Local and Regional Carbon Dioxide Emissions Estimates for 2005-2010 for the UK

Technical Report







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Executive summary

The local and regional carbon dioxide (CO_2) emissions estimates for 2005-2010 are produced in order to provide a nationally consistent evidence base for use in tracking carbon reduction policy. These estimates can be used by local authorities (LAs) and other relevant organisations as an important body of information to help identify high emitting sources of CO_2 and energy intensive sectors, to monitor changes in CO_2 emissions over time, and to help design carbon reduction strategies.

This report, prepared by AEA on behalf of the Department of Energy and Climate Change (DECC), sets out how the local and regional CO_2 emissions estimates for 2005-2010 were compiled. The full dataset – which is classified as a National Statistic – and statistical summary can be found on the DECC website[1].

The dataset provides a spatial disaggregation of CO_2 emissions from the UK Greenhouse Gas Inventory (GHGI), part of the National Atmospheric Emissions Inventory (NAEI), on an end user basis. This means that emissions from the production and processing of fuels, including the production of electricity, are reallocated to users of these fuels to reflect total emissions for each type of fuel consumed. The disaggregation methodology is complex, and different approaches are used to make best use of the quantity and quality of suitable data that are available for each sector.

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

- DECC sub-national gas and electricity consumption statistics[2];
- Point source emissions from large industrial installations;
- High resolution emissions distribution maps developed under the NAEI programme; and,
- Land use, land use change and forestry (LULUCF) regional data supplied by the Centre of Ecology and Hydrology (CEH).

National end user emissions data are used to calculate emission factors for each activity. Local authority activity data are then multiplied by the relevant emission factor to generate an estimate of emissions in each LA. This dataset and the GHG inventory as a whole are subject to continuous improvement in order to increase confidence in the estimates. Efforts are concentrated each year on topics identified in both inventory and emissions mapping improvement plans with the aims of improving accuracy and reducing uncertainties.

The main improvements made this year are:

- Emissions from Northern Ireland (NI) electricity use: DECC subnational electricity consumption statistics have been used to distribute the CO_2 emissions from the use of electricity. In previous years, NI household numbers were used to distribute emissions in the domestic sector and ONS employment figures for the non-domestic sector. More information is given on this new methodology in **Section 2.2**.
- Mapping distribution grids for industrial and commercial use of solid and liquid fuels: the maps have been updated making use of the latest Energy Consumption UK data; Display Energy Certificate data; and employment distributions from the Inter-Departmental Business Register (IDBR). More information is given on this new methodology in **Section 5**.

[1] http://www.decc.gov.uk/en/content/cms/statistics/climate_stats/gg_emissions/laco2/laco2.aspx
[2] http://www.decc.gov.uk/en/content/cms/statistics/energy_stats/regional/regional.aspx

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1 Introduction

1.1 Purpose of the work

The dataset provides a spatial disaggregation of the CO_2 from the UK Greenhouse Gas Inventory (GHGI), part of the National Atmospheric Emissions Inventory (NAEI), on an end user basis. The CO_2 emissions are estimated, by sector, for each local authority in the UK. The data help identify the key sources of CO_2 emissions in each area; allows changes in CO_2 emissions over time to be monitored and can help mitigation actions to be targeted.

1.2 Methodology

This is the technical report for the Local and Regional CO_2 Emissions Estimates for 2005 - 2010 for the UK. It provides a detailed technical description of the methodology.

The dataset is provided in detail in a spreadsheet that accompanies this report (230812 Local CO2 NS release - 2005-10 data.xls). A summary of results and two further methodology documents also accompany this dataset on the DECC website[3]:

- **Statistical summary.** This document provides a commentary on trends and patterns shown in the data.
- **Employment based energy consumption mapping in the UK.** The method statement was updated this year and gives a detailed description of the improvement work to update the modelling of small industrial, commercial and public admin emissions for the 2010 inventory.
- **Mapping Carbon Emissions and Removals for the Land Use, Land Use Change and Forestry Sector.** A detailed description of the methods used to compile the Local estimates of Land Use, Land Use Change and Forestry emissions.

The following chapters explain the technical approaches used to generate estimates of CO_2 emissions according to energy use in each sector.

1.3 The UK Greenhouse Gas Inventory

The UK official Greenhouse Gas inventory (GHGI) is compiled annually by AEA on behalf of DECC as part of the NAEI programme. The GHGI is compiled and reported using international best practice 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 the European Monitoring Mechanism (EUMM) and is used to assess compliance with the targets set nationally and internationally such as in the Kyoto Protocol.

A consistent method and common base of activity data is used across the NAEI programme. This provides internally consistent inventories and emissions projections of greenhouse gases and air quality pollutants.

1.4 End User basis for reporting emissions

Carbon dioxide 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 format in

[3] http://www.decc.gov.uk/en/content/cms/statistics/climate_stats/gg_emissions/laco2/laco2.aspx

which emissions from the production and processing of fuels (including the production electricity) are reallocated to consumers of these fuels to reflect the total emissions relating to that fuel use. This difference in reporting mainly affects emissions related to electricity generation from power stations and refineries. This is in contrast to the 'at source' emission reporting in which emissions are attributed to the sector that emits them directly. End user GHG emissions at UK level are reported by DECC as National Statistics; however these emissions will be slightly higher than those shown in the local authority breakdown as they include emissions from Crown Dependencies and some other excluded sources which are deemed not to belong to a particular LA.

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 and used in other areas. The method used follows, as closely as possible, that used for the end user emissions calculated as part of the GHGI and reported by DECC and Defra at the national level[4].

Sectors where emissions occur can be divided into three categories in the NAEI:

- Energy Producers (the production and processing of fuels including electricity);
- Energy Users (such as residential, industrial and road transport); and
- Others (which emit CO_2 but where the emissions are 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 2010 split into these three types of sectors.

The end user model reallocates emissions from energy supply industries to each energy user sector in the inventory in proportion to the amount of energy used by each. 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 an iterative approach to emissions estimation from the end users which terminates when all fuel producers have no more fuel to reallocate 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.

For more information on end user emissions calculations, please see the National Inventory Report[5].

[4] The estimates presented in this report are not directly comparable with the National and Devolved Administration 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 requirements of international inventory compilation (IPCC 2006a) specifies that national datasets of fuel consumption (i.e. the DECC Digest of UK Energy Statistics, DUKES) must be used. The EU ETS data for 2005-10 are not fully consistent with DUKES but were used during the compilation process of allocating consumption to particular industrial consuming sectors.

[5] http://uk-air.defra.gov.uk/reports/cat07/1204251150_ukghgi-90-10_Annexes_issue2_print_v1.pdf

Table 1 UK Total Primary Emissions of CO_2 (kt CO_2 2010)

Sector	Anthracite & Coal	Coke	Solid Smokeless Fuel	Natural Gas	Oil	Electricity	Non Fuel	Total
Energy Supply								
Coke production		786					572	1,357
Collieries - combustion	12						160	172
Gas Leakage							7	7
Gas production				4,987	587		575	6,149
Oil Production				9,440	1,468		3,806	14,713
Iron and steel - flaring		1,434					91	1,525
Power stations	91,301			64,870	2,086		1,712	159,970
Refineries - combustion				1,033	15,342			16,375
Solid smokeless fuel production	128							128
Energy Consumption								
Industry: Iron & Steel	152	11,314		1,264	365		1,247	14,342
Industry: Other Combustion	4,731			25,355	8,672		1,006	39,764
Industry: Other Processes	1,595	165		1,740	6,439		5,329	15,267
Commercial	25			9,640	291		31	9,987
Agriculture	3			363	3,698		47	4,111
Miscellaneous							275	275
Rail Transport	50			3	1,947			2,000
Domestic	1,867	32	882	71,746	10,040		1,621	86,188
Public	354			7,892	193			8,439
Road Transport					110,660		138	110,798
Land Use Change							-4,409	-4,409
Water Transport: National Navigation					*2,278*		*78*	*2,356*
Air Transport					*2,008*			*2,008*
Military Transport (Air & Water)					*2,938*			*2,938*
Exports								*0*
International aviation and shipping								*0*
Total	100,217	13,731	882	198,333	169,012	0	12,287	494,462

Table 2 UK Total end user emissions of CO_2 (kt CO_2 2010)

Sector	Anthracite & Coal	Coke	Solid Smokeless Fuel	Natural Gas	Oil	Electricity	Non Fuel	Total
Energy Supply								
Energy Consumption								
Industry: Iron & Steel	167	13,953		1,312	459	1,377	1,247	18,514
Industry: Other Combustion	4,757			26,319	10,266	46,275	1,006	88,623
Industry: Other Processes	1,603	196		1,826	7,214	-	5,329	16,168
Commercial	25			10,007	325	38,707	31	49,094
Agriculture	3			376	4,141	2,027	47	6,595
Miscellaneous							275	275
Rail Transport	50			3	2,181	1,953		4,187
Domestic	1,877	38	1,002	74,472	11,293	59,712	1,621	150,015
Public	355			8,192	216	8,616		17,379
Road Transport					124,377		138	124,515
Land Use Change							-4,409	-4,409
Water Transport: National Navigation					2,551		78	2,630
Air Transport					1,785			1,785
Military Transport (Air & Water)					3,298			3,298
Exports		287	13		8,213	2,255		10,768
International aviation and shipping					5,023			5,023
Total	8,838	14,474	1,016	122,506	181,343	160,921	5,363	494,462

Legend and Notes:

Energy producers	Energy Users	Others (CO_2 emissions not related to fuel use)

Sectors: *Excluded from Local CO_2 estimates in italics;*

2 Industrial and Commercial Electricity

2.1 Allocating Emissions to Electricity Consumption

Electricity consumption data for 2005-2010 at Local Authority level for England, Wales and Scotland are published on the DECC website[6]. More limited data are also available for Northern Ireland (see **Section 2.2**). These datasets have been used to map CO_2 emissions from electricity generation to the point of consumption. The emissions associated with electricity consumption have been estimated using an average UK emission 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 2010 (MacCarthy *et al*, 2012). The factors used are shown in **Table 3**.

Annualised electricity consumption data was compiled at meter point using Meter Point Administration Number (MPAN) level data. This data product is compiled by agents of the electricity suppliers, who collate/aggregate electricity consumption levels for each MPAN. The locations of these meters were determined from the Gemserve database supplied by ECOES (Electricity Central Online Enquiry Service). Where the address information is not available in the Gemserve database the Royal Mail Postcode Address File (PAF) is used to obtain a full address and postcode and reduce unallocated consumption. Using this approach 98.5 per cent of total consumption within Great Britain during 2010 is accurately allocated to a Local Authority (LA) area (DECC, 2012).

Each meter is allocated a profile class, which enables consumption of domestic customers (profiles 1 and 2) to be identified from the consumption of industrial and commercial customers (profiles 3 to 8). However as part of the data validation process all profile 1 and 2 customers with a recorded consumption greater than 100,000 kWh, and those with a consumption greater than 50,000 kWh with address information indicating non-domestic use were reclassified as industrial and commercial customers (DECC, 2012).

The end user CO_2 emission for electricity consumption from the NAEI (as shown in **Table 3**) was distributed across the LAs in proportion to the consumption data for both domestic and industrial and commercial users.

Table 3 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	174,414	334,561	0.521
2006	183,120	332,495	0.551
2007	179,761	325,464	0.552
2008	176,358	319,082	0.553
2009	154,269	308,414	0.500
2010	158,667	310,601	0.511

There has been a continuous drop year on year in electricity consumption and the associated emissions, with a large drop between 2008 and 2009 associated with the economic recession. In 2010, electricity consumption and emissions are slightly higher than in 2009. This is due to the coldest December on record, and the stabilisation of the economic downturn may also have contributed.

[6] http://www.decc.gov.uk/en/content/cms/statistics/regional/electricity/electricity.aspx

In previous years, 2005-2008, there has been an increase in the average electricity emission factor due to an increase in the proportion of electricity produced using coal. But a record low in coal use in 2009 resulted in a reduction in this average emission factor. An increase in coal consumption and a decrease in nuclear power (due to technical problems at some stations) have led to an increase in the average emission factor of 2% between 2009 and 2010. Supply from gas also increased during this period (DECC, 2011b).

