passenger km / passenger journey /vehicle kilometre for light rail

PTE	GMPTE Manchester Metrolink[30]	Centro Midland Metro	Nexus Tyne and Wear Metro	SPT Glasgow Underground	SYPTE Sheffield Supertram
Million kWh Traction *Traction and other including depot*	16.0	6.9	*72.9*	6.9	14.7
Total CO_2 emissions (million kg)	8.6	3.7	*39.1*	3.6	7.9
Passenger km million (DfT data used)	204	(51)	313	(42)	(42) check
Passenger journeys million (DfT data)	19.9	4.9	39.8	(13)	14.8
Loaded light rail km million (DfT data)	(4.4)	(1.6)	(6.2)	(1.2)	(2.4)
CO_2 per passenger km (g)	42.2	72.1	*125.1*	86.9	188.3
CO_2 per passenger journey (g)	432.6	750.7	*982.6*	246.5	534.4
CO_2 per loaded light rail km (g)	1957	2299	*6312*	3040	3295

Discussion
In terms of overall outcomes the analysis showed that for Manchester Metrolink and Tyne and Wear the results are consistent with analysis (per passenger km) for the DEFRA guidelines for GHG Company Reporting (Appendix three). The Manchester Metrolink figure is 42.2 g compared with DEFRA figure of 42.1 g and the Tyne and Wear Metro is 125.1 g compared with the DEFRA figure of 120.7 g.

[30] Note KwH data is for 2005 and other data is for 2006.

However, the analysis also flagged up that there is a difference in the emissions where kWh are supplied for just traction (Manchester Metrolink) and where kWh are supplied for traction, depot lighting and other energy uses (Tyne and Wear Metro). Tyne and Wear Metro were unable to provide separate data as power is supplied via a number of substations. A straightforward comparison between Tyne and Wear Metro and the other light rail systems is therefore not appropriate.

The other PTEs also showed significant variation in light rail emissions, for example g CO_2 per passenger journey/km for the Sheffield Supertram are higher than for Manchester Metrolink. There are explanations for this, Supertram's 'high' figure is due to the type of vehicles used and the extra energy required to cope with Sheffield's topography - steeper gradients will result in greater energy use.

Conclusions and recommendations

In terms of approaches to carbon footprinting for light rail we recommend a 'top down' approach based on electricity consumption (kWh) since, overall, this data was readily available to the PTEs. Furthermore, the vehicle type within each PTE is the same therefore the 'bottom up' approach would not result in the increased understanding of the contribution of the different vehicle types, (unlike in bus and rail).

Individual, PTE-specific, emission factors for light rail should be used. This is primarily because there is significant variation between the PTEs (much greater than for buses and trains). However, caution is required in using these factors to compare PTEs. A straightforward comparison between Tyne and Wear and the other light rail systems is not appropriate and with the other PTEs there are additional issues, for example topography, which would need to be taken into consideration. The weighted average figure is consistent with the DEFRA guidelines for GHG company reporting figure.

Table 3.27 Light rail carbon footprint data

Light rail	CO_2 (g) passenger journey	CO_2 (g) per passenger km	CO_2 (g) per Light rail km
GMPTE Manchester Metrolink	432.6	42.2	1957
Centro Midland Metro	750.7	72.1	2299
SPT Glasgow underground	246.5	86.9	3040
SYPTE Sheffield Supertram	534.4	188.3	3295
Average	491.1	97.4	2647.8
Weighted average	445.2	70.3	2371.2
DEFRA guidelines for GHG company reporting figure		65 g 2007 78 g 2008	

Ideally, a consistent set of electricity consumption data should be used across all the PTEs. Currently, the majority of PTEs use data that only includes electricity consumed for rolling stock traction, whilst Tyne and Wear Metro use electricity consumption data that includes traction energy as well as electricity consumed for heating/lighting in depots, etc. In keeping with the approach used for bus and rail the former approach (i.e. only including traction energy) was agreed as the way forward[19]. Tyne and Wear Metro could consider whether energy monitoring, in the future, could provide data solely for rolling stock traction. Alternatively, all PTEs, with light rail systems, could supply traction and depot energy use data and the percentage of these two different sources to total energy use, could be calculated and used to factor down the Tyne and Wear Metro electricity consumption data so that it was just traction. This traction only data would then be used.

We also note that, at present, the Transport Direct carbon calculator does not include light rail and our discussions with the DfT[31] suggest that this will not be introduced in the short term as other updates to the calculator will take priority. The PTEs[19]suggested that the inclusion of light rail was seen as potentially useful, but may not be practical given the wide variation in performance between the systems and the current lack of traction only data for Tyne and Wear metro.

3.5 Comparisons with private transport

The following section provides information on the CO_2 emissions associated with the use of different types of private cars. This reflects that one of the aims of the project was to assist PTEG in understanding the CO_2 savings associated with their policies. The private car, in many cases, will be the main alternative to the public transport mode. CO_2 emissions per vehicle km for different vehicle types are shown in Table 3.28. Note that diesel vehicles have lower CO_2 emissions than petrol vehicles, but can produce higher levels of air quality pollutants.

CO_2 per vehicle kilometre

Table 3.28 CO_2 (g) per km emissions for different vehicle types

Vehicle segment	Examples	Petrol (CO_2 (g) per km)	Diesel (CO_2 g per km)
Mini	Smart City Coupe Vauxhall Agila	162.2	135.7
Supermini	Vauxhall Corsa, Renault Clio	176.6	147.7
Lower medium	Vauxhall Astra, VW Golf	200.9	172.7
Upper medium	Ford Mondeo Audi A4	218.5	192.2
Executive	BMW 5 Series Mercedes CLK- class	265.3	231.4
Luxury	Bentley continental BMW 7 Series	359.9	313.9
Sports	Mazda – MX – 5 Mercedes – SLK – class	276.1	240.8
Duel purpose 4 x 4	Land Rover discovery Toyota RAV4	305.4	266.4
MPV	Volkswagon Touran Ford Galaxy	242.2	212.0
The average car = 204.2 g CO_2 per vehicle km			

Sources:
1) DEFRA (2008) Guidelines to DEFRA's GHG Conversion Factors – Annexes
Note that the CO_2 emission factors presented in this table are based on the emissions measured for different vehicle size categories under legislative drive cycle (NEDC – New European Drive Cycle), with an uplift factor of 15% applied to represent real-world driving conditions. This uplift has been agreed with DfT, but is subject to change in the future, should better data become available.
2) SMMT (2008) Motorfacts for the examples of the different vehicle segments

CO_2 per passenger kilometre

To calculate g CO_2 per passenger km information on car occupancy is required. Average car occupancy and car occupancy by trip purpose are shown in Table 3.29 and Table 3.30.

[31] Personal communication with the DfT (Susannah Johnson)

Table 3.29 Average car occupancy

Year	Average car occupancy
2002	1.59
2003	1.58
2004	1.57
2005	1.58
2006	1.58

Source: DfT (2006) National Travel Trends

Table 3.30 Car Occupancy by Trip purpose

Trip Purpose	Average car occupancy
Commuting	1.2
Business	1.2
Education	2.0
Shopping	1.7
Personal Business	1.5
Leisure	1.7
Holiday / day trip	2.0
Other	2.0
Average	1.6

Source: DfT (2006) National Travel Trends

The average car occupancy of 1.6 was applied to the CO_2 emissions per vehicle km provided in Table 3.28 thereby allowing CO_2 emissions per passenger km to be calculated. The results are shown in Table 3.31

Table 3.31 CO_2 per passenger km

Vehicle segment	Examples	Petrol (CO_2 g per passenger km)	Diesel (CO_2 g per passenger km)
Mini	Smart City Coupe Vauxhall Agila	101.4	84.8
Supermini	Vauxhall Corsa Renault Clio	110.4	92.3
Lower medium	Vauxhall Astra VW Golf	125.6	107.9
Upper medium	Ford Mondeo Audi A4	136.6	120.1
Executive	BMW 5 Series Mercedes CLK- class	165.8	144.6
Luxury	Bentley continental BMW 7 Series	224.9	196.2
Sports	Mazda – MX – 5 Mercedes – SLK – class	172.6	150.5
Dual purpose 4 x 4	Land Rover discovery Toyota RAV4	190.9	166.5
MPV	Volkswagon Touran Ford Galaxy	151.4	132.5

The average car (unknown fuel) = 127.6 g CO_2 per passenger km

The market share of different vehicle (new) types is shown in Table 3.32 It should be noted that this is new vehicles rather than all vehicles, but it helps provides an illustration of the market split.

Table 3.32 The market share of different (new) vehicle types

Vehicle Segment	Market Share	
	1997	2007
Mini	0.7%	0.9%
Supermini	26.5%	32.1%
Lower medium	32.4%	30.0%
Upper medium	25.2%	16.1%
Executive	5.8%	4.3%
Luxury	0.7%	0.5%
Sports	2.9%	2.7%
Duel purpose 4 x 4	3.8%	7.3%
MPV	2.0%	6.0%

Discussion
A simple comparison of CO_2 emissions per passenger km for public and private transport is provided in Table 3.33 This shows that although rail and most light rail systems outperform the car, mini and supermini category cars could offer a 'carbon' advantage, or emit similar levels of carbon to the bus.

Table 3.33 CO_2 per passenger km (private and public transport)

Mode of transport	CO_2 per passenger km (g)
Bus (different assumptions on Euro standards)	102.9 – 111.8 114.0 –123.7
Light rail	42.2 – 188.3
Rail	54.9 – 85.2
Private vehicle	diesel/petrol
Mini	84.8 /101.4
Supermini	92.3/110.4
Upper medium	120.1 /136.6
Luxury	196.2 /224.9
MPV	132.5 /151.4
PTE range	106.6 - 127.2

However, not only does the degree of aggregation and assumptions need to be taken into account but these figures should also be viewed in context.

Car owners will, on average travel further distances than non-car owners (shown in Table 3.34). The public transport figures can therefore be considered to take into account 'extra' mileage, whereas the private vehicle figures do not.

Table 3.34 Distance per person per year by mode – households with and without a car

		Persons in households with a car			
Distance per person per year per mode	Persons in households without a car	Main driver	Other driver	Non driver	All
Walk	293	149	209	218	180
Car driver	94	7633	2977	50	4452

Car passenger	787	1360	2834	3594	2310
Other private transport	188	143	375	203	192
Bus and coach	821	121	334	437	256
Taxi and minicab	82	44	48	47	45
Other public transport	774	654	1081	365	607
All modes	3,040	10,104	7,857	4914	8042

Source: DfT (2006) National Travel Trends

There are a number of reasons for this:

1) Car ownership is more likely to result in discretionary trips than the use of public transport (the true financial costs of car ownership are hidden in a way that paying for public transport is not).

2) Car ownership can also impact on lifestyle decisions - where to live and to a certain extent where to work, which in turn can impacts on the distance travelled and therefore the total CO_2 emissions

3) Car ownership tends to link to higher income levels and the travel opportunities this affords. Conversely, good public transport services can delay / remove the purchase of a car (or a second car in some circumstances) this in turn reduces the potential for this additional travel.

It's also important to bear in mind the variations in vehicle occupancy that occur by time of day. For example for a commute trip (peak travel times) bus occupancy will be higher and car occupancy lower. CO_2 emissions per passenger km will therefore be lower for buses and higher for cars than the average. This is an important point to take into consideration if the emphasis is placed on carbon reduction and policies could be varied to reflect time of travel. Additional measures to complement 'carrot' measures (for example investment in peak hour public transport) may also be necessary. These 'stick' measures can include increased car parking charges and the introduction of high occupancy vehicle lanes. Such policies will help ensure maximum modal shift from car to public transport.

Conclusion and recommendations

Data is available which enables a comparison between public and private transport to be made.

