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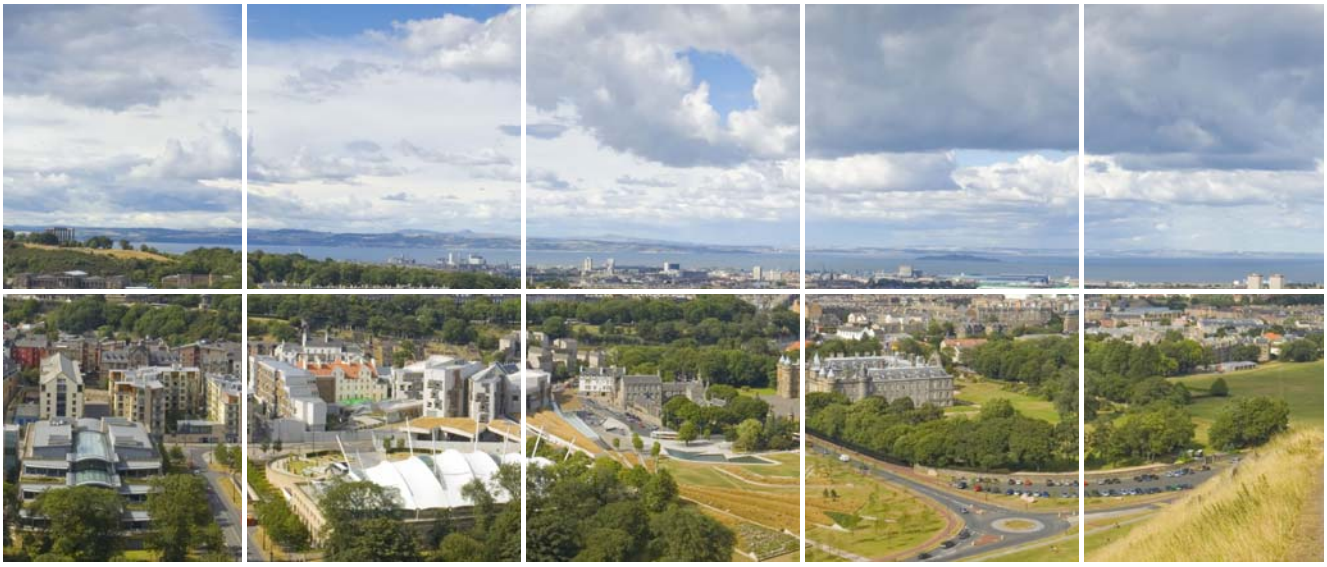

Local and Regional CO_2 Emissions Estimates for 2005 - 2006 for the UK

Report to Department for Environment, Food and Rural Affairs

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16th September 2008

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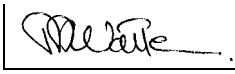
	Signature	
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Contents

1 Introduction

There is an increasing need for local and regional data on emissions of Carbon Dioxide (CO_2) because climate change mitigation needs to be tackled at a local level. In order to do this a consistent evidence base is required, to enable local authorities and other relevant organisations to prioritise and act effectively to reduce emissions.

AEA produces the official Greenhouse Gas Inventory for the UK[1] under the National Atmospheric Emissions Inventory programme on behalf of Defra[2]. A key element of the NAEI programme is the mapping of emissions of a large number of different air pollutants at 1km resolution across the UK. These data are used in air pollution modelling and for assessing emissions locally. Over the last 4 years AEA has developed a new dataset of CO_2 emissions by Local Authority and Government Office Regions, building on the NAEI emissions maps and incorporating experimental regional energy statistics from the Department for Business Enterprise and Regulatory Reform (BERR). The dataset was first compiled for 2003 and is done so on a consistent basis across the whole of the UK. The dataset is as far as possible consistent with nationally reported emissions to the UNFCCC and under the Kyoto Protocol.

This dataset provides a spatial disaggregation of the national CO_2 inventory on an End User basis in which emissions from the production and processing of fuels (including electricity) are reallocated to users of these fuels to reflect the total emissions relating to that fuel use. This is in contrast to 'at source' emissions in which all emissions are attributed to the sector that emits them directly. The End User basis for reporting emissions has been chosen for this dataset because it fully accounts for the emissions from energy use at the local level and does not penalise local areas for emissions from the production of energy which is then 'exported' to other areas. The method used follows as closely as possible that used for the End User emissions calculated as part of the NAEI and reported by Defra at the national level.

In addition to this Local CO_2 dataset, AEA has developed a 1km resolution dataset of CO_2 emissions, which can be used in conjunction with this data. The 1km CO_2 dataset provides nationally consistent CO_2 emission estimates for the year 2006. For the first time this year the 1km resolution CO_2 dataset has been calculated on an end user basis in order to be as far as possible consistent with this Local CO_2 dataset. These data will in due course be available through the NAEI website[3].

This report follows on from previous reports in this series describing the datasets for 2003 (Goodwin et al, 2005a), 2004 (King et al, 2006) and 2005 (King et al, 2007).

1.1 NATIONAL STATISTICS

Unlike the 2005 Local Authority emissions estimates published last year, this dataset has now been classified as full National Statistics, and is no longer considered "experimental". This gives users greater confidence in the estimates. In order to obtain this classification, a range of quality criteria set out by the UK Statistics Authority had to be met. To achieve this, there have been in particular, key improvements to the accuracy and comparability of the data. These include:

- Re-classification of BERR Local Authority energy statistics as National Statistics;
- Implementation of improved formal quality assurance procedures;
- Methodological improvements; and
- Reduced uncertainty in the accuracy of some of the data inputs.

In terms of comparability, a consistent time series has now been produced by re-calculating the 2005 estimates to reflect the methodological changes used in calculating the 2006 estimates. This is important as it allows changes to be monitored over time. Further, there is a commitment to back-cast any future improvements to methodology so that that a comparable series starting in 2005 is always maintained.

The base year for the dataset timeseries is 2005. Data for earlier years will not be made available because BERR data for gas and electricity are not available on a consistent basis for these years.

[1] This UK Greenhouse Gas inventory is used to report to the UNFCCC to monitor our progress towards the targets set in the Kyoto Protocol as well as to underpinning national policy making and targets. (Baggott *et al*, 2008)
[2] This work is part of the National Atmospheric Emissions Inventory (NAEI) programme (contract RMP/2106) with Defra Air and Environmental Quality and Global Atmosphere Divisions.
3 www.naei.org.uk

Improvements in the Quality Assurance and Quality Control procedures used in the compilation of this dataset have been made this year. The procedures follow a methodology consistent with that for the national inventory compilation. A key part of the QA procedure is transparency and this report provides an element of this transparency through the explanation of the methods used to compile the dataset. This report explains the data sources used and the key assumptions used when compiling estimates. Further details are also provided in the NAEI Mapping Methodology Report (Bush et al, 2007).

1.2 STRUCTURE OF THIS REPORT

Section 2 provides background information on the UK reported emissions of CO_2. Details of the method used to derive the local CO_2 data are provided in **Section 3**. **Section 4** presents the dataset and S**ection 5** considers data quality and reconciliation of this dataset with the UK reported emissions. **Section 6** outlines planned improvements for the dataset over the next couple of years and **Section 7** presents conclusions.

The dataset is provided in detail in a spreadsheet that accompanies this report (LocalRegionalCO2Emissions_2005-6.xls).

Four further documents accompany this report:

- **Mapping small industrial emissions**: A detailed description of the recent work to update the modelling of small industrial emissions.
- **Point Source Fuel Use Estimates**: Explanation of the methods used to estimate fuel use and emissions at point sources.
- **Mapping Carbon Emissions & Removals for the Land Use, Land Use Change & Forestry Sector**: A detailed description of the methods used to compile the Local estimates of Land Use, Land Use Change and Forestry emissions.
- **Explanation of the 1km resolution CO2 emissions data available from the NAEI**: to be supplied in due course.

2 Background

2.1 GREENHOUSE GAS INVENTORY

The UK official Greenhouse Gas inventory (GHGI) is compiled annually by AEA on behalf of Defra as part of the National Atmospheric Emissions Inventory (NAEI) programme. This follows international guidance and draws on a variety of national statistics and sector specific data sources. The UK GHGI is reported each year to the United Nations Framework Convention on Climate Change (UNFCCC) and will be used to assess compliance with the targets set nationally and internationally such as in the Kyoto Protocol.

A consistent method is used across the NAEI programme, providing consistent inventories and emissions projections for greenhouse gases and air quality pollutants.

2.2 END USER BASIS FOR REPORTING EMISSIONS

UK total CO_2 emissions are reported in a variety of different formats for different organisations and purposes each year. One of these is known as the End Users report in which emissions from the production and processing of fuels (including electricity) are reallocated to users of these fuels to reflect the total emissions relating to that fuel use. This is in contrast to the 'at source' emission reporting in which each emission is attributed to the sector that emits it directly. End User emissions are reported by Defra in the e-Digest of Environmental Statistics[4] and the Environment in Your Pocket publication[5].

The End User basis for reporting emissions has been chosen for this dataset because it fully accounts for the emissions from energy use at the local level and does not penalise local areas for emissions from the production of energy which is then 'exported' to other areas. The method used follows as closely as possible that used for the End User emissions calculated as part of the NAEI and reported by Defra at the national level[6].

Emission sectors in the NAEI are divided into three categories:

- Energy Supply (the production and processing of fuels including electricity);
- Energy Users (such as residential, industrial and road transport); and
- Others (which emit CO_2 but it is not related to fuel use, such as industrial process emissions, and land use change).

Table 1 on the next page shows the UK total CO_2 primary emissions in 2006 split into these three types of sectors.

The end user calculation procedure reallocates emissions from energy supply industries to each energy user sector in the inventory in proportion to the amount of energy used by these sectors. Some fuel producers use fuel from other producers, for example refineries use electricity. The refineries therefore 'receive' emissions from electricity producers and in turn these emissions are reallocated to the users of the refineries' products. This requires that an iterative approach be used to estimate emissions from the end users. The iterations stop when all fuel producers have no more fuel to relocate to End User. **Table 2** shows the total emissions in the UK inventory for the end user categories including both reallocated energy supply emissions and the primary emissions at the point of fuel use.

Table 17 and **Table 18** in **section 5.2** show a reconciliation between these reported national emissions and the emissions presented in the dataset described in this report.

[4] www.defra.gov.uk/environment/statistics/globatmos/index.htm
[5] www.defra.gov.uk/environment/statistics/eiyp/index.htm
[6] The estimates presented in this report are also not directly comparable with the National and Regional Greenhouse Gas Inventories for CO_2. This is because more detailed site specific data on emissions and fuel consumption data have been used, in order to include more accurate data on emissions from large sources at the local level. The more detailed data, from reports for the EU Emissions Trading Scheme for 2005, were not used in the compilation of the National Inventory for 2005 because of the requirements of international inventory compilation (IPCC 2006a) which specifies that national datasets of fuel consumption (i.e. the BERR Digest of UK Energy Statistics, DUKES) must be used. The ETS data for 2005 are not fully consistent with DUKES but were used during the compilation process of allocating consumption to particular industrial consuming sectors.

Table 1 UK Total Primary Emissions of CO_2 (kT CO_2 2006)

	Anthracite & Coal	Coke	Solid Smokeless Fuel	Natural Gas	Oil	Electricity	Non Fuel	Total
Energy Supply								
Coke production		522					626	1,148
Collieries - combustion	10						130	140
Gas production				1,129				1,129
Gas separation plant - combustion					765			765
Iron and steel - flaring		1,536					71	1,607
Offshore oil and gas				13,101			4,809	17,910
Power stations	128,541			51,326	2,411		1,675	183,954
Refineries - combustion				702	14,983			15,685
Solid smokeless fuel production	69							69
Energy Consumption								
Industry: Iron & Steel		16,093		1,697	404		1,757	19,951
Industry: Other Combustion	6,100	182		32,131	11,341		1,040	50,793
Industry: Other Processes	2,213	14		2,163	9,684		8,066	22,140
Commercial	389			20,638	624		41	21,692
Agriculture	12			372	3,847		49	4,280
Miscellaneous							424	424
Rail Transport				4	2,211			2,215
Domestic	1,478	89	730	67,406	9,583		1,981	81,269
Road Transport					120,129		170	120,299
Landuse Change							-1,953	-1,953
Water Transport: National Navigation					5,405		97	5,502
Air Transport					2,787		2	2,788
Military Transport (Air & Water)					2,747			2,747
Exports								
Grand Total	138,811	18,435	730	190,670	186,920		18,986	554,552

Table 2 UK Total End User emissions of CO_2 (kT CO_2 2006)

Sector	Anthracite & Coal	Coke	Solid Smokeless Fuel	Natural Gas	Oil	Electricity	Non Fuel	Total
Energy Supply								
Energy Consumption								
Industry: Iron & Steel	13	18,810		1,726	532	2,743	1,757	25,582
Industry: Other Combustion	6,126	207		32,675	12,765	53,767	1,040	106,580
Industry: Other Processes	2,222	16		2,210	10,815		8,066	23,329
Commercial	390			20,988	696	55,742	41	77,857
Agriculture	12			379	4,305	2,316	49	7,060
Miscellaneous							424	424
Rail Transport				5	2,474	1,626		4,105
Domestic	1,485	102	799	68,547	10,767	65,309	1,981	148,991
Road Transport					134,837		170	135,007
Landuse Change							-1,953	-1,953
Water Transport: National Navigation					6,037		97	6,134
Air Transport					3,131			3,131
Military Transport (Air & Water)					3,080			3,080
Exports		67	3		8,474	1,551		10,095
International aviation and shipping					5,128			5,128
Total	10,249	19,203	802	126,529	203,042	183,054	11,674	554,552

Legend and Notes:
Energy producers, Energy Users, Others (CO_2 emissions not related to fuel use);
Sectors: **Included in LA CO_2 estimates in bold;** *Excluded from Local CO_2 estimates in italics;*

3 Methodology

The dataset presented in this report provides a spatial disaggregation of the national CO_2 inventory on an End User basis. To do this Local Authority emissions must be estimated, then aggregated, per local area.

The statistics used to produce these estimates come from four main sources:

- BERR regional energy statistics[7];
- Point source emissions from large industrial installations;
- High resolution (1km) emissions distribution maps developed under the NAEI programme; and
- LULUCF regional data supplied by CEH.

Unlike the national estimates, industrial and commercial activities are grouped for the LA emissions estimates because of the nature of the input data – essentially because LA energy and fuel use data produced by BERR, a major input, groups them together. This means there are fewer sectoral splits available at the LA level than for the national end user emissions. For example, a detailed split cannot be provided of industrial emissions (e. g. iron and steel etc). As such, the sectoral Local Authority emissions estimates fall into 4 main groups:

- Industry / Commercial;
- Domestic;
- Transport; and
- Land Use, Land Use Change and Forestry.

Individual sub-components within each group are calculated and aggregated by Local Authority. Table 3 lists these sub-components, along with the data source type, and a reference to a more detailed methodology section explaining how that element is estimated. The diagram that follows the table illustrates the entire methodology.

Some sectors of the UK national inventory are not included in the Local CO_2 estimates because these could not be spatially disaggregated to LA level. These are off shore emissions from oil and gas extraction, domestic aviation emissions, fishing and coastal shipping. International aviation and shipping are excluded from the UK national inventory. Emissions in the UK Crown Dependencies and Overseas Territories are also not included in these estimates.

As explained in the previous chapter, the end user calculation procedure reallocates emissions from energy supply industries to each energy user sector in the inventory in proportion to the amount of energy used by these sectors. In the Local CO_2 dataset, the emissions related to energy supply (mostly at known point sources) are therefore not included at the location of the emission.