2.2 Electricity consumption in Northern Ireland

Following the creation of a single electricity market in Ireland, consumers can now choose their electricity supplier and confidentiality restrictions have been reduced. Figures for domestic electricity consumption in 2008-2009 and non-domestic electricity consumption in 2009-2010 at District Council level in Northern Ireland are now available on the DECC website[7]. Therefore this year the methodology has been improved to allocate CO_2 emissions from industrial and commercial electricity consumption in Northern Ireland using the the new sub-national NI non-domestic electricity statistics. These statistics are produced by DECC using aggregated meter point data derived from NIE's Distribution Use of System (DUoS) Billing system. The data are based on billed units and relate to final consumption at the point it was derived. These data therefore exclude autogeneration that does not pass through the public distribution network.

In previous years, emissions were modelled using total employment by LA from the Inter-Departmental Business Register (IDBR) database. The new methodology has been applied to the whole time series, so that in all earlier years the distribution of emissions is in proportion to the electricity consumption in 2009. This change has been responsible for large changes to emissions estimates in some LAs in NI compared to last year's version.

Data on total electricity sales as reported by NI suppliers has been provided to AEA through personal communication with DECC. The total electricity consumption in Northern Ireland for 2010 was 8,140 GWh, including 3,212 GWh for the domestic sector and 4,928 GWh for the industrial and commercial sector. There is some statistical difference between the total electricity sales provided in personal communication by DECC and the published meter point data, this remains unallocated.

2.3 Unallocated electricity

Where electricity sales within the DECC dataset have not been successfully allocated to specific LAs, they have been assigned to an additional 'unallocated' category. The DECC data also includes 4,500 GWh in 2010 of electricity as direct sales to high voltage lines that cannot be allocated to any region or LA due to the lack of information. Emissions associated with this electricity consumption are included in the final dataset as an unallocated item. The statistical difference between total electricity sales provided by DECC for Northern Ireland and the published meter point data is also included in the unallocated category.

This takes the overall percentage of electricity consumption unallocated to LAs, either because of geo-referencing problems, statistical differences or because it is direct sales, to 4.6% in the industrial and commercial sector and 0.4% in the domestic sector.

2.4 Traded electricity

Both Scotland and Wales are net exporters of electricity, with England importing electricity from both countries and from continental Europe. Northern Ireland trades electricity with the Republic of Ireland to which it is a net exporter. It also imports electricity from Scotland via the Moyle interconnector - these imports were greater than exports to the Irish Republic in

[7] http://www.decc.gov.uk/media/viewfile.ashx?filetype=4&filepath=11/stats/energy/sub-national-energy/5036-subnat-electricity-cons-stats-2010.xls&minwidth=true

the last four years. In 2009, Scotland exported 23.6 per cent of the electricity generated there to consumers elsewhere in the UK, but this fell to 20.8per cent in 2010. Transfers from Scotland to England between these two years fell by more than the decrease in Scottish generation over this period. Wales exported the equivalent of 23.7 per cent of its generation to consumers in England in 2009, falling to 22.3per cent in 2010 (DECC, 2011a).

3 Industrial and Commercial Gas Consumption

3.1 Allocating Emissions to Gas Consumption

The gas consumption data published by DECC provide estimates of gas consumption by the domestic sector and the industrial and commercial sector for each LA in Great Britain for 2005-2010; these are published on the DECC website[8]. These statistics are based on data obtained from xoserve[9] and groups of independent gas transporters. These data have been mapped to LA areas very accurately, using geographical information from the National Statistics Postcode Directory (NSPD).

Using this approach 99 per cent of total consumption within Great Britain during 2010 is accurately allocated to a Local Authority (LA) area. This year, DECC have made improvements to the address matching for Scotland particularly for industrial and commercial users (DECC, 2011a) which has resulted in some LAs having increased total gas consumption and will be associated with similar increases in CO_2 emissions.

The Annual Quantities (AQ) gas consumption data supplied to DECC from xoserve used in the sub-national analysis covers the gas year – the period covering 1 October through to the following 30 September.

The AQ data is an estimate of annualised consumption between two meter readings at least 6 months apart, with the closing reading taken within the period 1 October 2009 to 30 September 2010. However, not all AQs are recalculated each year, mainly because gas shippers have not provided any new meter readings. A weather correction factor is applied (except to sites that have automatic meter reading) so that AQ data are adjusted to normal weather conditions. Unfortunately, the data available to DECC via xoserve and the independent gas transporters does not enable the weather correction factor to be removed from the annual quantities, or for estimates on a calendar or financial year basis to be produced (DECC, 2011a).

For these reasons, the AQ cannot be exactly aligned to gas consumption data in DUKES, which are based on a calendar year and are not weather corrected, or to the sub-national electricity data which are partly calendar year and partly 31 January 2010 to 30 January 2011 (DECC, 2011a).

DECC uses the gas industry standard cut-off point of 73,200 kWh to identify small and medium business consumers. This incorrectly allocates many small businesses to the domestic sector and, conversely, a small number of larger domestic consumers to the non-domestic sector. It also means that meters can change sectors from year to year.

To ensure non-disclosure agreements are maintained, some suppression of data for the largest gas consumers has taken place. This relates to the industrial and commercial consumption data and comprises approximately 40 power stations and 70 large industrial users. However the LA areas in which these users are located are known, as is the total gas usage by the large (excluded) users. Energy use and 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

[8] http://www.decc.gov.uk/en/content/cms/statistics/energy_stats/regional/gas/gas.aspx
[9] 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.

Trading Scheme reports to regulators. This database and the method used to obtain estimates of emissions and fuel use at point sources is described in **Section 4**. These data are included in the Large Industrial Installations sector – Sector C, along with point source emissions from other fuels.

Data from the Environment Agency database of reported emissions in the EU Emissions Trading Scheme (EU ETS) has been used to estimate fuel use from 2005 to 2010. 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. The differences are described in **Section 4**.

The comparison between the DECC estimated gas consumption for the excluded sites and gas consumption as estimated by AEA from the NAEI points source database is shown below in **Table 4**. The difference between these figures is due mainly to two reasons. Firstly, different scopes apply for different reporting requirements; emission reporting in some instances only requires reporting for a particular furnace rather than an entire site, it is not clear whether exclusions from the sub-national dataset are for whole sites or single meters. Secondly, the company names used in the point source database and those supplied by xoserve are not always consistent and it is therefore not possible to match them all with absolute certainty.

The total industrial and commercial emissions from end user gas consumption in this Local Authority dataset is consistent with those in the UK national inventory, no emissions are excluded from the dataset total as a result of the differences described above. This means that the difference between the AEA and DECC estimated gas consumption from large point sources (25% in 2010) is spread across the DECC Local Authority gas consumption data, effectively increasing the implied emission factor (IEF) for gas use by a small amount (IEFs shown in **Table 6**).

Table 4 Comparison of DECC excluded gas consumption and AEA calculated gas consumption at large point sources

Gas consumption excluded from sub-national dataset (GWh)	2005	2006	2007	2008	2009	2010
DECC estimated excluded gas	110,327	88,519	100,686	100,460	99,735	94,996
AEA estimated excluded gas	72,665	76,688	78,791	77,755	71,181	70,969
Percentage difference	-34%	-13%	-22%	-23%	-29%	-25%

3.2 Gas consumption in Northern Ireland

Data for Northern Ireland has been added to the DECC dataset using information on total Northern Ireland gas consumption from energy providers Phoenix and Firmus energy.

3.3 Calculating CO_2 Emissions

In order to calculate the total amount of CO_2 emission represented by the DECC 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 from the national total end user emissions. This calculation is shown in **Table 5** where the national sectors using gas are listed at the top, with a total emission associated with this consumption of 48,034 kt CO_2 in 2010. Emissions associated with the large gas users not including power stations (9,931 kt CO_2 in 2010) are taken off 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. The result of the calculation is a national total gas emission consistent with the DECC sub-national gas consumption dataset. This is used to calculate an implied CO_2 emission factor for gas to apply to the disaggregated gas data at LA level. The implied emission factors are shown in **Table 6**.

Table 5 Calculation of CO_2 emission equivalent to DECC LA gas consumption (kt CO_2)

GHGI End User Emissions by Sector		2005	2006	2007	2008	2009	2010
Industry and commercial (not including power stations)		59,306	55,215	52,309	52,930	44,924	46,623
Agriculture	+	438	387	384	413	356	376
Processes [(1)]	+	1,363	1,017	1,414	1,182	901	1,035
Total Local CO_2 Industry and Commercial gas use emission	=	61,106	56,619	54,107	54,525	46,181	48,034
Large users (not including power stations) excluded from this dataset	-	11,333	10,648	11,115	11,118	9,781	9,931
Domestic consumption	+	73,887	70,531	67,816	68,783	63,694	74,472
Total emission to distribute using the DECC sub-national gas data		123,660	116,502	110,808	112,190	100,094	112,576

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

Table 6 Gas CO_2 emission factors used in this analysis

Year	Total UK Emission for Gas (to distribute using DECC gas data) (kt CO_2)	Total Consumption (GWh)	Total consumption in DUKES for comparison (GWh)	Gas CO_2 Factor (kt CO_2 per GWh)
2005	123,660	663,626	665,789	0.187
2006	116,502	631,890	633,462	0.184
2007	110,808	617,325	603,902	0.179
2008	112,190	590,360	618,499	0.190
2009	100,094	542,994	554,001	0.184
2010	112,576	545,409	622,703	0.206

It is important to note that the compilation of the DECC sub-national gas consumption dataset uses a 17 year average weather correction, which takes account of the warmer weather in more recent years. This is done in order to observe long-term energy consumption trends without being affected by particularly warm or cold years. The total UK CO_2 emissions from gas consumption in the Local CO_2 dataset are consistent with those from the national inventory which is based on the Digest of UK Energy Statistics (DUKES)[10] which is not weather corrected. The national emissions from gas consumption are allocated to LAs based on the DECC sub-national gas consumption data which are weather corrected. This results in a partial weather correction whereby the impact of changes in the weather are still evident in the time series for an individual Local Authority but the magnitude of change is reduced.

The magnitude of the weather correction is particularly evident for 2010 in **Table 6** above, the implied emission factor is much higher because it was an extremely cold year and more

[10] http://www.decc.gov.uk/en/content/cms/statistics/publications/dukes/dukes.aspx

gas was used, as shown in the DUKES column. The DECC subnational gas consumption dataset is weather corrected.

4 Large Industrial Installations

4.1 Data sources and summary of methods

Emissions from large industrial installations are mapped using the NAEI database of point sources. For this End User dataset an additional calculation is made in order to account for the CO_2 emitted during the processing of fuels used in industrial installations. For more information on End User inventories see **Section 1.4**.

The site specific estimates of emissions have been compiled from a number of detailed data sources that report fuel consumption and/or emissions:

- Information on fuels burnt during 2005-2010 which is held in the Environment Agency (EA), Scottish Environment Protection Agency (SEPA), and the Department of the Environment in Northern Ireland (DoE (NI)) databases of installations that are in the EU Emissions Trading Scheme (ETS).
- Information on emissions of CO_2 from combustion processes during 2005-2010 which have been reported by operators regulated under IPPC to the EA for inclusion in the Pollution Inventory (PI), to SEPA for inclusion in the Scottish Pollutant Release Inventory (SPRI) and to DoE (NI) for inclusion in their Inventory of Sources and Releases (ISR). These are hereafter described as the IPPC data sets.

Some additional data, supplied by trade associations or individual process operators have been used to inform the development of the point source fuel use estimates, and in the case of steelworks, these data are used directly in the generation of point source data.

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; and
- Other sites for which EU ETS annual emissions data are available.

In order to produce a consistent dataset for all sectors and years to be used in this and other emissions mapping work, the following key methods are used for calculating and checking point source emission estimates:

- Direct use of EU ETS fuel consumption data
    - Fuel consumption data is checked against inventory classifications and DUKES fuel consumption data. There can be differences in terms of scope of reporting.

[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 1.4**

    - Emissions from EU ETS point sources make up approximately 7% of all point source emissions in the Local CO_2 dataset for 2010. This percentage would be much higher in energy supply sectors.
- Estimates based on fuel consumed by processes outside the scope of ETS (IPPC data)
    - Relationships between these installations and those that report the EU ETS need to be established in order to prevent double counting. This also helps to gain information on sources of emissions at installations and the types of fuels used where this is not published.
    - Emissions from these point sources make up approximately 93% of all points source emissions in the Local CO_2 dataset for 2010.
- Gap filling and modelled estimates where data are not available
    - In the above sources of data, there are often gaps. These can be due to installations falling below reporting thresholds for certain years or because of the changing scope of reporting requirements. A judgement needs to be made about whether these gaps are realistic or if emissions need to be estimated to fill the gap.

More information is given on the above key methods in **Section 4.2** below.

