





National Atmospheric Emissions Inventory

Local and Regional Carbon Dioxide Emissions Estimates for 2005–2018 for the UK

Technical Report

Prepared by Ricardo Energy & Environment for BEIS

GA0216

Department for Environment Food & Rural Affairs

Department for Business, Energy & Industrial Strategy

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Contact:

Ben Pearson

t: +44 1235 75 3086

e: ben.pearson@ricardo.com

Authors:

Lara Turtle, Ben Pearson, Joe Richardson, Ioannis Tsagatakis

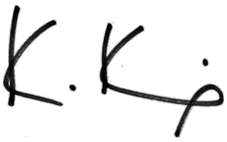
Approved By:

Katie King

Date:

12th June 2020

Signed:



Executive summary

The local and regional carbon dioxide (CO_2) emissions estimates for 2005-2018 are produced in order to provide a nationally consistent evidence base for sub-national greenhouse gas emissions. These estimates can be used as an important body of information by local authorities (LAs) and other relevant organisations to help identify high emitting sources of CO_2 and energy intensive sectors, monitor changes in CO_2 emissions over time and to help design carbon reduction strategies.

This report, prepared by Ricardo Energy & Environment on behalf of the Department for Business, Energy & Industrial Strategy (BEIS), sets out how the local and regional CO_2 emissions estimates for 2005-2018 were compiled. The full dataset – which is classified as National Statistics – and statistical summary can be found on the gov.uk website[1].

The dataset provides a spatial disaggregation of territorial 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:

- BEIS 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 UK Centre for Ecology & Hydrology (UKCEH), under the NAEI programme.

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 most significant improvements made this year were to estimates of emissions from the LULUCF sector. Emissions from forest land (4A) were revised due to the reconciliation of harvest volume and forest age data. There were revisions to the cropland sector (4B) due to a change in soil carbon density for crop management. Further improvements in the LULUCF sector were made as a result of new activity data for deforestation to grass and settlement (4C2 and 4E2 respectively), and to soil (4C and 4E) (UKCEH 2020).

[1] https://www.gov.uk/government/statistics/local-authority-emissions-estimates
[2] https://www.gov.uk/government/collections/sub-national-gas-consumption-data
[2] https://www.gov.uk/government/collections/sub-national-electricity-consumption-data

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1 Introduction

1.1 Purpose of the work

The dataset provides a spatial disaggregation of the CO_2 emissions 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; allow 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 - 2018 for the UK. It provides a detailed technical description of the methodology.

The dataset is provided in detail in a spreadsheet that accompanies this technical report (2005-2018_UK_local_authority_and_regional_CO2_emissions_data_tables.xlsx). A summary of results and four further methodology documents also accompany this dataset on the gov.uk website[3]:

- **Statistical release.** A short document providing a commentary on trends and patterns shown in the data.
- **Technical report.** This report, which provides a summary of the methodology used to calculate carbon dioxide emissions (CO_2) at local authority (LA) level.
- **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.
- **Employment based energy consumption in the UK.** A detailed methodological report describing the methods used to estimate the energy use at the UK level by the smaller industrial, commercial and public sectors and to model the distribution of the energy use across the UK at 1×1km resolution.

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 Greenhouse Gas inventory (GHGI) is compiled annually by a consortium, led by Ricardo Energy & Environment, on behalf of BEIS 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 Regulation (MMR), and is used to assess compliance with the UK's domestic and international emissions reduction targets. 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

These statistics cover territorial CO_2 emissions, meaning CO_2 emissions that occur within the UK's borders. These 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 which emissions from the production and processing of fuels, and the production of electricity, are reallocated to final consumers of the energy to reflect the total emissions relating to that energy use. This difference in reporting mainly

[3] https://www.gov.uk/government/statistics/local-authority-emissions-estimates

affects emissions related to electricity generation from power stations and fuel processing in refineries. This is in contrast to the 'by source' emission reporting in which emissions are attributed to the sector that emits them directly. Emissions from sources other than the production and processing of fuels are reported in the same way under both the 'end user' and 'by source' approaches, based on the location of the emission. End user GHG emissions at UK level are reported by BEIS as National Statistics; however, these emissions will be slightly higher than those shown in the local authority breakdown as they include emissions from some excluded sources which are deemed not to belong to any particular LA.

The end user basis for reporting emissions has been chosen for this dataset because it 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 BEIS 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).

[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 BEIS Digest of UK Energy Statistics, DUKES) must be used. The EU ETS data for 2005-18 are not fully consistent with DUKES but were used during the compilation process of allocating consumption to particular industrial consuming sectors.

Table 1 shows the UK total CO_2 by-source emissions in 2018 split into these three types of sectors.