However, as the discussion highlights there are a number of factors which need to be taken into consideration when undertaking this comparison. We recommend that if such a comparison is undertaken, it should be part of a larger appraisal which takes these other factors into account.

4 Life Cycle Carbon Footprinting

Key findings:

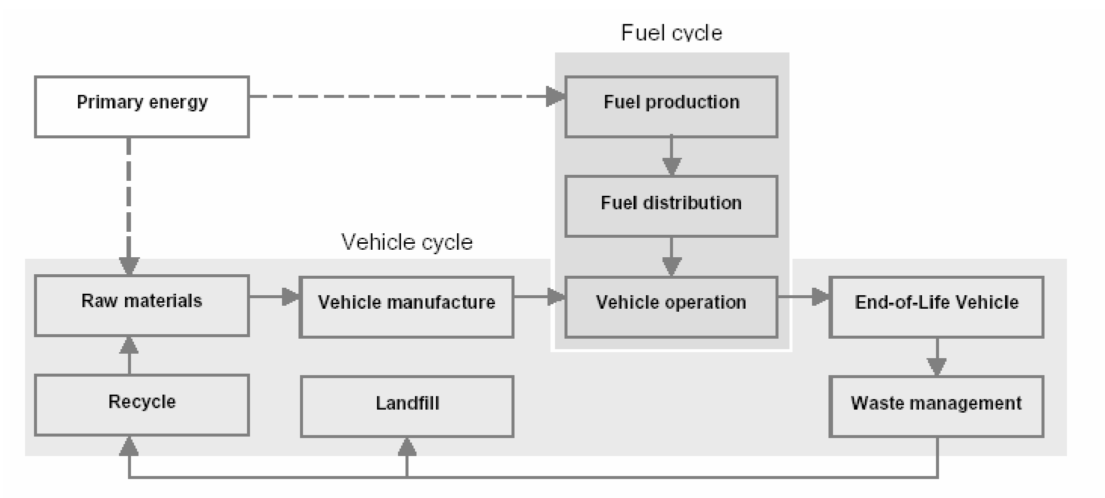
- The majority of the carbon generated by public transport vehicles is from their use rather than from their construction, maintenance and disposal.
- The carbon footprinting of public transport carried out by other public sector and private sector bodies does not take into account the emissions from the full life cycle instead it considers vehicle use only.
- For these reasons AEA suggests that 1) the carbon footprinting figures used by PTEs should be for vehicle use only rather than the full life cycle 2) A full life cycle approach is used but the contribution from vehicle use emissions clearly stated to enable a fair comparison with other public sector and private sector bodies.
- If the latter option is chosen this should be kept under review as carbon footprinting based on full life-cycle analysis will become more common over time.

The environmental impacts of vehicles can be divided into two categories:

- Impacts associated with the production, processing and use of the fuel (fuel cycle)
- Impacts that arise during the manufacture, maintenance and disposal of the vehicle (vehicle cycle)

This is shown in Figure 4-1.

Figure 4-1 Life Cycle Analysis



This project has, so far, concentrated on the emissions associated with the use of the fuel. The following section considers the CO_2 impacts of the remainder of the fuel cycle and emissions associated with the vehicle cycle. A two-stage approach was followed. Firstly, a life cycle analysis tool was used to calculate fuel and vehicle life cycle emissions for bus, light rail and rail. The contribution these emissions made to the life cycle emissions was then calculated. Secondly, this contribution was set in the context of other studies on life cycle emissions. Approaches that other organisations have taken on life cycle analysis are then briefly considered.

4.1 Bus Life Cycle Emissions

AEA used SimaPro Life Cycle Analysis software to provide information on the CO_2 emissions associated with the remainder of the fuel cycle and the vehicle cycle.

The results are as follows:

Fuel cycle:

- Bus fuel production and fuel distribution – **0.515 kg** CO_2 per kg of fuel used

Vehicle Cycle:

- Bus manufacture (including raw materials) – **32600 kg** CO_2 per bus
- Bus maintenance – **17400** kg CO_2 per bus
- Bus disposal – **1360 kg** CO_2 per bus

To place this into context an understanding of average bus use emissions over the lifetime of a vehicle is necessary. Assuming average bus emissions of 900 g CO_2 per vehicle km, the bus travels at 30 km per hour and is used 7 hours a day and 300 (out of 356) days and the bus has a 'life span' of 12 years[32] then:

Total distance is: 210 km per day x 300 days x 12 years = 756,000 km

Total emissions are: 900 g CO_2 per km x 756,000 km = **680,400** kg CO_2

Hence, the emissions from the use of a bus amounts to 680,400 kg CO_2 in the course of its lifetime.

The emissions associated with bus fuel production for the above lifetime of the vehicle also need to be calculated. To convert 900 g CO_2 into fuel use, first need to convert to C (carbon) i.e. 900 X 12/44 which is equivalent to 245.45 g of carbon. This carbon then needs to be converted to fuel using the 1000/863 ratio (i.e. 1.158) (Appendix one). Each bus km therefore uses 284.24 g of fuel. Therefore 756,000 km is 286607 kg of CO_2 associated with fuel production.

The emissions associated with the different life cycle elements of bus use, and the percentage contribution are set out below in Table 4.1.

Table 4.1 Bus Use Life Cycle Emissions

Source of emissions	CO_2 emissions (kg)	% contribution to total emissions
Bus manufacture	32,600	3.4%
Bus maintenance	17,400	1.8%
Bus disposal	1,360	2.1%
Bus vehicle use	680,400	72.01%
Bus fuel production	213,494	22.6%
Total	945,254	100%

4.2 Train Life Cycle Emissions

AEA used SimaPro Life Cycle Analysis software to provide information on the CO_2 emissions associated with the remainder of the fuel cycle and the vehicle cycle. Information was only available on electric train vehicles.

Vehicle cycle:

- Train manufacture (included raw materials):
  - ICE – 2.1 million kg CO_2 per train

[32] TTR (2008) Report for PTEG - Scenarios and Opportunities for Reducing GHG / Pollutants from Bus Fleets in PTEs / SPT

- Locomotive – 352 thousand kg CO_2 per train
- Long distance train – 145 thousand kg CO_2 per train
- Regional train – 295 thousand kg CO_2 per train

- Train maintenance:
  - ICE – 1.7 million kg CO_2 per train
  - Locomotive – 98.4 thousand kg CO_2 per train
  - Long distance train – 945 thousand kg CO_2 per train
  - Regional train – 58.3 thousand kg CO_2 per train

- Train disposal:
  - ICE – 20.2 thousand kg CO_2 per train
  - Locomotive – 7980 kg CO_2 per train
  - Long distance train – 3940 kg CO_2 per train
  - Disposal regional train – 840 kg CO_2 per train

Again these emissions need to be placed into context of the lifetime use of the train.

Regional trains (electric use)

A typical electric regional train has an average lifespan of 30 years and 4400 g CO_2 per vehicle kilometre. Assuming an average train speed of 50 km per hour and that the train is in operation for 7 hours a day, 300 days a year:

Total distance is: 350 km per day x 300 days x 30 years = 3.15 million km

Total emissions are: 4400 g CO_2 per km x 3150000 km = 13.9 million kg CO_2

4400 g of carbon is equivalent to 8.20 kWh of electricity use. A total of 25830000 kWh are used. Fuel cycle CO_2 emissions are 0.033 kg per kWh electricity consumption[33]. A total of 852, 390 kg CO_2 are emitted for train fuel production. The emissions associated with the different life cycle elements of regional electric train use, and the percentage contribution are set out below in Table 4.2

Table 4.2 Regional Train (electric use)

Source of emissions	CO_2 emissions (kg)	% contribution to total emissions
Regional train manufacture	295000	2.0%
Regional train maintenance	58300	0.4%
Regional train disposal	840	0.0%
Regional train vehicle use	13860000	92.0%
Regional train fuel production	852390	5.7%
Total	15066530	100.0%

4.3 Light rail Life Cycle Emissions

AEA used SimaPro Life Cycle Analysis software to provide information on the CO_2 emissions associated with the manufacture and disposal of light rail (trams) and those associated with the manufacture of fuel associated with light rail use.

The results are:

Fuel Cycle

- 0.033kg per kWh.[34]

[33] Based on Simapro and Defra Company Reporting Guidelines information
[34] Based on Simapro and Defra Company Reporting Guidelines information

Vehicle Cycle

- Light rail (tram) manufacture (including raw materials) = 59700 kg CO_2 per vehicle.
- Light rail (tram) maintenance = 56000 kg CO_2 per vehicle.
- Light rail (tram) disposal = 2180 kg CO_2 per vehicle.

Again these emissions need to be placed into context of the lifetime use of the light rail system for example assuming a lifespan of 25 years and 2500 g CO_2 per vehicle kilometre. Assuming a train speed of 55 km per hour and that the train is in operation for 12 hours a day, 300 days a year, life-cycle CO_2 emissions can be calculated as follows:

Total distance is: 660 km per day x 300 days x 25 years = 4,950,000 km

Total emissions are: 2500 g CO_2 per km x 4,950,000 km = 12,375,000 kg CO_2

Analysis based on data from Table 4.3 suggests that 5 kWh of electricity is used per light rail km, so, for light rail fuel production (i.e. extraction and processing of fuels used in power stations):

Total kWh is: 4,950,000 km x 5 kWh = 24,750,000 kWh

Total CO_2 emissions associated with fuel production: 24,750,000 kWh x 0.033 kg = 816750 kg

Table 4.3 Light rail (diesel use)

Source of emissions	CO_2 emissions (kg)	% contribution to total emissions
Light rail manufacture	59700	0.5%
Light rail maintenance	56000	0.4%
Light rail disposal	2180	0.0%
Light rail vehicle use	9900000	93.0%
Light rail fuel production	816750	6.1%
Total	10834630	100.0%

Discussion
The SimaPro analysis suggests that while there is some variation between the different modes, overall vehicle use dominates the life cycle analysis, and is followed by emissions associated with fuel use production.

4.4 Lifecycle studies literature review

AEA undertook a literature review on:

1) Life Cycle Analysis on private vehicles - three studies:
   - EUCAR/CONCAWE/JRC (2007);
   - Ecolane (2006); and
   - Argonne Greet Model (2006).
2) Life Cycle Analysis on public transport vehicles - two studies:
   - Barba-Gutierrez et al (2005); and
   - Struckl and Stribersky (2006).

Each of these is discussed in turn below.

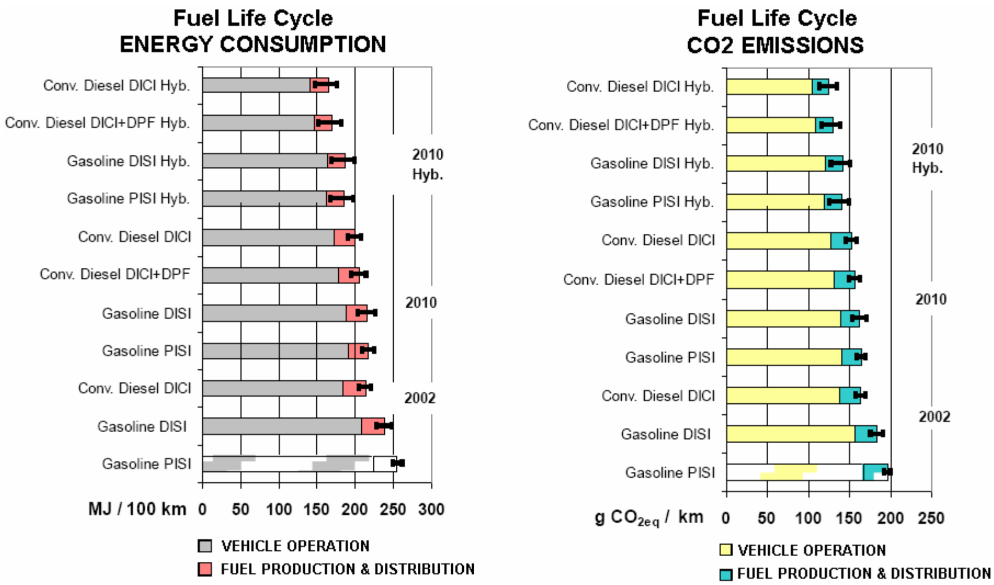
4.4.1 EUCAR/CONCAWE/JRC study

The EUCAR/CONCAWE/JRC study[35] took into account the fuel cycle highlighting that, for conventional gasoline and diesel fuel engines, *vehicle operation* (called a “tank-to-wheel” pathway),

[35] EUCAR, CONCAWE, European Commission – Joint Research Centre (2007). *Well-to-Wheels Analysis of Future Automotive Fuels and Powertrains in the European Context. Well-to-Wheels Report. Version 2c*. [online] Available at: http://ies.jrc.ec.europa.eu/WTW

contributes the vast majority (65 to 80%) of the total energy consumption and CO_2 emissions of the entire fuel life cycle, as shown below in (grey bar and yellow bar respectively).