As mentioned previously, the data presented in this report are not fully consistent with the UK Greenhouse Gas Inventory (including the Devolved Administration GHGI)[12] because of the use of emissions data reported by operators and also the EU ETS dataset, both of which are independent of the DECC national statistics on fuel use which are used for the UK and Devolved Administration GHGI. However, analyses carried out as part of the GHGI programme of work indicate that the EUETS and other operators' data are broadly in line with DECC energy statistics, and it is estimated that the use of operators' data leads to a difference in estimated carbon emissions of less than 1% of the UK national total. The advantage of using more detailed, installation-specific, data from operators is that this ensures the use of the best possible information on the fuels used at each industrial and commercial site, even if the total fuel use across the UK is marginally different from that reported in DUKES. Details of where the differences are most significant are given in **Section 4.4**.

The emissions in the NAEI point source database are calculated as 'at source' emissions rather than by end user. Therefore, where appropriate (only for fuel combustion emissions) an end user increment, representing CO_2 emissions arising from fuel production (e.g. refineries), is also allocated to that end user.

For the purposes of reporting emissions by fuel type a simplified classification of fuel types has been used. This is shown in **Table 7**.

Table 7 Fuel categories for reporting emissions

Fuel Name	Fuel Category
Natural gas	Natural gas
Burning oil	Oils
DERV	Oils
Fuel oil	Oils
Gas oil	Oils
LPG	Oils

[12] Reconciliation tables can be found here: http://www.decc.gov.uk/en/content/cms/statistics/climate_stats/gg_emissions/laco2/laco2.aspx

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

The point source data cover the period 2005-2010. There is a programme of continuous improvement and revisions have been made to the point source data for 2005-2009 in a few instances where additional data have become available, or where other changes (such as changes to the methodology of the UK GHGI) have an impact on the point source data. Most point source data, however, will be unchanged from the values used in the previous version of the local and regional estimates of CO_2.

4.2 Detailed estimation methods

The derivation of estimates from the above data sources is described in the following sections. There are a number of sectors which are problematic, and a short section outlining these issues then follows.

4.2.1 Fuel use for EU ETS processes

The EA have provided access to data for installations in England and Wales which reported fuel consumption and CO_2 emissions in 2005-2010 under the EU ETS. Equivalent data was also received from DoE (NI), and from SEPA (Scotland).

The type and quantity of fuels burnt by EU ETS processes are included in the data provided by the regulatory authorities and these fuels have all been assigned to one of the standard fuel types used in the NAEI (e.g. coal, fuel oil, gas oil). Each process has also been allocated to one of the industrial sector classifications used in the NAEI – these are, in turn, based on the classification used in DUKES.

4.2.2 Estimating fuel use for non-EU ETS processes

A large number of combustion processes are not currently covered by the EU ETS in the UK, for example many driers and furnaces are currently outside the scope of the scheme. In these cases, data may be available from other sources including the Integrated Pollution

Prevention and Control (IPPC) data sets (the PI in England and Wales, the SPRI in Scotland and the ISR in Northern Ireland), and so these are compared with the EU ETS data in order to identify additional emissions present in the IPPC data. Care has had to be taken to correctly match up those installations reporting under IPPC that also report in the EU ETS data sets, in order that the comparison is accurate. The EU ETS data provided by the EA includes some information on the relationship between the processes covered by EU ETS applications and processes reporting to the PI, but in most cases it has been necessary to use expert judgement in order to define the connections between EU ETS and IPPC installations. This is not always straightforward in that the two data sets quite often have different operator names, site names, or site addresses for installations that appear to refer to the same site, and there are also instances where a single IPPC installation relates to multiple EU ETS installations, and *vice versa.* It has taken time to unpick the two sets of data and to understand the relationships between the installations in the EU ETS data, and those in the IPPC data sets, and this has led to revisions to the point source data over the previous few years. Although there are still areas of uncertainty in this 'mapping' of EU ETS sites to IPPC sites, we believe that it is now largely finalised for existing EU ETS installations and that there should be less need for revision of data in future due to changes in assumptions in this area.

Once the relationship between installations in the two data sets has been established, it is a simple task to compare the reported emissions and to check which installations report additional emissions in the IPPC data, or which only report emissions in the IPPC data. These additional emissions in the IPPC data are added to the point source database. There are also instances where installations report lower emissions in the IPPC data, but these do not need to be considered further and can be ignored.

The additional IPPC data are initially just emissions from an unknown source, and so the next step is to assign those emissions to an emission source category. These additional emissions result from the fact that the scope of reporting is often different in EU ETS and the IPPC data, and that the scope of IPPC is wider. Most importantly, the UK currently uses the medium definition of combustion installations which covers the production of electricity, heat or steam for the purposes of energy production. This means that, for example, most furnaces used to produce chemicals or melt metals are not currently covered by EU ETS in the UK, although this will change with the start of Phase III of the scheme in 2013. The IPPC data for some installations can combine the emissions from combustion processes that are covered by EU ETS with emissions from processes that are not, for example a chemical industry site could have steam-raising boilers (covered by both EU ETS and IPPC data), and product driers (covered only by IPPC). The IPPC data sets can also include carbon from biological fuels such as wood, as well as carbon from non-combustion processes such as chemical syntheses and fermentation.

Finally there is also the possibility that the additional emissions in the IPPC dataset are due to the use of different assumptions, provisional data or due to errors. Therefore, as well as identifying the relationship between EU ETS and IPPC installations, it is also necessary to have an understanding of the reasons the scope of emissions is different, and particularly whether additional carbon emissions from the IPPC installation is related to non-ETS combustion using fossil fuels, use of biofuels, some non-combustion process, or is anomalous. This is done using expert judgement, supported by some in-depth research for some of the most significant sites in order to determine the exact scope of both EU ETS and IPPC installations, although limited access to documentation of the scope of EU ETS and IPPC permits, and the resource-intensive nature of the investigations needed, mean that our understanding of the relationship between the two data sets is still developing. This aspect of the points data processing is expected to improve still further in future years, although we believe that far fewer revisions will need to be made in the next few years compared with previous versions of the data.

Once expert judgements have been made about the nature of the additional emissions in the IPPC data sets, these emissions are assigned to fuels or other GHGI emission source categories where appropriate, or removed from the point source data if considered likely to be either biocarbon or anomalous.

4.2.3 Gap-filling and modelled estimates

All of the data sets have, or seem to have gaps in reporting; they are not fully complete. In the case of EU ETS, the scope of the scheme has changed over time and various installations were able to 'opt-out' in Phase I. A voluntary *de minimis* limit was introduced in 2008 which allowed operators to exclude individual combustion units that were < 3 MW th from their rated thermal input calculation such that many installations no longer exceeded the 20 MW th limit requiring their inclusion in the scheme. The IPPC data sets do not require reporting of emissions below set 'reporting thresholds' so some installations where carbon emissions are close to that threshold value, report emissions in some years where the threshold is exceeded, and report no emission value in years when it is not. If left unchanged, these gaps and data inconsistencies could lead to unreliable emissions time-series data for individual installations and for local authority areas and so expert judgement is used to assess the time-series and to fill gaps where appropriate, usually by extrapolation of data from other years. We take account of the fact that some apparent gaps in data will actually be due to plant closures or mothballing of plants, or plants not being in existence in a few cases where there are gaps at the start of the time-series. It is likely that we are not aware of all details of plant commissioning and plant closures, so some revisions might be necessary in this part of the processing in future years.

A final aspect of the point source data is the inclusion of a limited set of data where emissions are modelled rather than based on operators' data. This is necessary for some processes operated under IPPC which emit relatively small quantities of carbon dioxide and therefore almost invariably do not need to report emissions, for example various small electric arc steelworks, and chemical waste incinerators. It is also done for certain types of process that are not included in the IPPC data sets at all, such as small glassworks. Finally, it is done in instances where IPPC data cannot easily be used, examples in this instance being MSW incinerators where emissions reported in the IPPC data could be dominated by carbon dioxide from waste containing biological carbon, but would also include carbon dioxide from fossil fuels burnt to support the incineration process.

4.2.4 Estimating fuel use for steelworks

The development of estimates for integrated steelworks is dealt with separately here since it presents unique challenges. The estimates utilise a range of data sources:

- DUKES provides detailed fuel use data for the iron and steel sector;
- The PI provides emission estimates for CO_2 for each integrated works but no fuel data. The estimates are site totals only: no breakdown by process is given;
- EU ETS data provides fuel use data but does not break it down fully by process type;
- Tata Steel Ltd (the operator of the processes) provides CO_2 emission estimates by process type but not by fuel type.

Unfortunately, none of these sources of data give a fully detailed picture of fuel use and related emissions by process. In addition, the data sources are not completely consistent for all years (in large part because the scope of the data sets is different) and so judgements need to be made about how to combine the various data in order to generate fuel use estimates. Overall, the data from Tata Steel is the most complete set of emissions data across the time series, while the EU ETS dataset is considered the most accurate in terms of fuel use. Therefore, the fuel use patterns shown in the EU ETS data are used to disaggregate the emissions data provided by Tata Steel. The Tata Steel data did include emissions from some additional installations such as reheat furnaces during Phase I of EU

ETS and, so the emissions from these furnaces are assigned to fuels based on expert judgement.

4.3 Areas of uncertainty in the fuel use estimates

There are a number of issues which produce uncertainty in the local authority CO_2 emission estimates and related fuel use estimates:

- Emission and fuel use estimates for processes which report to the PI/SPRI/ISR (under IPPC regulations) but not to EU ETS are based on AEA assumptions about fuels used because IPPC does not require reporting of fuel split. These assumptions are based on an evaluation of data such as:
    - Integrated Pollution Control (IPC) authorisation documents which are quite old now but do give an accurate picture of processes in the early to mid 1990s;
    - IPPC authorisation documentation which are much more up to date but only available for a smaller number of processes;
    - recent emissions data for pollutants such as metals and SO_2 that could indicate the use of solid or liquid fuels;
    - our general knowledge of a particular process and typical fuels used for that type of process;
    - geographical location e.g. processes in very rural areas, Northern Ireland etc. are somewhat less likely to burn gas; and
    - any information on processes available from other sources such as DUKES or the internet.

The uncertainty can be broken down into two issues. Firstly, and perhaps most serious, is the significant level of uncertainty for a relatively small number of sites over the exact nature of the emission sources. This type of uncertainty is obviously greatest for processes within certain sectors where emissions could result from numerous sources such as use of biofuels and wastes in combustion processes as well as fossil fuels and non-combustion processes. These sectors would include the chemical, food & drink, and paper industries.

The second issue is uncertainty over the fuels burnt at installations where it is assumed that fuel combustion is taking place. For many sectors of industry, there is a relatively straightforward choice of fuel – natural gas, or less usually oil (usually fuel oil if large-scale but gas oil is often used on a small-scale or as a backup fuel) or coal. As already stated, reported emissions of SO_2 or metals can indicate coal or fuel oil use, so normally, in the absence of emissions data for these pollutants, our assumption has been that gas is the most likely fuel used. In Northern Ireland and some rural areas, gas use is less likely and fuel oil, for example more likely. For many sites, the expert judgements used to allocate emissions to fuels to introduce uncertainty but we believe that in most cases the uncertainty is low.

For some sectors, the choice of fuel is more difficult and indeed a range of fuels may be burnt on many sites. Metal industry sites may use coke, and chemical industry sites may burn chemical by-products as well as conventional fossil fuels.

As well as these general areas of uncertainty, some specific issues should be noted:

- Fuel use estimates for cement works prior to 2008 are uncertain because most sites opted out of EU ETS. So while national fuel use data are believed to be very accurate (being supplied by the industry itself), very little information is available at the level of individual sites. CO_2 is emitted both from fuel combustion but also from the calcination of the limestone and dolomite used to make the cement clinker. Prior to 2006, emissions data from the PI/SPRI/ISR did not indicate how much CO_2 was 'thermal' in nature and how much was 'chemical' and so cannot be used to give an accurate estimate of fuel use by site. The system of separate reporting of chemical and thermal CO_2 for each site for 2006-2008 eased this problem, allowing an accurate split of fuel-related and calcination-related emissions for the opted-out sites for 2006 and 2007,but this gave no indication of the actual fuels burnt at each site. Reporting of data in the EU ETS increased in 2008 to cover all sites due to the end of opt-outs and so in theory these fuel use data could be used to estimate the fuel mix at each plant in earlier years. However, the national data show that there have been some significant changes in fuel use over the last 5 years and this is supported by EU ETS data for those plants didn't opt out. The national mix of fuels was previously used for each of the opted out sites. However, this caused inconsistencies in the time-series. An improvement this year was to reconcile the national fuel use data for 2005-2007 and the 2008 ETS data more fully. This is expected to need further adjustments as any additional information becomes available but will immediate improve the consistency of time-series data for many sites.