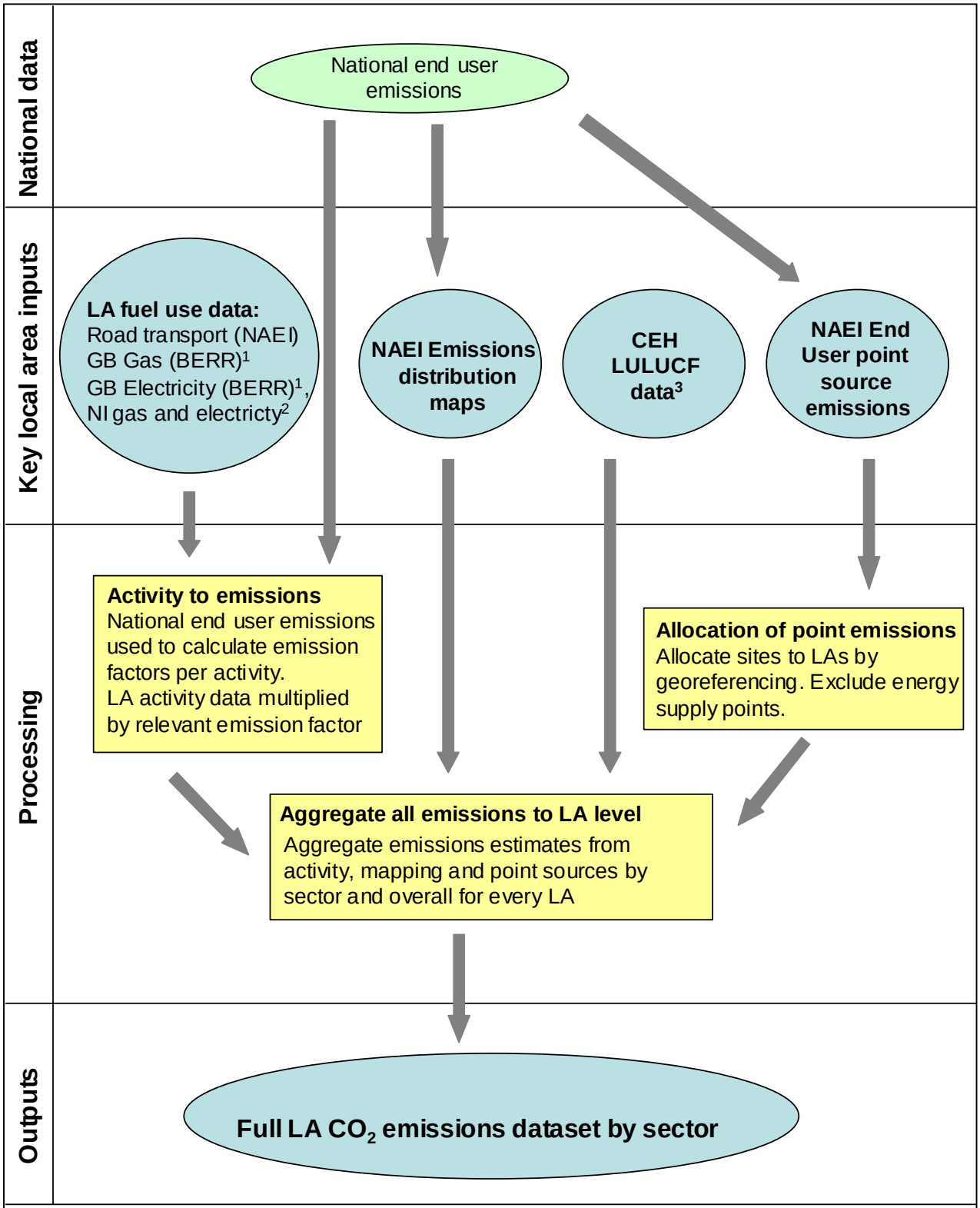
[7] www.berr.gov.uk/energy/statistics/regional/index.html

Table 3 Methodology summary for Local CO_2 reporting sectors and fuels

Report section	Sector	Data source / method summary
3.1	Industrial, Commercial and Agriculture Electricity	BERR regional energy statistics; Surrogate employment data to model NI consumption distribution
3.2	Industrial, Commercial and Agriculture Gas	BERR regional energy statistics. Further data for Northern Ireland from Phoenix Gas and individual point sources.
3.2	Industrial Gas (Large users)	Point source emissions for large industrial installations.
3.3	Industrial and Commercial Oil (1)(2)	Point source emissions for large industrial installations.
3.3	Industrial and Commercial Solid Fuel (4)	
3.3	Industrial and Commercial Wastes And Biomass	Remaining emissions distributed using high resolution (1km) emissions distribution of fuel use based in employment distributions and fuel intensity by sector.
3.3	Industry Process Gases	
3.3	Industry Non Fuel	
3.4	Industry Off-Road Machinery	High resolution (1km) emissions distribution maps developed under the NAEI programme
3.5	Agriculture Oil (3)	High resolution (1km) emissions distribution maps developed under the NAEI programme
3.5	Agriculture Solid Fuel	
3.5	Agriculture Non Fuel	High resolution (1km) emissions distribution maps developed under the NAEI programme
3.6	Diesel Railways	High resolution (1km) emissions distribution maps developed under the NAEI programme
3.7	Domestic Electricity	BERR regional energy statistics; Surrogate population data to model NI consumption distribution
3.8	Domestic Gas	BERR regional energy statistics; Further data for Northern Ireland from Phoenix Gas.
3.9	Domestic Oil	High resolution (1km) emissions distribution maps developed under the NAEI programme
3.9	Domestic Solid Fuel	
3.10	Domestic Home And Garden Machinery	High resolution (1km) emissions distribution maps developed under the NAEI programme
3.10	Domestic Household Products	
3.11	Road Transport Petrol (A roads)	Based on the NAEI data used by AEA to compile the BERR road transport fuel estimates. Emissions from fuel combustion in the road transport sector based on detailed DfT traffic census data and NAEI emissions factors.
3.11	Road Transport Petrol (Motorways)	
3.11	Road Transport Petrol (Minor roads)	
3.11	Road Transport Diesel (A roads)	
3.11	Road Transport Diesel (Motorways)	
3.11	Road Transport Diesel (Minor roads)	
3.11	Road Transport Other	
3.12	LULUCF Emissions: Agricultural Soils And Deforestation	LULUCF regional data supplied by CEH
3.12	LULUCF Emissions: Other	
3.12	LULUCF Removals	
	Unallocated emissions	Emissions not allocated for confidentiality reasons or because of problems with geo-referencing
	Sectors not included in these estimates that are included in National totals	Aviation (4), Offshore gas and oil, Shipping (including coastal shipping and fishing) (4)

Notes
(1) Includes the management of airports (support vehicles, stationary heating and power)
(2) Includes industry autogeneration of electricity
(3) Includes agricultural off-road machinery
(4) International aviation and shipping are outside scope of the UK inventory and are therefore not included in the National Totals
(5) Colours represent the high level sectors: industrial/commercial, domestic, road transport and LULUCF

Figure 1 Summary of data sources, transformations and flows used to compile the Local CO_2 emissions



Notes:
[1] BERR LA electricity and gas use data are now National Statistics meaning the data meet stringent data quality criteria. Emissions related to these sources account for a large proportion of total local emissions.
[2] NI (Northern Ireland) LA electricity must be modelled based on population (domestic) and employment (industrial / commercial) data as only total NI electricity consumption is included in the BERR dataset.
[3] Land Use, Land Use Change and Forestry data supplied by the Centre for Ecology and Hydrology

3.1 INDUSTRIAL AND COMMERCIAL ELECTRICITY CONSUMPTION

Electricity consumption data for 2005 and 2006 published on the BERR website[8] has been used to map carbon dioxide emissions from electricity generation to the point of consumption. The emissions associated with electricity consumption have been estimated using an average UK factor for the relevant year in terms of kT CO_2 per GWh. This average allocates equal shares of coal, gas, oil and renewable powered generation to all of the electricity consumers and is derived from the UK inventory for 2006. The factors used are shown in **Table 4**.

Local electricity consumption data was compiled using data from the administrative systems of the electricity companies' data aggregators. The domestic electricity consumption data was calculated by BERR from actual or estimated meter readings of around 28¾ million electricity meters across Great Britain. The location of these meters were determined by their MPANs (Meter Point Administration Numbers) from the Gemserve database of meters ECOES (Electricity Central Online Enquiry Service).

For the industrial and commercial sector, these include non-half hourly meters classified as industrial and commercial, some nominally domestic meters with consumption of over 100,000kWh and also meters with addresses indicating commercial use such as unmetered, street lighting or temporary builders' supplies.

Further work has been undertaken for the 2006 dataset by BERR on reducing the number of unallocated MPANs resulting just 0.8% of consumption unallocated to a Local Authority. Further improvements have been made through the removal of duplicated data and re-allocation of large domestic users from the industrial and commercial sector and vice versa for small commercial meters. The dataset has been classified as National Statistics for 2005 and 2006[9].

The CO_2 emission for electricity consumption from the NAEI (as shown in **Table 4**) was distributed across the Local Authorities based on the consumption data for both domestic and industrial and commercial users.

Table 4 Electricity CO_2 factors used in this analysis

Year	Total UK Emission for Electricity	Total Consumption GWh	Electricity CO_2 Factor (kT CO_2 per GWh)
2005	172,959	334,561	0.517
2006	181,503	332,495	0.546

Reconciliation by BERR with total electricity consumption reported in DUKES found the result to be an over estimate of 1.3% of the GB total electricity consumption (BERR, 2007a). The consumption data are not for exactly a calendar year and some consumption is estimated as opposed to actual metered consumption. Overall it is therefore a good match with DUKES totals.

The BERR data also includes 6,600 GWh of electricity as direct sales to high voltage lines that cannot be allocated to any region or Local Authority due to the lack of information. Emissions associated with this electricity consumption are included in **Table 15** as an unallocated item. This takes the overall percentage of industrial and commercial electricity consumption unallocated to LAs, either because of geo-referencing problems or because it is direct sales, to 3%.

The BERR dataset does not provide a distribution of electricity consumption in Northern Ireland but data on total electricity sales are available in the Energy Trends article (BERR, 2007a). The total electricity consumption in Northern Ireland is 8063 GWh of which the domestic sector is 3242 GWh and the remainder of 4821 GWh is industrial and commercial. The distribution of industrial and commercial consumption has been modelled using total employment by Local Authority. This does not provide a true picture of electricity consumption and better data will be sought for future revisions of this dataset. BERR are hoping to improve their dataset to include Northern Ireland for 2007. This should be possible because there is now no longer a monopoly supplier of electricity and hence data will not be disclosive.

[8] www.berr.gov.uk/files/file43304.pdf
[9] National Statistics must meet rigorous quality criteria, therefore there can be greater confidence in the accuracy of the data for these years

Northern Ireland trades electricity with the Republic of Ireland to which it was a net exporter in 2006. It also imports electricity from Scotland via the Moyle interconnector, but these imports were less than the net exports to the Irish republic in 2006. In 2006 Northern Ireland imported 905 GWh of electricity from Scotland, but exported 1,778 GWh to the Republic of Ireland. The total generating capacity within Northern Ireland is 9,632GWh, of which gas accounted for two-thirds in 2006.

3.2 INDUSTRIAL AND COMMERCIAL GAS CONSUMPTION

The gas consumption data published by BERR provides estimates of gas consumption by the domestic sector and the industrial and commercial sector for each Local Authority in Great Britain for 2005 and 2006 (BERR, 2007a). The estimates have been compiled by BERR using 22.2 million records provided by xoserve[10] and independent transporters at meter point level with high quality address and postcode data and consumption. This data has been mapped to local authority areas very accurately, using geographical information from the National Statistics Postcode Directory (NSPD).

The compilation of this uses a 17 year average weather correction, taking account of the warmer weather in more recent years. However the xoserve dataset still retains the same issue as in previous years concerning the lack of an accurate way to differentiate between domestic and industrial consumers. A crude cut off point of 73,200 kWh is used to classify consumers, which incorrectly allocates many small and medium businesses to the domestic sector. BERR is continuing to investigate whether a better classification can be produced, either through linking the meter point data to external business databases or by using information on the electricity meter point database.

Furthermore for reasons of disclosure, the publication of the data has required suppression of data for some of the largest gas consumers. This relates to the industrial and commercial consumption data and equates to about 35% of all gas use and comprises 33 power stations and 70 large industrial users. However the local authority areas in which these 103 users are located are known as is the total gas usage by the large (excluded) users (by Government Office Region) and users in Northern Ireland. AEA has used information from BERR matched against point source emissions data from the NAEI point source database to be able to include emissions from these large users in the dataset.

Emissions estimates for the excluded sites have been calculated by AEA using the data from the NAEI point source database, which uses a combination of public domain emissions data and data from the EU Emissions Trading Scheme reports to regulators to estimate energy use. This database is described further in **Section 3.3**. The method used to obtain estimates of emissions and fuel use at point sources is described in the document **Point Source Fuel Use Estimates** accompanying this report.

Data from the Environment Agency database of reported emissions in the EU Emissions Trading Scheme has been used to estimate fuel use in 2005 and 2006. There are however some discrepancies between the DUKES fuel use statistics and those either reported in the EU-ETS or calculated by AEA. These differences mean that the data presented here for Industrial and Commercial emissions of CO_2 are not fully consistent with the UK GHGI inventory. The differences are described in the supporting document **Point Source Fuel Use Estimates**.

The comparison between the BERR quoted gas consumption for the excluded sites and gas consumption as estimated by AEA form the NAEI points source database shows good overall agreement, see **Table 5**. Northern Ireland is included with power stations in the table below because this is how the numbers were reported by BERR (BERR, 2007a).

[10] xoserve was set up in May 2005 after the restructuring of the gas distribution network. xoserve's role is to deliver transportation transactional services to gas shippers (suppliers) on behalf of the gas transporters.

Table 5 Comparison of BERR excluded gas consumption and AEA calculated gas consumption at large point sources and Northern Ireland

	Gas consumption reported by BERR (GWh)		Gas consumption calculated by AEA (GWh)	
	2005	2006	2005	2006
Power stations + Northern Ireland	302,827	295,229	314,597	245,526
Large industrial users	110,327	96,812	102,669	94,135
All excluded users	413,154	392,041	417,266	339,661

Gas consumption in Northern Ireland

Data for Northern Ireland has been added to the BERR dataset using information on total Northern Ireland gas consumption from Phoenix Gas. For small industrial and commercial users the total consumption is 498 GWh and for large users the total is 1,424 GWh in 2006 (Quinn, 2008). This does not include the powerstation at Ballylumford but it is assumed to include all other large users.

Calculating CO_2 Emissions

In order to calculate the total amount of CO_2 emission represented by the BERR LA gas consumption (i.e. without the excluded large gas users) it is necessary to remove the CO_2 emissions associated with these large users users from the national total End User emissions. This calculation is shown in **Table 6** where the national sectors using gas are listed at the top, with a total emission associated with this consumption of 57,981 kt CO_2 in 2006. Emissions associated with the large gas uses not including powerstations (13,953 kilotonnes of CO_2 in 2006) are taken from this total then domestic gas use emissions are added to the result. Power stations emissions are not included because they are distributed by electricity consumption as discussed above. The result of the calculation is a national total gas emission consistent with the BERR gas consumption dataset. This is used to calculate average CO_2 emission factors for gas to apply to the disaggregated gas data at LA level. The implied emission factors are shown in **Table 7**.

Table 6 Calculation of CO_2 emission equivalent to BERR LA gas consumption

Sector		kT CO_2 2005	kT CO_2 2006
NAEI emission for Industry and commercial (not including power stations)		59,003	56,006
Agriculture	+	425	379
Processes (1)	+	1,149	1,597
Total Local CO_2 Industry and Commercial gas use emission		60,577	57,981
Large users (not including power stations) excluded from this dataset	-	14,231	13,953
Domestic consumption	+	72,204	68,547
Total emission to distribute using the BERR gas data		118,550	112,576

(1) Emissions from using natural gas as a feedstock for ammonia production

Table 7 Gas CO_2 emission factors used in this analysis

Year	Total UK Emission for Gas	Total Consumption GWh	Gas CO_2 Factor (kT CO_2 per GWh)
2005	118,550	670,698	0.177
2006	112,576	631,776	0.178

3.3 OTHER INDUSTRIAL AND COMMERCIAL EMISSIONS

The industrial sectors in the NAEI are mapped using a combination of point source estimates of emissions and area source employment based distributions. For some sectors the site specific emissions totals are equal to the NAEI emissions estimate for that sector. In other cases there are sectors that are have no identified point sources. The remaining emission is then treated as an 'area source' and distributed across the UK using modelled high resolution (1km) emission distributions based on detailed employment and fuel use data. Small industrial combustion is an example of a sector for which the area source distribution is particularly important but there are also some identified point sources.

Point Source Emissions

The NAEI database of point sources has been mentioned already in this report. Further details are provided below and also in the document **Point Source Fuel Use Estimates** supporting this report.

The site specific data have been compiled from a number of sources:

- Environment Agency Pollution Inventory;
- EU Emissions Trading Scheme Installations that reported emissions to the Environment Agency for 2005 and 2006;
- SEPA European Pollutant Emission Register;
- Northern Ireland Inventory of Statutory Releases;
- The UK's National Allocation Plan for the EU carbon emission trading scheme;
- And other information obtained from AEA's industry contacts.

Point source fuel and CO_2 emissions estimates have been made for the following sectors:

- Power stations, refineries; coke ovens[11]
- Other plant regulated as combustion processes under Integrated Pollution Control (IPC);
- Integrated steelworks;
- Cement clinker manufacture;
- Lime manufacture;
- Other plant regulated under IPC;
- Other sites for which ETS annual emissions data were available.

The methodology used to calculate the fuel use and emissions at point sources is described in the document **Point Source Fuel Use Estimates** accompanying this report. The data presented in this report are not fully consistent with the UK Greenhouse Gas Inventory (including the Devolved Administration GHGI) because of the use of emissions data reported by operators and also the ETS dataset rather than using BERR national statistics on fuel use. The more detailed data has provided better information on the fuels used at industrial and commercial sites but the total fuel use across the UK is therefore different from that reported in DUKES. The document **Point Source Fuel Use Estimates** includes details of where these differences are most significant.