The end user model reallocates emissions from energy supply industries to each energy use sector in the inventory in proportion to the amount of energy used by each. Some fuel producers use fuel from other fuel 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 users. **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 (Brown *et al.*, 2020).

Table 1 UK Total Primary emissions of CO_2 (kt CO_2 2018)

Sector	Anthracite & Coal	Coke	Solid Smokeless Fuel	Natural Gas	Oil	Electricity	Non Fuel	Grand Total
Energy Supply								
Coke production	-	600	-	-	-	-	205	805
Collieries - combustion	-	-	-	15	-	-	85	99
Gas Leakage	-	-	-	-	-	-	7	7
Gas production	-	-	-	3,540	1,141	-	589	5,270
Oil Production	-	-	-	7,162	1,741	-	3,682	12,585
Iron and steel - flaring	-	925	-	-	-	-	16	941
Power stations	14,687	-	-	46,630	458	-	5,374	67,149
Refineries - combustion	-	-	-	2,568	10,480	-	-	13,049
Solid smokeless fuel production	212	-	-	-	79	-	-	291
Energy Consumption								
Industry: Iron & Steel	91	8,376	-	884	61	-	794	10,206
Industry: Other Combustion	2,288	-	-	21,893	10,262	-	66	34,508
Industry: Other Processes	1,573	-	-	1,608	6,562	-	7,016	16,759
Commercial	30	-	-	11,343	339	-	603	12,316
Agriculture	-	-	-	192	4,283	-	340	4,814
Miscellaneous	-	-	-	-	-	-	238	238
Rail Transport	41	-	-	2	1,733	-	-	1,776
Domestic	1,475	-	695	56,780	7,407	-	29	66,386
Public	74	-	-	7,738	175	-	-	7,988
Road Transport	-	-	-	-	111,665	-	63	111,729
Inland Waterways	-	-	-	-	895	-	-	895
Land Use, Land-use Change and Forestry	-	-	-	-	-	-	-10,773	-10,773
Water Transport: National Navigation	-	-	-	-	4,947	-	-	4,947
Air Transport	-	-	-	-	2,065	-	-	2,065
Military Transport (Air & Water)	-	-	-	-	1,609	-	-	1,609
Exports	-	-	-	-	-	-	-	-
International aviation and shipping	-	-	-	-	-	-	-	-
Total	20,471	9,901	695	160,354	165,903	-	8,334	365,658

Table 2 UK Total End user emissions of CO_2 (kt CO_2 2018)

Sector	Anthracite & Coal	Coke	Solid Smokeless Fuel	Natural Gas	Oil	Electricity	Non Fuel	Total
Energy Supply								
Energy Consumption	112	10,155	-	917	66	495	794	12,539
Industry: Iron & Steel	2,304	-	-	22,719	12,035	19,707	66	56,830
Industry: Other Combustion	1,584	-	-	1,669	7,181	-	7,016	17,449
Industry: Other Processes	30	-	-	11,772	371	16,454	603	29,230
Commercial	-	-	-	199	4,698	1,051	340	6,287
Agriculture	-	-	-	-	-	-	238	238
Miscellaneous	41	-	-	2	1,900	1,154	-	3,098
Rail Transport	1,485	-	993	58,923	8,152	25,176	29	94,757
Domestic	75	-	-	8,030	191	3,552	-	11,849
Public	-	-	-	-	123,174	59	63	123,296
Road Transport	-	-	-	-	984	-	-	984
Inland Waterways	-	-	-	-	-	-	-10,773	-10,773
Land Use, Land-use Change and forestry	-	-	-	-	5,423	-	-	5,423
Water Transport: National Navigation	-	-	-	-	1,634	-	-	1,634
Air Transport	-	-	-	-	1,770	-	-	1,770

Military Transport (Air & Water)	-	-	15	-	6,071	541	-	6,627
Exports	-	-	-	-	4,421	-	-	4,421
International aviation and shipping	5,631	10,155	1,007	104,231	178,070	68,188	-1,625	365,658
Total	5,631	10,155	1,007	104,231	178,070	68,188	-1,625	365,658

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 2005-2018 at Local Authority level for England, Wales and Scotland are published on the gov.uk website[5]. 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 units 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 2018 (Brown et al., 2020). The factors used are shown in **Table 3**. 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.

Annualised electricity consumption data were 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 Gemserv database supplied by ECOES (Electricity Central Online Enquiry Service). Where the address information was not available in the Gemserv database the Royal Mail Postcode Address File (PAF) was used to obtain a full address and postcode and reduce unallocated consumption.