- Fuel use estimates for lime works are somewhat less uncertain because these typically burn a single fuel (in most cases gas). However, a handful of sites do burn a varying mixture of solid and liquid fuels and, as for cement works carbon dioxide is emitted both from fuel combustion but also from the calcination of the limestone used to make the lime. This brings with it similar problems to those associated to cement works. The system of separate reporting of chemical and thermal CO_2 for each site during 2006-2008 eased this problem and the EU ETS data for 2008 has been used to improve the estimates for solid and liquid fuels. One further problem at some sites is that emissions reported in the PI also include other sources of CO_2, such as gas-fired CHP plant, and driers. However, in these cases, cross-comparison with EU ETS data for 2008 can give an indication of the proportion of emissions from the lime kilns (using solid fuels) compared with other plant (using gas and liquid fuels).

- Integrated steelworks use fuels in many processes and these uses include fuel transformations and combustion processes. The absence of a single, complete set of data for steelworks, means that fuel use estimates are based on combining data sets which are not fully consistent. Discussions with Tata Steel have helped us to better understand the differences between different data sets.

- A number of other processes produce CO_2 both from the combustion of fuels and from chemical transformations. Examples include primary aluminium production; electric arc steel-making; chemical processes such as production of ammonia, soda ash & titanium dioxide; and glass-making. Emissions data given in the PI/SPRI/ISR will include both 'thermal' and 'chemical' CO_2 for each site, but these are only reported separately in the PI and then only for some sites for the period 2006-2008, with the separate reporting being dropped again in 2009. Use of PI/SPRI/ISR data therefore requires assumptions to be made about the split between fuel-related and non-fuel related emissions.

- A number of processes reporting in the PI/SPRI/ISR only may use process-wastes as fuels, and this may not be taken account of in the fuel use estimates. Generally, unless we have good evidence to the contrary, it is assumed that all reported CO_2 emissions are from fossil fuels but, in the chemical and food industries in particular, it is quite possible that some of the emission is from process wastes.

The overall impact of these issues cannot be easily quantified, but we believe that good progress towards resolving most of them has been made and that, while further improvements could be made in the future, widespread changes to the time-series of emission estimates are very unlikely.

4.4 Comparison of site specific estimates with the GHGI

A comparison between the total CO_2 estimates by sector for the large fuel consumers (points) and the sector emission totals in the GHGI are summarised in **Table 8**.

Table 8 Comparison of Total CO_2 Emission Estimates at Point Sources by Sector with GHGI data (kilotonnes CO_2)

Source Name	GHGI	Points	Points total as percentage of GHGI total
Cement – decarbonising	3,792	3, 754	99%
Cement production – combustion	1,996	2,000	100%
Iron and steel - combustion plant	9,215	7,785	84%
Blast furnaces	3,333	3,130	94%
Sinter production	1,658	1,676	101%
Basic oxygen furnaces	109	721	659%
Electric arc furnaces	18	79	449%
Primary aluminium production – general	286	413	144%
Ammonia production – feedstock use of gas	978	808	83%
Ammonia production – combustion	509	509	100%
Lime production - non decarbonising	608	700	115%
Lime production – decarbonising	234	1096	469%
Brick manufacture – Fletton	96	93	97%
Railways – stationary combustion	3	3	104%
Glass – general	434	405	93%
Incineration - chemical waste	170	187	110%
Miscellaneous industrial/commercial combustion	9,982	179	2%
Other industrial combustion	35,258	22,850	65%
Public sector combustion	8,439	1,879	22%

a – Point sources excluded from Local CO_2 estimates because these are energy suppliers not end users.
b – These sources includes some emissions from onshore facilities. These sectors are excluded from the Local CO_2 estimates.

Table 8 compares the summed emissions for point sources and the national (GHGI) emission for sectors other than energy suppliers and other excluded sectors

In one instance (**ammonia production – combustion)** the figures in the GHGI and point source database are the same, because the same data are used to generate both figures. In many other cases, the point source emission is lower than the national emission and this is not necessarily an issue since many smaller processes will not be included in the point source data. For example, the point source emissions for **other industrial combustion**, **public sector combustion**, and **miscellaneous industrial/commercial combustion** are only a small fraction of GHGI emissions, because many combustion plants in these sectors are too small to be included in the EU ETS data, PI, SPRI or ISR. The figures for **iron & steel – combustion plant** are closer since the sector is dominated by fuel consumption at a small number of large plants which are included in the point source data whereas the remaining small users are not included. In the remaining cases, the differences are due to inconsistencies between the GHGI and the point source emissions, and some commentary on these differences is given below.

Blast furnaces, sinter production, **basic oxygen furnaces**, all show differences between the GHGI and the points sources database figures with the GHGI being higher in the case of **blast furnaces** and lower in the case of **sinter production** and **basic oxygen furnaces**. The points data are based on EU ETS and Tata Steel data, while the GHGI figures are derived using DUKES energy data and a carbon-balance type approach. However, the sum of the emissions from all three sources is only 8% higher in the points data than the GHGI.

Electric arc furnace emissions are much higher in the points. This is probably mostly due to the inclusion of fuel-related emissions in the data used to generate the points data, which means that the numbers are not directly comparable.

Point source emission estimates for **lime production – decarbonising** are much higher than those in the GHGI, while for **lime production – non decarbonising**, the emissions, which have previously been quite dissimilar, are now close following revisions to this sector. The GHGI figure for decarbonising is based on lime production statistics but these data contain various gaps, and the points data indicate that the GHGI data should be reviewed. This source has been placed on the national GHGI improvement programme for development.

Primary aluminium production – general emissions are significantly higher in the points database and these estimates are based on PI/SPRI data while GHGI data use estimated activity data and a literature-based emission factor. The difference could be due in part to differences in scope (with PI/SPRI data possibly including some fuel-related emissions.

Table 9 shows fuel consumption estimates by fuel type. In each case the data derived here are compared with data taken from the GHGI.

Table 9 **Comparison of Estimates of Point Source CO_2 Emissions by Fuel with GHGI data (emissions in kilotonnes CO_2)**

Fuel category	Fuel	GHGI	Points	% points
Natural gas	Colliery methane	6	36	645%
	Natural gas	118,003	22,938	19%
Oils	Burning oil	12,253	19	0%
	Fuel oil	1,757	469	27%
	Gas oil	11,942	310	3%
	LPG	3,633	51	1%
	OPG	510	1,881	369%
Process gases	Blast furnace gas	10,091	9,201	91%
	Coke oven gas	693	482	70%
Solid fuels	Coal	8,134	4,842	60%
	Anthracite	642	93	14%
	Coke oven coke	1,420	1,480	104%
	Petroleum coke	501	95	19%
	Other Smokeless	882	-	0%
Wastes and bio fuels	Scrap tyres	171	172	101%
	Waste oils	679	99	15%
	Waste solvent	233	286	123%

Table 9 compares the data for fuels used at point sources with the national (GHGI) data, but excludes fuels used by energy suppliers and other excluded sectors. The point source data would be expected to be lower than the GHGI figure because of the absence of smaller combustion processes from the point source data. This is true for most of the most important fossil fuels – natural gas, burning oil, fuel oil, gas oil, LPG, blast furnace gas, coke oven gas, petroleum coke, anthracite and coal. Burning oil and LPG are very much lower, as these fuels are almost exclusively used in small equipment, and point sources use no ‘other smokeless fuels’ at all. Gas oil emissions are also much lower in the points, which reflects the fact that most gas oil is used in off-road vehicles or mobile machinery. The point source data are higher for three fossil fuels – colliery methane, OPG, and coke oven coke. In the case of the latter two fuels, it is known that there are inconsistencies between data available in DUKES and other fuel data such as that given in EU ETS data sets for multiple years, and so there is a possibility that the GHGI figures are too low for these fuels. In the case of OPG, it is also possible that there may be misallocation of some other fuels to OPG in the EU ETS data sets, since all EU ETS data for ‘refinery gas’ has been assumed to be OPG whereas refinery gas systems typically have backup fuels such as LPG or natural gas to maintain supply if insufficient OPG is available. Further review of the approach for treatment of the

refinery gas data in EU ETS data sets may be worthwhile. The reason for the discrepancy for colliery methane is not known, however this is a very minor fuel.

The emissions of other fuels in the points data look reasonable, for example fuels such as coal, coke oven gas, blast furnace gas and petroleum coke are all expected to be burnt in larger plant and the points figures for these fuels are a significant proportion of the GHGI total. In the case of wastes and biofuels, the picture is mixed. points figures for scrap tyres and waste solvents are slightly higher than those in the GHGI, suggesting the GHGI underestimates the use of those fuels. The waste oil burnt by the point sources is only a small proportion of the GHGI total. Waste oil is believed to be used as a fuel by many small users including roadstone coating plants and garages.

In summary, it is apparent that the correlation in the CO_2 emission and fuel consumption estimates derived from the GHGI and the point source data is not always consistent. Sometimes this difference is small, and sometimes the difference is acceptable because the point source data are not designed to cover all UK sources in a given sector. Some progress towards reducing differences is likely in the future due to the availability of more EU ETS data and via other industry inputs. However, it should be noted that the development of the fuel use estimates involves the need to make numerous assumptions and that eliminating most or all of the uncertainty would require very high investment in research.

4.5 Year to year consistency within the fuel use estimates

The point source data which are used as the basis of these fuel use estimates have been produced for the period 2005 – 2010 and considerable effort has been expended to ensure as much consistency from year to year as possible. Where data for a particular plant are available for some years but not for others, then a judgement has been made regarding whether to leave the ‘gaps’ or to fill them using the data reported for other years. As a general starting point, it has been assumed that it is more likely that gaps in reporting are due to the operator not being required to report, rather than that the process was not in existence.

Changes to the scope of reporting, particularly in EU ETS, as well as changes in the availability of data from one year to another can also affect time series consistency. Most problematic are those instances where for some years only EU ETS data are available, while for other years, only PI/SPRI/ISR data are available. In these cases, it is difficult to judge whether changes in emissions from one year to another are due to actual changes or if they just represent differences in the scope of reporting for EU ETS and PI/SPRI/ISR. As more data has become available and more will be in the future, we are improving our understanding of these processes, and revisions may be required to improve the point source data.

5 Industrial and Commercial 'Other Fuels'

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 NAEI's UK total emissions estimate is entirely accounted for by point source emissions (see **Section 4**). In this instance all of the emissions would be mapped as point sources. In other cases there are sectors that have no identified point sources, in which case all emissions are mapped as an area source. Many sectors however, are comprised of a combination of point source and area source emissions. In this situation point source emissions are mapped explicitly and the remaining residual emission[13] is treated as an 'area source' and distributed across the UK using modelled high resolution (1 km^2) 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.

5.1 Area source emissions: High resolution employment based distributions

Emission distribution maps for the small industrial combustion, public services, commercial and agriculture (stationary combustion) sectors have been updated for the 2010 inventory. The 2010 inventory update was a significant improvement for this dataset and the new distribution maps have been used to revise the 2005-10 emissions distribution for these sectors. The method used is described in the document **Employment based energy consumption mapping in the UK**[14] on the DECC website. The following data sets are used:

- Office of National Statistics Inter-Departmental Business Register (IDBR) which provides data on employment at business unit level by Standard Industrial Classification (SIC) code
- Energy Consumption in the UK data on industrial and service sector fuel usage[15]
- Site-specific fuel consumption as described in **Section 4**. These are compiled from data for regulated processes reported in the EA Pollution Inventory, Scottish SPRI, DoE NI Inventory of Statutory Releases, by the EU-ETS and from other data obtained by the inventory
- Display Energy Certificates in England and Wales for public sector buildings / offices larger than 1000m^2

The first step was to allocate NAEI point sources to SIC sector and to identify the relevant individual businesses at these locations in the IDBR employment database. This was in order to be able to calculate the energy for each sector which is already accounted for by point sources (see **Section 4)** and therefore estimate the total residual energy which needs to be distributed using the employment data. **Table 10** describes the calculations done in the services sectors for oil use.