Figure 4-2 Energy Consumption and CO_2 Emissions for different vehicles



Similar proportions were found for natural gas (CNG), biogas (CBG) and LPG engines.

It was also found that hybrid vehicles could bring an additional energy consumption reduction of about 15% for gasoline and 18% for diesel.

4.4.2 ECOLANE study

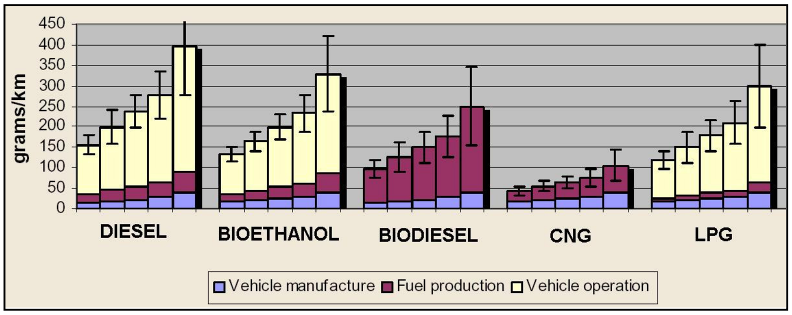
The Ecolane study[36] found that, according to the type of fuel, a passenger car's CO_2 emissions (g/km) during its vehicle manufacture, operation and fuel production processes vary greatly according to the type of fuel considered, as shown below in Figure 4-3.

CO_2 emissions are:

- in diesel cars, far greater during the ***vehicle operation*** process than during the two other processes (approximately 80%);
- in biodiesel cars, non-existent during the ***vehicle operation*** process, while fuel production stage accounts for more then 80% of their total CO_2 emissions.

[36] Ecolane (2006) Life Cycle Assessment Of Vehicle Fuels and Technologies. Report for the London Borough of Camden

Figure 4-3 CO_2 emissions for different fuel production for different stages of the life cycle

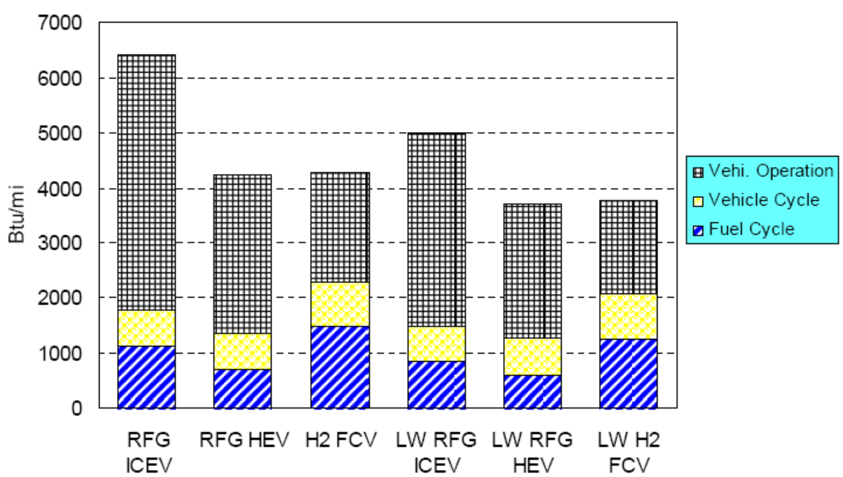


4.4.3 Argonne National Laboratory's GREET Model

The Argonne model[37] calculated energy usage and GHG emissions for the *entire fuel & vehicle life cycle*, which includes the vehicle cycle, the fuel cycle, and the ***vehicle operation*** stages and thus providing a comprehensive view of energy use and emissions.

Results for energy use (Figure 4-4) show that per-mile total, fossil and petroleum energy use for light-weight vehicles (HEVs and FCVs types) is significantly lower than that for conventional internal combustion engine vehicles (ICEV), and that ***vehicle operation*** energy usage account for more than 65% of total energy usage during the entire fuel & vehicle life cycle.

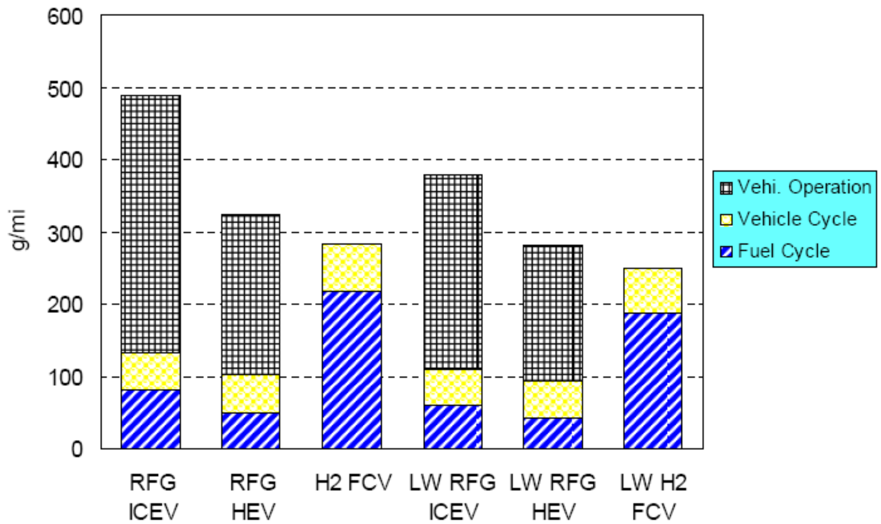
Figure 4-4 Energy for different vehicle types



As for GHG emissions, Figure 4-5 shows that for conventional internal combustion engine vehicles, CO_2 emissions during the ***vehicle operation*** phase account for over 70% of the total fuel and vehicle life cycle emissions, while for hydrogen-fuelled vehicles there are no CO_2 emissions during the vehicle operation phase.

[37] The Argonne model Argonne National Laboratory, Energy Systems Division (2006). *Development and Applications of GREET 2.7 — The Transportation Vehicle-Cycle Model.* Argonne, Illinois, 124 pages.

Figure 4-5 CO_2 emissions for different vehicle types



4.4.4 A Life Cycle Assessment of Bus Transportation

Barba-Gutierrez et al[38] undertook a life cycle assessment of bus and private transportation using SimPro 5.1. The analysis was modelled on a trip between two main cities in Northern Spain. The life cycle assessment looked at CO_2 and other environmental impacts including air quality pollutants. The results of the analysis suggest that vehicle use (for buses and private vehicles) is the main cause of pollution. However, it also noted that the maintenance phase is a significant source of solid waste. The research concluded that bus (coach) transport is a more environmentally friendly means of transport than the car in the whole life cycle of transportation services.

4.4.5 Life Cycle Analysis of a Light Rail Vehicle

Struckl and Stribersky[39] undertook life cycle analysis of a light rail (metro) vehicle. The results are shown in Table 4.4. Vehicle operation was found to contribute 90.1% of the energy consumption, which ties in well with the Simapro analysis. It should be noted that the contribution from raw materials and maintenance was higher than in the Simapro analysis.

Table 4.4 Life Cycle Assessment of Light rail (metro) vehicle

Source of Energy Use	% Contribution to total energy use
Manufacturing	0.0%
Raw materials	4.2%
Maintenance	5.2%
Recycling	0.4%
Vehicle use	90.1%
Delivery	0.1%

The research also provided a number of recommendations to reduce energy use including roles for automatic train operation, and optimisation of vehicle design.

[38] Y.Barba-Gutierrez, P.L. Gonzalez-Torre and B.Gonzalez (2005) A Life Cycle Assessment in the Service Sector: the case of bus and private transportation

[39] Struckl W and Stribersky (2006) Life cycle Analysis of the Energy Consumption of a Rail Vehicle (Light) http://www.allianz-pro-schiene.de/cms/upload/media/themen/umweltbericht/workshops/20060919/08-Vortrag%20Stribersky-060919.pdf

4.4.6 Discussion

The results from the literature review for both private and public vehicles ties in well with the results from the Simapro analysis with vehicle use dominating. The use of alternative vehicles and fuels changes this. For example hydrogen-powered vehicles have minimal emissions in vehicle use and much higher emissions in the fuel production stage.

4.5 Approaches taken by other organisations

At present, there are two main carbon footprinting/GHG inventory standards in use:

- GHG Protocol developed by the WBCSD and the WRI
- ISO 14064 standard

A Carbon Trust standard has also been recently introduced and a Publicly Available Specification is being developed by the Carbon Trust and DEFRA. Below, we briefly discuss what the standards involve and their use by different organisations. It should be noted that, at present, the emphasis is on emissions that companies directly control for example fuel use rather than manufacture.

4.5.1 WBCSD and the WRI GHG Gas Protocol

The GHG protocol initiative is an accounting tool used to measure and manage greenhouse gas emissions. It is used by companies and corporations across the world including: Alcoa, Caterpillar, Dupont, General Electric, General Motors, Unilever and Volkwagen.

The protocol divides emissions into three categories:

- Scope 1 – Direct GHG emissions from sources that are owned or controlled by the company.
- Scope 2 – Indirect GHG emissions from the consumption of purchased electricity.
- Scope 3 – All other indirect emissions, e.g. from company's upstream and downstream activities as well as emissions associated with outsourced / contract manufacturing, leases or franchises.

The manufacture of vehicles would fall into scope 3.

Typically a carbon footprint must include Scope 1 emissions, and most organisations also chose to report Scope 2 emissions since this includes electricity purchased from an energy supplier which is a major component of overall GHG emissions. It is optional to report Scope 3 emissions and whether an organisation chooses to do this will depend very much on their specific circumstances and profiles.

The scope of carbon footprints that have been undertaken include:

- Caterpillar – Scope 1 and 2[40]
- General Motors – Scope 1, 2 and 3[41]. Where categories of Scope 3 are not owned or controlled by GM, GM engages with relevant stakeholders and supports programs to manage GHG emissions in a product's life cycle
- Ford – Scope 1 and 2[42]

4.5.2 ISO 14064 Standards

The ISO 14064 Standards for Greenhouse Gas Accounting and Verification were first published on 1 March 2006 by the International Organization for Standardization (ISO) in order to "provide government and industry with an integrated set of tools for programmes aimed at reducing greenhouse gas emissions, as well as for emissions trading". The ISO 14064 is very similar in content to the WBCSD/WRI GHG protocol initiative, with the main difference being that it specifies what needs

[40] http://www.cdproject.net/admin/attachedfiles/Responses/40928/1101/2007Carbon%20Disclosure.Caterpillar%20Inc.doc
[41] http://www.gm.com/corporate/responsibility/reports/05/600_environment/7_seventy/670.html
[42] http://www.ford.com/aboutford/microsites/sustainability-report-2006-07/envPerformanceClimateStabilizationEstimate.htm

to be done with regards to compiling a GHG inventory or carbon footprint without providing detailed guidance on how to go about doing it.