The emissions in the NAEI point source database are calculated as 'at source' emissions rather than by end user. Therefore where appropriate (only fuel combustion emissions) the emissions have been adjusted to include the additional end user increment applicable to the fuel used.

For the purposes of reporting emissions by fuel type a simplified classification of fuel types has been used. This is shown in **Table 8**.

[11] Emissions in the energy supply and fuel production sectors are not included at the point of emissions in the dataset accompanying this report. These emissions have been redistributed to the locations of the relevant fuel consumption. See **section 2.2**.

Table 8 Fuel categories for reporting emissions

Fuel Name	Fuel Category	Fuel Name	Fuel Category
Natural gas	Natural gas	Anthracite	Solid fuels
Burning oil	Oils	Coal	Solid fuels
DERV	Oils	Coke	Solid fuels
Fuel oil	Oils	Petroleum coke	Solid fuels
Gas oil	Oils	SSF	Solid fuels
LPG	Oils	Landfill gas	Wastes and biofuels
Naphtha	Oils	Sewage gas	Wastes and biofuels
OPG	Oils	Wood	Wastes and biofuels
Orimulsion	Oils	MSW	Wastes and biofuels
Petrol	Oils	Scrap tyres	Wastes and biofuels
Lubricants	Oils	Waste oils	Wastes and biofuels
Blast furnace gas	Process gases	Clinical waste	Wastes and biofuels
Coke oven gas	Process gases	Waste solvent	Wastes and biofuels
Sour gas	Process gases	Benzole & tars	Wastes and biofuels

Area source emissions: High resolution employment based distributions

Emissions distribution maps for the small industrial combustion, public services, commercial and agriculture (stationary combustion) sectors have been updated for the 2006 inventory. This is a significant improvement for this dataset and the new distribution maps have also been used to revise the 2005 emissions for these sectors. The method used is described in the document **Mapping small industrial emissions** accompanying this report. The following data sets are used:

- Office of National Statistics Inter-Departmental Business Register (IDBR) 2007 which provides data on employment at business unit level by Standard Industrial Classification (SIC) code; and
- BERR Energy Consumption in the UK data on industrial and commercial sector fuel usage for 2005. (BERR, 2007b)

The SIC codes in the IDBR database were matched with the BERR energy datasets in order to calculate total employment by BERR energy sector. From this a fuel intensity per employee was calculated. These intensities could then be applied to employment distributions across the UK to make maps of fuel use.

In the case of the industrial sectors this energy intensity calculation was done at the level of 4 figure SIC codes (over 250 separate industry types) to retain the level of detail required for the mapping. Any aggregation of SIC codes would have resulted in a reduction in the quality of the final distribution. The BERR fuel data was reported for coal, manufactured fuel (SSF), LPG, gas oil, fuel oil and natural gas. These were aggregated to calculate industry specific fuel intensities for Coal, SSF, Oil and Gas.

In the case of the commercial and public service sectors the employment data was aggregated to be equivalent to the energy data provided by BERR. These sectors are shown in **Table 9**.

Table 9 Service sector energy consumption sub-sectors and NAEI sectors

Service sector energy consumption sub sectors	NAEI emissions sector
Commercial Offices	Commercial
Communication and Transport	Commercial
Hotel and Catering	Commercial
Other	Commercial
Retail	Commercial
Sport and Leisure	Commercial
Warehouses	Commercial
Education	Public admin and services
Government	Public admin and services
Health	Public admin and services

The IDBR employment data at local unit level were aggregated to 4 figure SIC codes at 1km resolution using grid references provided as part of the database. The employment totals for each sector were then multiplied by the appropriate fuel intensity values to make fuel use distributions across the UK. It has been assumed that fuel intensity for each sector is even across the sector. This is a simplification of reality but necessary because of a lack of more detailed estimates of fuel use.

The resulting fuel distributions have been refined using a subsequent set of modelling steps:

- Sites of employment corresponding to the locations of the highest emissions (as defined by the NAEI point source database) have been removed from the distributions. This is in order to prevent double counting of emissions at these locations (emissions are mapped as point sources).
- High-resolution gas consumption data at Middle Layer Super Output Area (MSOA) has been used to adjust the distribution of gas predicted by the employment and energy intensity data. An adjustment has also been applied in Northern Ireland based on Local Authority level gas consumption data.
- Based on expert knowledge of fuel use by industry and businesses the distributions of Fuel Oil and Gas Oil have been modified so that consumption is lower per employee in grid squares covered by Smoke Control Areas through the use of a weighting factor.
- The distribution of coal has been further limited to outside the locations of Smoke Control Areas.
- There have been no maps generated of Smokeless Solid Fuel consumption as part of this work. According to the BERR dataset (Energy Consumption in the UK Table 4.6) there is only one sector using manufactured fuel (Manufacture of coke oven products). The emissions from this sector will be mapped predominantly by point sources and any residual will be mapped using a simple employment distribution.

Further maps of employment have also been generated from the IDBR database to be used as proxy datasets for non-fuel based emissions distributions. Examples of these are dry cleaning, petrol stations and industrial chemical manufacture.

Summary of improvements for 2006

The modelling described above is an update of previous work for the NAEI maps. The key elements of the improvement are:

- Updated data from the IDBR data reflecting current levels of employment in all sectors;
- Updated data on fuel consumption by sector from BERR;
- Much better quality measured gas consumption data from BERR, both at 1km resolution and at the MSOA and Scottish Intermediate Geography level, and LA level in Northern Ireland;
- Revised assumptions regarding solid and liquid fuel consumption including adjustments for oil use in London based on the LAEI.

3.4 INDUSTRIAL OFF-ROAD EMISSIONS

For some sectors a simple map of employment has been used instead of fuel use. These are mostly for sectors where process emissions are important but also for estimating the distribution of industrial off-road emissions. These have been mapped using a distribution of employment in heavy industries.

3.5 AGRICULTURE

Agriculture stationary combustion has also been mapped using the IDBR employment data. The distribution of solid and liquid fuels has been made based on the geographical distribution of gas availability, i.e. with these fuels located in grid squares with no gas available. The method used to calculate the gas availability distribution is explained in the supporting document **Mapping small industrial emissions.**

Agriculture off-road emissions are distributed using a combination of arable, pasture and forestry land use data. Each of these land cover classes was weighted according to the off-road machinery activity on each land use. This used data on the number of hours of use of tractors and other machinery on these land use types, sourced by AEA for improving the UK inventory in this sector.

The agriculture non-fuel sector consists of CO_2 emissions from the breakdown in the atmosphere of pesticides applied to crops. These are distributed using a map of arable land cover as a surrogate for this activity.

3.6 DIESEL RAIL TRANSPORT

It is not possible to separate electricity consumed by the railways from that consumed by other commercial and industrial activities in the BERR dataset. Therefore it is not possible to report all rail emissions as a separate sub-sector within the transport sector. Instead both diesel and electric emissions from the rail sector are included in the commercial and industrial sector, and within this only diesel emissions can be shown as a separate sector.

The UK total diesel rail emissions are compiled from three journey types: freight, intercity and regional. Emissions are calculated based on fuel use reported in DUKES. Rail emissions for locomotive diesel are distributed across Great Britain using maps of rail links and details of the number of vehicle kilometres by the three journey types on each rail link. Emissions are distributed across the rail network by assigning an appropriate emission from journey type to each rail link. The emissions along each rail link are assumed to be uniformly along the length of the rail link, as no information on load variations is yet available. The map for Great Britain was compiled in 2000.

Rail emissions for locomotive diesel are distributed across Northern Ireland using data from Translink (Smyth, 2006) on amounts of fuel used on different sections of track aggregated to Local Authority. These data are for passenger trains only as there is no freight activity in Northern Ireland.

3.7 DOMESTIC ELECTRICITY CONSUMPTION

Electricity consumption data for 2005 and 2006 published on the BERR website (BERR, 2007a) has been used to map carbon dioxide emissions from electricity generation to the point of consumption. The emissions associated with electricity consumption have been estimated using an average UK factor for the relevant year in terms of kT CO_2 per GWh. This average allocates equal shares of coal, gas, oil and renewable powered generation to all the electricity consumers and is derived from the UK inventory for 2006. The factors used are shown in **Table 4**.

Local electricity consumption data was compiled using data from the administrative systems of the electricity companies' data aggregators. The domestic electricity consumption data was calculated by BERR from actual or estimated meter readings of around 28¾ million electricity meters across Great Britain. The location of these meters were determined by their MPANs (Meter Point Administration Numbers) from the Gemserve database of meters ECOES (Electricity Central Online Enquiry Service).

Reconciliation with data in DUKES by BERR found the result to be an over estimate of 3.9% of the GB total domestic electricity consumption (BERR, 2007a). This is possibly because of the inclusion of some non-domestic users within this dataset as a result of the requirement for the arbitrary cut-off of 100,000 kWh above which the user is assumed to be industrial or commercial. Other reasons for the differences are that the consumption data are not for exactly a calendar year and some consumption is estimated as opposed to actual metered consumption.

The BERR dataset does not provide a distribution of electricity consumption in Northern Ireland but data on total electricity sales are available in the Energy Trends article (BERR, 2007a). The total electricity consumption in Northern Ireland is 8063 GWh of which the domestic sector is 3242 GWh and the remainder of 4821 GWh is industrial and commercial. The distribution of domestic consumption across Northern Ireland has been modelled using population counts by Local Authority. This does not provide a true picture of electricity consumption and better data will be sought for future revisions of this dataset. BERR are hoping to improve their dataset to include Northern Ireland for 2007. This should be possible because there is now no longer a monopoly supplier of electricity and hence data will not be disclosive.

More information on how CO_2 emissions from electricity consumption are aggregated to Local Authority can be found in **Section 3.1**.

3.8 DOMESTIC GAS CONSUMPTION

Gas consumption estimates for the domestic sector (BERR, 2007a) have been used to calculate CO_2 emissions for the domestic gas sector using an average emission factor across the UK (see **Table 7**). More information about how the BERR gas consumption data were produced is provided in Section 3.2.

Gas consumption in Northern Ireland

Data for Northern Ireland has been added to the BERR dataset using information on total Northern Ireland gas consumption from Phoenix Gas. For the domestic sector the total consumption is 1120 GWh in 2006 (Quinn, 2008).

3.9 OTHER DOMESTIC FUEL USE

High resolution (1km) distributions of domestic non-gas fuel use in Great Britain were produced for the 2004 estimates (and updated for Northern Ireland in for the 2005 estimates) and were used to generate the emissions estimates presented in this report. These are modelled distributions making use of data from BERR and BRE. The method used to compile these distributions is described in the NAEI mapping methodology report (Bush et al, 2007) and explained briefly in this section.

New data were made available to AEA by BERR in 2006 providing high resolution maps of domestic gas use across Great Britain. This consisted of numbers of gas customers and amounts of gas use per 1km square for 2005, and data on electricity use, specifically type 2 meters (economy 7 type meters).

Data were also calculated by BRE on behalf of Defra for this work. They have provided data on total energy use by dwelling type and by fuel type, and regional data on the numbers of households using different fuels (BRE 2006). Gas consumption accounts for 72% of domestic non-electricity energy use therefore the new high resolution gas data from BERR provides a huge improvement in understanding the spatial distribution of fuel consumption in Great Britain.

In summary the method calculated the amount of gas use in a 1km square compared to a theoretical gas consumption on the basis of complete gas coverage, i.e. every dwelling using the average gas demand for that dwelling type. The difference between the actual gas consumption and this theoretical amount was then calculated. The number of households represented by this residual energy demand was calculated and these households were apportioned to different fuels. This apportionment was based on Economy 7 electricity use, assumptions about fuel use within and outside smoke control areas and regional data from BRE on fuel usage by household type.

It has been assumed that:

- coal is burnt exclusively outside Smoke Control Areas,
- oil is burnt outside the biggest cities (of greater than 250,000 populations) but inside the smaller cities in grid squares where there is residual demand
- smokeless solid fuels (SSF, coke, anthracite) are burnt exclusively within smoke control areas.

Northern Ireland

The BERR 1km resolution gas consumption data and BRE fuel use data used in updating mapping approach in Great Britain are not available in Northern Ireland. As a result an alternative method has been used for domestic fuel mapping for Northern Ireland. New modelling was undertaken in 2007 for the 2005 maps but maintain consistency with a previous methodology with updated datasets (Pye and Vincent, 2003).

The fuel use grids have been generated from a wide range of data sources including:

- Northern Ireland Housing Executive household data (supplied by the NIHE 2006 PRAWL property database)
- Gas household data (supplied by Phoenix Gas 2005)
- Belfast household data (from fuel use survey undertaken by Belfast City Council 2001)
- Northern Ireland Census output area households data (supplied by the 2001 Census)
- The Northern Ireland Interim House Condition Survey 2004.
- The Northern Ireland 2005 Home Energy Conservation Report
- Other household data not covered by the above (from number of sources, including Housing Condition Survey (HCS) data).
- Household fuel use survey data from 16 Northern Ireland Local Authorities collected under their obligations to Review and Assessment of air quality under the UK's Air Quality Strategy (AQS)

Using these data it was possible to update the bottom up approach developed by Pye and Vincent (2003). The fuels used by the Northern Ireland housing stock was characterised as follows:

- Geographic household distribution. Derived from the 2001 Census at an output area level and scaled to 2004 using information from the 2004 HCS and 2005 HECA report for Northern Ireland.
- Fuels used in the NIHE social housing stock. Derived from the NIHE's 2005 PRAWL database.
- Fuels used in the private housing stock. Derived from the 2001 detailed HCS, scaled to 2004 using information from the 2004 HCS and 2005 HECA report for Northern Ireland.
- Distribution of Households connected to gas. Derived from Phoenix Gas 2005.
- Fuels used in in Belfast. Derived from 2001 Belfast City Council fuel use survey
- Geographical distribution of Smoke Control Areas. Derived from GIS data provided by DoE Northern Ireland.

Using these data a detailed estimate of domestic fuel use across Northern Ireland in 2005 was possible. The method used to combine these datasets was consistent with that developed for the previous set of Northern Ireland fuel use distributions. Full details of the methodology are available in Pye and Vincent (2003).

3.10 OTHER DOMESTIC EMISSIONS

The NAEI source called domestic house and garden machinery is also included in the domestic sector for the LA CO_2 estimates. Domestic household products includes emissions from the use of petroleum waxes and detergents. These emissions are distributed across the UK Local Authorities according to the population distribution in the 2001 Census.

3.11 ROAD TRANSPORT

Road transport fuel use estimates for 2006 at Local Authority level were again compiled this year by AEA for BERR. The method used is described in this section, with improvements for 2006 described at the end of the section. Further improvements are planned for the 2007 maps (See section 6.1).

Hot exhaust emissions and the related fuel consumption are calculated within the NAEI using fuel consumption and emission factors for each vehicle type. These in turn are calculated on the basis of the composition of the vehicle fleet (age profile and fuel mix) from the DVLA's national licensing data and are based on the assumption that the fleet mix is the same everywhere on the UK road network. There are currently no regional variations in either the age of the fleet or the fuel mix.

Emission factors and fuel consumption factors

Fuel consumption factors and emission factors combined with traffic data for 6 major classes of vehicles are used to estimate national fuel consumption and emissions from passenger cars, light goods vehicles (LGVs), rigid heavy good vehicles (HGVs), articulated HGVs, buses/coaches and mopeds/motorcycles. The vehicle classifications are further sub-divided according to fuel type (petrol or diesel) and the regulatory emission standard the vehicle or engine had to comply with when manufactured or first registered. The vehicle Euro emission standards apply to the pollutants nitrogen oxides, particulate matter, carbon monoxide and hydrocarbons but not to CO_2 or fuel consumption. Nevertheless, the Euro standards are a convenient way to represent the stages of improvement in vehicle or engine design that have led to improvements in fuel economy and are related to the age and composition profile of the fleet. For example, the proportion of pre-Euro 1, Euro 1, Euro 2 and Euro 3 vehicles in the national car fleet can be associated with the age of the car fleet (year-of-first registration).

Fuel consumption and emission factors are expressed in grams of fuel or emissions respectively per kilometre driven for each detailed vehicle class and are taken from two distinct data sources.

- Vehicle emission test data provided by the Transport Research Laboratory (TRL) over different drive cycles from measurements on a limited sample of vehicles;
- Car manufacturers' data on CO_2 emissions and surveys with freight haulage companies on fuel efficiency of HGVs.

However, the amount of fuel that a vehicle consumes in travelling a certain distance depends on many parameters. Most important is the driving cycle, how much stopping and starting a vehicle does, how aggressively the vehicle is driven, how much load is applied to the vehicles engine (due to its laden weight or road incline), how well maintained it is, tyre inflation and use of air conditioning etc. It is impossible to know about all these parameters for every vehicle on the road and averages have to be used for what are in fact quite variable rates of fuel consumption for different groups of vehicle types.