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[13] Residual emission is the national total minus the point source emission total for the relevant sector
[14] Document can be found at http://www.decc.gov.uk/en/content/cms/statistics/climate_stats/gg_emissions/laco2/laco2.aspx
[15] http://www.decc.gov.uk/en/content/cms/statistics/publications/ecuk/ecuk.aspx

Table 10 Calculation of service sector oil consumption in 2009 (thousand tonnes of oil equivalent)

Sectors	Sub-sectors	Final UK energy consumption (ECUK Tables)	Total fuel from site-specific datasets (e.g. Points sources)	Total residual energy for modelling
Agriculture - stationary combustion	Agriculture	284.75	0.26	**284.49**
Miscellaneous industrial / commercial combustion	Communication and Transport	4.11	2.64	**1.46**
Miscellaneous industrial / commercial combustion	Commercial Offices	98.41	4.81	**93.60**
Miscellaneous industrial / commercial combustion	Hotel and Catering	56.97	0.01	**56.96**
Miscellaneous industrial / commercial combustion	Other	53.02	0.04	**52.99**
Miscellaneous industrial / commercial combustion	Retail	54.86	0.00	**54.86**
Miscellaneous industrial / commercial combustion	Sport and Leisure	5.30	0.22	**5.09**
Miscellaneous industrial / commercial combustion	Warehouses	314.25	0.01	**314.24**
Public sector combustion	Education	210.95	2.22	**208.73**
Public sector combustion	Government	113.66	15.59	**98.08**
Public sector combustion	Health	45.70	16.77	**28.92**

This retained the level of detail across emissions subsectors required for the mapping, as the use of total energy by SIC codes would have resulted in a reduction in the quality of the final distribution. This is considered to be a major improvement for the new version set of maps compared to previous similar modelling.

The employment data by SIC codes in the IDBR database were matched with the DECC energy consumption datasets (energy consumption UK table 5.6[16]) datasets in order to calculate total employment for each sector for which energy consumption data were available. Fuel intensity per employee was calculated for each sector. For commercial and public service sectors the employment data needed to be aggregated to match the level of aggregation of the energy data.

In the case of industrial sectors, a comparable approach was used; where this energy intensity calculation was done at the level of 2 figures SIC codes (**Table 11**). Energy consumption data were available for coal, manufactured fuel (SSF), LPG, gas oil, fuel oil and natural gas. These were aggregated to calculate industry specific fuel intensities for coal, oil and gas.

Table 11 Industrial sub-sectors by SIC codes

SIC(2003) codes	Description
14	Other mining and quarrying
15	Manufacture of food products and beverages
16	Manufacture of tobacco products
17	Manufacture of textiles
18	Manufacture of wearing apparel; Dressing and dying of fur

[16] http://www.decc.gov.uk/en/content/cms/statistics/publications/ecuk/ecuk.aspx

19	Manufacture of leather and leather products
20	Manufacture of wood and wood products
21	Manufacture of pulp, paper and paper products
22	Publishing, printing and reproduction of recorded media
24	Manufacture of chemicals, chemical products and man-made fibres
25	Manufacture of rubber and plastic products
26	Manufacture of other non-metallic mineral products
27	Manufacture of basic metals
28	Manufacture of fabricated metal products (except machinery and equipment)
29	Manufacture of machinery and equipment
30	Manufacture of office machinery and computers
31	Manufacture of electrical machinery and apparatus
32	Manufacture of radio, television and communication equipment and apparatus
33	Manufacture of medical, precision and optical instruments, watches and clocks
34	Manufacture of motor vehicles, trailers and semi-trailers
35	Manufacture of other transport equipment
36	Manufacture of furniture
37	Recycling
41	Collection, purification and distribution of water
45	Construction

The IDBR employment data at local unit level were aggregated to 2 figure SIC codes at 1 km^2 resolution using grid references provided as part of the database. The employment totals for each sector were then multiplied by the appropriate fuel intensity per employee values (as explained above) 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 LA 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 with Natural Gas availability 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 DECC dataset (Energy Consumption in the UK

Table 4.6[17]) there is only one sector using manufactured fuel (Manufacture of coke oven products).

5.2 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.

[17] http://www.decc.gov.uk/en/content/cms/statistics/publications/ecuk/ecuk.aspx

6 Combustion in the Agriculture sector

Electricity and gas consumption in the agriculture sector are included in the DECC local gas and electricity datasets described in **Sections 2 and 3** and therefore the consumption of these fuels related to the agriculture sector cannot be disaggregated.

Consumption of solid and liquid fuels has been calculated 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 **Employment based energy consumption mapping in the UK[18].**

Off-road emissions associated with activity in the agriculture sector 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.

[18] Document can be found at http://www.decc.gov.uk/en/content/cms/statistics/climate_stats/gg_emissions/laco2/laco2.aspx

7 Railways

It is not possible to separate electricity consumed by the railways from that consumed by other commercial and industrial activities in the DECC 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 sub-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 uniform along the length of the rail link, as no information on load variations is yet available. In 2009, minor updates on the rail link location have been incorporated with the use of the latest available OS rail link layer. Higher priority is given to the rail links around the Greater London area.

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 LA. These data are for passenger trains only as there is no freight activity in Northern Ireland.

Emissions from Railways now include emissions from combustion of coal which have recently been included in DUKES. Coal use is thought to only be in heritage railways however there is not currently enough information on heritage railway locations to map these accurately. These emissions make up 2% of all railway emissions in the Local CO_2 data and have been mapped using the same method as for regional rail emissions.

8 Domestic Electricity Consumption

Electricity consumption data for 2005 to 2010 published on the DECC website[19] 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 2010. The factors used are described in **Section 2**.

Electricity consumption reported in the sub-national dataset does not match exactly with DUKES. 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 50,000 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[20].

The DECC dataset outlined above does not currently provide a distribution of electricity consumption in Northern Ireland. However, following the creation of a single electricity market in Ireland, consumers can now choose their electricity supplier and confidentiality restrictions have been reduced. Figures for domestic electricity consumption in 2008-2009 at District Council level in Northern Ireland are now available on the DECC website[6]. These statistics are produced by DECC using aggregated meter point data derived from NIE's Distribution Use of System (DUoS) Billing system. In previous years, emissions were modelled using household counts in each LA.

This year the methodology has been improved to allocate carbon dioxide emissions from domestic electricity consumption in Northern Ireland using the new DECC statistics. As these data are not available for the whole time series, the distribution of electricity consumption between LAs for 2008 has been used for the years 2005-2008 and the distribution for 2009 has been used for 2009 onwards. It is a more appropriate method than previously used and this change has been responsible for large changes to emissions estimates in some LAs in NI compared to previous versions.

Data on total electricity sales have been provided to AEA through personal communication by DECC. The total electricity consumption in the domestic sector in Northern Ireland is 3,212 GWh and there is some statistical difference between the total electricity sales provided in personal communication by DECC and the published meter point data, this remains unallocated.

More information on how CO_2 emissions from electricity consumption are aggregated to LA can be found in **Section 2**.

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[19] http://www.decc.gov.uk/en/content/cms/statistics/regional/electricity/electricity.aspx
[20] http://www.decc.gov.uk/en/content/cms/statistics/publications/trends/trends.aspx

9 Domestic Gas Consumption

The gas consumption data published by DECC provides estimates of gas consumption by the domestic sector and the industrial and commercial sector for each LA in Great Britain for 2005-2010; these are published on the DECC website[21]. The gas consumption estimates for the domestic sector have been used to calculate CO_2 emissions for the domestic gas sector using an average emission factor across the UK (see **Table 6**). More information about how emissions estimates from gas consumption data were produced is provided in **Section 3.**

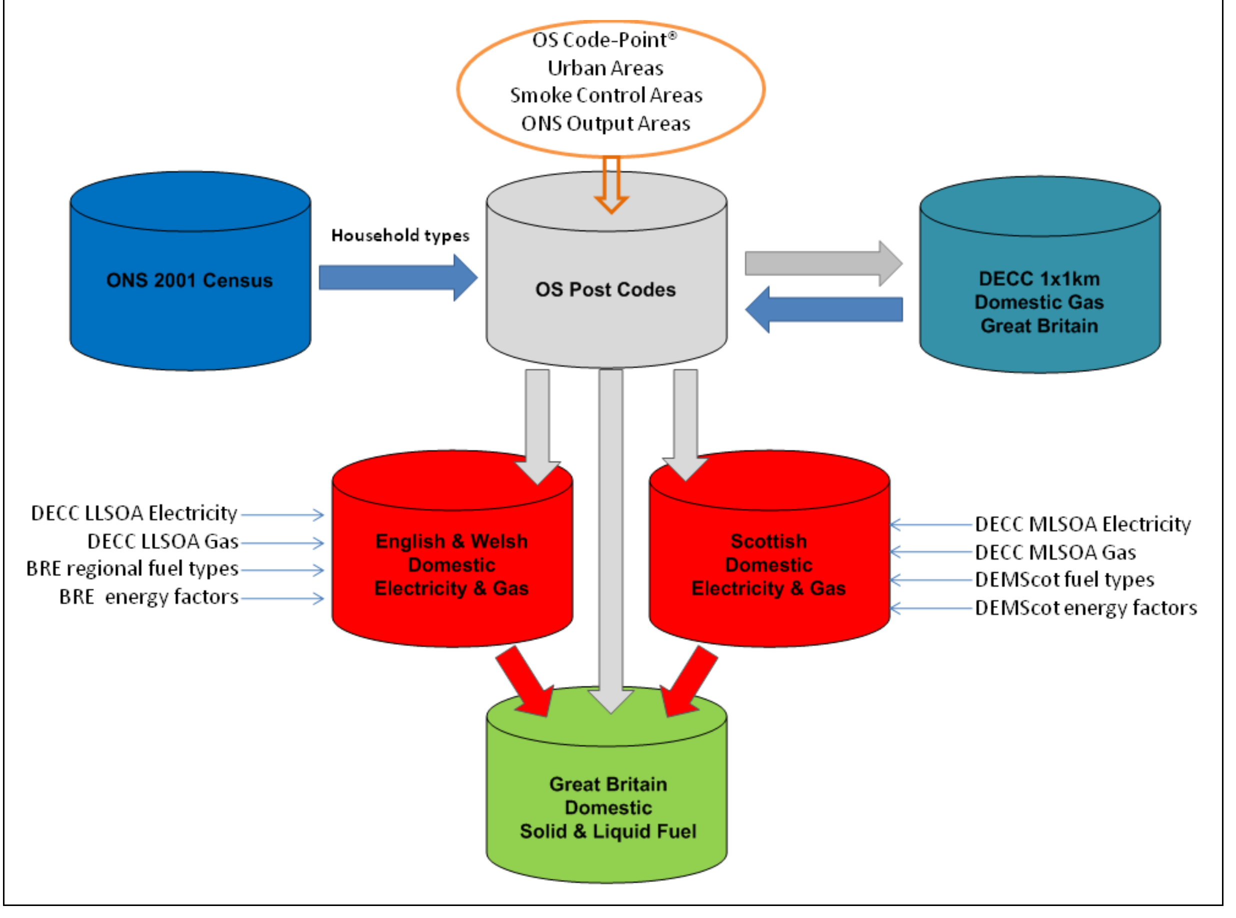
[21] http://www.decc.gov.uk/en/content/cms/statistics/energy_stats/regional/gas/gas.aspx

10 Domestic 'Other Fuels'

High resolution distributions of domestic solid and liquid fuel use in Great Britain have been updated for the energy estimates and were used to generate the emissions estimates presented in this report. In 2008 and 2009, two mapping methods were implemented; one method being applied to England, Scotland and Wales (Great Britain) and the other method to Northern Ireland. This approach was necessary owing to varying levels of data quality and availability in Northern Ireland compared to the rest of GB where higher resolution datasets were more readily available.

A summary of the methodology is provided below. **Figure 1** presents a high level summary of the data model for GB which was built to manipulate and analyse the large quantities of data used in this study.

Figure 1 NAEI Domestic model diagram



The following data series were used in the model, a summary how they we implemented in the model is given in **Table 12** below:

1. Ordnance Survey Code-Point data[22]
2. Office for National Statistics 2001 Census returns on Household types
3. DECC sub-national energy consumption statistics[23]:
    i. electricity and gas at Lower Level Super Output Area (LLSOA) 2008 for England and Wales
    ii. electricity and gas at Middle Level Super Output Area (MLSOA) 2008 for Scotland
    iii. 1x1km gas consumers & consumption for Great Britain
4. Domestic Energy Model data for Scotland[24]
5. Data from BRE on total energy use by dwelling and fuel type and regional data on the numbers of households using different fuels[25]

Table 12 Description of methods using the above data series

Task & data series used	Application
1	OS Code Point geographies were used to generate a spatial resolved database at full postcode level. Post codes were also assigned urban area, Smoke Control Area and ONS Output Areas attributes (**Figure 4**).
2	ONS 2001 census returns on household types were used to calculate percentages of house types within each Output Area
3 i, ii & iii	Sub National energy statistics were used to generate domestic electricity and gas spatial distribution databases for England / Wales and Scotland respectively. Comparing the total number of dwellings within output areas, with gas and economy 7 consumers, a residual fuel component was estimated. Sub National energy statistics were used to generate domestic electricity and gas spatial distribution databases for England / Wales and Scotland respectively. Comparing the total number of dwellings within output areas, with gas and economy 7 consumers, a residual fuel component was estimated.
4 & 5	BRE and DEMScot domestic energy model assumptions used in combination with the postcode database to generate the domestic solid and liquid fuels distribution across Great Britain.