As with the GHG protocol initiative emissions are reported in three stages:

- Direct
- Energy indirect
- Other indirect

As with the Scope 3 emissions in the ISO 14064 standards the reporting of other indirect emissions is optional.

4.5.3 Carbon Trust Standard

To achieve the Carbon Trust Standard compliance needs to be demonstrated in three key areas:

1. Calculation of an appropriate carbon footprint

The Carbon Trust's approach to carbon footprint measures is based on the WBCSD and the WRI Greenhouse Gas Protocol Initiative accounting procedure and the ISO 14064 Standards.

The minimum footprint required for initial certification includes the following emission sources:

- Electricity consumption
- Gas consumption
- Other onsite fuel consumption
- Fuel consumption in vehicles owned by the organisation which are based at premises covered by the assessment

Once the initial certification is achieved, companies will be required to increase the coverage of the carbon footprint for the next certification period to include:

- Process emissions (e.g. emissions associated with the manufacture of chemical or metal products).
- Fugitive emissions (e.g. leakage of HFCs from refrigeration or air conditioning systems).
- Emissions from business travel including public transport, private car and flights (in vehicles not owned by the organisation).
- Organisations may choose to include other emissions sources.

Therefore the reporting of other indirect emissions is optional.

2. Demonstration of carbon footprint reduction

The Carbon Trust Standard requires a demonstration of an emissions reduction, either:

- An absolute reduction in emissions compared to the previous footprint measurement, OR
- An equivalent reduction in a carbon efficiency benchmark (e.g. tCO_2 per £m turnover). The required relative reduction rate for organisations based in OECD countries is 2.5% p.a.

3. Evidence of good carbon management practices

Evidence that the organisation is acting effectively to respond to climate change is required through action in the following areas:

- Governance i.e., policy, responsibilities, reporting
- Carbon accounting i.e., procedures for data collection and data quality
- Carbon management i.e., targets, reduction programmes, investments and training

4.5.4 Publicly Available Specification

The British Standards Institute (funded by the Carbon Trust and DEFRA) has developed a Publicly Available Specification (PAS 2050) for carbon footprinting products and **services** across their **lifecycles.** PAS:

- Considers all lifecycle stages along the supply / value chain of a product or service, i.e. from raw materials to end of life
- Includes the six GHGs identified under the Kyoto Protocol
- Can be used by all sizes and types of organisation

4.5.5 Discussion

At present, companies focus on the accounting of their direct emissions (which they have control of) rather than indirect emissions (which are effectively controlled by another organisation). However, in the future there is likely to be move towards ‘full‘ lifecycle analysis, this is covered in Scope 3 of the WBCSD and the WRI Greenhouse Gas Protocol Initiative accounting procedure, the indirect emissions part of ISO14064 and the other emissions element of the Carbon Trust standard. All lifecycle stages are part of the PAS 2050 specification.

4.6 Conclusions and recommendations

The Simapro analysis and the literature review on both private and public transport highlight that emissions from vehicle use dominate life cycle analysis.

We recommend that in the short term the focus of PTEG and the PTEs should continue to be on the emissions associated with vehicle use. If the PTEs are interested in calculating the total carbon footprint of a new scheme, it may be appropriate for a ‘factor up approach’ (for example an additional 10% for light rail and 30% for bus based on vehicle use emissions) to be used. It should be noted that, if this approach is used then vehicle use emissions should be clearly stated to enable a fair comparison with emission figures from other transport sector organisations, which are just reporting on these emissions (and are not using a life cycle approach). Consideration should, also be given to the role of the PTEs in facilitating and ensuring, in the future, a more robust life cycle analysis.

In the longer term, it will be important to ensure that when investing in new vehicles (such as electric or, hydrogen) that the non-vehicle use phases of the life cycle (e.g. the fuel cycle phase) receive detailed consideration, since research suggests (Figure 4-5) that these phases may make a greater contribution to overall emissions than the vehicle use phases. It will be important to ensure that any carbon savings gained in the vehicle use phase are not offset by more carbon being produced in, say, the fuel cycle phase.

Carbon footprinting / greenhouse gas inventory standards include the WBCSD and the WRI GHG protocol, ISO 14064 and the Carbon Trust. To achieve the latter standard requires a carbon reduction and to assist them in future target setting and achievement, the PTEs may wish to consider the use of this standard.

5 Carbon footprinting of PTE projects

Key findings:

- There is limited 'off the shelf' guidance or best practice for carbon footprinting the overall plans, policies and programmes of PTEs – in particular on the construction of the public transport infrastucture.
- AEA has identified a number of ways in which the PTEs could contribute to this area: the use of a carbon calculator to assess the potential impact of schemes; the undertaking of real life case studies and procuring in a low carbon way – placing an onus on suppliers to provide information on their lower carbon activities.

The main objective of this task is to enable PTEG and the PTEs to carbon footprint the full range of activities associated with its plans, programmes and policies through the development of guidelines so that the CO_2 emissions associated with transport infrastructure projects could be assessed and compared.

The approach used involved a review of the:

- Existing standards and guidelines for carbon footprinting in the construction sector
- Literature on carbon construction costs for transport specific infrastructure for example new railway stations and park and ride schemes
- Approaches that other organisations undertake

5.1 General standards, guidelines and approaches

5.1.1 Environment Agency's Carbon Calculator for Construction Activities

The Environment Agency (EA) has developed a carbon calculator aimed at construction activities, and this has been used on all of its major construction projects from November 2007. The carbon calculator is an Excel spreadsheet[43] that calculates the embodied CO_2 of materials plus CO_2 associated with their transportation. It also considers personal travel, site energy use and waste management, thus helping to assess and compare the sustainability of different designs (in CO_2 terms) and to influence option choice at the options appraisal stage. It will also help highlight where 'big win' carbon savings on specific construction projects can be made.

[43] The spreadsheet is available to download for free at the URL http://www.environment-agency.gov.uk/commondata/103601/carbon_calculator_2_1883909.xls

An example of the construction tool is provided below in .

Figure 5-1 Example of the Environment Agency Construction tool

Conversion (miles to km)	Miles	Kilometres
		0.0

Material quantities should be entered in tonnes (except where noted)

he conversion column will help users to calculate tonnage, but it is up to users to make the calculation and enter the tonnage themselves.

v 2.1 © Environment Agency

Category	Construction material	Unit Conversion or Density	Embodied tCO_2 per tonne of material	Quantity (tonnes)	Distance between source of supply and site (km)	Mode of transport			Footprint (tonnes fossil CO_2) Embodied	Transport	Sum
Quarried Material	Quarried aggregate	2.0 tonnes/m3	0.008	10000	100	Road			80.0	317.4	397.4
	Recycled aggregate	2.0 tonnes/m3	0.00369								
	Asphalt	0.7 tonnes/m3	0.045								
	Bricks	2.4 tonnes/1000	0.2	1000	100	Rail			200.0	4.1	204.1
	Facing Bricks	2.4 tonnes/1000	0.85								
	Clay	1.9 tonnes/m3	0.2								
	Vitrified clay pipe DN 100 & DN 150	2.4 tonnes/m3	0.41								
	Vitrified clay pipe DN 200 & DN 300	2.4 tonnes/m3	0.47								
	Vitrified clay pipe DN 500	2.4 tonnes/m3	0.524								
	Sand	1.85 tonnes/m3	0.0053								
	Soil	1.7 tonnes/m3	0.024	100	100	Rail			2.4	0.4	2.8
	Stone: general	2.0 tonnes/m3	0.021								
	Stone gravel/chippings	2.0 tonnes/m3	0.016								
	Slate	2.7 tonnes/m3	0.0295				Reset				
	Sub-total			11100					282.4	322.0	604.4
Timber	Timber: general	0.5 tonnes/m3	0.476	250	1000	Water			119.0	2.2	121.2
	MDF	14 kg/m2*20mm	0.58								
	Particle Board	6 kg/m2*20mm	0.48								
	Plywood	11 kg/m2*20mm	0.75								
	Sawn Hardwood	0.6 tonnes/m3	0.47	1000	250	Road			470.0	79.4	549.4
	Sawn Softwood	0.5 tonnes/m3	0.44	1000	20000	Water	Reset		440.0	179.4	619.4
	Sub-total			2250					1029.0	261.0	1290.0
		Conversion	tCO2/t	Tonnage	Distance	Mode	% Recycled	Source of recycled copper			
	Copper: general	8.9 tonnes/m3	5.57								

5.1.2 The Promoting Sustainable Business Competitiveness in Construction SMEs project

This project, run by the Sustainability Centre in Glasgow, provides free assistance to small and medium sized construction sector enterprises in the West of Scotland, in order to help companies to make their businesses more efficient and competitive, as well as to improve awareness of environmental and sustainability issues. The project is also developing resources that can be accessed by all construction SMEs to assist in addressing sustainability issues.

Concerning carbon footprinting, the project has developed a rough guide to the types of questions a company will be asked when measuring its carbon footprint.

These include materials used in:

- Wall construction – Brick / Stone / Block / Metal Framed / Clad Wood
- Roof construction – Slate / Tile/ Asbestos / Metal / Wood/
- Linings – Plastics / Non Combustible / Fibre board / Combustible

A guide to construction business carbon footprints will be also available soon (PSBiCSMEs, 2008). It is based on data from their experience of analysing carbon footprints over 10 years and is compliant with all existing standards including the WBCSD and WRI GHG protocol.

5.1.3 BREEAM family of assessment methods and tools

The BREEAM family of assessment methods and tools are designed to help construction professionals understand and mitigate the environmental impacts of their activities including: management, health and well being, energy, transport, water, material and waste, land use and ecology and pollution.

BREEAM Buildings and BREEAM Tools act at different stages of the construction process: i.e. for the manufacture of building materials (life cycle analysis of materials in BREEAM Specification: The Green Guide) through design stage (BREEAM Envest and BREEAM Buildings) during construction (BREEAM Smartwaste) and post construction (BREEAM Buildings).

The methods and tools also cover different scales of construction activity. BREEAM Developments is useful at the master planning stage for large development sites like new settlements and communities. BREEAM Buildings assesses the operational and the embodied environmental impacts of individual buildings. BREEAM Specification and BREEAM LCA look at the environmental impacts of construction materials.

5.2 Guidance on carbon costs of PTE infrastructure

To help inform our assessment of the construction costs of new PTE infrastructure we undertook a review of:

- Simapro Life cycle analysis tool.
- Public transport operator websites and company reports.
- Online journal and publication databases. Key words included carbon footprint, bus stop, and transport infrastructure. Databases included:
    - Sciencedirect
    - British Library direct
    - BNET
    - Science magazine
    - Emerald
    - Ilied

In addition, we undertook a:

- General web-based literature search

The results were extremely limited. AEA therefore contacted manufacturers and PTEs to obtain information on the use of different construction materials used in public transport infrastructure (for example bus shelters, park and ride schemes, and bus/rail stations) and then use this, in a ‘bottom up’ approach, to inform the development of carbon construction costs. Useful information was available on bus shelters (from GMPTE), which enabled a carbon footprint to be calculated (see Table 5.1).

Table 5.1 CO_2 emissions associated with bus shelter construction

Organisation	Bus Shelter materials	CO_2 emissions factors	Total CO_2 emissions
Euroshel	Shelter is 3 metres by 2 metres 175 kg of stainless steel and 19 kg of polycarbonate / glass.	Steel 4.92 kg CO_2 per kg Polycarbonate 6.04 kg CO_2 / per kg Flat glass coated 0.626 kg /per kg	975.76 kg with polycarbonate 872.89 kg with glass
Littlethorpe shelters of Leicester	Picqua wood from FSC certified forests. Shelters typically use 0.75 cubic metres.	Sawn timber hardwood 47 kg CO_2 / M^3 Sawn timber softwood 46.1 kg CO_2 / m^3	35.25 kg Hardwood 34.58 kg Softwood

However limited information was available on transport hubs, with no comprehensive details of material types and quantities available. AEA noted that in particular construction firms were reluctant to divulge details.