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). In addition, profile 1 and 2 meters are reallocated to the industrial and commercial sector if annual consumption is greater than 100,000 kWh. Also re-allocated to the industrial and commercial sector are those consuming over 50,000 kWh with address information indicating non-domestic consumption (BEIS 2019b).

Table 3 Electricity CO_2 factors used in this analysis

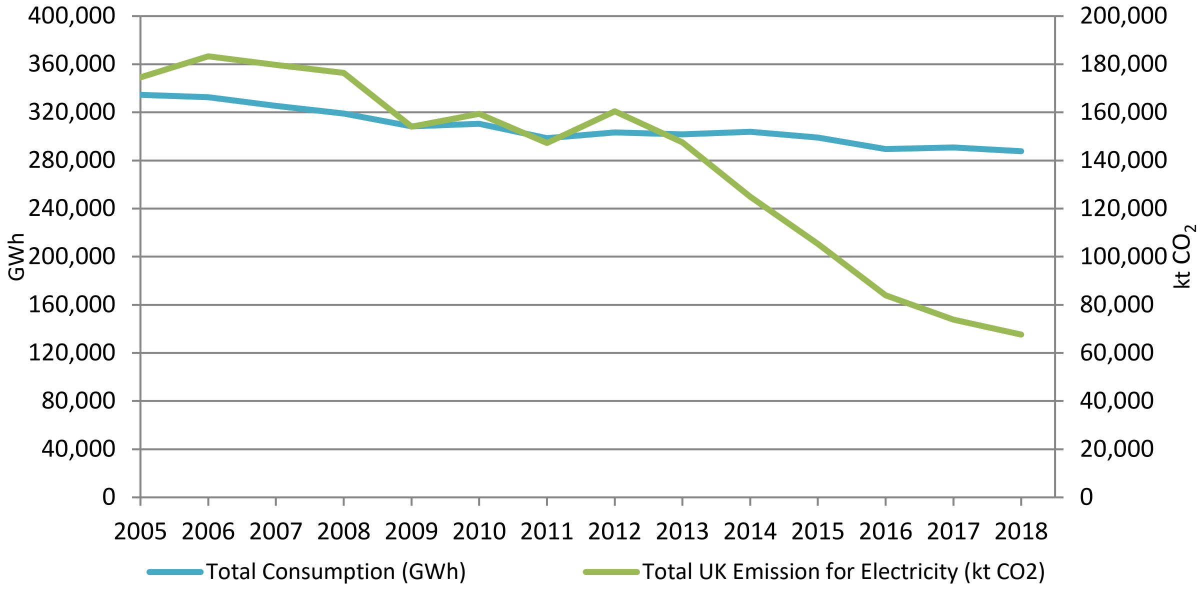
Year	Total UK Emission for Electricity (kt CO_2)	Total Consumption (GWh)	Electricity CO_2 Factor (kt CO_2 per GWh)
2005	174,579	334,561	0.522
2006	183,296	332,495	0.551
2007	179,730	325,464	0.552
2008	176,415	319,082	0.553
2009	154,085	308,414	0.500
2010	159,335	310,601	0.513
2011	147,212	298,537	0.493
2012	160,500	303,210	0.529
2013	147,567	301,689	0.489
2014	124,878	303,878	0.411
2015	105,367	298,962	0.352
2016	84,006	289,381	0.290

[5] https://www.gov.uk/government/collections/sub-national-electricity-consumption-data

2017	73,876	290,691	0.254
2018	67,647	287,697	0.235

Note: includes Northern Ireland electricity consumption

Figure 1 Time-series of electricity consumption and associated emissions in the UK



From 2005 to 2009 there was a continuous decrease in electricity consumption and a similar trend in the associated emissions, with a drop in consumption between 2008 and 2009 likely to be associated with the economic recession. Emissions in 2009 declined due to both the reduction in consumption and due to a reduction in carbon intensity of generated electricity. In 2010, electricity consumption and emissions were slightly higher than in 2009. This was likely to be due to the coldest December on record, and the stabilisation of the economic downturn may also have contributed. In 2011, electricity consumption was lower again due to a warmer winter. After 2011 consumption rose again, but since 2014 it has fallen to below 2011 levels. The long-term trend from 2005 is a noticeable decrease (BEIS 2019a). However, from 2012 onwards the production of emissions reduces at a much quicker rate than the consumption rate of electricity, likely due to switch away from coal in the overall generation mix, toward gas and renewable generation, and some improvements in the efficiency of generating plants.