Further information was also provided by BRE on total energy use by dwelling and fuel type and regional data on the numbers of households using different fuels (BRE, 2006). The BRE data provided estimates of the gas use per household for various categories of house type (e.g. detached, semi-detached etc.).

It has been assumed that:

- Coal is burnt exclusively outside Smoke Control Areas;
- Oil is burnt outside large urban areas (of greater than 100,000 population) 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;

[22] November 2009 release
[23] http://www.decc.gov.uk/en/content/cms/statistics/regional/regional.aspx
[24] DEMScot 2010
[25] Domestic Energy Fact File 2006

- Wood consumption is assumed to have the same distribution as coal.

Within Northern Ireland, a comparable approach is used using datasets specific to Northern Ireland and the particular domestic fuel use characteristics of this part of the UK. Datasets used to characterise the emissions from Northern Ireland domestic fuel consumption include:

1. Ordnance Survey Code-Point data;
2. Ordnance Survey Address Point data;
3. Interim update on Northern Ireland House Condition Survey (HCS) 2009;
4. Northern Ireland House Condition Survey (HCS) data 2001;
5. Northern Ireland Housing Executive (NIHE) 2009 survey of tenanted properties;
6. Gas connections information for domestic properties provided by Phoenix Gas;
7. Gas connections information for domestic properties provided by Firmus Gas;
8. Data from BRE on total energy use by dwelling and fuel type and regional data on the numbers of households using different fuel.

From these datasets an updated bottom-up approach to the characterisation of domestic fuel emissions was prepared using local data. The table below describes briefly how the datasets above have been used to compile the mapped emission estimates for Northern Ireland.

Task & data series used	Application
1, 2 and 3	An up-to-date geographic distribution of housing and house type was prepared using Ordnance Survey Code Point, Address Point data and information from the 2001 Census (ONS, as for GB) at an output area level and scaled to 2009 using information from the 2009 HCS. Geographical distribution of Smoke Control Areas, derived from GIS data provided by DoE Northern Ireland is used to allocate housing to Smoke Control Areas.
3 and 4	Fuels used in the private housing stock is derived from the 2001 detailed HCS and is scaled to 2009 using information from the 2009 HCS
5	Fuels used in social housing stock is taken from the 2009 NIHE
6 and 7	Distribution of Households connected to gas is derived from Phoenix Gas and Firmus Gas 2009
8	BRE domestic energy model assumptions are used in combination with the postcode database to generate the domestic solid and liquid fuels distribution across Northern Ireland.

In order to verify the modelled data for domestic fuel consumption in Northern Ireland, a comparison has been made between the numbers of each household type using a certain fuel type within the model, and the corresponding data from the House Condition Survey. This is illustrated in the scatter plots below. Since the R^2 value is close to 1, this indicates that there is a good relationship between the datasets, giving confidence in the accuracy of the modelling approach.

Figure 2 Verification of liquid fuel use between NAEI modelling and House Condition Survey data in Northern Ireland

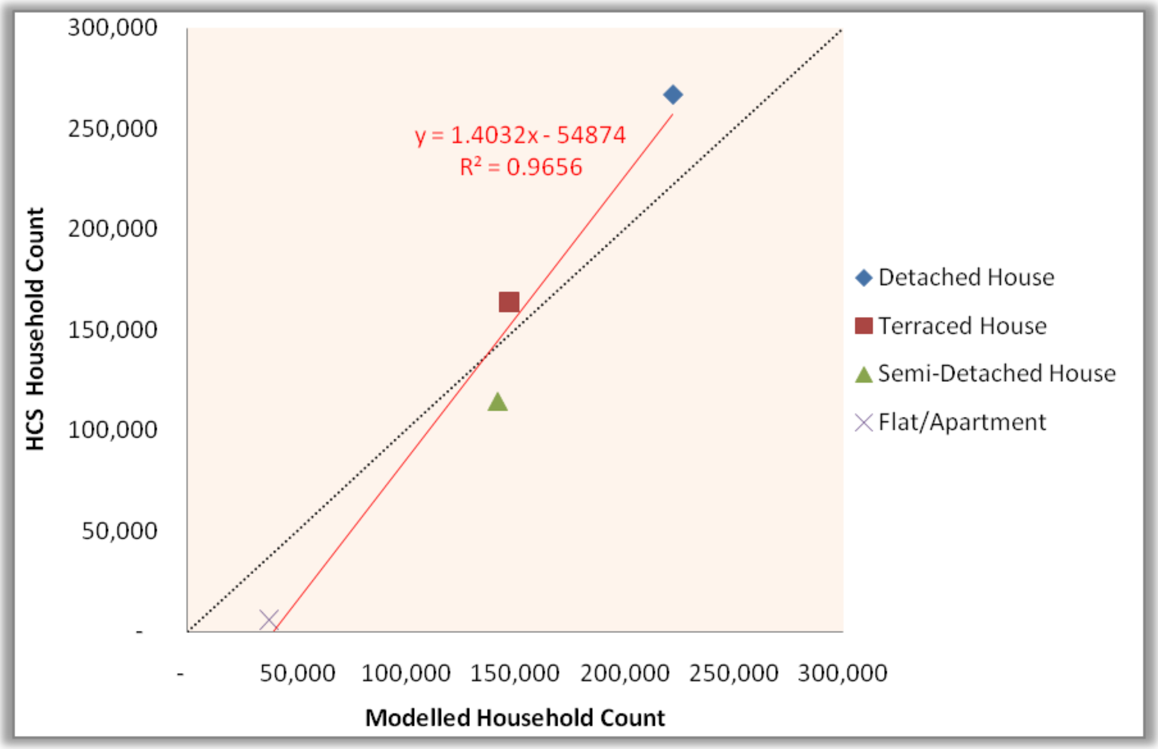


Figure 3 Verification of solid fuel use between NAEI modelling and House Condition Survey data in Northern Ireland

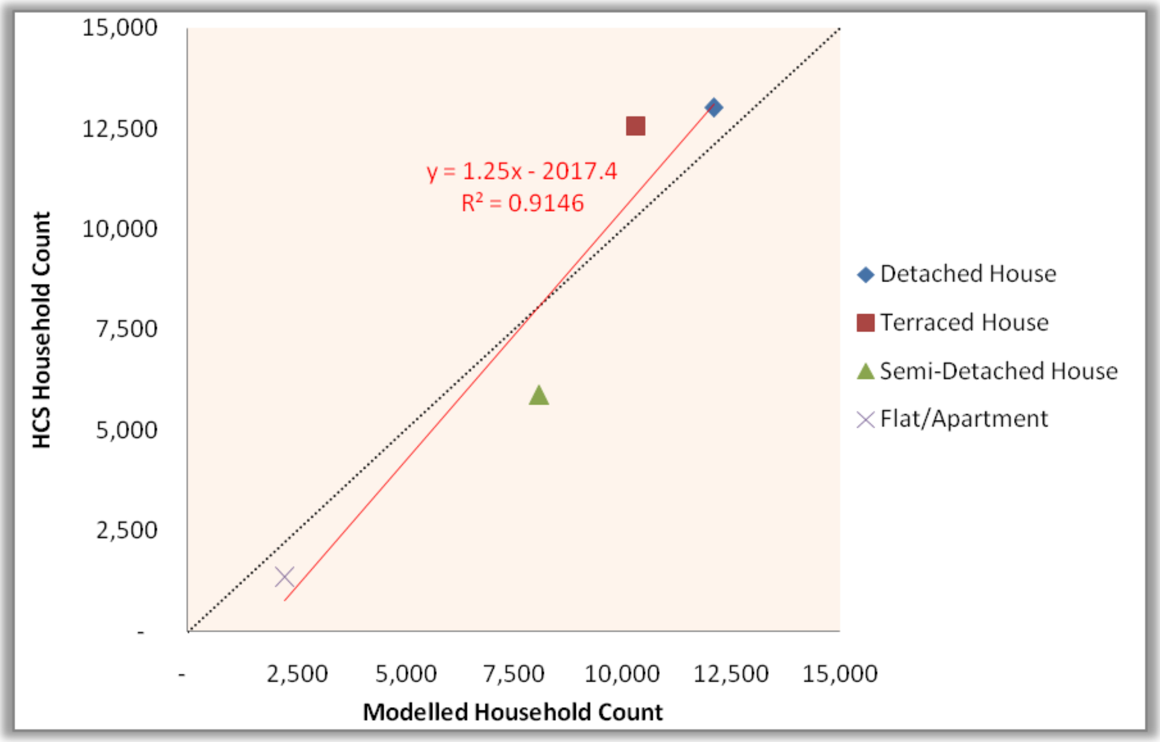


Figure 4, on the next page shows the geographical resolution of the domestic modelling, the outputs of which are then aggregated up to LA level.

Figure 4 The geographical resolution of the domestic modelling

11 Road Transport

Road transport fuel use estimates for 2010 at LA level were compiled by AEA for DECC. The method used is described in this section, with improvements for 2010 summarised at the end of the section.

11.1 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 estimates from passenger cars, light goods vehicles (LGVs), rigid and articulated heavy goods vehicles (HGVs), buses/coaches and mopeds/motorcycles. The vehicle classifications are further sub-divided by 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 and Euro 1-4 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 per kilometre driven respectively for each detailed vehicle class and are taken from the following data sources.

- Vehicle emission test data provided by the Transport Research Laboratory (TRL) on behalf of DfT, over different drive cycles from measurements on a limited sample of vehicles;
- NO_x emission factors for all vehicle types (except motorcycles) and emission degradation methodology for light duty vehicles based on COPERT 4 (v8.1);
- Car manufacturers' data on CO_2 emissions and surveys with freight haulage companies on fuel efficiency of HGVs;
- Figures from DfT on the Bus Service Operators Grant system (BSOG), an audited subsidy, directly linked to the fuel consumed on local bus services. From this, the costs and hence quantity of fuel used for local bus services are calculated.

However, the amount of fuel that a vehicle consumes in travelling a certain distance depends on many parameters including; the driving cycle, how much stopping and starting a vehicle does, how aggressively the vehicle is driven, the load applied to the vehicle's 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 evaluate all of these parameters for every vehicle on the road and as a result averages are used for what are in fact quite variable rates of fuel consumption for different groups of vehicle types.