The fuel consumption factors used in the NAEI calculations are polynomial functions expressing the relationship between fuel consumption rate and average vehicle speed for each class of vehicle. These are based on measurements of fuel consumption and emission rates for samples of in-service vehicles taken off the road and tested under controlled laboratory conditions over a range of different operational drive cycles. The factors used by the NAEI come largely from a database held by TRL of factors measured over different test cycles that simulate real world conditions. However, we have had to fill in gaps using expert judgement, especially for more modern classes of vehicles and technologies that have yet to be tested. This is especially the case for large HGVs and buses where the test sample size is small; it is very expensive to carry out these tests and they require special facilities. Using average speed of a vehicle is itself a crude, but so far the only kind of indicator, to the way a vehicle operates. There could be many different cycles, all with the same average speed, that have different amounts of acceleration and deceleration built into them and for each of these, the fuel consumption rate will be very different.

Emissions for the key air quality pollutants (NO_x, PM_{10}, $PM_{2.5}$, SO_2, NMVOC, Benzene, 1,3-butadiene, and CO) are calculated using speed related emission factors multiplied by vehicle flows on the road network. For other pollutants such as CO_2 and heavy metals, fuel consumption is used as a proxy for the distribution of emissions.

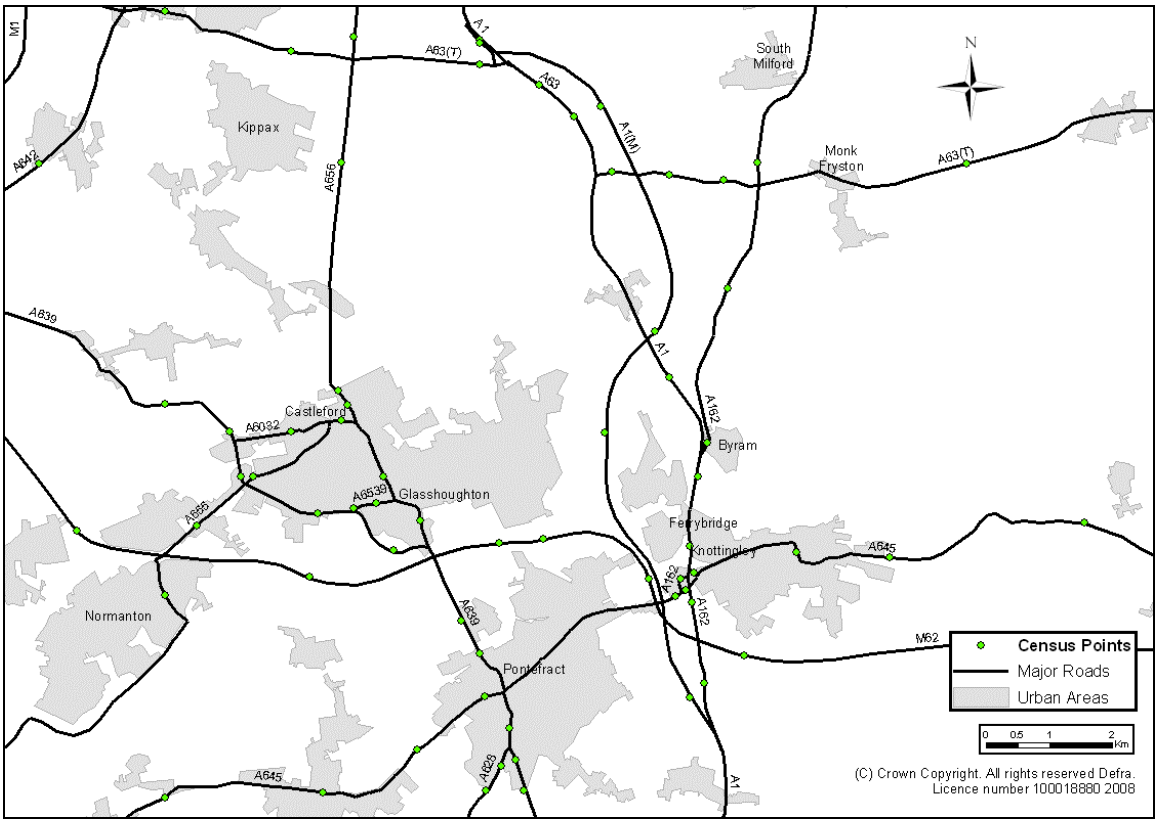
The fuel consumption maps are calculated from the speed related fuel consumption factors multiplied by vehicle flows. The method for calculating these maps is described in the next section.

Road transport mapping methodology

The base map of the UK road network used for calculating the hot exhaust road traffic emissions is derived from the Ordnance Survey Meridian dataset (see **Figure 2**). This provides locations of all roads (motorways, A roads, B roads and Unclassified roads) in Great Britain. In addition a dataset of roads in Northern Ireland was obtained from the Department of Environment Northern Ireland (DoE NI). This provides all major roads and most minor roads (but not all unclassified roads).

Traffic flow data for major roads (A roads and motorways) is available on a census count point basis for both GB (DfT, 2007) and Northern Ireland (Roads Service, 2006). However, the coverage in GB is considerably more dense than that for NI, although some new NI count points were available from 2004. The traffic flow data includes counts of each type of vehicle as an annual average daily flow. These have been aggregated up to annual flows by simply multiplying by 365. The Annual Average Daily Flow statistics take account of seasonal variation through the use of 'expansion factors' applied to the single day counts based on data from automatic counts for similar roads and vehicle types. Some Northern Ireland count points only record total vehicles, rather than a split of different vehicle types. An average vehicle split has therefore been applied to these. Each traffic count point has been allocated to a section of the major road network according to the road name and its proximity to the road – i.e each link has the nearest count point assigned to it. Calculations of emissions and fuel use have been done at the 1km resolution level by splitting each road link using an intersection with a 1km grid.

Figure 2 A map to illustrate the detail in the road network and count point database.



Traffic flow data is not available for minor roads on a link by link basis. Instead regional average flows by vehicle type have been applied to each type of minor road – B and C roads or unclassified roads. These data were obtained from Department for Transport. For Northern Ireland vehicle-specific minor road

flows have been calculated from data in the Traffic and Travel Information 2003 report which provides average flows for all vehicle types by minor roads and also average vehicle splits by the same road types.

It has been assumed that there are no regional variations in either the age of the fleet or the fuel mix. The fuel splits for passenger cars and LGVs in 2005 are provided in Table 10. For other vehicles, it has been assumed that 100% of motorcycles are fuelled by petrol and 100% of heavy goods vehicles and buses run on diesel.

Table 10 UK fuel split by vehicle type on minor roads 2005

Vehicle	Fuel type	% of fleet
Cars	Diesel	18.5
Cars	Petrol	81.5
LGVs	Diesel	90.1
LGVs	Petrol	9.9

Each major road link has been assigned an area type using the DfT definitions of urban area types shown in **Table 11** below. Vehicle speeds have then been assigned to different road types (built up and non-built up A roads and motorways) within each area type based on information provided by DfT which is described in the Greenhouse Gas Inventory report for 2003 (Baggott et al, 2005).

Vehicle kilometres of travel (VKM) by each vehicle type were calculated from the traffic flow rates, fuel splits and the lengths of each road type. VKM numbers are then multiplied by fuel consumption or emission factors taking into account the speed on the road of concern. These calculations were performed for each major road link in the road network resulting in maps of fuel use by fuel type and emissions by pollutant aggregated to 1km resolution across the UK.

For 2006 it was assumed that the spatial pattern of UK vehicle kilometres (VKMs) on minor roads was the same as that modelled for 2003. Total 2006 VKM totals for GB (DfT 2006a) and Northern Ireland (Roads Service, 2006) were distributed across this pattern to generate revised minor road km maps for 2006.

Table 11 Department for Transport Urban Area Type Classification

Area Type ID	Description	Population
1	Central London	N/A
2	Inner London	N/A
3	Outer London	N/A
4	Inner Conurbations	N/A
5	Outer Conurbations	N/A
6	Urban Big	> 250,000
7	Urban Large	>100,000
8	Urban Medium	> 25,000
9	Urban Small	> 10,000
10	Rural	N/A

The average speed approach to estimating emissions for different traffic conditions is overly simplistic but at present it is the only appropriate method for national scale modelling. However, work has shown that for modelling vehicle emissions for an inventory covering a road network on a national scale, it is sufficient to calculate emissions from emission factors in g/km related to the average speed of the vehicle in the drive cycle (Zachariadis and Samaras, 1997). Emission factors for average speeds on the road network are then combined with the national road traffic data.

Improvements to fuel consumption estimates for the 2006 inventory

Some of the fuel consumption factors used in the NAEI road transport emissions estimates have been revised in the 2006 inventory. These revisions were based on new data and better understanding of the effects of technology. Some changes were made to those factors that had previously been estimated after discussions with engineers at DfT. Another important revision was made to the fuel consumption rates used for HGVs. More direct use was made of statistics published by DfT from an annual survey of hauliers on the average miles per gallon of lorries of different sizes. These data would be based on a larger and probably more representative sample of HGVs than the test data previously used and will

reflect the types of conditions actually experienced on UK roads, including for example the typical load factor (a measure of how fully loaded a vehicle is by weight). The data published each year by DfT give a complete time-series of fuel efficiency of lorries and were used in conjunction with existing fuel consumption-speed relationships to estimate fuel consumption by different types of lorries on different types of roads. It should be noted that after adopting these DfT statistics, we found that DfT have themselves brought into question their own data have produced revised figures in August 2008.

From the above and the description of the method provided earlier, it should be possible to appreciate why there are uncertainties in the estimation of fuel consumption by road vehicles in the UK when calculated using a detailed bottom-up method in conjunction with traffic data.

In previous years' inventories, it had always been the case that our calculated UK fuel consumption exceeded the national fuel sales figures quoted in DUKES. In the 2005 version of the inventory, the calculated consumption of diesel exceeded the DUKES figure for 2005 by 17% and for petrol by 12%. Using the new fuel consumption factors in this year's inventory has considerably closed the gap (compare blue highlighted figures in **Table 12** and **Table 13**) so that now the calculated total for diesel consumption in 2005 is 3% less than the DUKES figure and the calculated total for petrol consumption is 2% more than the DUKES figure; the comparisons between model and DUKES figures are similar for 2006 and in fact for many earlier years.

The changes made to the fuel consumption factors have also affected the distribution of fuel used by different vehicle types and **Table 12** shows the breakdown in the modelled values of fuel consumption by vehicle type for 2005 based on last year's (2005) version of the inventory (2005 GHGI) and the figures for 2005 and 2006 from this year's version of the inventory (2006 GHGI)[12]. So comparing this year's figures for 2005 and last year's gives an indication of the affect of methodological changes; comparing this year's figure for 2005 and the figure for 2006 gives an indication of 'actual' changes in fuel consumption between these years due to changes in traffic and fuel efficiencies of vehicles.

Table 12 Fuel consumption calculated in the 2005 and 2006 versions of the GHGI from traffic data and fuel consumption factors for individual types of vehicles.

Mt fuel		2005 GHGI	2006 GHGI	
		2005	2005	2006
Cars	Petrol	19.97	18.07	17.70
	DERV	4.89	4.36	4.68
	All Cars	24.86	22.42	22.38
LGV	Petrol	0.50	0.45	0.45
	DERV	5.78	5.15	5.23
	All LGV	6.27	5.59	5.68
HGV	Artic	7.16	4.12	4.19
HGV	Rigid	3.54	3.93	3.97
ALL HGV		10.71	8.05	8.16
Buses		1.35	1.35	1.38
Motorcycles		0.16	0.16	0.15
All DERV		22.72	18.90	19.46
All Petrol		20.62	18.68	18.29
All Vehicles		**43.34**	**37.57**	**37.76**

N.B No normalisation applied to results to match with data in DUKES.

[12] These figures are the 'raw' modelled estimates before normalising to the DUKES totals. International guidelines for reporting CO_2 emissions state that emissions must be based on the amount of fuel purchased in each country. To satisfy this requirement, the GHGI therefore applies a normalisation procedure to the calculated fuel consumption (and hence CO_2 emissions) to ensure they add up to the figures for petrol and diesel consumption reported in DUKES.

Table 13 Fuel consumption statistics derived from DUKES 2005 and 2006

Mt Fuel	DUKES 2005	DUKES 2006	
	2005	2005	2006
All DERV	19.44	19.43	20.14
All Petrol	18.47	18.47	17.88

N.B a small fraction of the reported fuel use for road transport is assumed to be off road machinery and vehicles to these numbers are not exactly the same as those reported in DUKES.

It has previously been explained that because the GHGI calculated fuel consumption was higher than the figures in DUKES the difference was due to fuel tourism especially hauliers purchasing diesel on the European continent. However, model uncertainty must always have been a contributing factor. The fact that the calculated fuel consumption is now so much closer to the DUKES figures is encouraging, and the trend seems to be consistent over a long time series. The fuel tourism factor is therefore likely to be smaller than previously thought.

The changes made to the fuel consumption factors used in this year's inventory will manifest themselves differently in different areas and local authority regions. This is because the fuel consumption factors were modified to varying degrees for different vehicle types – some were changed considerably, while others were hardly changed at all. Therefore the overall impacts of the changes in a given local authority region will depend on the different types of vehicles travelling on these roads, as surveyed by DfT.

Improvements to road transport mapping for the 2006 inventory

Each year we receive a new database of traffic counts from DfT and DoENI and these are used to update the allocation of count points to the road network. In addition, checks are performed on this allocation to ensure that as far as possible the most up to date data are used at each location.

Significant effort has been invested in the 2006 maps to check the allocation and to remove duplicate old count points where there are new count points from DfT. It is not possible within time and budget constraints to undertake a comprehensive check of all data but instead we use a prioritised process looking at roads with new count points and the highest flows.

Emissions on A roads and motorways have been reported separately for the 2006 dataset, a split that is not available in the BERR dataset. The split between A roads and Motorways has been done on the basis of the road class assigned to each road link in the DfT database.

The estimates for this sector are subject to some uncertainty, in particular for the minor road estimates; see **Table 16** later in this report. However the approach uses the best statistics that are available on a consistent basis across the UK.

There are two other small sources of emissions from road traffic included in the inventory. These are combustion of waste lubricants and emissions from LPG vehicles. Both of these sources are distributed across LAs using estimates of total vehicle kilometres calculated from the NAEI maps of traffic flows.

3.12 LAND USE, LAND USE CHANGE AND FORESTRY EMISSIONS

Land Use, Land Use Change and Forestry (LULUCF) activities produce as well as remove atmospheric CO_2. Generally emissions are produced from soils and liming of soils and are removed through forest growth. Currently in the UK, LULUCF activities are a net removal of emissions from the atmosphere.

The Centre for Ecology and Hydrology (CEH) in Edinburgh annually prepares estimates of the uptake (removal from atmosphere) of CO_2 by afforestation and net loss or gain of carbon dioxide from soils (emissions to or removals from the atmosphere) for inclusion in the UK GHG Inventory. These emissions are classified as the LULUCF Sector for inclusion in the UK GHG Inventory (CEH 2008).

The estimates are reported according to the new NFR (the UNECE Nomenclature For Reporting) classification of sources and removals. Figures for 2006 are shown in Table 14. The emissions are also divided into the categories used for reporting these emissions in the dataset of Local CO_2 estimates.

The emissions to the atmosphere are given as positive values; the removals from the atmosphere are given as negative values.

The estimates for 2006 were made using dynamic models of change in stored carbon driven by land use change data. For forestry, the model deals primarily with plant carbon and is driven by the area of land newly afforested each year. Changes in soil carbon are driven by estimated time series of land use transitions between semi-natural, cultivated (farm), woodland and urban. The models, and those for other LULUCF activities, are run for each of the four devolved administrative regions of the UK. 2004 was the first year this had been reported in map format at a scale below the devolved administrations (England, Scotland, Wales and Northern Ireland); here the results are reported from preliminary methods to provide estimates of LULUCF emissions and removals at the scale of Local Authority within the UK.

In the 2006 dataset, a new source has been included under NFR code 5A2 for wildfires.