The average electricity emission factor is dependent on the mix of electricity generation types used that year. Increases in emission factor from 2005-08 are due to an increase in the proportion of electricity produced using coal. During 2010, an increase in coal consumption and a decrease in nuclear power (due to technical problems at some stations) led to a spike in the average emission factor. Supply of gas also increased over this period (DECC, 2011). In 2012, rises in the price of natural gas caused another spike in average electricity emission factor, as UK power generation switched from using natural gas to coal. From 2013 onwards, the price of natural gas relative to coal has reversed and is cheaper than coal (DECC, 2012 and DECC, 2014). Since then, the average electricity emission factor has been rapidly declining. In 2018, the emission factor was the lowest it had been since 2005, due to the continuing decrease in coal fired generation as a result of of a number of power stations closures, both temporary and permanent, the conversion of a second unit at Drax from coal to biomass, and an increase in the carbon price floor in April 2015. In addition, there are increases in the share of low carbon electricity generation due mostly to consistently increasing renewable capacity over the timeseries. Nuclear generation has fallen slightly over the timeseries, however this has been substantially outweighed by the increase in electricity from renewable sources.. Overall, the emission factor has declined by 55% between 2005 and 2018.

2.2 Electricity consumption in Northern Ireland

Following the creation of a single electricity market in Ireland in late 2007, consumers could choose their electricity supplier, and confidentiality restrictions on the consumption data were reduced. As a result of this, figures for domestic electricity consumption by calendar year from 2008-2011 and non-domestic electricity consumption in 2009-2011 at District Council level in Northern Ireland are available on the gov.uk website[6]. Data for domestic consumption for financial years since 2012/2013 have been available since December 2015, and are now an annual publication. These statistics are produced by BEIS using aggregated meter point data derived from Northern Ireland Electricity'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. Therefore, this dataset excludes autogeneration that does not pass through the public distribution network. In order to develop a consistent time-series from 2005-18 utilising both the calendar and financial year data, the subnational datasets are scaled such that the total is consistent with BEIS calendar year sales data for Northern Ireland. Missing LA-scale data for years 2005-9 and 2018 are similarly extrapolated such that the total is consistent with calendar year sales data.

In addition, total electricity sales, as reported by NI suppliers, are available in annual sub-national electricity and gas consumption reports (e.g. BEIS 2019a). For all years, there is a statistical difference between total electricity sales and the sum of published meter point data (e.g. BEIS 2019d) because of incomplete records at the detailed scale. Therefore, some additional consumption needs to be distributed to Local Authorities, including the unallocated sector, on the basis of the year-specific relative consumption within each to account for this. This additional consumption is split between domestic and non-domestic use on the basis of the year-specific ratio that may be derived from the published meter consumption dataset. For 2015, data on total electricity sales have been estimated due to concerns over time-series consistency from the sub-national publication. This is based on interpolation between 2014 and 2016 data from BEIS, using trends in 2014-16 data from DfE NI. Data from BEIS is not available for 2018 and this is therefore similarly estimated based on extrapolation of 2017 data from BEIS using trends from DfE NI. Total electricity consumption in Northern Ireland in 2018 is thus estimated to be 7,651 GWh, 0.1% higher than in 2017.

2.3 Unallocated electricity

Where electricity sales within the datasets have not been successfully allocated to specific LAs, they have been assigned to an additional 'unallocated' category. The BEIS data also includes around 3-4 TWh of electricity as direct sales to high voltage lines that cannot be allocated to any region or Local Authority due to a lack of accurate address information. Emissions associated with this electricity consumption are included in the final dataset as an unallocated item.

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 4.2% in the industrial and commercial sector and 0.15% in the domestic sector in 2018.

[6] https://www.gov.uk/government/collections/sub-national-electricity-consumption-in-northern-ireland#local-authority-data

3 Industrial and Commercial Gas Consumption

3.1 Allocating Emissions to Gas Consumption

The gas consumption data published by BEIS provide estimates of gas consumption by the domestic sector and the industrial and commercial sector for each LA in Great Britain for 2005-2018; these are published on the gov.uk website[7]. These statistics are based on data obtained from Xoserve[8] 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).

The Annual Quantity (AQ) gas consumption data supplied to BEIS 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 but ideally close to a year apart, with the closing reading taken within the period 1 October to 30 September. However, not all AQs are recalculated each year, mainly because gas shippers have not provided any new meter readings. In these cases, the previous year's data is carried forward.

A weather correction factor is applied (except to sites that have automatic meter reading) so that AQ data are adjusted to normal weather conditions. The methodology for this adjustment is detailed in the 'Overview of weather correction of gas industry consumption data' published by DECC in November 2014[9]. Unfortunately, the data available to BEIS (formerly DECC) via Xoserve and the independent gas transporters does not currently 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, 2012).