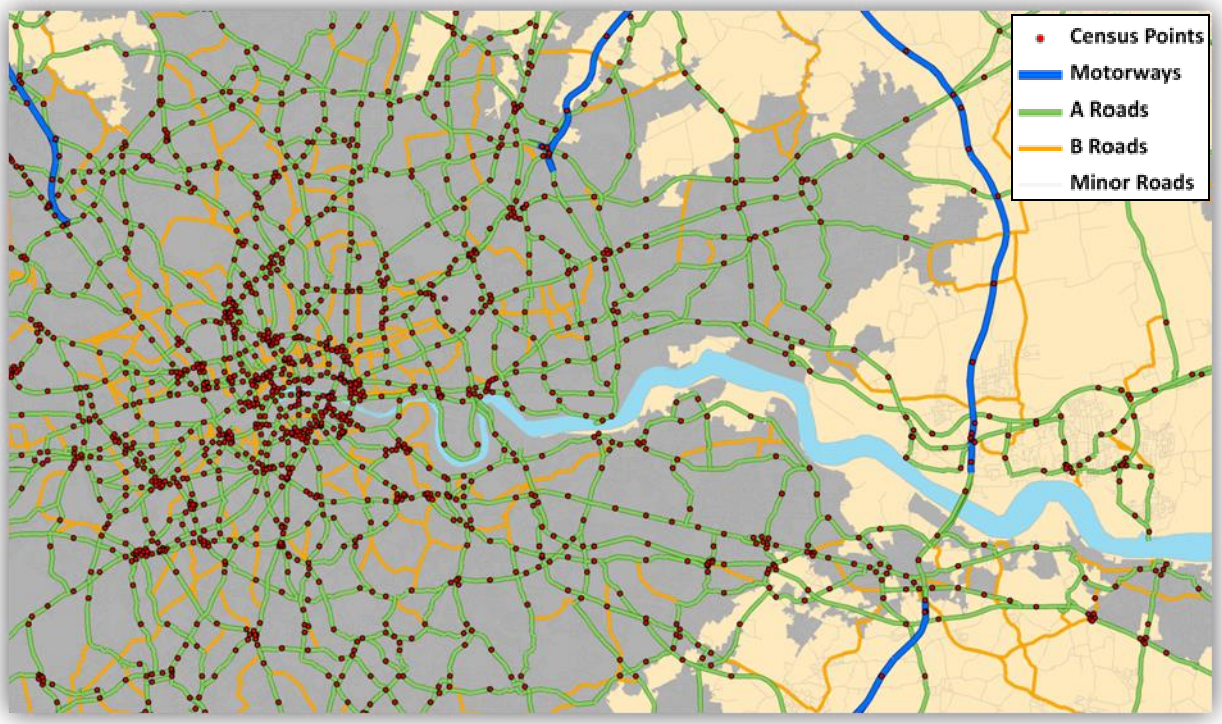
The fuel consumption factors used in the NAEI calculations are polynomial functions expressing the relationship between fuel consumption rate and average vehicle speed for each class of vehicle. These are based on measurements of fuel consumption and emission rates for samples of in-service vehicles 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 from a combination of the TRL-maintained database and the COPERT 4 (v8.1) database – both include factors measured over different test cycles that simulate real world conditions[26]. 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 levels of acceleration and deceleration built into them and for each of these, the fuel consumption rate will be very different.

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. For CO_2, fuel consumption is used as a proxy for the distribution of emissions.

11.2 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 5**). 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 Land & Property Services which is responsible for all of the Ordnance Survey of Northern Ireland.

Figure 5 **Illustration of the detail in the road network and count point database**



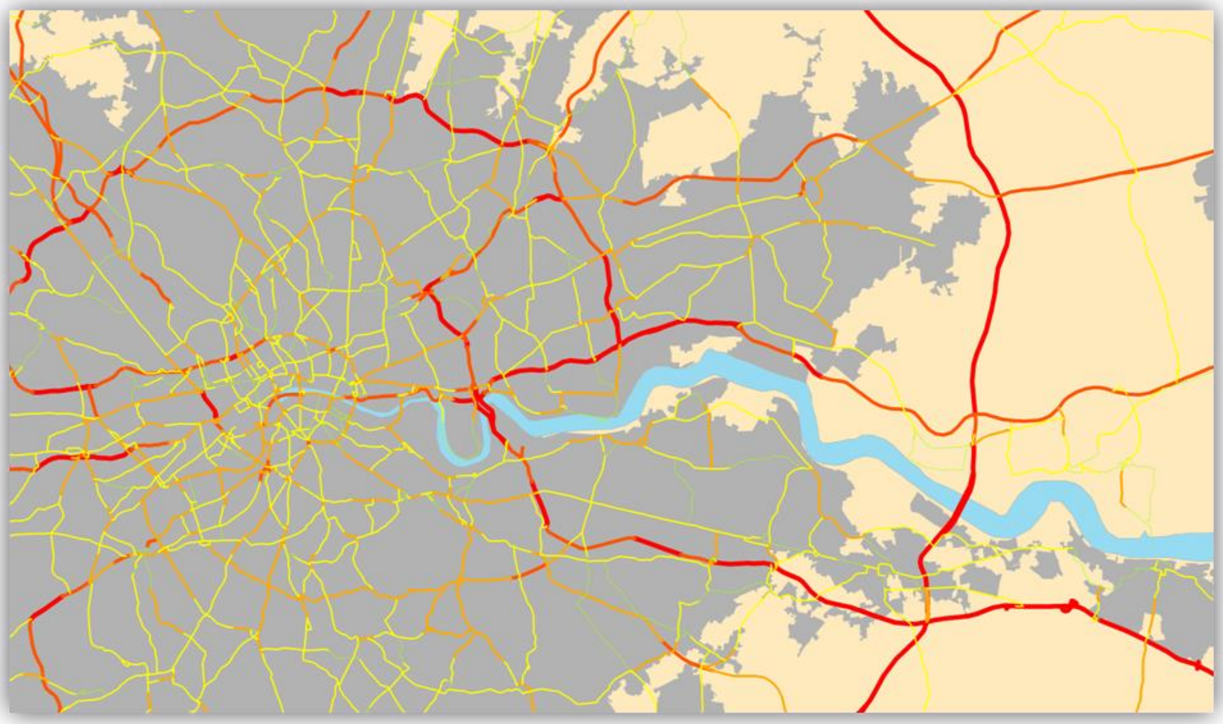
11.2.1 Mapping traffic on major roads:

Traffic flow data for major roads (A roads and motorways) are available on a census count point basis for GB (DfT, 2011). Northern Ireland data were not available for 2010 when the road transport mapping was undertaken, therefore 2009 data were used (Roads Service, 2010). The coverage of roads in GB is considerably denser than that for Northern Ireland, although some new Northern Ireland count points become available each year. 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 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.

[26] http://naei.defra.gov.uk/report_link.php?report_id=693

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 by using a GIS script – i.e. each link has the nearest count point with the same road name assigned to it (**Figure 6**).

Figure 6 Flows are assigned to the road links using a GIS script



11.2.2 Mapping traffic on minor roads:

Traffic flow data are not available on a link by link basis for the majority of minor roads. But where these data are available they have been used to enhance the accuracy of the mapping. Minor road count points have been allocated to minor roads in a similar way to that described for major roads, but also using census point local parameters (LA, Area type). Traffic flows in the majority of minor roads have been modelled based on average regional flows and fleet mix (data from DfT) in a similar way to previous years. 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 2010 Traffic and Travel Information report which provides average flows for all vehicle types by minor roads and also average vehicle splits by the same road types.

County level vehicle kilometre estimates from DfT (unpublished) have been provided to ensure consistency between the NAEI and DfT modelling and has been used to correct at County level the estimates of vehicle kilometres in the NAEI mapping.

11.2.3 Vehicle fleet composition

A development in the 2010 NAEI was the use of DfT's Automatic Number Plate Recognition (ANPR) data to define the fleet composition on different road types for the whole of GB while combining DA-country specific vehicle licensing data (DVLA data) to define regional variation (DfT, 2010). The ANPR data is used in two aspects for the 2010 inventory to define:

- Petrol and diesel mix in the car and LGV fleet on different road types (urban, rural and motorway);
- Variations in age and Euro standard mix on different road types.

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. More information on the revised methodology can be found in the UK Informative Inventory Report[27].

11.2.4 Fuel consumption calculations

The next step after mapping vehicle movements is to apply the emissions and fuel consumption factors discussed earlier.

Each major road link has been assigned an area type using the DfT definitions of urban area types shown in **Table 13** 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.

Table 13 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

Vehicle kilometre estimates for each road link are multiplied by fuel consumption (or emission factors) taking into account the average 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. Each road link is then split into sections according to the LA boundaries which then allow aggregation of fuel consumption estimates for each LA across the UK.

A similar calculation is done for minor roads, using average speeds for different types of minor roads and applying the relevant fuel consumption factor for that road type to the vehicle kilometre data modelled as described above. These calculations are undertaken at a resolution of 1 km^2 across the UK and the results are aggregated to LA boundaries for the estimates of fuel consumption published by DECC.

The use of an average speed approach to estimating emissions for different traffic conditions is a necessary simplification of real world conditions. 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.

11.3 Continuous improvements for road transport

Methodologies for calculating fuel consumption and emissions are periodically updated as our understanding of the factors that affect them improves. In addition, the input data used to calculate them are updated as DfT revises information, provides more detail in the information gathered and as new information becomes available. Consequently, revisions to the trends in calculated values of road transport fuel consumption and emissions are an inevitable consequence as the science and evidence base improves. The NAEI uses consistent data and approaches to meet the needs of GHGI compilations.

[27] http://uk-air.defra.gov.uk/reports/cat07/1203221052_UK_IIR_2012_final.pdf

The inventory this year has used Automatic Number Plate Recognition for the first time to define fleet composition on different road types. More information on this can be found in **Section 11.2.3**.

11.4 Other Road transport emissions

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.

12 Land Use, Land Use Change and Forestry Emissions

Land Use, Land Use Change and Forestry (LULUCF) activities are both a source and sink for 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 2012).

The estimates are reported according to IPCC classification of sources and removals. Estimates for 2010 are shown in **Table 14**. Categories are presented in the table in the order of the absolute magnitude of the net emissions or removals. 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.

This year for the first time, mapped LULUCF emissions and removals have been estimated for all years from 2005 to 2010 to provide a fully consistent time series of data from the CEH model. Previously it was only possible to estimate the latest year and apply that distribution to earlier years. This is a more accurate method because it reflects activity data for the appropriate area and time. This change in methodology has caused a smaller change in emissions/removals for Local Authorities than overall national inventory changes.

For some Local Authorities, a large change in emissions/removals for the LULUCF sector has been observed between years in the Local CO_2 dataset. The largest of these time series changes is associated with forest land. Soil carbon fluxes due to the planting of forests can take many decades to reach equilibrium – forests start out their lives as large carbon sinks – the trends observed are a consequence of a falloff in the sequestration potential of forest land planted many years ago.

Full details of the methodology used by CEH to estimate emissions and removals by LA for 2010 are provided in a separate document supporting this report: **Mapping Carbon Emissions & Removals for the Land Use, Land Use Change & Forestry Sector**[28]

Table 14 Emissions of CO_2 from Land Use Change and Forestry 2010 (kt CO_2)

Category	Activity	2010 UK total $ktCO_2$ emission (+) or removal (-)
5B2	Cropland (soil)	11,083.0
5A	Forest Land	-10,658.0
5C2	Grassland (soil)	-9,081.9
5E2	Settlements (soil)	6,024.8
5G*	Harvested Wood Products	-3,894.4

[28] http://www.decc.gov.uk/en/content/cms/statistics/climate_stats/gg_emissions/laco2/laco2.aspx

Category	Activity	2010 UK total $ktCO_2$ emission (+) or removal (-)
5B1	Cropland remaining Cropland (lowland drainage)	1,063.3
5B1	Cropland remaining Cropland (Yield improvement)	-640.4
5B	Liming of Cropland	485.5
5C	Liming of Grassland	419.4
5D1	Wetlands remaining Wetlands	263.0
5C2	Land converted to Grassland (deforestation to grass)	128.1
5B2	Cropland (non-forest biomass)	124.3
5E2	Land converted to Settlements (non-forest biomass)	100.9
5E	Land converted to Settlements (deforestation to settlements)	90.5
5A2	Wildfires	89.2
5C2	Land converted to Grassland (Non-forest biomass)	-6.6
	Total	**-4409.2**

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

13 Uncertainty Analysis

As with any inventory, the end user LA CO_2 emissions estimates are associated with a degree of uncertainty. This section describes how uncertainty has been analysed in this dataset.

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

- Uncertainty in national emissions: estimates of the percentage error relating to the national total emissions by sector;
- Uncertainty in the spatial distribution of emissions: an assessment of the degree of correlation between modelled and real world distributions of fuel consumption, activity and emissions;
- The proportion that each sector contributes to emissions in each LA.

Overall uncertainties in the 2010 emissions have been estimated using the sum of the squares method for propagating errors through calculations. This method uses the input data on estimates of component uncertainties as described in the following sections.

13.1 Uncertainty in the national sectoral GHG emissions

Uncertainty estimates for the national total GHG emissions, according to IPCC sector[29], are calculated in the UK's greenhouse gas inventory. This analysis is published in the UK's National Inventory Report, which is updated annually, most recently published for the 2010 inventory (MacCarthy *et al.*, 2012).

The uncertainty 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 15**.

13.2 Uncertainty in the geographical distributions

The uncertainties in the geographical distributions of emissions for each sector are difficult to quantify. Experts familiar with the mapping methods and emissions by sector have estimated semi-quantitative distribution uncertainties using expert judgement when the 2009 local CO_2 estimates were compiled. With the exception of the DECC 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

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

Greenhouse Gas Inventories (IPCC, 2006b). **Table 15** provides notes on each sector to help to explain the reasons for the uncertainty scores chosen.