Full details of the methodology used by CEH to estimate emissions and removals by Local Authority for 2006 are provided in a separate document supporting this report: **Mapping Carbon Emissions & Removals for the Land Use, Land Use Change & Forestry Sector**

Table 14 Emissions of CO_2 from Land Use Change and Forestry 2006 (kT CO_2)

		LA CO_2 Categories		
NFR Code	Description	LULUCF Emissions: Agricultural Soils And Deforestation	LULUCF Emissions: Other	LULUCF Removals
5A1	Forest Land remaining Forest Land			
5A2	Land converted to Forest Land			-15,243
5A2	Wildfires			131
5B1	Cropland remaining Cropland (Yield improvement)			-640
5B1	Cropland remaining Cropland (lowland drainage)		1,151	
5B	Liming of Cropland	457		
5B2	Land converted to Cropland (non-forest biomass)		244	
5B2	Land converted to Cropland (soil)		14,068	
5C1	Grassland remaining Grassland (Peat extraction)		422	
5C	Liming of Grassland	313		
5C2	Land converted to Grassland (non-forest biomass)			-198
5C2	Land converted to Grassland (deforestation to grass)	117		
5C2	Land converted to Grassland (soil)			-8,639
5D1	Wetlands remaining Wetlands			
5D2	Land converted to Wetlands			
5E1	Settlements remaining Settlements			
5E2	Land converted to Settlements (non-forest biomass)			-51
5E	Land converted to Settlements (deforestation to settlements)	66		
5E2	Land converted to Settlements (soil)		6,203	
5F1	Other Land remaining Other Land			
5F2	Land converted to Other Land			
5G	Harvested Wood Products *		-354	
	Total	953	21,734	-24,640

* not included in the LA estimates because of insufficient data for distributing the emissions

4 Results

The results of this work are presented at a variety of levels of detail. **Figure 3** on the next page shows total CO_2 emissions per capita by Local Authority. **Figure 4** and **Figure 5** show regional totals at the sector level and **Table 15** below shows regional totals for the detailed sectors and fuels. Local Authority level detailed data are available in the spreadsheet that accompanies this report (LocalRegionalCO2Emissions_2005-6.xls). The spreadsheet contains a detailed breakdown of emissions by sector and fuel for 2005 and 2006 together with population counts and per capita emissions. Further maps are provided in on the pages following **Table 15**.

Some additional classifications of Local Authorities have been included in the results spreadsheet. The NUTS (Nomenclature of Units for Territorial) Level 3 area codes and names[13] and Local Area Agreement areas have also been included in order that the data can easily be aggregated up to these areas. NUTS3 codes and names have not been included for Scotland because the Local Authorities in Scotland do not exactly match with the NUTS classification in Scotland.

The Defra Classification of Local Authority Districts and Unitary Authorities in England has been included in order to identify the level of rurality within these administrative areas. A similar classification is not available for Wales, Scotland or Northern Ireland.

Figure 10 presents CO_2 emissions on a 1km resolution map. Data at this spatial resolution are generated as part of the NAEI programme and for the first time this year will be available for CO_2 on an end-user basis including the distribution of electricity emissions. The data will be available in due course via the NAEI website (www.naei.org.uk).

[13] NUTS (Nomenclature of Units for Territorial Statistics) is a hierarchical classification of spatial units that provides a breakdown of the European Union's territory for producing regional statistics which are comparable across the EU. NUTS4 is comparable with Local Authorities and NUTS3 is broadly comparable to Counties or equivalent in the UK.

Figure 3 Emissions of CO_2 per Capita by Local Authority (tonnes CO_2, excluding LULUCF)

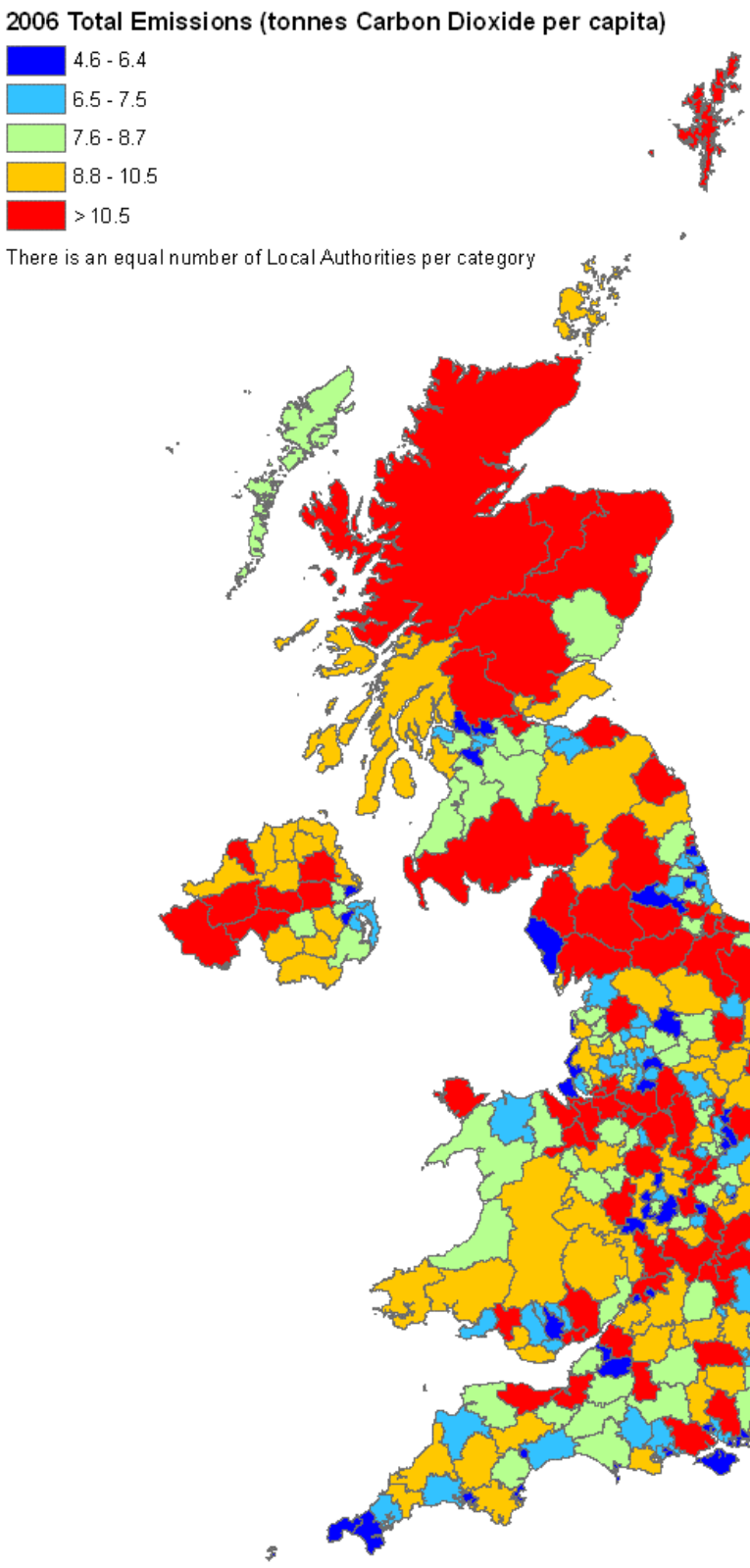


Figure 4 CO_2 emissions by Government Office Region, 2005-2006 (kT CO_2)

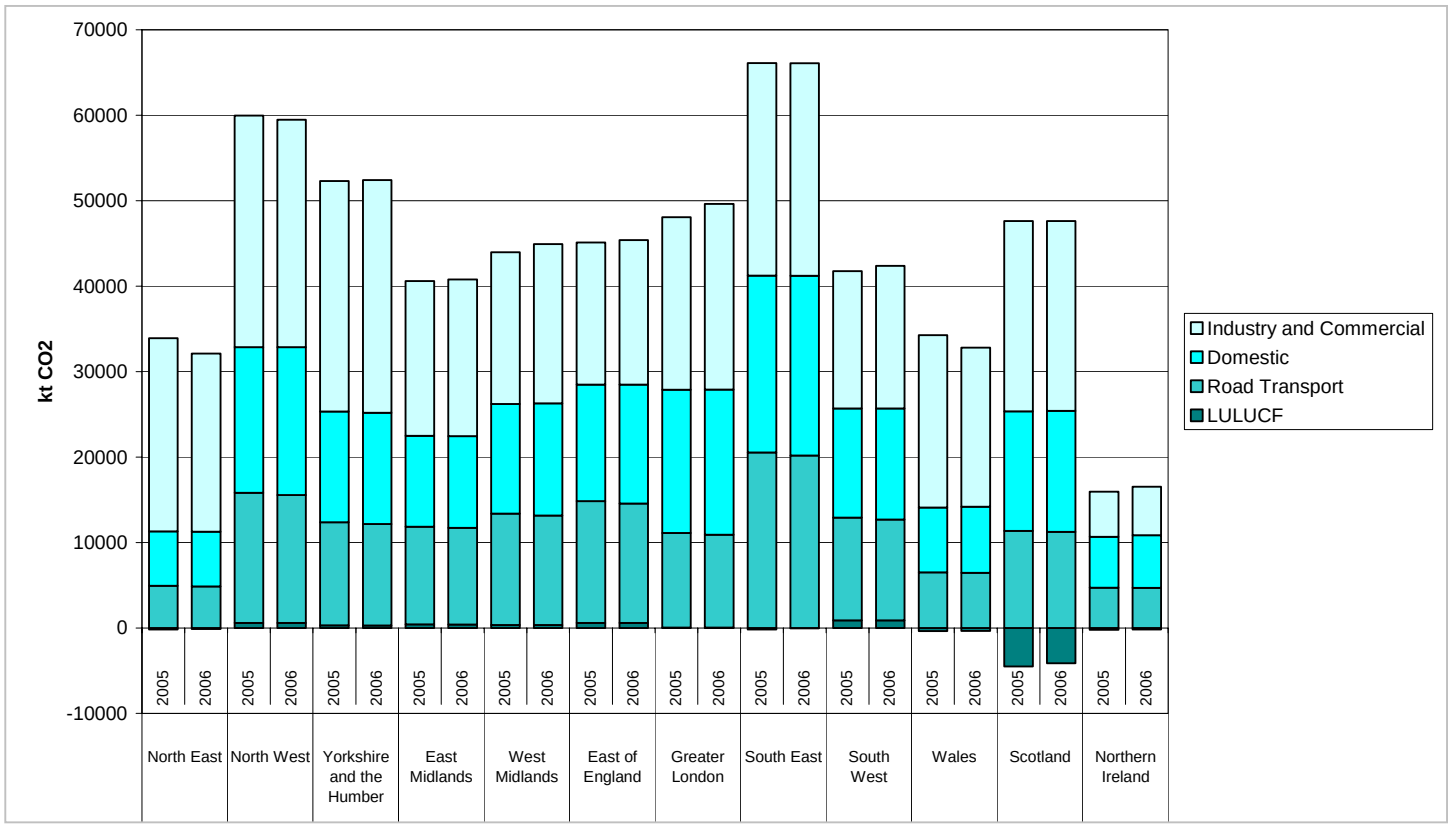


Figure 5 CO_2 emissions by Government Office Region, per capita 2005-2006 (tonnes CO_2) not including LULUCF

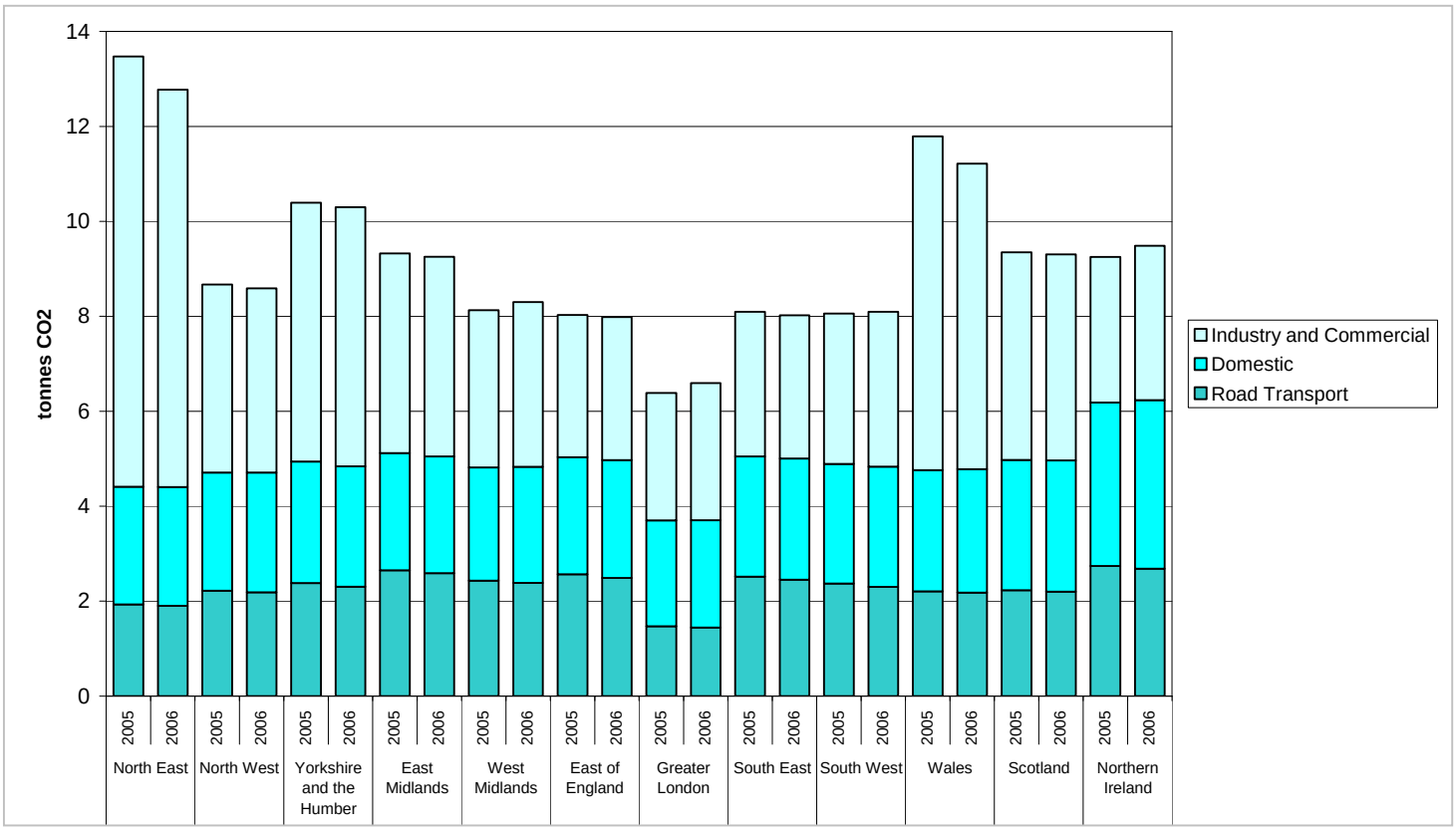


Table 15 Detailed results for Government Office Regions, 2006 (kT CO_2)

Sector	North East	North West	Yorkshire and the Humber	East Midlands	West Midlands	East of England	Greater London	South East	South West	Wales	Scotland	Northern Ireland	Unallocated	Total
A. Industry and Commercial Electricity	5,085	12,749	9,366	8,182	9,444	9,186	15,908	13,446	8,616	6,438	9,450	2,632	4,919	115,419
B. Industry and Commercial Gas	2,227	5,541	4,864	3,163	3,829	3,574	4,703	4,280	2,587	2,315	4,425	348	3	41,859
C. Industry and Commercial Large Gas Users	2,600	3,362	1,254	201	250	49	37	1,765	1,021	446	1,297			12,283
D. Industry and Commercial Oil	1,107	1,627	1,394	1,403	1,082	1,518	323	1,933	1,566	1,147	3,956	864		17,921
F. Industry and Commercial Solid fuel	4,527	494	2,214	1,475	1,072	622	13	779	521	1,746	583	606		14,653
G. Industry and Commercial Process gases	4,434	32	6,216	53	130	18	8	20	33	4,430	35	4		15,413
H. Industry and Commercial Wastes and biofuels	42	184	57	110	46	50	24	129	42	38	62	19		803
I. Industry and Commercial Non fuel	708	934	1,245	2,323	1,117	658	13	733	469	1,327	590	402		10,520
J. Industry Offroad	420	1,105	972	933	1,093	847	568	1,071	804	511	760	284		9,367
K. Diesel Railways	93	229	267	243	239	159	115	344	353	160	259	11		2,474
L. Agriculture Oil	147	335	242	257	311	210	9	342	672	526	776	488		4,315
M. Agriculture Solid fuel	0	1	1	1	1	1	0	1	2	1	2	1		12
N. Agriculture Non fuel	1	1	4	6	3	8	0	4	5	1	5	1		39
O. Domestic Electricity	2,453	7,157	5,221	4,646	5,697	6,536	7,479	9,302	6,104	3,057	6,614	1,770	48	66,084
P. Domestic Gas	3,620	9,325	6,863	5,513	6,632	6,271	9,212	9,968	5,024	3,544	6,210	203	2	72,387
Q. Domestic Oil	108	400	161	326	416	859	30	1,279	1,577	703	633	3,801		10,293
R. Domestic Solid fuel	134	186	615	116	222	69	13	233	129	308	538	352		2,915
S. Domestic House and Garden Oil	17	44	33	28	35	36	48	53	33	19	33	11		389
T. Domestic Products	66	176	130	109	138	141	188	209	129	76	132	44		1,538
U. A-Roads Petrol	1,197	2,431	2,136	2,469	2,163	2,994	2,511	4,084	2,678	1,734	2,671	1,095		28,162
V. A-Roads Diesel	1,264	2,428	2,589	3,380	2,333	3,767	2,560	3,803	2,673	1,764	3,151	1,040		30,752
W. Motorways Petrol	139	2,021	997	823	1,429	1,001	206	2,671	1,089	438	781	200		11,798
X. Motorways Diesel	231	3,534	2,298	1,765	2,770	1,792	292	3,759	1,681	635	1,374	237		20,369
Y. Minor Petrol	1,049	2,425	2,005	1,473	2,165	2,333	2,798	3,253	1,940	962	1,612	1,077		23,090
Z. Minor Diesel	960	2,080	1,785	1,350	1,879	2,018	2,456	2,507	1,676	908	1,617	1,006		20,242
ZA. Road Transport Other	22	65	49	45	55	60	49	95	54	30	48	22		594
ZB. LULUCF Emissions Soils & Deforestation	34	49	74	90	71	116	2	101	130	68	176	42		953
ZC. LULUCF Emissions Other	619	1,174	1,049	1,113	1,092	1,437	128	1,332	2,270	1,752	8,434	1,819	-354	21,865
ZD. LULUCF Removals	-772	-634	-827	-796	-813	-960	-79	-1,464	-1,508	-2,152	-12,733	-2,034		-24,771
Total	32,532	59,455	53,276	40,800	44,899	45,372	49,614	66,033	42,369	32,931	43,493	16,344	4,617	531,736