For these reasons, the AQ cannot be exactly aligned to gas consumption data in the Digest of UK Energy Statistics (DUKES) (BEIS 2019c), 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 annual from 31st January to 30th January (BEIS 2019a).

BEIS uses the gas industry standard cut-off point of 73,200 kWh to identify small and medium business consumers (BEIS 2019b). 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. BEIS estimate that around 2 million small businesses are incorrectly identified as domestic as a result of this cut-off (BEIS 2019b). These domestic and non-domestic definitions are applied for the purposes of the Local and Regional CO_2 Emissions Estimates 2005-2018.

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 110 large industrial, commercial or public sector 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 Ricardo Energy & Environment using the data from the NAEI point source database, which uses a combination of public domain emissions data and data from the EU Emissions Trading System (EU ETS) reports to regulators. This database and the method used to obtain estimates of emissions and fuel use at point sources are described in **Section 4**. These data are included in the Large Industrial Installations sector – Sector C, along with point source emissions from other fuels.

These exclusions from the Xoserve dataset are determined by considering sites consuming over 58,600,000 kWh per year which have any of the following attributes:

- Shared Supply Meter Point (SSMP) – i.e. 2 or more Gas Shippers to the site
- On Shorthaul Tariff Charge (due to close proximity to an input terminal)
- Daily Metered site on Connected System Exit Points (large meter point connected to a pipeline which is owned and operated by Independent Gas Transporters)
- An Interconnector

[7] https://www.gov.uk/government/collections/sub-national-gas-consumption-data
[8] 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.
[9] https://www.gov.uk/government/publications/overview-of-weather-correction-of-gas-industry-consumption-data

- Site with Telemetry equipment

Data from the NAEI points source database, based on an Environment Agency database of reported emissions in the EU ETS, have been used to estimate fuel use from 2005 to 2018. There are however some discrepancies between the DUKES fuel use statistics and those either reported in the EU ETS or calculated by Ricardo Energy & Environment. 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 BEIS estimated gas consumption for the excluded sites and gas consumption as estimated by Ricardo Energy & Environment 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 of industrial and commercial emissions from end user gas consumption in this LA 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 Ricardo Energy & Environment and BEIS estimated gas consumption from large point sources is spread across the BEIS LA gas consumption data, effectively increasing the implied emission factor (IEF) for gas use by a small amount (IEFs shown in **Table 7**).

Table 4 Comparison of BEIS excluded gas consumption and Ricardo Energy & Environment calculated gas consumption at large point sources

Gas consumption excluded from sub-national dataset (GWh)	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
BEIS estimated excluded gas	110,327	88,519	100,686	100,460	99,735	94,996	96,224	102,576	105,000	100,623	97,891	100,552	103,284	105,402
Ricardo estimated excluded gas	79,195	82,035	82,994	83,050	74,219	73,100	68,793	66,298	60,112	57,954	55,639	53,707	57,550	53,152
Difference	31,132	6,484	17,692	17,410	25,516	21,896	27,431	36,278	44,888	42,670	42,252	46,845	45,734	52,250
Difference as a percentage of total gas consumption	4%	1%	3%	3%	4%	3%	5%	6%	8%	8%	8%	9%	9%	10%

3.2 Gas consumption in Northern Ireland

Data for Northern Ireland have been added to the BEIS dataset using information on total Northern Ireland gas consumption from energy providers Airtricity and Firmus energy. As of the 2005-2018 LA CO_2 dataset, data from 2015-2017 has been replaced with BEIS sub-national gas consumption statistics, which provides total consumption, number of meters and average consumption per meter for each District Council area in Northern Ireland (BEIS 2019e). Comparison of the new BEIS data with previous data from gas suppliers suggested that usage had been underestimated. 2005-14 estimates based on data from gas suppliers have therefore been re-based using 2015 consumption at LA level from the BEIS subnational estimates ensuring a more consistent timeseries and more accurate estimates for consumption in early years.

3.3 Calculating CO_2 Emissions

In order to calculate the total amount of CO_2 emission represented by the BEIS 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. For this calculation, emissions from gas consumption in Northern Ireland are also removed from total UK emissions as Northern Ireland gas consumption are not weather corrected and it is therefore more accurate to use a UK-wide average emission factor for this part of the gas consumption.

This calculation is shown in **Table 5** where the industrial sectors using gas are listed at the top, with emissions associated with the large gas users and Northern Ireland removed from this total and domestic gas use emissions are added at the bottom. Northern Ireland emissions are calculated by applying the implied emission factor calculated in **Table 6** to gas consumption data reported by energy suppliers. The Northern Ireland implied emission factor is calculated using the total UK end user emissions from the inventory and the total end user (all sectors other than energy suppliers) gas consumption. The result of the calculation in **Table 5** is a national total gas emission consistent with the BEIS sub-national gas consumption dataset. The resultant implied CO_2 emission factors for the BEIS sub-national gas consumption dataset are shown in **Table 7**.