5.3 Approach taken to carbon costing of projects by comparable organisations

AEA investigated how the carbon footprint of transport construction activities would be / was measured by UK organisations and developments in order to ascertain what methodologies were being used and what information was being captured. The following were considered large-scale developments and thus more likely to have carbon accounting systems in place:

- The London Olympics

AEA reviewed the London Olympics "Sustainable Development Strategy" and this provided general information on what they are doing to minimise their carbon emissions. However, no information was provided on how they are measuring their carbon footprint. AEA also reviewed the Olympics Transport Consultation document and the Thames Gateway Annual Report 2007/08, however there was no information on carbon footprinting. AEA contacted the Olympic Development Authority (ODA), and at their request emailed the query, this was re-sent, but AEA did not receive a response before this report was submitted.

- Heathrow Terminal 5 (T5)

AEA contacted BAA for information about their approach to the carbon footprinting of T5. BAA did not measure the carbon footprint of T5 construction, neither was a carbon footprint of ancillary transport linkages and their operations established. BAA were able to provide us with vital statistics which would enable a crude estimate of the carbon / energy embodied in T5 as a structure to be made. BAA made crude estimates of the carbon savings achieved through the logistics planning arrangements (e.g. rail opposed to road trucks).

- Cabot circus, Bristol

Cabot Circus is a regeneration project in Bristol city centre and is due for completion in Autumn 2008. 80% of materials used in the building works are from recycled materials. We contacted Land Securities (who are managing the project) for further information, but did not receive a response.

- St David's 2, Cardiff

St David's 2 is due for completion in 2009, and is also managed by Land Securities, whom we contacted for further information. When construction first started at St David's 2 a few years ago, they did not ask contractors for the information required for a carbon footprint. However, they have now started asking their contractors to measure and report site energy and water usage, and vehicle mileage. Data on the latter has been difficult to collect since vehicles may make several stops on a single journey. Furthermore, to convert miles to CO_2 information on the type of vehicle is required, which has not always been easy to gather.

5.4 Conclusion and recommendations

The literature review revealed that there was useful general guidance on the carbon footprinting of construction activities, but limited research and therefore guidance on the approaches to the carbon footprinting of public transport projects and associated construction activities. As a result AEA undertook further research – contacting operators and manufacturers and reviewing approaches used for 'real life' large construction projects. Through this research it became clear that this is a developing policy area which few comparable organisations appear to have yet engaged in a comprehensive way.

AEA suggests that in terms of ways forward the PTEs may:

1) Assess the potential impacts of different schemes through experimenting with a carbon calculator such as the Environment Agency's construction tool (alternatively they could set up their own) to help assess the potential CO_2 impacts of different transport infrastructure projects. The BREEAM assessment tools and methods would also be invaluable.

2) They may also want to develop a real life case study based on forthcoming (pre-specified) build schemes.

3) Procure in a low carbon way – using the tender bid process to request detailed information from construction companies on the materials that they wish to use and the approach that the companies will take to ensure that the projects are as low carbon as possible.

6 Conclusions and recommendations

The key conclusions, recommendations and issues to discuss from each of the sections are summarised below.

Section 1 – Approaches to the carbon footprinting of transport operations

- ‘Top down’ (fuel use) and ‘bottom up’ (vehicle km and vehicle types) approaches to carbon footprinting are both used and both are valid.
- The private sector tends to use a ‘top down’ approach primarily because they can easily access the fuel use data of their operations. The public sector uses a mixture of ‘top down’ and ‘bottom up’ approaches.
- There is overlap between the different (private and public sector) carbon footprinting approaches.
- The availability of data will be the most important determinant in the approach to use for the PTEs (discussed further in section 3).

Section 2 – The project data collection process

- The data collection took longer than anticipated. This would need to be accounted for in any updates of the project.
- A data request form could help in the data collection process; an example is provided in Appendix four.
- The PTEs may wish to consider asking different departments to store data in a centrally located area.
- DfT government statistics also provide a useful source of information.

Section 3 – Data analysis

Bus

- ‘Bottom up’ (vehicle km, vehicle standards) information was available from the PTEs.
- CO_2 per vehicle km, per passenger km, and per passenger journey could all be calculated. However, assumptions for some of the PTEs had to be made.
- These outcomes (vehicle km, passenger km and passenger journey) tied in well overall with Government and private sector figures.
- ‘Top down’ fuel use data was available from BERR and this overall dataset matched well with the ‘bottom up’ approach.
- In terms of carbon footprinting for bus ***AEA recommends a ‘bottom up’ approach*** (based on compiling data on vehicle emission standards and vehicle km driven) ***complemented by a ‘top down’ approach*** (the use of BERR fuel data). This could change in the future if information from the bus operators on fuel use became available.
- Going forward, the PTEs could either use ***single factors based on an average (common PTEG values)*** this has validity in relation to entities like Transport Direct, since it enables a comparison to be made with single figures for London and the country as a whole or ***individual, PTE-specific, bus emission factors*** which are of value for benchmarking purposes and provide a greater degree of specificity**.**
- When looking at the current results for bus it is important to recognise that gaps in the data and the resulting use of assumptions impacts on the reliability of the results.

Rail

- ‘Top down’ information (diesel fuel use and electricity use in kWh) was available from Northern Rail (this covered GMPTE, Merseytravel, Nexus, SYPTE and WYPTE).
- ‘Bottom up’ information (e.g. patronage, vehicle classes and fuel use by vehicle class) was also available from Northern Rail and from Centro and SPT.
- CO_2 per vehicle km, per passenger km, and per passenger journey could all be calculated. However, significant assumptions had to be made.
- These outcomes (vehicle km, passenger km and passenger journey) tied in well with Government and private sector figures.
- In terms of carbon footprinting for rail ***AEA recommends the use of a combination of a ‘bottom up’ and a ‘top down’ approach.***

- ***AEA suggests that steps are taken to ensure that there is continued access to Northern Rail data*** (this will help facilitate data updates*).* AEA suggests that ways in which closer relationships between the PTEs and the other rail operators could develop are discussed.
- Going forward, the PTEs could either use ***single factors based on an average (common PTEG values)*** this has validity in relation to entities like Transport Direct or ***individual, PTE-specific, rail emission factors*** which are of value for benchmarking purposes and provide a greater degree of specificity.
- When looking at the current results for rail it is important to recognise that gaps in the data and the resulting use of assumptions impacts on the reliability of the results.

Light Rail

- 'Top down' information (energy use in kWh) was available for all of the PTEs.
- CO_2 per vehicle km, per passenger km, and per passenger journey could all be calculated.
- GMPTE and Nexus information is currently used in developing DEFRA guidelines for GHG Company Reporting. In the future ***AEA suggests*** this should be updated to include data from the other PTEs.
- In terms of approaches to ***carbon footprinting for light rail we recommend a 'top down' approach based on electricity consumption (kWh).***
- Discussions with the PTEs suggest that ***just traction energy should be considered,*** rather than traction and depot use.
- ***Individual figures for each of the PTEs*** for each of the ***light rail metrics*** should be used, because of significant differences in CO_2 emission factors across the different light rail systems. However, a weighted average also has value in enabling a comparison to be made with the emission factor used in the DEFRA guidelines for GHG Company Reporting.
- When looking at the current results for light rail it is important to recognise that gaps in the data and the resulting use of assumptions impacts on the reliability of the results.

Comparison with private transport

- Detailed information is available on the CO_2 emission factors (g CO_2 per vehicle km and per passenger km) for different private vehicle types.
- A comparison of the carbon emissions from public and private transport can therefore be made.
- However, there are a number of factors which need to be taken into consideration when undertaking this comparison. ***We recommend that if such a comparison is undertaken, it should be part of a larger appraisal which takes these other factors into account***.

Section 4 – Life Cycle Carbon Footprinting

- SimaPro life cycle analysis suggested that **CO_2 emissions from vehicle use dominate life cycle CO_2 emissions.** A literature review on life cycle analysis on private and public transport corroborated these findings.
- The carbon footprinting of public transport carried out by other public sector and private sector bodies does not take into account the emissions from the full life cycle instead it considers vehicle use only.
- For these reasons AEA suggests that either 1) the carbon footprinting figures used by PTEs should be for vehicle use only rather than the full life cycle or 2) A full life cycle approach is used but the contribution from vehicle use emissions clearly stated to enable a fair comparison with other public sector and private sector bodies.
- If the latter option is chosen this should be kept under review as it is likely that carbon footprinting based on full life-cycle analysis will become more common over time.

Section 5 – Carbon footprinting of PTE Projects

- There is **limited 'off the shelf' guidance or best practice for carbon footprinting** the overall plans, policies and programmes of PTEs – in particular on the construction of the public transport infrastucture.
- A 'bottom' up data collection approach was undertaken by AEA, however limited information on transport hubs was available.
- A review of approaches for 'real life' construction schemes (transport and other) suggested that carbon footprinting received limited consideration.
- ***We suggest that the PTEs*** may want to:

- **1)** ***Assess the potential impacts of different schemes*** (e.g. new train hub) through the use of a scenarios approach and a carbon calculator or the BREEAM assessment tools and methods.
- ***2) Develop a real life case study*** based on forthcoming (pre-specified) build schemes.
- **3)** ***Procure in a low carbon way***, placing an emphasis on construction companies to provide information on the carbon impacts of the materials they will use and the steps they will take to minimise these impacts.
- PTEs may also wish to consider the ***above in the context of the carbon neutral requirement for new buildings***, and given the limited consideration of transport infrastructure at present the potential for the PTEs to become leading authorities in this area.

Appendices

Appendix 1: Bus Carbon Footprinting methodologies

National Atmospheric Emissions Inventory

Outcome: 822 g CO_2 per vehicle km

The National Atmospheric Emissions Inventory (NAEI) compiles estimates of emissions to the atmosphere from UK sources such as cars, trucks, power stations and industrial plants. This inventory is essential in terms of the UK reporting its emissions under its European and international commitments. For example the UK greenhouse gas inventory (GHGI), which the UK submits under the Kyoto Protocol is based on the same data sets used in the NAEI, and the GHGI is compiled to Intergovernmental Panel on Climate Change guidelines.

Calculation of carbon dioxide emissions
Emissions of **carbon dioxide** are calculated for all road transport from the consumption of petrol and diesel fuels. Data on petrol and diesel fuels are taken from the Digest of UK Energy Statistics (DUKES) published by the Department for Business Enterprise and Regulatory Reform (BERR) and corrected for consumption by off-road vehicles.

In 2006, 18.14 Mtonnes of petrol and 20.15 Mtonnes of diesel fuel (DERV) were consumed in the UK. It was estimated that of this, around 1.5% of petrol was consumed by off-road vehicles and machinery, leaving 17.88 Mtonnes of petrol consumed by road vehicles in 2006.

To convert this to carbon emissions the emission factors set out below.

Table 1.1 Fuel Based Emissions Factors for Road Transport kg/tonne Fuel

Fuel	C
Petrol	855
Diesel	863

Therefore carbon emissions for road transport in 2006 were 31.47 MtC in 2006.

The contribution of different vehicle types (including buses) can be estimated based on **fuel consumption figures** and **traffic data.**

Average fuel consumption figures for buses for respective Euro Emission standards and road type in the UK are shown below.