Figure 6 Domestic CO_2 per capita emissions by Local Authority for 2006

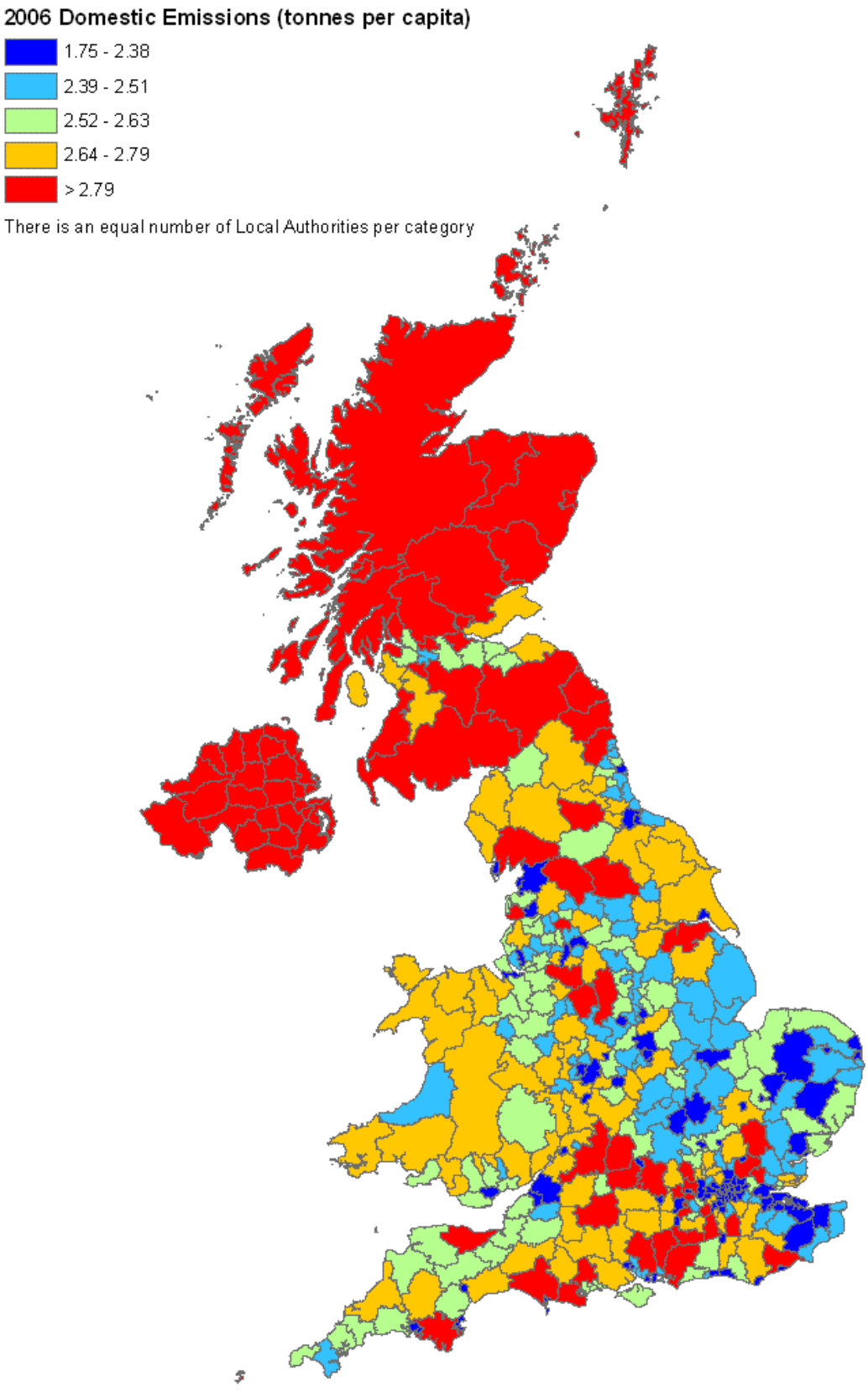


Figure 7 Industrial and commercial per capita CO_2 emissions by Local Authority for 2006

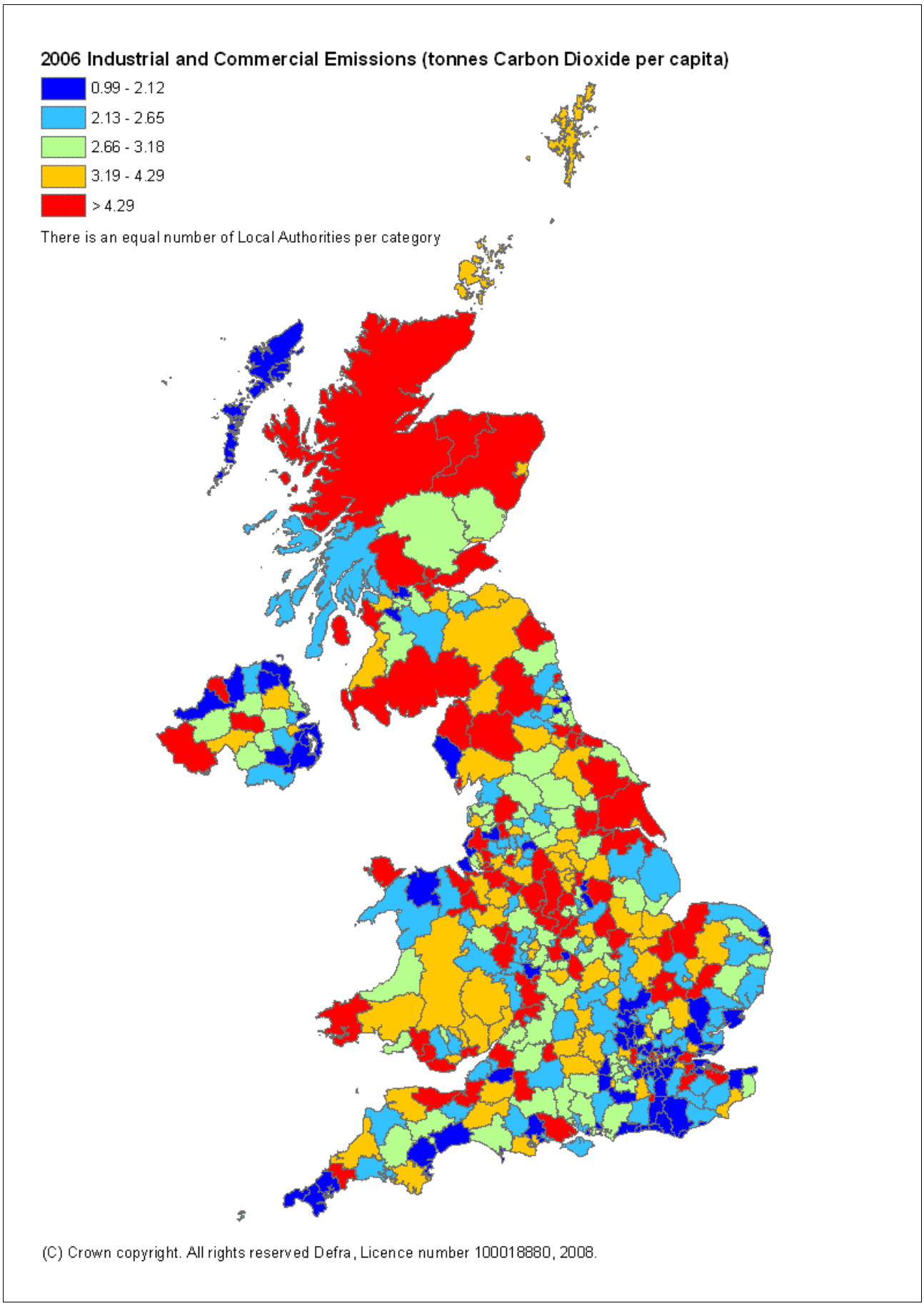


Figure 8 Road Transport CO_2 emissions per capita by Local Authority for 2006

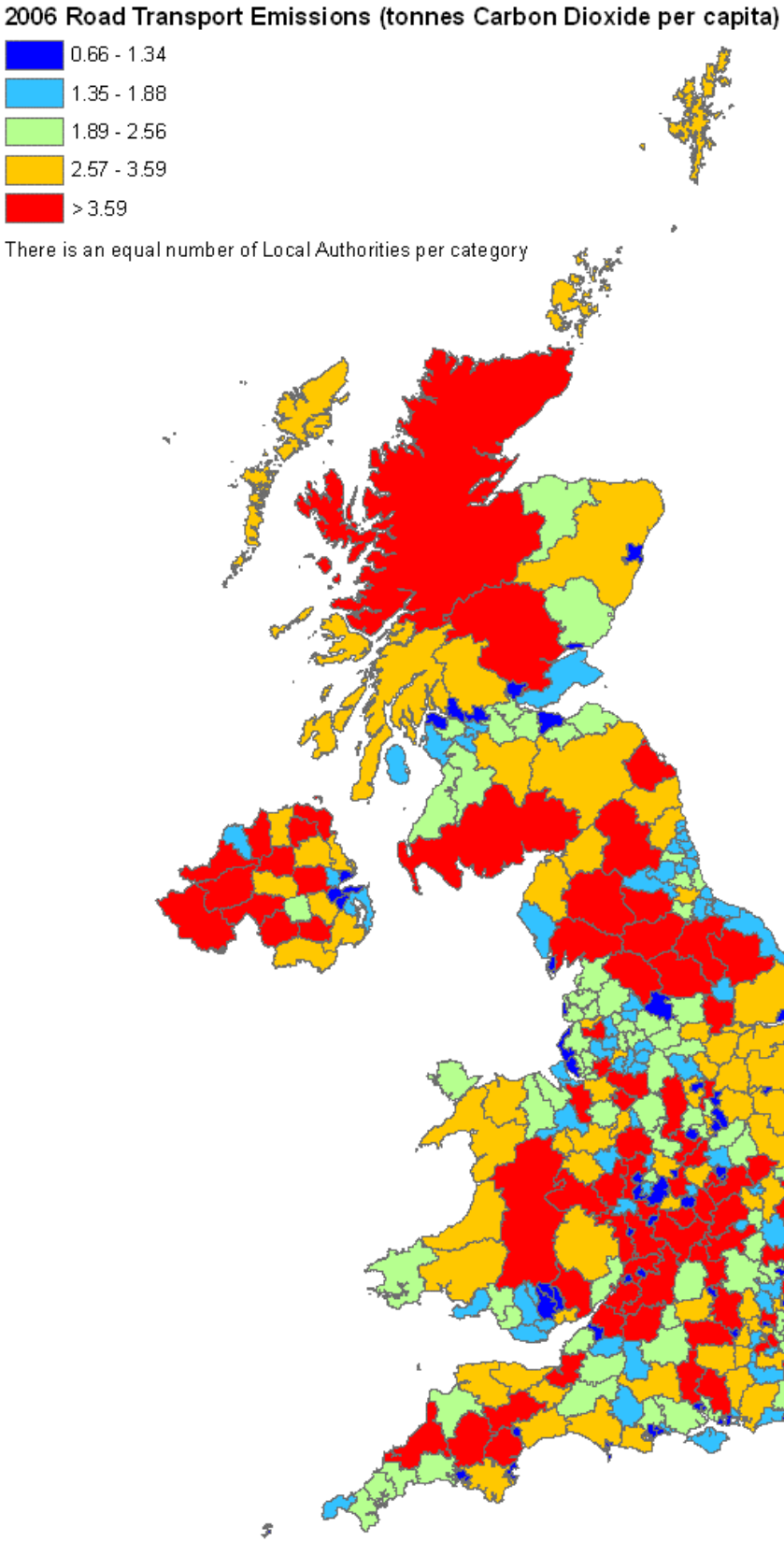


Figure 9 Land use change CO_2 emissions per capita by Local Authority for 2006

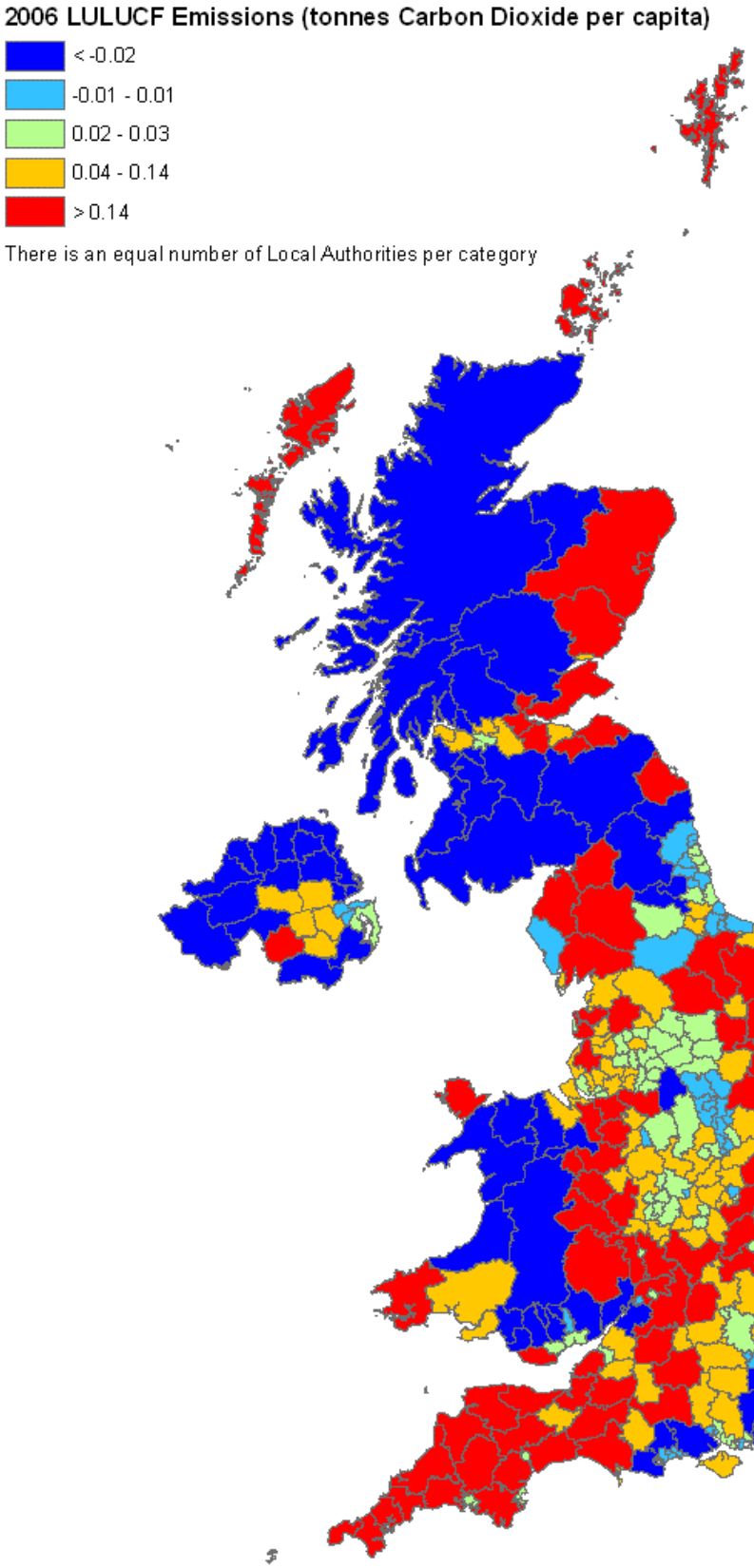
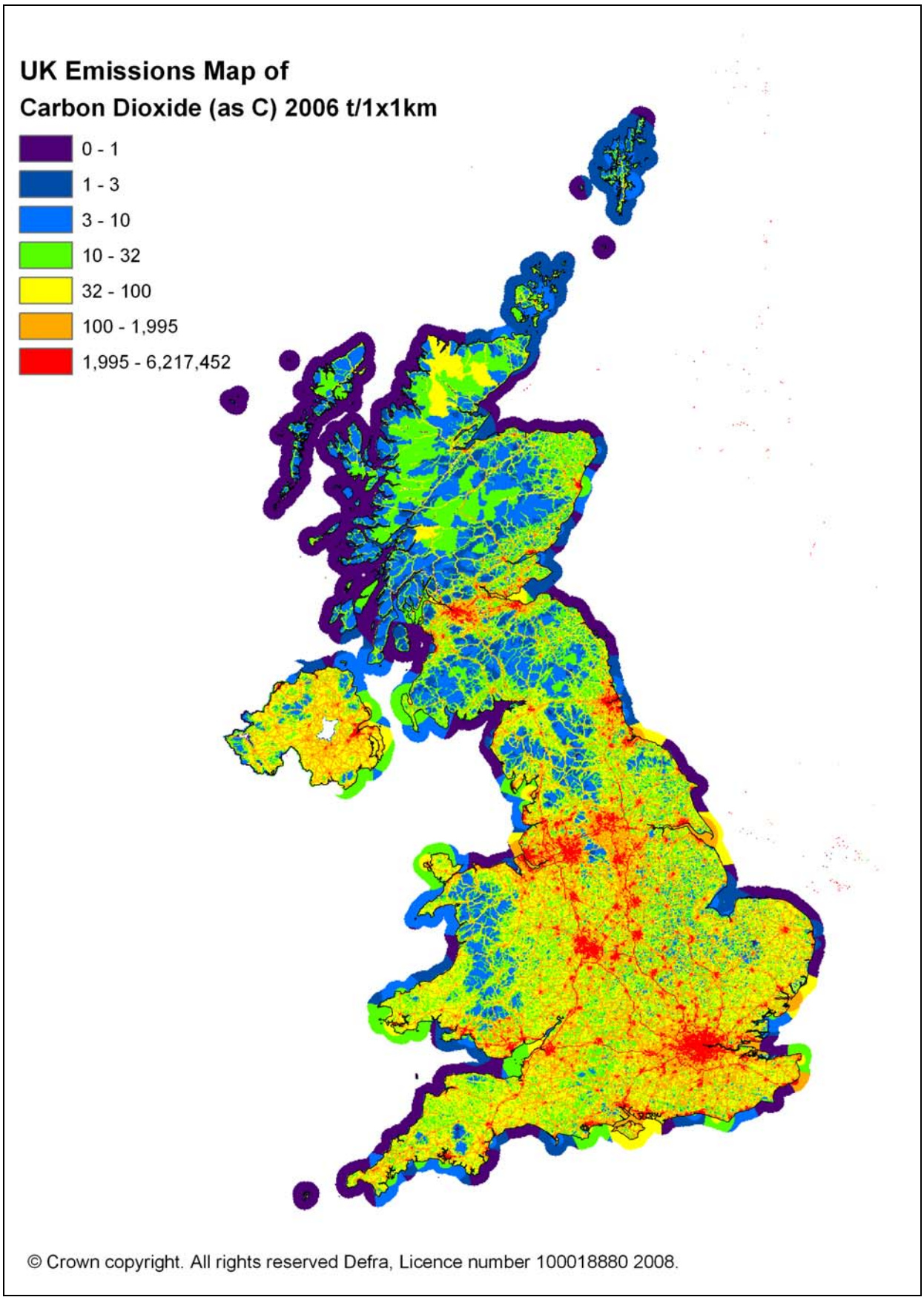