These data are revised for the entire timeseries each year due to a variety of factors, primarily improvements to the UK GHGI (Brown et al., 2020) and to DUKES commodity balances (BEIS 2019c).

All emissions used in these calculations are ‘end user’ emissions and include emissions from the production and transportation of gas. Power stations’ emissions are not included in any of these calculations as they are distributed by electricity consumption.

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

GHGI End User Emissions by Sector		2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Industry and commercial combustion (not including power stations)		59,002	55,011	51,892	53,578	44,737	47,193	42,752	44,582	46,098	41,731	42,556	43,399	43,489	44,280
Agriculture combustion	+	438	389	385	272	282	263	260	223	212	207	189	193	195	199
Processes [1]	+	1,249	963	1,299	1,094	874	1,011	651	1,031	903	985	1,076	952	1,177	829
Total Local CO_2 Industry and Commercial gas use emission		60,689	56,362	53,576	54,944	45,893	48,467	43,663	45,837	47,212	42,923	43,822	44,544	44,861	45,308
Large users (not including power stations) excluded from this dataset	-	12,601	11,954	12,411	12,541	10,755	10,252	9,496	9,399	8,446	7,787	7,565	7,353	7,837	7,119
Northern Ireland	-	734	745	762	901	911	1,089	1,071	1,160	1,206	1,296	1,142	1,114	1,255	1,221
Domestic combustion	+	74,030	70,878	68,022	69,161	66,432	74,831	59,360	65,965	66,458	54,727	57,345	58,492	56,447	58,923
Total emission to distribute using the BEIS sub-national gas data		121,384	114,541	108,425	110,662	100,660	111,957	92,456	101,243	104,019	88,567	92,460	94,569	92,216	95,891

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

Table 6: Northern Ireland gas CO_2 emission factors calculated from UK inventory data

Year	Total UK Emission for Gas	Total Consumption (GWh)	NI Gas CO_2 Factor (kt CO_2 per GWh)
2005	134,719	695,034	0.194
2006	127,241	658,798	0.193
2007	121,598	630,924	0.193
2008	124,105	645,281	0.192
2009	112,325	583,754	0.192
2010	123,299	642,029	0.192
2011	103,022	536,040	0.192
2012	111,802	581,612	0.192
2013	113,670	589,264	0.193
2014	97,650	506,200	0.193
2015	101,166	524,984	0.193
2016	103,036	538,751	0.191
2017	101,309	529,529	0.191
2018	104,231	546,820	0.191

Table 7: Gas CO_2 emission factors used for Great Britain

Year	Total UK Emission for Gas (to distribute using BEIS gas data)	Total Consumption in BEIS gas data (GWh)	GB Gas CO_2 Factor (kt CO_2 per GWh)
2005	121,384	660,515	0.184
2006	114,541	628,733	0.182
2007	108,425	614,093	0.177
2008	110,662	586,455	0.189
2009	100,660	539,058	0.187
2010	111,957	540,642	0.207
2011	92,456	513,166	0.180
2012	101,243	510,047	0.198
2013	104,019	498,402	0.209
2014	88,567	501,285	0.177
2015	92,460	490,982	0.188
2016	94,569	486,568	0.194
2017	92,216	505,705	0.182
2018	95,891	508,289	0.189