Table 1.2 Average Fuel Consumption figures for Buses (g fuel/km)

Buses	Urban	Rural	Motorway
Pre-1998	399	178	229
88/77/EEC	386	174	224
Euro I	319	195	213
Euro II	288	191	208
Euro III	288	191	208
Euro IV	279	185	202
Euro V	271	179	196

The equations relating fuel consumption to average speed (which is linked to road type) are based on the set of tailpipe $CO_{2.}$ The TRL equations were derived from their large database of emission measurements compiled from different sources covering different vehicle types and drive cycles.

These fuel consumption factors are combined with relevant bus traffic data and then compared with BERR figures for total fuel consumption in the UK published in DUKES. A normalisation procedure is used to correct the figures for each vehicle class so that the total calculate fuel consumption adds up to the DUKES figures.

Average fleet weighted emissions for buses for different road types are shown below.

Table 1.3 Fleet weighted emissions for buses (g CO_2 per km)

Urban	942
Rural	616
Motorway	669

Alternative fuels

At present, emissions from road transport consumption of biofuels are not included in the inventory. There are no definitive centralised statistics from BERR on the amount of biofuels consumed by road transport in the UK. The total amount is still relatively small, although it is growing each year.

DEFRA guidelines for GHG Company Reporting

Outcome: 89.1 g CO_2 per passenger km

DEFRA's guidelines include conversion factors to help companies convert existing data sources into CO_2 equivalent data. The data can then be incorporated into a company's Greenhouse Gas inventory.

There are direct links between the GHGI and the NAEI and DEFRA's guidelines for GHG Company Reporting. However, it should be noted that some of the transport factors have been developed especially for the company reporting guidelines and are not used in the Greenhouse Gas Inventory (or in the NAEI). This is because the Greenhouse Gas Inventory reports at a different level of sector detail and follows internationally agreed rules for reporting emissions.

Emission factors in gCO_2/vehicle km for buses in different legislative Euro classes operated on different types of road conditions are shown in the following table and are based on fuel efficiency factors (g fuel/km) taken from the UK's Greenhouse Gas Inventory report "*UK Greenhouse Gas Inventory, 1990 to 2004: Annual Report for submission under the Framework Convention on Climate Change*". The factors are based on emissions tests on a limited sample of buses over different drive cycles carried out at different research facilities in Europe.

Table 1. 4 CO_2 Emissions from different bus emission classes (from the UK GHG Inventory)

G CO2 /km	Urban	Rural – single carriageway	Rural – dual carriageway	Motorway
Pre – 1998	1254	561	683	718
Pre- Euro I	1212	547	669	704
Euro I	1003	613	656	669
Euro II	905	600	640	654
Euro III	905	600	640	654
Euro IV	878	582	620	635
Euro V	851	564	601	615

The split of the journey types – urban, rural (single and dual carriageway) and motorway is shown in the below table and is the split of journey types used in the UK GHG inventory.

Table 1.5 Split of Journey types

Road type	Urban	Rural – single carriageway	Rural – dual carriageway	Motorway
Percentage of bus vehicle km	62%	23%	6%	9%

Using these percentages and the above CO_2 emission factors for different road types, an overall average CO_2 emission factor can be calculated for all types of roads (i.e. combining earlier tables). It is assumed that all buses run the above proportions on the different road types.

Table 1.6 Average emissions for all journeys by bus emission standard

	Average for all journeys (gCO_2/km)
Pre-1988	1011
Pre-Euro I	980
Euro I	862
Euro II	796
Euro III	796
Euro IV	772
Euro V	748
Fleet average	822

Bus vehicle km travelled by buses meeting the different Euro standards are estimated by the UK Greenhouse Gas Inventory (GHGI) (and used in the DEFRA's Company Reporting Guidelines). This information is linked to the age distribution of the fleet calculated in a fleet turnover model using data on new vehicle registrations from DfT's licensing statistics and historic trends in survival rates of buses of different ages. The proportion of bus vehicle kilometre travelled by the different Euro standards is shown below.

Table 1.7 Proportion of bus vehicle km travelled by buses meeting the different Euro Standards

	Average for all journeys (gCO_2/km)	Proportion of bus vehicle km (%)
Pre-1988	1011	4
Pre-Euro I	980	6
Euro I	862	9
Euro II	796	38
Euro III	796	43
Euro IV	772	0
Euro V	748	0
Fleet average	822	100

A national average load factor is estimated using information from the Department for Transport's Transport Statistics Great Britain and is shown below.

Table 1.8 Calculation of the average load factor for buses

	Billions	Source
GB passenger km by buses	48	Transport Statistics Great Britain – Table 1.1
GB vehicle km by buses	5.2	Transport Statistics Great Britain 7.2
Passengers per bus	9.2	

Please note that this approach will be amended slightly in the 2008 version – this report will be updated accordingly.

Transport Direct carbon calculator

Outcome: 89.1 g CO_2 per passenger km

Transport direct is a website funded by the DfT which provides travel planning information for members of the public. The site incorporates a carbon calculator which people to compare the carbon emissions of journeys by different modes for example car compared with bus.

The metric used is g CO_2 per passenger kilometre and is calculated based on NAEI and DEFRA Company Reporting Guidelines. The value is the same as DEFRA Company reporting guidelines and it is 89.1g CO_2 per km.

DFT New Approach to Appraisal

Emission figures are not provided

The New Approach to Appraisal is an analysis tool " which appraises the economic, environmental and social impacts of all transport proposals that require Department for Transport funding or approval". In such a way, all transport plans and schemes are evaluated and presented to decision-makers and analysts, while the public and the scheme promoters are provided with evidence on whether a specific transport plan or scheme should be progressed.

For road vehicles, the following steps apply for the calculation of carbon emissions:

1) ***Calculation of Fuel Consumption***: fuel consumption (FC), expressed in litres/kilometre (l/km) is calculated by using fuel consumption formula outlined below. Fuel consumption should be calculated for both scenarios (with and without scheme) and for every year of operation of the scheme and for petrol and diesel fuels;

Fuel consumption is estimated using a function of the form:

$$L = a + b.v + c.v^2 + d.v^3$$

Where:
L = consumption, expressed in litres per kilometre;
v = average speed in km per hour; and
a, b, c, d are parameters defined for each vehicle category.

The parameters needed to calculate the fuel consumption element of vehicle operating costs are given below.

Table 1.9 Fuel Vehicle Operating Cost Formulae Parameter Values (litres per km 2002)

Vehicle Category	A	b	c	D
Public service vehicle	0.63466867	-0.01898970	0.00027431	-0.0000012161

2) ***Calculation of Carbon Emission Levels*** *for each year*: Fuel consumption can be converted into carbon emissions by multiplying fuel consumption by the grams of carbon released from burning 1 litre (gCarbon/l) of petrol or diesel. For each year from 2005 to 2020 these values (grams of carbon/litre) are provided below.

Table 1.10 Carbon emissions associated with fuel consumption

Year	Carbon emissions from petrol/bioethanol blend	Carbon emissions from diesel/biodiesel blend
2005/6/7	627.57	717.5 (2631 g CO_2)
2008	618.94	707.29
2009	614.23	701.19
2010	609.27	696.23
2011	608.74	695.64
2012	608.22	695.04
2013	607.70	694.44
2014	607.17	693.84
2015	606.65	693.25
2016	606.13	692.65
2017	605.61	692.05
2018	605.08	691.45
2019	604.56	690.85
2020 and onwards	604.04	690.26

2a) It is worth noting that the usage of biofuels will reduce these values. When blended with conventional fuels (as a result of the Renewable Transport Fuel Obligation which will come into effect in April 2008) the figures will drop significantly: for instance, the 2005-7 value will be a constant 627.57 g Carbon/litre, whereas, the emissions from a petrol and bioethanol blend will be drop to 618.23 g Carbon/litre in 2008 and 606.55 in 2015 up to 604.04 in 2020 and onwards.

3) ***Calculation of the Change between the two scenarios for each over a*** 60-year appraisal period.

4) ***Estimation of the Social Cost of Carbon (SCC)***: a series of values in terms of pound (£) per tonne of carbon, following DEFRA's guidance called *Valuing the social cost of carbon emissions* [44] is used to estimate the value of the global damage from an additional tonne of carbon emitted. The central value for 2006 is 78.66 £/tonne of carbon (in 2002 prices), rising by £1 per year. Only the central value is required, but if a scheme is particularly large or the impact on carbon emissions is likely to be high, then the upper and lower bound values should be provided (as shown in Table 2 of the Unit).

Go Ahead

Outcome: 490 g CO_2 per passenger journey

Go- Ahead (in their company reports) provides data on fuel use, CO_2 from bus use and total passenger journeys.

- CO_2 from bus use is 268,823.23 tonnes.
- Passenger journeys – 548 million.

The 490 g CO_2 per passenger journey figure is based on dividing the CO_2 from bus use figure by the number of passenger journeys.

In terms of achieving the CO_2 from bus use figure it is not clear what assumption have been made. Data on fuel use is provided (109,763,000 litres). However, applying standard emission factors to this for example the DfT 2631 g CO_2 per litre results in a slightly higher figure of 288,786 tonnes.

National Express

Outcome: 99g CO_2 per passenger km

National Express uses the WBCSD's and WRI's Greenhouse Gas Protocol Initiative – the Corporate GHG Accounting and Reporting Standard (Corporate Module).

The assessment methodology follows as similar approach to that used in the National Atmospheric Emissions Inventory and DEFRA's Company Guidelines for Company Reporting in that:

- Carbon emission sources are identified
- A calculation approach is chosen (recognises that when direct monitoring not available accurate emission data can be calculated from fuel use data)
- Data is collected and emission factors chosen
- Calculation tools are applied (companies may substitute their own GHG calculation methods provided they are more accurate than or at least consistent with the GHG protocol corporate standard approaches.

The key issue is the emission factor chosen. Analysis of the calculation tools suggests that each litre of diesel fuel would produce 751 g of carbon which is in line with (though slightly higher than) NAEI and DfT emission factors.

[44] Available at: http://www.defra.gov.uk/environment/climatechange/research/carboncost/pdf/aeat-scc-report.pdf

Appendix 2: Rail Carbon Footprinting methodologies

National Atmospheric Emissions Inventory

Outcome: Intercity 8873 g CO_2 per vehicle kilometre

Outcome: Regional 657 g CO_2 per vehicle kilometre

For electric trains a ‘top down’ approach is used and emissions are based on fuel consumption data from BERR.

For diesel trains emissions are split into three categories: freight, intercity and regional. Emission estimates are based on train travelled and gas oil consumption by the railway sector. Gas oil consumption is estimated from data provided by the Association of Train Operating Companies (ATOC).

Carbon dioxide emissions are calculated using fuel based emission factors and fuel consumption data. The fuel consumption is distributed according to:

- Rail km data taken from the National rail trends yearbook (2007) for the three categories.
- Assumed mix of locomotives for each category.
- Fuel consumption factors for different type of locomotive.

DEFRA guidelines for GHG Company Reporting

Outcome: 60.2 g CO_2 per passenger kilometre

The national rail factor is for average emissions per passenger kilometre for diesel and electric trains in 2005/2006. The factor is from the DfT NMF Environmental Model and has been calculated based on total electricity and diesel consumed by the railways in 2005/06 provided by ATOC, and the total number of passenger km for 2005/06 from DfT rail statistics. The factors for conversion of kWh electricity into CO_2 are based on the 2005 grid mix.

Transport Direct calculator

Outcome: 60.2 g CO_2 per passenger kilometre

The metric used is g CO_2 per passenger kilometre and is calculated based on NAEI and Defra Company Reporting Guidelines.

The value is the same as Defra Company reporting guidelines.

National Express

As with the calculation of bus emissions National Express uses the WBCSD's and WRI's Greenhouse Gas Protocol Initiative Corporate GHG accounting for calculating rail emissions.

The worksheets behind this reference UK and US Government data (including Defra figures from 1999).

In the analysis for rail National Express have used Defra's 2007 emission factor dataset which includes some updated emissions factors have been used.