Figure 10 1km resolution emissions map of CO_2 for 2006[14]



[14] Land use and Land Use Change emissions are not included in this map because 1km resolution data are not available for this sector

5 Data Quality and Reconciliation

5.1 UNCERTAINTY ANALYSIS

The existence of uncertainty is not a serious problem provided that it can be described, and its effect on the outcome of the analysis quantified. This section describes how uncertainty has been analysed in this dataset.

Overall uncertainties in the emission estimates for each local authority have been assessed by combining three variables. Two of these three variables are sets of uncertainty estimates:

- Errors in national emissions: estimates of the percentage error margin of the national total sector emissions;
- Errors in the spatial distribution of emissions: an assessment of the uncertainty in the way that the emissions are distributed between LAs; and,
- The proportion that each sector contributes to emissions in each Local Authority.

Overall uncertainties in the 2006 emissions have been estimated using the sum of the squares method for propagating errors through calculations. This method used the input data on estimates of component uncertainties as described in the following sections.

Errors in the national sectoral GHG emissions

Estimates of the errors (uncertainty) on the national total GHG emissions, according to IPCC sector[15], are calculated in the UK's greenhouse gas inventory. This error analysis is published in the UK's National Inventory Report, which is updated annually, most recently published for the 2006 inventory (Choudrie *et al.*, 2008).

The error analysis in the national inventory is calculated using a Monte Carlo simulation, based on assigning probability distribution functions (PDFs) to each emission factor and piece of activity data. Errors in the UK GHG inventory are expressed as $2s/E$, where E is the central (best) estimate of the emission and s is one standard deviation of the mean.

The emission sectors used for the local CO_2 estimates do not match the sectors reported in the National Inventory Report. Therefore the percentage error values have been combined, via calculation of a weighted average (weighted by emission in each subsector and by fuel), in order to give national emission percentage error for each of the sectors. These percentage errors are shown in **Table 16**.

Estimated errors in the geographical distributions

The uncertainties in the geographical distributions of emissions for each sector are very difficult to quantify. Experts familiar with the mapping methods, the emissions inventory and emissions by sector have estimated distribution uncertainties using expert judgement assigned to the emission sector when the 2006 local CO_2 estimates were compiled. With the exception of the BERR data on gas and electricity no quantitative estimates of uncertainty for the individual components exist. Therefore numerical uncertainties have been estimated using 'Expert Judgment' through a process of 'Expert Elicitation' as described in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006b). **Table 16** provides notes on each sector to help to explain the reasons for the uncertainty scores chosen.

The estimates for the domestic and industrial gas and electricity emissions have been obtained from BERR. They are based on the amount of the consumption that was located correctly based on allocating meter locations to Local Authorities.

Other industrial emissions data (large gas users, wastes and biomass and non-fuel emissions) are considered to have fairly low uncertainty as many of these sources are at known locations.

Higher uncertainties have been estimated for sources where the locations of emissions are not well known. The road transport emissions are a significant source with a higher uncertainty than the other biggest

[15] The Intergovernmental Panel on Climate Change (IPCC) has devised a reporting nomenclature for greenhouse gases where the gases are reported in six major categories.

sources (electricity and gas use). The main reason for this is the use of sample data to represent both vehicle movements and emission factors. Average daily flows and average speeds are used on major road links which does not take account of fluctuations in flows and speeds through the day or year. Regionally average flows and speeds are assumed on minor roads because there is not sufficient data to model this more accurately. However, the best available national datasets are used.

Average fleet weighted emission factors are used, derived by the NAEI road transport team based on detailed data on emissions tests and the mix of ages of vehicle types in the fleet. No regional variation in fleet ages is included in the modelling. This could be possible using DVLA data on car registrations but assumptions would be needed regarding the amount influence on local emissions from separately defined local and national average fleet mixes because many cars are used at locations away from their place of registration (particularly company cars, vans and HGVs). Introducing a regional variation in the sizes of engines in the fleet and the petrol / diesel split rather than age would have more influence on the results, partly because newer cars have to meet increasingly tighter standards for air quality pollutants but not CO2. However, previous sensitivity analysis has found that variations in fleet composition have little effect on the overall results (Goodwin et al, 2005b).

High uncertainty values are assigned to some sectors. In particular the combustion of coal and liquid fuels in small industry/commercial/public service and to a lesser extent in the domestic sector. This is because there is very limited knowledge of the distributions of coal and liquid fuel use. This work does not take into account localised renewable consumption or energy efficiency through the use of CHP and does not attempt to correct or fill gaps in the BERR electricity use or gas use datasets.

The estimates of emissions for minor roads also have relatively high uncertainty. There are too few measurements of traffic movements on minor road links to allow detailed modelling to be undertaken therefore regional traffic flows are used.

Table 16 also shows the percentage of UK total emissions in each sector. This is presented here to show the relative importance of each sector but these numbers are not used in the uncertainty analysis. The uncertainty analysis uses actual amounts of emissions in each LA rather than a UK average.

Combining the uncertainty estimates using Sum of Squares Method

The three variables set out at the start of this section have been combined as follows. The percentage emission error in each LA total CO_2 estimate is calculated using the Sum of the squares method using the equation below.

$$Percentage\ Error\ for\ each\ LA = \frac{\sqrt{\sum_{sectors} e^2 \left(i_1^{\,2} + i_2^{\,2} \right)}}{\sum_{sectors} e}$$

where: e is the local emission in the LA for a given sector;
i_1 is the UK emission uncertainty error for that sector;
i_2 is the mapping emission uncertainty error for that sector.

Table 16 Summary of information used in uncertainty analysis and comments on data quality

Sector	Percentage of 2006 emissions %	National emission error %	Geographical Estimated % error	Comment
Industrial, Commercial and Agriculture Electricity	22%	1.40%	1.2%	The BERR dataset of electricity consumption has some unallocated consumption. Based on 98.8% of postcodes being located correctly
Industrial, Commercial and Agriculture Gas	8%	1.47%	0.007%	BERR geographical allocation for gas is very good. However the BERR definition of domestic gas consumers includes some small commercial users. But there is no numerical estimate of this uncertainty
Industrial Gas (Large Users)	0.6%	1.47%	5%	Good location information for point sources but still some emissions modelled
Industrial and Commercial Oil	3%	7.03%	30% (points 5%)	Area emissions for all of these sectors are modelled using employment and fuel intensity factors. There will be spatial variations in energy intensity that is not taken into account. Good location information for point sources but still some emissions modelled
Industrial and Commercial Solid Fuel	0.7%	1.54%	30% (points 5%)	
Industrial and Commercial Wastes And Biomass	0.1%	18.50%	30% (points 5%)	
Industry Process Gases	0.1%	5.89%	30% (points 5%)	
Industry Non Fuel	0.3%	4.37%	30% (points 5%)	
Industry ETS installations (all fuel types)	9%	1%	1%	Estimated % error. Grid references for sites provided by operators. Emissions reported and verified though ETS but some variation in quality of monitoring of emissions.
Industry Off-Road Machinery	2%	1.91%	30%	This sector is poorly characterised because little is known about the spatial distributions of these machines.
Agriculture Oil	0.5%	1.86%	30%	Modelled estimates using fuel and employment distributions for stationary combustion; landuse data used to distribute machinery emissions.
Agriculture Solid Fuel	0.8%	1.00%	10%	Modelled estimates using fuel and employment distributions. Emissions are only for stationary sources so uncertainty is lower than for oil, which includes mobile sources
Agriculture Non Fuel	0.002%	19.41%	30%	Land use maps are used to distribute the application of pesticides.
Railways	0.01%	1.69%	30%	Emissions are distributed using an old dataset of rail movements for GB and more recent data for NI.
Domestic Electricity	12%	1.40%	0.1%	The BERR dataset of electricity consumption has some unallocated consumption. Based on 99.9% of postcodes being located correctly
Domestic Gas	14%	1.47%	0.002%	BERR geographical allocation for gas is very good. However the BERR definition of domestic gas consumers includes some small commercial users. But there is no numerical estimate of this uncertainty
Domestic Oil	2%	2.84%	10%	Estimates made using complex modelling of household energy demand compared with known gas usage
Domestic Solid Fuel	1%	8.78%	10%	Estimates made using complex modelling of household energy demand compared with known gas usage
Domestic Home And Garden Machinery	0.1%	4.69%	10%	Emissions mapped on population distribution but distribution of garden machinery is not correlated with population density because of smaller garden sizes etc in densly populated areas
Domestic Household Products	0.3%	19.47%	10%	Emissions mapped on population distribution which is reasonably well correlated with use of household products
Road Transport Petrol (A roads & motorways)	8%	4.93%	5%	Activity data are good quality annual average traffic count points. Emissions calculated using complex modelling of fleet mix and average speeds on different roads.
Road Transport Diesel (A roads & motorways)	4%	2.29%	5%	
Road Transport Petrol (Minor roads)	10%	4.93%	10%	Activity data are calculated from regional average traffic flows and vehicle splits. Emissions calculated using complex modelling of fleet mix and average speeds on different roads.
Road Transport Diesel (Minor roads)	4%	2.29%	10%	
Road Transport Other	0.1%	9.45%	30%	Locations of LPG use and burning of engine oil are not known and are therefore distributed across all road traffic activity.

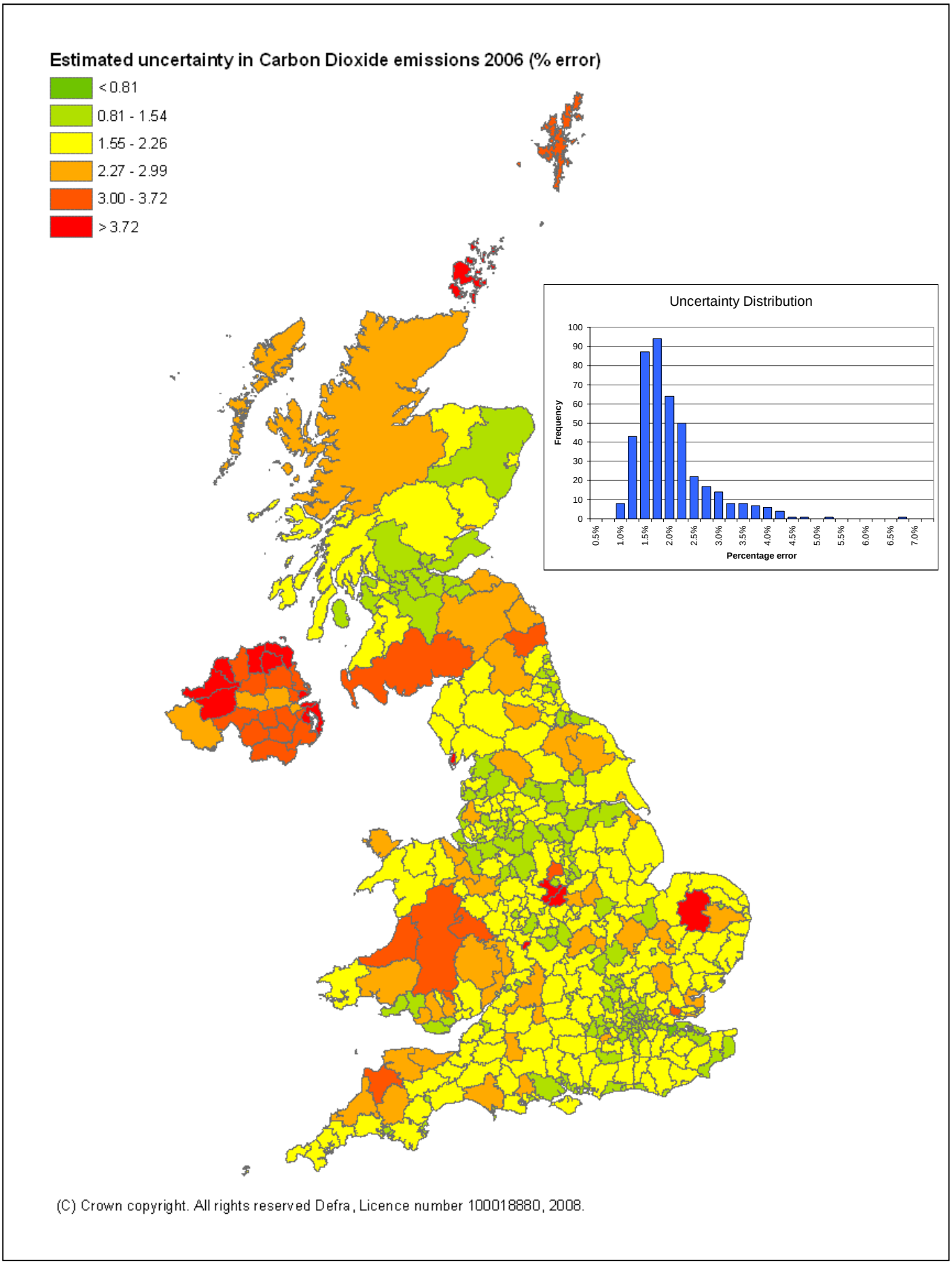
Results of the uncertainty analysis

Figure 11 shows how the errors calculated from the sum of the squares method vary across England. The percentage error is 2.5 or lower for most LAs. The limited spread around the mean may seem surprising given the size of some of the uncertainties in **Table 16**, particularly for mapping uncertainties. Two factors are relevant: the smallest uncertainties tend to be for the largest emissions, and uncertainties within individual sectors cancel against uncertainties in other sectors within each local authority area to a significant extent. The latter may have important consequences for setting abatement levels by sector within each local authority without further analysis at a more local level.

The emissions are dominated by the electricity and gas use in domestic, industrial and commercial sectors for which the UK estimates and the mapping distributions have low percentage errors. Higher overall percentage errors occur where the dominance of gas supply is lower so there are more emissions from solid and liquid fuels in the domestic and business/industry sectors, such as in Mid Wales, Devon and Cornwall and Northumberland.