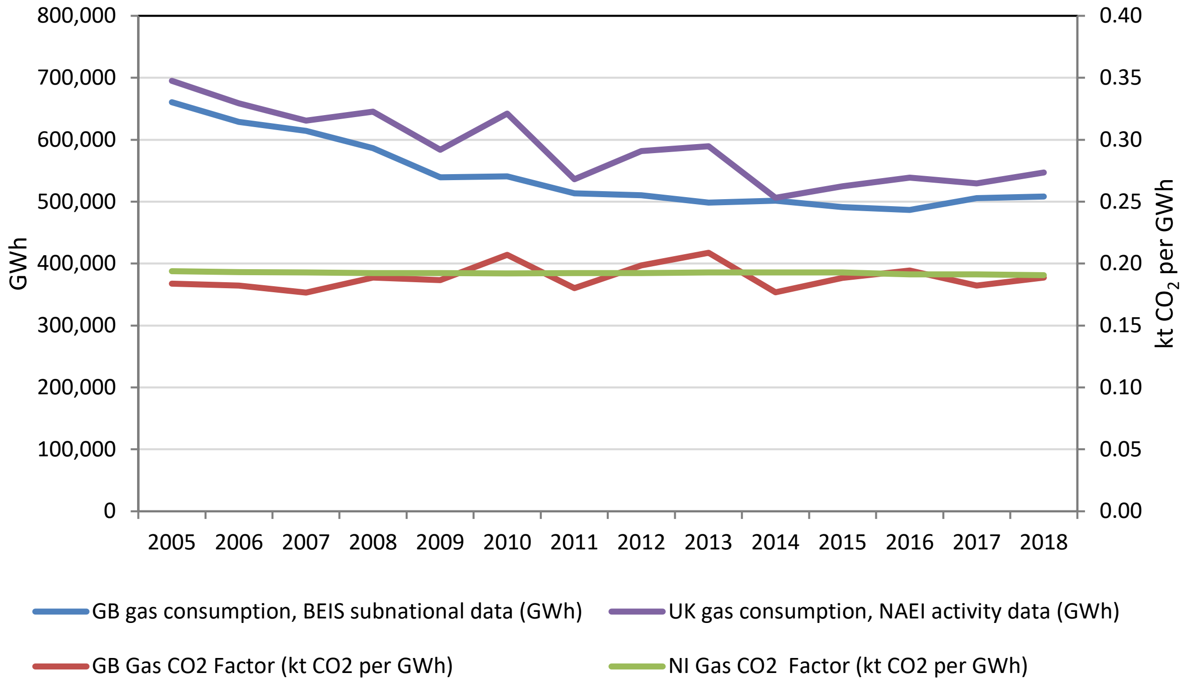
It is important to note that the compilation of the BEIS sub-national gas consumption dataset uses a weather correction factor based on a Met Office model using historic data[10]. This takes account of the warmer weather in more recent years (BEIS 2019b). This is done in order to observe long-term energy 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 DUKES which is not weather corrected. The national emissions from gas consumption are allocated to LAs based on the BEIS sub-national gas consumption data which are weather corrected. This results in a partial weather correction whereby the impacts of changes in the

[10] For more information on weather correction, please see the National Grid's Gas Demand Forecasting Methodology note: https://www.nationalgrid.com/sites/default/files/documents/8589937808-Gas%20Demand%20Forecasting%20Methodology.pdf

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 7** above, the implied emission factor is much higher because it was an extremely cold year and more gas was used. Similarly, there is another rise in 2012 and in 2013 the implied emission factor rose further, just above the level seen in 2010, due to the unusually cold weather in the latter months of 2012 and the first half of 2013. In 2014 and 2015, the implied emission factors are lower because they were warm years. In 2015, emissions have increased relative to 2014, whilst consumption has declined, since temperatures in the early months of 2015 were much lower than in 2014 (BEIS 2019a). The effect of the weather correction can be observed by comparing implied emission factors used for Northern Ireland (not corrected, shown in **Table 6**) and Great Britain (weather corrected, shown in **Table 7**).

Figure 2 Natural Gas consumption and emission factors, weather-corrected and non-weather-corrected



In **Figure 2**, total natural gas consumption decreases by 3.3% for 2018 compared with 2017, likely as a result of warmer temperatures experienced in 2018, despite notable seasonal variations (BEIS 2019c).

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 Local Authority CO_2 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 2005-2018 which is held in the Environment Agency (EA), Scottish Environment Protection Agency (SEPA), Natural Resources Wales (NRW), and the Northern Ireland Department of Agriculture, Environment & Rural Affairs (DAERA) databases of installations that are in the EU ETS.
- Information on emissions of CO_2 from combustion processes during 2005-2018 which have been reported by operators regulated under IPPC to the EA and NRW for inclusion in the Pollution Inventory (PI), to SEPA for inclusion in the Scottish Pollutant Release Inventory (SPRI) and to the Northern Ireland Environment Agency for inclusion in their Pollution Inventory (PIV). 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) and, more recently, Integrated Pollution Prevention and Control (IPPC);
- Integrated steelworks;
- Cement clinker manufacture;
- Lime manufacture;
- Other plant regulated under IPC and IPPC; 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 and CO_2 emission data;
    - Fuel consumption data are checked against inventory classifications and DUKES fuel consumption data. There can be differences in terms of scope of reporting.
- Estimates of emissions from processes outside the scope of ETS, based on IPPC and industry data;

[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**

  - Relationships between these installations and those that report the EU ETS need to be established in order to prevent double counting of emissions and fuel consumption. This also helps to gain information on sources of emissions at installations and the types of fuels used where this is not published.