DfT Network Modelling Framework Environmental Model

Metric – CO_2 tonnes (by rail service) can be converted to km

The Rail Model was developed to assess the most significant environmental impacts and the environmental damage costs associated with all rail services included in the DfT's Transport's new NMF.

In order to develop both the emissions model and the noise model, a significant amount of detailed railway and environmental data were required. These data included the following:

- **Rolling stock data** – including train configurations, power output data for each rolling stock class and train configuration, and emission factor data;
- **Timetable data** – Timetables from the Network Modelling Framework for 2005 and 2009 were used to develop the emissions and noise models.
- **Energy consumption data** – Annual energy consumption data for both diesel and electric passenger services, disaggregated by train operating company were obtained from the Association of Train Operating Companies (ATOC).
- **Geographical co-ordinate data for the Strategic Rail Network** – Detailed co-ordinate data for each route link (Strategic Route Section) were obtained from the Network Modelling Framework. The co-ordinate data were used to map the whole railway network against the "Area Types" included in the National Transport Model (each Area Type relates to a different average population density value). This allowed the damage costs associated with the impacts of local air pollution and noise to be fully quantified (the damage costs for PM_{10} emissions and noise are both highly dependent on the numbers of people resident near to the emissions/noise source).

The emissions model is able to estimate atmospheric emissions associated with any rail service included in NMF timetables for any year up to 2068. Model outputs can be disaggregated by Strategic Route, Strategic Route Section, and National Transport Model (NTM) Area Type. The model calculates energy consumption and energy output data for each rail service and uses these parameters in conjunction with rolling stock emission factor data, power station emission factors data, and data on the carbon and sulphur content of gas oil and diesel fuel in order to estimate emissions of CO_2 (and air pollutants).

- The diesel consumption and electricity consumption data generated by the model are normalised by calibrating the model outputs against actual rolling stock energy consumption data for each train operating company published by ATOC; hence the emissions estimates produced by the model for each rail service are validated and corrected using real-world data.

- Estimates of **CO_2 emissions from diesel trains** are calculated in the model using the normalised diesel consumption data calculated for each train. CO_2 emissions from diesel trains are directly proportional to fuel consumption.

- For **electric trains**, the model quantifies annual emissions using electricity consumption data in conjunction with national average power station emission factor data. Current power station emission factors are based on data published by the Department for Business, Enterprise and Regulatory Reform (BERR). For future years, emissions per rail kilometre associated with electric trains are likely to decline as the UK power station energy mix changes – in particular, over the medium to long term, there are likely to be significant reductions in average CO_2 emissions. The model has been designed to take this factor into account as a set of power station emission factors for each year between 2005 and 2068 have been developed and included in the model.

- The model includes the provision to quantify the emissions associated with future variants of current rolling stock designs that will have improved emission performance due to the need to meet the limit values set out in the European Commission's Non-Road Mobile Machinery Directive if/when diesel traction units are re-engined. Data on new types of rolling stock that are not currently in operation can also be added to the model, as and when such trains come into service (or when data on these trains becomes available).

Eurostar

Outcome: 2007 value – London to Paris 21.1g CO_2 per passenger km

Outcome: 2007 value – London to Brussels 39.8 g CO_2 per passenger km

As all Eurostar trains are powered by electricity the emissions from Eurostar trains depended on two parameters - the energy consumption of the train - and the emissions from the electricity generated to power the train. AEA in their analysis for Eurostar assessed both parameters to estimate the emissions per train and per route. This has been combined with load factors to derive the emission per passenger km.

The Eurostar values include emissions from the electricity used to power trains and auxiliary power used on board, and all electricity transmission losses (from the national high voltage network and from the rail transmission system). Assessments were provided using both the average UK electricity mix as well as the emissions data from Eurostar's specific electricity provider (when in the UK) as they had lower CO_2 emissions per unit of electricity supplied.

The study used route specific load factors to assess the emissions per passenger carried, and the emissions per passenger km. It has also considered how these emissions might change in the future with the new high-speed Eurostar service (CTRL2), and the future electricity generation mix. Journey delays were not taken into account.

Table 2.1 Estimated emission factors for different diesel train types (g/km)

Train type	CO_2
Class 37	11270
Class 47	16723
Class 56	21441
Class 58	21441
Class 60	20154
Class 66	19147
Class 67	9277
Class 47+7 passenger coaches	9764
Class 101 (1PC + 1TC)	2606
Class 116 (2PC + 0TC)	2420
Class 117 (2PC + 1TC)	3351
Class 121 (1PC + 0TC)	1564
Class 122 (1PC + 0TC)	1713
IC125 (2PC)	12170
Class 141/1 (2PC + 0TC)	2085
Class 143/6 (2PC + 0TC)	2011
Class 144 (2PC + 0TC)	1862
Class 144 (3PC + 0TC)	2606

Class 150 (3PC + 0TC)	3202
Class 153/0 (1PC + 0TC)	1415
Class 156 (2PC + 0TC)	2234
Class 156 (3PC + 0TC)	2904
Class 158/0 (2PC + 0TC)	2793
Class 158/0 (3PC + 0TC)	3723
Class 159/0 (3PC + 0TC)	3723
Class 165 (2PC + 0TC)	1824
Class 165 (3PC + 0TC)	2979
Class 166/0 (3PC + 0TC)	2979
Class 221 (1PC + 3TC)	2594
Siemens future diesel 3 car unit	5570

Appendix 3: Light rail Carbon Footprinting methodologies

The light rail factors[45] were based on an average of factors for the Tyne and Wear Metro, Docklands Light Rail (DLR) service, the Manchester Metrolink and the Croydon Tramlink. Figures for the DLR and Croydon Tramlink for 2006/07 were taken from Transport for London's 2007 environmental report[46].
The factors for Tyne and Wear Metro and the Manchester Metrolink were based on annual electricity consumption and passenger km data provided by the network operators for 2003/4 and a CO_2 emission factor for electricity generation on the national grid from the UK Greenhouse Gas Inventory for 2006 (for consistency with the DLR and Croydon Tramlink figures).

The average emission factor was estimated based on the relative line km of the four different rail systems in the absence of total vkm or pkm activity data (see Table 3.1 below). The average is weighted by relative line km.

Table 3.1 Emissions per Light Rail system

Type		g CO_2 per pkm	Line km
Tyne and Wear Metro	Light rail	120.7	59
DLR (Docklands Light Rail)	Light rail	74.0	27
Croydon Tramlink	Tram	42.0	28
Manchester Metrolink	Tram	42.1	39
Average*		78.0	

[45] DEFRA (2008) Guidelines to DEFRA's GHG Conversion Factors: Methodology for Transport Emissions http://www.defra.gov.uk/environment/business/envrp/pdf/passenger-transport.pdf
[46] TfL's 2007 environmental report is available at: *http://www.tfl.gov.uk/assets/downloads/corporate/TfL-environment-report-2007.pdf*

Appendix 4: Data Request Form

Please send the data to us in the format you find easiest**, for example a spreadsheet or word document. We can handle complex or detailed information so the format in which you already hold it will be acceptable.**

All information will be treated as confidential **and we are happy to sign disclaimers to this effect.**

Please send us 2006/2007 data, **if this data is not available, please send us data from earlier years.**

Please also send us **any** comments on the data **and/or any** additional information **we may find useful**

Thank you in anticipation of your support. Your response will be invaluable in taking this important research forward.

Bus

1) Bus vehicle kilometres
Carbon emissions are directly related to vehicle kilometres driven. **Could you therefore please provide information on vehicle kilometres by bus route number on a weekday and weekend (include Saturday and Sunday).** We wish to, with the help of the PTEs, classify the information, where possible into urban and rural, and information at the bus route level will help us achieve this. An understanding of the urban and rural split will enable us to make informed judgements on the speed of buses, which relates to fuel use and therefore carbon emissions.

This information will be treated as confidential. However, we recognise that information at the bus route number level is commercially sensitive, and if you are unable to provide data in this format could you please provide information at the level you feel appropriate, for example the PTE area.

For the weekday could you please provide information for the morning period of 8am to 9am and the total for the day, and for the weekend the total for each day (Saturday and Sunday). *If the information is not available for these timescales please use timescales (e.g. annual) you have information for.*

2) Patronage

The Transport Direct, and other carbon calculators, typically provide an average value for carbon emissions per passenger kilometre. However, passenger load factors vary throughout the day, and an understanding of how this impacts on carbon emissions per passenger kilometre will be invaluable in helping develop and improve the accuracy of Transport Direct and other carbon calculators and also help increase the understanding of the impact of policies, for example bus priority measures in the am peak.

Could you therefore **please provide information on the number of passengers carried on a weekday and weekend by bus route number.** For the weekday **could you please provide information for the morning period of 8am to 9am and the total for the day, and for the weekend the total for each day** (Saturday and Sunday). *If the information is not available for these timescale please use timescales (e.g. annual) you have information for.*

Bus route numbers will help us classify the information. This information would be treated as confidential. However, we recognise that information at the bus route number level is commercially sensitive, and if you are unable to provide data in this format could you please provide information at the level you feel appropriate, for example the PTE area.

3) Passenger Kilometres
Information on passenger kilometres travelled will help inform the carbon emission calculations, it can be used in conjunction with fuel use to provide a generic carbon per passenger kilometre value.

Could you therefore **please** provide information on the **passenger kilometres carried on a typical weekday and weekend by bus route number. For the weekday could you please provide information, if possible, for the morning period of 8am to 9am and the total for the day.** *If the information is not available for these timescales please use timescales you have information for.*

This information would be treated as confidential. However, we recognise that information at the bus route number level is commercially sensitive, and if you are unable to provide data in this format could you please provide information at the level you feel appropriate, for example the PTE area.

4) Fuel use

Carbon emissions are directly related to fuel use, information on fuel use is therefore invaluable in calculating carbon footprints. Biodiesel can offer carbon reductions on conventional fuels. Could you please provide information **on the** type of fuel **(conventional or biodiesel) and** amount of fuel used **by** bus route number**, if at possible, we understand this may be difficult.**

If biodiesel is used**, could you** please advise on the % blend. **Information on any time scale - day/ week / year will be fine**

This information would be treated as confidential. However, we recognise that information at the bus route number level is commercially sensitive, and if you are unable to provide data in this format could you please provide information at the level you feel appropriate, for example the PTE area.

5) Information on bus types
To help understand the impact of, and potential for the use of ‘greener’ technologies in the bus fleet a detailed understanding of the current mix is necessary.
Please provide information, (in the format which is most convenient to you) which will help us complete the following table (continues on the next page).

Again the information will be treated as confidential.

Engine/abatement variations	2006/07 fleet numbers	Vehicle km	Fuel *(diesel, electricity, biodiesel)*	Vehicle size/Operational variants
Pre-Euro				
Euro 1				
Euro2				
Euro3				
Euro4				
EURO-5				
Pre Euro+DPF				
EURO-1+DPF				
EURO-2+DPF				
EURO-3+DPF				
Pre Euro+DPF+EGR				
EURO-1+DPF+EGR				
EURO-2+DPF+EGR				
EURO-3+DPF+EGR				
EURO-1+DPF+SCR				
EURO-2+DPF+SCR				
EURO-3+DPF+SCR				
Other (e.g. hybrid)				
Retrofit technology				

Appendix 5: Bus analysis

CO_2 Emissions associated with Vehicle Use

Information on Euro standards and the split between each PTE is shown in Table 5.1. To convert this to CO_2, emissions from the different bus classes and different journeys (Table 5.2) need to be taken into account and the results are shown in Table 5.3. For example in the GMPTE region, because all bus services operate under urban traffic conditions, the CO_2 emissions calculation is based on the urban figures in Table 5.2. By contrast, in the SPT region bus services are a mixture of urban and rural services and consequently the CO_2 calculation procedure uses urban and rural data from Table 5.2. For Centro, no Euro standard information was available, so an average based on the other PTEs was used.