In % terms the smallest estimated spread for any local authority is for Gravesham in the South East (±0.8%) which has large emissions from a number of ETS installations, whilst the largest spread is for the Derry in Northern Ireland (±6.5%) because of the lack of gas supply and high dependence on oil and a large industrial contribution.

Figure 11 Estimated errors in the CO_2 emissions 2006 (not including LULUCF emissions)



5.2 RECONCILIATION

This section provides a comparison between the emissions reported for the national inventory aggregated to the Local CO_2 sectors (**Table 17**, which is derived from the numbers in **Table 2**) and the results presented in this report (**Table 18**). These tables show good consistency for the sector totals. Key differences are listed below.

Table 17 UK Inventory End User Totals aggregated to Local CO_2 sectors (kT CO_2 2006)

	Fuel					
Sector	**Solid**	**Gas**	**Oil**	**Electricity**	**Non fuel**	**Total**
Industrial and Commercial	27,785	57,981	25,314	116,194	11,329	238,603
Agriculture	12	Included in I&C	4,305	Included in I&C	49	4,366
Railways		Included in I&C	2,474	Included in I&C		2,474
Domestic	2,386	68,547	10,767	65,309	1,981	148,991
Road Transport			134,837		170	135,007
LULUCF Emissions					-1,953	-1,953
Total (equivalent to Local CO_2 dataset)	**30,183**	**126,529**	**177,696**	**181,503**	**11,577**	**527,488**
Exclusions						
Domestic Shipping						*6,134*
Domestic Aviation						*2,626*
Military Transport (Air & Water)						*3,080*
Exports						*10,095*
International aviation and shipping						*5,128*
Grand Total						**554,552**

Table 18 Emissions Presented in Local CO_2 dataset (kT CO_2 2006)

	Fuel					
Sector	**Solid**	**Gas**	**Oil**	**Electricity**	**Non fuel**	**Total**
Industrial and Commercial	14,653	54,142	27,287	115,419	26,736	238,237
Agriculture	12		4,315		39	4,366
Railways			2,474			2,474
Domestic	2,915	72,387	10,682	66,084	1,538	153,605
Road Transport			135,007			135,007
LULUCF Emissions					-1,953	-1,953
Total emissions distributed across LAs	**17,579**	**126,529**	**179,765**	**181,503**	**26,359**	**531,736**

(a) The Local CO_2 dataset classifies Blast Furnace and Coke oven gas as process gases and these are included in the Non fuel column whereas for the UK total they are included in the Solid fuel column.
(b) Additional road traffic emissions are included in the Local CO_2 dataset, representing imported fuel used on UK roads.

The key differences between these two dataset are as follows:

- The fuel specific totals for the Industrial and Commercial sector show a big difference for solid fuels and non-fuel emissions. This is because of a difference in definition of blast furnace gas and coke oven gas between these two datasets. These gases are aggregated into the solid fuel column for the national total end user dataset because they are derived from coke. However for the Local CO_2 dataset they have been classified as process gases and hence aggregated into the non-fuel column. The total emission from these gases was 15,494kt CO_2 in 2006.

- The emissions from gas and electricity show slightly different splits between domestic and industry and commercial. These are due to the differences in total consumptions for these sectors between the Local fuel consumption data and those published in DUKES.

- The other differences in the domestic line are due to differences in classification of fuels between these two datasets: petroleum coke (85 kt CO_2) is classed as an oil in the national end user dataset and peat (443 kt CO_2) is classed as non fuel. Both of these fuels are classed as solid fuel in this local CO_2 dataset.

- The 11kt CO_2 discrepancy in the line for agriculture (between Oil and Non fuel emissions) is due to a difference in classification of engine lubricant emissions. This is classified as non fuel in the National End User reporting and as an oil based emissions for the Local CO_2 dataset.

- The remaining differences in the industrial and commercial sector amount to 4,248 kt CO_2 in 2006 (1.8%) across solid fuel, oil and non-fuel emission. These differences are the only actual differences in total emissions between these two datasets as opposed to differences in aggregation and exclusions. They are due to the differences between the estimates of emissions at large point sources and those in the national totals. A detailed explanation for these differences is provided in the supporting document **Point Source Fuel Use Estimates**.

There are some key changes to the 2005 dataset compared with the 2005 dataset published in 2007. These are as follows:

- The split between domestic and industrial and commercial electricity and gas is now fully consistent with the fuel consumption at LA level provided by BERR. A constant CO_2 emission factor for each fuel has been applied across each dataset rather than constraining the domestic emissions to match the UK GHGI totals.

- More large gas users have been identified because of new data available from BERR.

- MSW incineration is now not included because this is part of Energy Supply and therefore emissions are distributed by electricity consumption.

- Some changes have been made to the point source emissions in order to achieve, as far as possible, a consistent timeseries.

- Road transport emissions fuel consumption factors have been updated resulting in lower emissions from this sector (see **section 3.11**).

6 Planned improvements to the dataset

The emissions inventory programme has a key objective of continuous improvement in response to changing data requirements, data availability and new research. This therefore applies as much to the mapping of emissions as to the compilation of the National totals. At the start of each NAEI annual cycle a horizon scanning report will be written. This will consider the latest developments in data and policy needs for the emission maps as a whole and from this a detailed set of recommendations for continuous improvements will be made to Defra. This will inform the focus of the updating and development of the emission maps during that year.

There are some key areas identified for improvements in relation to the CO_2 maps for 2007. The main area is road transport and the planned improvements are detailed below. Furthermore, a review and update of the 'other fuels' (i.e. non-gas and non-electricity) domestic emissions modelling will be undertaken during the 2008 inventory year. This will be required because the current maps will be out of date by that time.

6.1 ROAD TRANSPORT

A peer review of the NAEI method for road transport emissions mapping was undertaken in 2008. The output of this review included the following planned improvements which draw on developments in DfT and the London Atmospheric Emissions Inventory.

Review of speeds data

The data on average speeds by road type used in the NAEI/GHGI and the mapping will be reviewed in the light of the assumptions used in the DfT National Transport Model / Forge and the assumptions used in the London Atmospheric Emissions Inventory (LAEI). The assumptions on speeds have a significant impact on fuel consumption but are equally important for the air quality pollutants. We would like to be able to apply the DfT speeds data at the finest geographical resolution available and in as consistent a way as possible with the National Transport Model. To this end we would like to have access to detailed maps and/or assumptions about the allocation of individual roads to the various road types and Area types within the NTM/FORGE model.

Vehicle fleet

Data and methods relating to vehicle fleet composition will also be reviewed. In particular a recent review of differences between the NAEI and the LAEI has highlighted the need to include further detail on the buses and taxis in London.

The LAEI contains information specific to the London taxi fleet (Mittal et al, 2007), which assumes the fleet mix shown in **Table 19** compared to the fleet mix assumed in the NAEI for all diesel cars.

Table 19 Comparison of LAEI Taxi fleet composition and NAEI diesel cars (2004)

Euro Class	NAEI Diesel Cars	LAEI Taxis
Pre-Euro 1	3.7%	12.01%
Euro 1	21.1%	43.82%
Euro 2	22.6%	25.76%
Euro 3	52.5%	18.42%

In addition, within the LAEI, the proportion of passenger vehicles (cars) classified as taxis (and therefore constrained to the fleet mix above) is variable across London; the LAEI taxi fleet mix varies across the congestion-charging zone, central, inner or outer London. There are no assumptions on fleet mix for taxis in the NAEI, where the taxi fleet is assumed to conform to the diesel passenger car fleet at a national level. The LAEI's assumptions relating to taxi fleet are expected to result in a higher percentage mix of diesel/petrol vehicles in the fleet than would otherwise occur in the NAEI.

In addition, the LAEI also includes detailed information on the London bus fleet. **Table 20** presents the fleet mix for London buses applied within the LAEI.

Table 20 LAEI bus fleet composition

Class	No. of vehicles	Proportion by class
Hydrogen Fuel Cell	2	0.03%
Euro 3 + Trap + SCR	11	0.13%
Euro 3 + Trap	4034	48%
Euro 2 + Trap + SCR	8	0.09%
Euro 2 + Trap	2974	36%
Euro 2 + CAT	83	1%
Euro 2	537	6%
Euro 1	107	1%
Pre Euro	608	7%

At a national level the 2004 NAEI assumes the fleet mix for buses shown in **Table 21**. Aggregating the LAEI bus fleet to comparable Euro definitions within the NAEI for comparative purposes indicates a lower proportion of low Euro class buses in the LAEI.

Table 21 Comparison of Bus fleet in NAEI and LAEI

Euro Class	NAEI Buses	LAEI Buses
Pre-Euro 1	13%	7%
Euro 1	11%	1%
Euro 2	41%	43%
Euro 3 or higher	35%	48%

These observations illustrate the assumptions of cleaner, more fuel-efficient fleets within the LAEI for these vehicle classes. Their adoption within the NAEI in future compilation rounds may provide benefits and should investigated as a practicable development option.

Use of LAEI-specific fleet data for buses will only affect the inventory for the air quality pollutants in London; the effect on fuel consumption and CO2 emissions will be minimal as the Euro classes do not significantly affect fuel consumption and CO2 emissions.

As well as using more London-specific fleet data for taxis and buses in London, it is also planned to use more specific fleet information for Northern Ireland where the mix of diesel cars in the fleet is higher than in Great Britain.

Minor roads

The current data used for mapping fuel use and emissions on minor roads was generated for the 2003 inventory. The geographical distribution of fuel consumption and emissions is not currently updated each year. It is planned that we will produce new maps of minor road fuel consumption and emissions of key air pollutants for the 2007 inventory year. These will be produced using the best available data from DfT on traffic flows, speeds and estimated vehicle kilometres at the finest geographical resolution that is available. We will recalculate the fuel and emissions distributions in a similar way to that done previously (see section 2) using Ordnance Survey data on road types and locations together with average flows and speeds for a variety of road types. Actual measured flows can be applied to the roads for which measurements are available. Checks will be undertaken to compare total modelled vkm by Local Authority with the DfT statistics. These LA level statistics are available from DfT but are not published because of uncertainties in the data, which need to be taken into account in the use of the data.

As part of this new mapping we will also take account of the more detailed data that are available from the LAEI on minor roads. However there are some inconsistencies in the methods used between the NAEI and LAEI that need to be better understood before we can progress this. The recent review of the LAEI and NAEI undertaken by AEA included the following paragraphs.

The length of non-major road network (non-motorway and non-A roads) for the London area characterised in the NAEI's minor road grids is estimated at 13,378 km. A comparable dataset within the LAEI has not been identified, although the length of non-major road links in the LAEI's detailed link-by-link dataset is estimated at 2,573 km. Comparing these two minor road datasets indicates a discrepancy of approximately 10,000 km of road length. We have assumed that this discrepancy, at least in part, relates very small minor roads not characterised in the LAEI's detailed road link datasets. However, it is not clear from the LAEI datasets whether or how these road types are characterised in the LAEI and, therefore, it is not possible to provide a reality check on the assumed minor road lengths in the NAEI. Maintenance of consistency in the NAEI and LAEI minor roads length datasets is recommended as a practicable development option for the NAEI.

The LAEI cites the bvkm on all non-major roads (LTS and minor roads in the LAEI datasets) as 12.6 bvkm. Within the NAEI, the conceptually comparable dataset is cited as having a total of 21.1 bvkm, clearly substantially higher estimate of vehicle kilometres.

Minor road traffic flow data are not available on a link-by-link basis within the NAEI. Instead regional average flow data by vehicle type from DfT are applied to each minor road type (B-roads and C-roads and unclassified roads) and a grid of road network lengths (derived from OS Meridian data product) (Bush et al 2007). This approach is necessary at a national level to simplify the mapping approach for minor roads whilst achieving adequate characterisation of the minor road flows and vehicle kilometres. It is recognised, however, that at a local level, this approach results in an over simplification of traffic conditions.

The poor correlation in minor road vehicle kilometres presented above, clearly raise questions on whether this metric is adequately characterised for the London area in the NAEI. The LAEI's bottom-up estimates are expected to provide both a higher level of accuracy and greater relevance to the London area and it is recommended, therefore, that these data be evaluated for inclusion in future compilations of the NAEI to better characterise minor road flow rates and network lengths where practicable.

Fuel consumption factors

Each year the components of the NAEI national estimates of emissions (fuel consumption factors etc) will be reviewed to consider what changes in methods might effect the current or previous years in the time series. Changes to previous years estimates will be made where appropriate to ensure a consistent timeseries.

The GHGI/NAEI programme is continuously looking to update and improve methodology and emission and fuel consumption factors as more information becomes available. The issue of fuel consumption and the contributions made by different vehicle types on different road types is also of great interest to transport modellers and policy makers in DfT and AEA are currently in discussion with them and TRL on many of the issues covered in this briefing note.

TRL have for the past two years been undertaking a review of road transport emission factors and modelling methodologies on behalf of DfT and they are due to report on this shortly. The DfT intend to put the TRL reports with conclusions and recommendations for a period of consultation after which any necessary changes to the GHGI/NAEI methods will be agreed with Defra and DfT and then adopted. This means that it is possible that the next version of the inventory (2007) will again show changes from the current 2006 version.

Geographical distribution of traffic flows

The major roads vkm, fuel and emissions maps are updated each year with new traffic flow data available for all existing count points. Some new count points are also added each year. These are always incorporated into the current year maps to provide year on year changes in traffic flows and hence emissions as far as the data allows.

This year on year update has not previously been undertaken for the minor road mapping. However if data of sufficient quality are available from DfT to allow temporal change in minor road traffic flows to be estimated then this will be done.

Further more significant minor road improvements are planned following the results of the current new survey of minor road traffic flows. There are currently 4,500 minor road count points and the same points are surveyed each year. The 1999 benchmark survey provides data on the pattern of traffic across the country by LA and these are adjusted each year using national growth factors based on the survey. The new benchmark survey is underway in 2008/9. This involves an additional 12,000 sample sites during 2008 and

2009, resulting in a total of 16,000 sites initially. This will then be split into a rolling panel so that around 5000 are surveyed annually. This will provide regional growth factors and better Local authority estimates of total traffic on minor roads.

The first growth factors data based on the expanded survey will be available during summer 2011. However DfT will have a complete 'baseline' of minor road traffic for the 2009 survey in summer 2010. We therefore plan to use these data when compiling maps for the 2009 inventory at the end of 2010.

DfT are considering whether the sample frame for 'major' roads should be based on A and B roads and how this might be achievable. Work on this should happen later in 2008. If DfT make a change, that will occur during the 2010 data year, i.e. results delivered in 2011.

Consistent Geography for Major road traffic flows

The DfT road traffic statistics team currently use a very simplified ITN (Integrated Transport Network) layer of OS MasterMap to map road links. DfT have allocated the census points to the ITN layer and hope to create and maintain a consistent dataset based on the ITN updates from OS. It is also hoped the DfT allocation will be updated to link it to a less generalised ITN within the next year. This will make it more consistent with the level of detail required by the NAEI mapping.

DfT will also be reviewing other sources of data on traffic flows – Highways Agency, Welsh Assembly surveys.

Quality Ratings

DfT are planning to consider quality ratings for the data that they produce using the detailed census data. This is a requirement of a recent quality review at DfT. Regional quality ratings are planned but LA level ratings may be possible. These could be included in the uncertainty analysis for the Local CO_2 estimates.

7 Conclusions

- This data set is published for the first time as National Statistics. It is a key resource for Local Authorities to use in establishing the evidence base and setting a baseline for action on climate change mitigation.

- The results show a wide variation in per capita emissions across the UK ranging in 2006 from –4.0 tonnes in Argyll and Bute in Scotland (where LULUCF removals outweigh all emissions) up to 172.7 tonnes in the City of London. However both of these examples are outliers in this dataset. The lowest emission per capita is 3.9 tonnes in Highland in Scotland and the next highest per capita emission is 68.6 tonnes in North Lincolnshire, Yorkshire and the Humber. The average per capita emission is 8.8 tonnes. Variations are caused mainly by differing amounts of industrial and commercial activity.

- The analysis of uncertainties presented in this report shows a range of uncertainty of ±0.8% to ±6.5%. The highest uncertainty tends to be in to be rural areas that are dependent on non-gas fuels and that have a higher percentage of minor road traffic.

- Data quality continues to improve as a result of further development of mapping methods. The modelling of small industrial emissions has been updated for the 2006 dataset, with these improvements also applied for the updated 2005 estimates. Further improvements will be made over the coming years, with road transport the particular focus for the 2007 inventory year.

- The dataset of 1km resolution CO_2 emissions has also been mentioned in this report. This dataset has been developed over a number of years from the UK Greenhouse Gas Inventory by AEA. For the first time this year the 1km dataset is presented as emissions by end user, consistent as far as possible with the LA level data. This further level of geographical detail can be used to provide Local Authorities with more detail to better target emissions reduction activities.

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