Uncertainty estimates for the domestic and industrial gas and electricity emissions have been obtained from DECC. They are based on the amount of the consumption that was located correctly based on allocating meter locations to LAs. However it is also necessary to take account of the amount of estimated meter readings used to calculate these consumption data and the cut-off point used to determine whether meters are classed as domestic or non-domestic (see **Sections 2.1** and **3.1**) therefore the higher uncertainty estimates set out in **Table 15** are used.

The mapping of emissions has been divided into point and area sources. In general, mapped point source data is expected to be more accurate than that for area sources since it is predominantly based upon reliable data used for regulatory purposes. As we have seen, area source emissions are mapped using a variety of surrogate data types of varying quality. As part of this process, every attempt is made to utilise the highest quality data (within overall budgetary constraints), however, in some cases the surrogate statistics used may be poorly suited to this task.

Other industrial emissions data (large gas users, wastes and biomass and non-fuel emissions) are considered to have fairly low uncertainty as the geographical location of many of these sources and energy consumption are well reported (see **Section 4**).

The main reasons for uncertainties in the road transport sector are the use of sample/survey 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, state of the art national datasets are used in all cases where these are made available and the mapping approach is compliant with the method recommended by international guidance of the EMEP/EEA air pollutant emission inventory guidebook[30].

High uncertainties are assigned to some sectors. In particular, the combustion of coal and liquid fuels in small industry, commercial, public service sectors, 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 DECC 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 15 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.

13.3 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.

[30] http://www.eea.europa.eu/publications/emep-eea-emission-inventory-guidebook-2009

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

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

Sector	Percentage of 2010 UK emissions excluding LULUCF	National emission error	Geographical Estimated error	Comment
A. Industry and Commercial Electricity (GB)	20.8%	1.1%	3.0%	97.7% of postcodes have been located correctly. Additional estimate of uncertainty has been made based on 20% of MPAN readings being estimates.
A. Industry and Commercial Electricity (NI)	20.8%	1.1%	3.0%	97.8% of postcodes have been located correctly. Additional estimate of uncertainty has been made based on 20% of MPAN readings being estimates.
B. Industry and Commercial Gas	8.6%	1.2%	3.0%	DECC geographical allocation for gas is good. However the DECC definition of domestic gas consumers includes some small commercial users. But there is no numerical estimate of this uncertainty
C. Large Industrial Installations	0.6%	2.0%	5.0%	Good location information for point sources but still some emissions modelled
C. Large Industrial Installations - EU ETS	7.8%	1.0%	1.0%	Estimated % error. Grid references for sites provided by operators. Emissions reported and verified though ETS but some variation in quality of monitoring of emissions.
D. Industrial and Commercial Other Fuels	4.4%	2.7%	30.0%	Area emissions 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
E. Agricultural Combustion	0.9%	1.2%	30.0%	Modelled estimates using fuel and employment distributions for stationary combustion; land use data used to distribute machinery emissions.
F. Railways	0.5%	1.2%	30.0%	Emissions are distributed using an old dataset of rail movements for GB and more recent data for NI.
G. Domestic Electricity (GB)	12.4%	1.1%	3.0%	98.8% of postcodes have been located correctly. Additional estimate of uncertainty has been made based on 20% of MPAN readings being estimates.
G. Domestic Electricity (NI)	12.4%	1.1%	7.6%	Based on 92.4% of postcodes being located correctly.
H. Domestic Gas	14.9%	1.2%	3.0%	DECC geographical allocation for gas is very good. However the DECC definition of domestic gas consumers includes some small commercial users. There is a 3% difference between domestic/non-domestic categories in LACO2 and national inventory.
I. Domestic 'Other Fuels'	3.3%	3.1%	20.0%	Estimates made using complex modelling of household energy demand compared with known gas usage. Emissions mapped on population distribution but distribution of garden machinery is not correlated with population density because of smaller garden sizes etc in densely populated areas. Emissions mapped on population distribution which is reasonably well correlated with use of household products

J. Road Transport (A roads)	11.3%	2.5%	5.0%	Activity data are good quality annual average traffic count points. Emissions calculated using complex modelling of fleet mix and average speeds on different roads.
K. Road Transport (Motorways)	5.8%	2.5%	5.0%	Activity data are good quality annual average traffic count points. Emissions calculated using complex modelling of fleet mix and average speeds on different roads.
L. Road Transport (Minor roads)	8.8%	2.5%	20.0%	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.
M. Road Transport Other	0.1%	5.2%	30.0%	Locations of LPG use and burning of engine oil are not known and are therefore distributed across all road traffic activity.

13.4 Results of the uncertainty analysis

Figure 7 shows how the errors calculated from the sum of the squares method vary across England. The percentage error is 3 or lower for 83% of LAs. The limited spread around the mean may seem surprising given the size of some of the uncertainties in **Table 15**, particularly for mapping uncertainties. Two factors are relevant:

1. the smallest uncertainties tend to be for the largest emissions
2. uncertainties within individual sectors cancel against uncertainties in other sectors within each LA area to a significant extent.

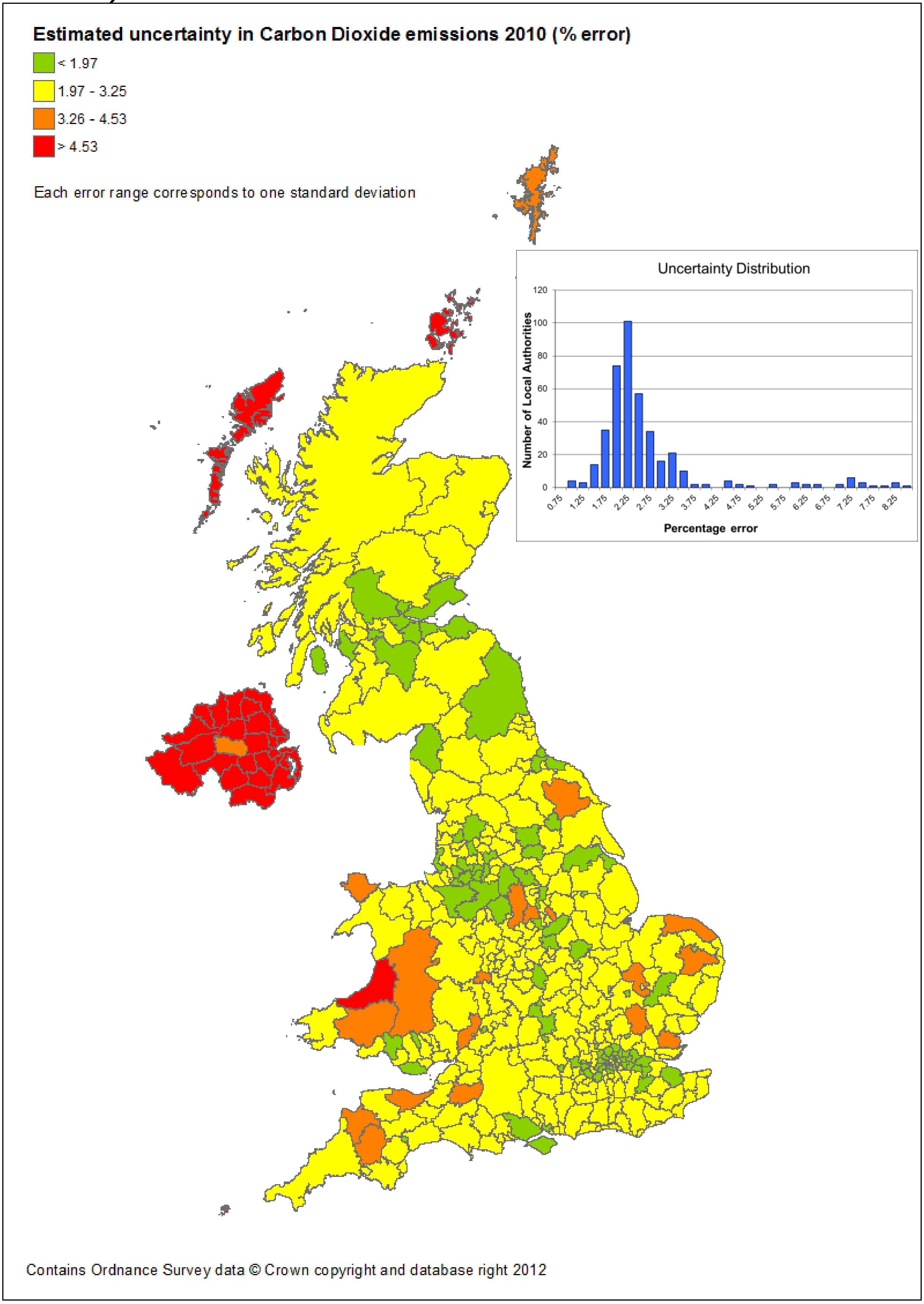
The latter may have important consequences for setting abatement levels by sector within each LA without further analysis at a more local level.

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.

In percentage terms the smallest estimated spread for any LA is for Neath Port Talbot in Wales (± 0.9%). This LA has a significant level of emissions from a number of EU ETS installations. The largest spread is for Moyle in Northern Ireland (± 8.4%) because of the lack of gas supply, little industry and high dependence on oil and solid fuels.

Comparing this with the National and Devolved Administration GHG Inventories, the uncertainty introduced on the national carbon dioxide emissions for 2010 was 2%. For Scotland, Wales, Northern Ireland and England; the comparable uncertainty estimates were 10%, 3%, 7% and 2% respectively.

Figure 7 Estimated errors in the CO_2 emissions 2010 (not including LULUCF emissions)



14 References

BERR (2007) Energy Consumption in the UK, www.berr.gov.uk/energy/statistics/publications/ecuk/page17658.html

BRE (2006) a dataset compiled by BRE for AEA on behalf of Defra based on modelling used to compile the Domestic Energy Fact File for 2004.

Bush T, Tsagatakis I, Passant N, Griffin, A and Pearson B. (2008) UK Emission Mapping Methodology 2007. Report to The Department for Environment, Food and Rural Affairs, Department for Energy and Climate Change, Welsh Assembly Government, the Scottish Executive and the Department of the Environment for Northern Ireland. AEA, Harwell, UK

CEH (2012). Inventory and projections of UK emissions by sources and removals by sinks due to land use, land use change and forestry. S. Hallsworth and A. M. Thomson. Edinburgh, CEH.

DECC (2010) Energy Trends December 2010 http://www.decc.gov.uk/en/content/cms/statistics/publications/trends/trends.aspx

DECC (2011a) Energy Trends December 2011 http://www.decc.gov.uk/en/content/cms/statistics/publications/trends/trends.aspx

DECC (2011b) Energy Trends March 2011 http://www.decc.gov.uk/en/content/cms/statistics/publications/trends/trends.aspx

DECC (2012) Energy Trends March 2012 http://www.decc.gov.uk/en/content/cms/statistics/publications/trends/trends.aspx

DfT (2010), personal communication with Mike Dark, Vehicle Licensing Statistics, Department for Transport

DfT (2011) *Transport Statistics Great Britain 2010 Edition* Department for Transport, Scottish Government Executive and Welsh Assembly Government, The Stationery Office, London http://www2.dft.gov.uk/pgr/statistics/datatablespublications/tsgb/

Hemingway J, *pers comm.* (2012) Email correspondence from DECC regarding electricity consumption data for Northern Ireland.

IPCC (2006a) 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 2 Energy, www.ipcc-nggip.iges.or.jp/public/2006gl/vol2.htm

IPCC (2006b) 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Chapter 3 Uncertainties, www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/1_Volume1/V1_3_Ch3_Uncertainties.pdf

MacCarthy J, Brown K, Webb N, Passant N, Thistlethwaite G, Murrells T, Cardenas L, Thomson A, Pang Y (2012) UK Greenhouse Gas Inventory, 1990 to 2010: Annual Report for submission under the Framework Convention on Climate Change. AEA report to DECC AEAT/ENV/R/3264, ISBN 978-0-9565155-8-2 http://naei.defra.gov.uk/report_link.php?report_id=693

Pye S and Vincent K (2003) Determining the impact of domestic solid fuel burning on concentrations of PAHs and sulphur dioxide in Northern Ireland, A report produced for the Department for Environment, Food and Rural Affairs; the Scottish Executive; the National Assembly for Wales and the Department of the Environment in Northern Ireland, AEAT/ENV/R/1498.

Roads Service (2010) *Traffic and Travel Information 2009* Incorporating annual traffic census and vehicle kilometres of travel, Report to Department for Regional Development, Northern Ireland

Smyth, C pers comm. (2006) Email correspondence from Translink.

Zachariadis, Th. & Samaras, Z, (1997), Int. J. of Vehicle Design, 18, 312

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