Table 5.1 Number of bus vehicles by Euro standard for each PTE

	Centro*	GMPTE	Merseytravel	Nexus	SPT	SYPTE	WYPTE
Pre Euro		306	107	287	415	88	115
Euro 1		712	349	49	270	160	199
Euro II		1335	268	527	860	320	321
Euro III		1003	355	476	578	312	275
Euro IV		143		92	98	68	320
Urban / Rural split		100% urban	90% urban 10% rural	100% urban	87% urban 13% rural**	Assumed 100% urban	98% urban 2% rural

* No Euro standard information was available, so an average based on the other PTEs was used.
** 4 % rural single carriageway and 9% rural dual carriageway

Table 5.2 CO_2 Emissions from different bus emission classes (from the UK GHGI)

G CO_2 /km	Urban	Rural – single carriageway	Rural – dual carriageway	Motorway
Pre Euro*	1233	554	676	711
Euro I	1003	613	656	669
Euro II	905	600	640	654
Euro III	905	600	640	654
Euro IV	878	582	620	635
Euro V	851	564	601	615

* Note that the Pre Euro is based on average of Pre 1998 and Pre Euro 1 information

Table 5.3 Average CO_2 emissions per km for all journeys

	Average for all journeys (g CO_2)						
	Centro*	GMPTE	Merseytravel	Nexus	SPT	SYPTE	WYPTE
Pre Euro	1207.53	1233.00	1171.20	1233.00	1154.34	1233.00	1220.64
Euro I	987.69	1003.00	966.15	1003.00	955.34	1003.00	995.63
Euro II	893.19	905.00	876.50	905.00	868.31	905.00	899.30
Euro III	893.19	905.00	876.50	905.00	868.31	905.00	899.30
Euro IV		878.00		878.00	842.32	878.00	872.46

* No Euro standard information was available, so an average based on the other PTEs was used.

To calculate average bus CO_2 emissions, the km travelled by the different vehicle classes need to be factored in. Buses that meet the different Euro standards will travel different distances, with newer buses expected to travel further. TTR have undertaken analysis for each PTE on how vehicle kilometreage could be split between the different Euro standards and this is shown in Table 5.4. Information from Table 5.3 and Table 5.4 is used to calculate fleet average emissions (shown in Table 5.5).

Table 5.4 Percentage split by vehicle type (distance based)

	Centro	GMPTE	Merseytravel	Nexus	SPT	SYPTE	WYPTE
Pre – Euro	4%	4%	5%	10%	10%	5%	12%
Euro 1	4%	10%	16%	2%	6%	8%	7%
Euro II	46%	38%	26%	35%	39%	32%	32%
Euro III	45%	42%	52%	45%	38%	46%	39%
Euro IV		6%		9%	7%	10%	10%
Hybrid / Electric			0.7% each				

Source: TTR (2008) Report for PTEG - Scenarios and Opportunities for Reducing GHG / Pollutants from bus fleets in PTEs / SPT

Table 5.5 Fleet Average Emissions

	Fleet Average g CO_2/km
Centro	900.61
GMPTE	926.30
Merseytravel	906.97
Nexus	946.38
SPT	900.32
SYPTE	935.59
WYPTE	941.92

Appendix 6: Rail Analysis

Total CO_2 emissions

CO_2 emissions per depot were calculated from the diesel fuel used (Table 6.1). Here, litres of diesel fuel were converted to tonnes and then using a 0.87 conversion factor into C and then into CO_2 using the ratio of 44/12.

Estimates of emissions per train class were then made (Table 6.2 and Table 6.3) using the percentage split on different train classes provided by Northern Rail. CO_2 emissions for electric trains were calculated from kWh information provided by Northern Rail. Here, kWh were converted into CO_2 using the electricity grid rolling average figure of 0.537 kg CO_2 per kWh.

Table 6.1 CO_2 emissions per train depot (Northern Rail trains)

	Litres of Fuel	Tonnes	Carbon tonnes	CO_2 (tonnes)
GMPTE				
Longsight	1693962	1408	1215	4456
Newton Heath	9955825	8276	7142	26187
Total				30643
Merseytravel				
Edgehill	1760773	1464	1263	4631
Nexus				
Heaton	4218777	3507	3026	11097
SYPTE				
Sheffield	4213180	3502	3022	11082
WYPTE				
Neville Hill	7043532	5855	5053	18527
Holbeck	1384905	1151	993	3643
York (50%)	448734.5	373	322	1180
Total				23350
Others (non PTEG)				
Blackpool	4536716	3771	3255	11933
Barrow	873745	726	627	2298
Hull	3127810	2600	2244	8227
York (50%)	448734.5	373	322	1180
Total (all)	32663162	27151	23432	85916

Table 6.2 CO_2 emissions per train class (diesel)

Train class	Proportion (%)	Fuel	Tonnes	Carbon tonnes	CO_2 tonnes
142	26.53	8665737	7203	6217	22794
144	11.43	3732933	3103	2678	9819
150	16.33	5332761	4433	3826	14027
153	4.08	1333190	1108	956	3507
155	2.86	933233	776	669	2455
156	18.78	6132675	5098	4399	16131
158	20.41	6665951	5541	4782	17534

Table 6.3 CO_2 emissions per train class (electric)

Train class	KWh	CO_2 (kg)	CO_2 (tonnes)
321 (operates on the Leeds – Doncaster service)	4033721	2166108	2166
323 (various Manchester services e.g. Manchester Piccadilly to Stockport)	16165717	8680990	8681
333 (Airedale and Wharfedale lines)	33077971	17762870	17763

Number of rail km
Rail km for diesel trains are shown below in Table 6.4, rail km for electric trains are shown in 6.5. The total number of rail km for Northern Rail is 47.43 million per year.

Table 6.4 Rail km for diesel trans

Train class	Rail km	Depot
142	5221299	Heaton
142	5358912	Newton Heath
142 Total	10580211	
144/2	1968512	
144/3	1604928	
144 Total		
150	6516224	
153	2483021	
155	1156646	
156	2464966	Heaton
156	5686138	Newton Heath
156 total	8151104	
158/2	7094630	
158/3	1763840	
158 total	8858470	

Table 6.5 Rail km for electric rail

Train class	Rail km
321	582566
323	2673216
333	2858086

CO_2 emissions for vehicle use were calculated by dividing the total amount of CO_2 emissions by the total number of rail km for each vehicle type (the results are shown in Table 6.6 and Table 6.7). For diesel this information is found in Table 6.2 and Table 6.4. For electric trains this was from Table 6.3 and Table 6.5. For comparison SRA data on emissions[47] for the different train classes are also included in the tables.

Table 6.6 CO_2 emissions per rail km (diesel)

Train class	CO_2 per vehicle km (g)	SRA data (train formation)
142	2154	
144	2748	2 PC + 0TC* = 1862 3 PC + 0TC* = 2606
150	2153	3 PC + 0TC* = 3202
153	1412	1415
155	2122	
156	1979	2 PC + 0TC* 2234 3 PC + 0TC* 2904
158	1979	2 PC + 0TC* 2793 3 PC + 0TC* 3273

* Note SRA data refers to train formation

Table 6.7 CO_2 emissions per rail kilometre (electric)

Train class	kWh per rail kilometre	CO_2 per kilometre	SRA data kWh per rail kilometre
321	6.92	3716	Class 321/322 (1 PC + 3TC) 5.88
323	6.07	3260	6.56
333	11.57	6213	3 car 14.38 4 car 15.00

Data used in the calculation of emissions per passenger journey is shown below.

[47] Strategic Rail Authority (2001) Rail Emission Model http://www.dft.gov.uk/pgr/rail/researchtech/research/railemissionmodel

Table 6.8 Percentage allocation for each of the PTEs (diesel trains)

Train Class	Rail km	GMPTE	Mersey travel	Nexus	SYPTE	WYPTE	Other
142	10580211	33%	14%	4%	6%	12%	32%
144	3573440	1%	0%	0%	26%	45%	29%
150	6516224	35%	16%	0%	6%	11%	31%
153	2483021	0%	0%	1%	23%	13%	63%
155	1156646	50%	0%	0%	0%	50%	0%
156	8151104	15%	5%	4%	12%	14%	50%
158	8858470	8%	11%	0%	9%	10%	61%

Table 6.9 Percentage allocation for each of the PTEs (electric trains)

Train Class	Rail km	GMPTE	Mersey travel	Nexus	SYPTE	WYPTE	Other
321	582566	0%	0%	0%	32%	66%	2%
323	2673216	54%	0%	0%	0%	0%	46%
333	2858086	0%	0%	0%	0%	74%	26%

Table 6.10 CO_2 Emissions (tonnes) per each PTE (diesel trains)

Diesel	GMPTE	Merseytravel	Nexus	SYPTE	WYPTE
142	7454.83	3171.31	835.66	1348.54	2735.65
144	71.68	0.00	0.00	2529.13	4385.35
150	4851.11	2309.19	43.41	828.92	1609.47
153	13.08	0.00	22.82	793.48	472.98
155	1227.20	0.00	0.00	0.00	1227.20
156	2462.46	792.25	709.84	1856.61	2305.68
158	1366.28	1969.69	0.00	1640.50	1820.80

Table 6.11 CO_2 Emissions (tonnes) per each PTE (electric rail)

Electric trains	GMPTE	Merseytravel	Nexus	SYPTE	WYPTE
321	0.00	0.00	0.00	695.93	1430.67
323	4719.51	0.00	0.00	0.00	0.00
333	0.00	0.00	0.00	0.00	13087.40

Table 6.12 Total emissions per PTE and G CO_2 per passenger journey

	GMPTE	Merseytravel	Nexus	SYPTE	WYPTE
Total CO_2 emissions Tonnes	22166	8242	1612	9693	29075
Number of passenger journeys Million	26.68	6.26	1.92	6.49	19.77
CO_2 per passenger journey (g)	830.82	1316.68	839.44	1493.55	1470.67

SPT data

Table 6.13 CO_2 emissions per train class (diesel and electric)

Train Class	Emissions	Journey
156 2 PC + 0 TC* 3 PC + 0 TC*	1979 (this project) 2234 (SRA) 2904 (SRA)	Glasgow – Mary Hill – Anniesland Glasgow – East Kilbride / Barrhead/ Kilmarock/ New Cumnock Grivan / Stanraer and Kilmarncok – Ayr/ Girvan / Stanraer Glasgow - Whifflet Glasgow – Paisley Canal Glasgow – Shotts
158 2PC + 0 TC* 3PC + 0 TC*	1979 (this project) 2793 (SRA) 3723 (SRA)	Glasgow – Mary Hill – Anniesland Glasgow – Cumbernauld Glasgow – Croy
170		Glasgow – Mary Hill – Anniesland Glasgow – Cumbernauld Glasgow – Croy
314	3356 (SRA)	Glasgow - Cathcart Circle/ Neilston/ Newton Glasgow - Wemyss Bay/ Gourock
318	4833 (SRA)	Glasgow - Larkhall/ Motherwell/ Coatbridge Central/ Cumbernauld/ Lanark Glasgow - Ardrossan / Largs/ Ayr Glasgow - Wemyss Bay/ Gourock
320		Glasgow - Springburn/ Airdrie/ Drumgelloch Glasgow - Milngavie/ Dalmuir/ Balloch/ Helensburgh Central
334	5236 (SRA)	Larkhall/ Motherwell/ Coatbridge Central/ Cumbernauld/ Lanark Glasgow - Springburn/ Airdrie/ Drumgelloch Glasgow - Milngavie/ Dalmuir/ Balloch/ Helensburgh Central Glasgow - Ardrossan / Largs/ Ayr Glasgow - Wemyss Bay/ Gourock

* Note: SRA data refers to train formation

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