- Gap filling and modelled estimates where data are not available;
  - In the above sources of data, there are often gaps where sites that report emissions in some years, do not do so in others. These gaps can be due to installations falling below reporting thresholds for certain years or because of the changing scope of reporting requirements, or simply because of plant closures or replacement. A judgement needs to be made about whether each of these gaps is realistic or if emissions need to be estimated to fill the gap.

More information is given on the above key methods in **Section 4.1.1** below.

As mentioned previously, the data presented in this report are not fully consistent with the UK GHGI (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 BEIS 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 EU ETS and other operators' data are broadly in line with BEIS 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 'by 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 8**.

Table 8: 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
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

[12] Reconciliation tables are published within the full dataset excel file.

Fuel Name	Fuel Category
Coke	Solid fuels
Peat	Solid fuels
Petroleum coke	Solid fuels
SSF	Solid fuels
Landfill gas	Wastes and biofuels
Sewage gas	Wastes and biofuels
Wood	Wastes and biofuels
Municipal solid waste (MSW)	Wastes and biofuels
Scrap tyres	Wastes and biofuels
Waste oils	Wastes and biofuels
Clinical waste	Wastes and biofuels
Waste solvent	Wastes and biofuels

4.1.1 Improvements

The point source data cover the period 2005-2018. There is a programme of continuous improvement and revisions have been made to the point source data for 2005-2017 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 the data that the operators of installations in England have reported for fuel consumption and CO_2 emissions in 2005-2018 under the EU ETS. Equivalent data were also received from NRW, (Wales), DAERA (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 each been assigned to one of the standard fuel types used in the NAEI (e.g. coal, fuel oil, gas oil). Each EU ETS 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 number of combustion processes are not covered by the EU ETS in the UK, for example small combustion installations would be outside the scope of the scheme. During phase I (2005-2007) and phase II (2008-2012) the scope of EU ETS was considerably narrower than now, with many sites not required to take part during phase I because of their involvement in other programmes, and driers, furnaces and similar types of installation that use heat in-situ not being covered at all until phase III started in 2013. In these cases, data may be available from other sources including the IPPC data sets. The IPPC data will also cover many of the combustion processes within the EU ETS data sets. It is therefore necessary to compare the IPPC data with the EU ETS data at the level of individual installations, 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 led to revisions to the point source data during the early years of these data being produced. There are likely still some areas of uncertainty in this ‘mapping’ of EU ETS sites to IPPC sites, but we believe that we now have a good understanding of the relationships for most existing EU ETS installations. Revision of data due to changes in assumptions in this area should now occur only rarely.

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, during phases I and II of the EU ETS, the UK used the medium definition of combustion installations which covers the production of electricity, heat or steam for the purposes of energy production. This meant that, for example, most furnaces used to produce chemicals or melt metals were not covered by EU ETS in the UK in 2012, although this has now changed 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 continually developing. This aspect of the points data processing is expected to improve still further in future years, although we believe that fewer revisions will need to be made in the future 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 the EU ETS, the scope of the scheme has changed over time and various installations were able to ‘opt-out’ in Phase I; for example, many cement kilns, brickworks and food & drink industry sites did not need to report. These and other opted-out sites then joined EU ETS for the start of phase II in 2008, but a voluntary *de minimis* limit was also introduced in that year 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. Many public sector sites such as hospitals and universities ceased reporting to EU ETS in 2008, presumably as a result of the *de minimis* rule. For EU ETS phase III, the definition of a combustion installation was changed to the ‘broad’ classification which meant that furnaces and similar devices that use heat directly were included under EU ETS. As a result, a large number of additional sites started to report to EU ETS in 2013, including many roadstone coating plants, food production sites, and metal industry sites.

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 in the EU ETS and IPPC data sets 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; and,
- SSI and Tata Steel Ltd (the operators of the processes) provide 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 operators are the most complete set of emissions data across the time series, while the EU ETS dataset is 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 operators. The operators' 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 included in the IPPC data sets but not in the EU ETS are based on Ricardo Energy & Environment 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 to us 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 important, 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 might be 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 the 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 IPPC data sets 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 7 years and this is supported by EU ETS data for those plants didn't opt out. For the early part of the time-series we estimate fuel use on a site-by-site basis, taking into account both the overall national trends in fuel use for 2005-2007, as shown in the industry's data, and the individual site preferences with regard to fuels, as shown in the 2008 EU ETS data.

- 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 onwards 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 IPPC data sets 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 the IPPC data sets therefore requires assumptions to be made about the split between fuel-related and non-fuel related emissions.
- A number of processes reporting in the IPPC data sets 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 emissions are 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 9**. Note that these are 'by source' emissions i.e. they exclude the reallocation of emissions from fuel production to end users.

Table 9: Comparison of Total CO_2 Emission Estimates at Point Sources by Sector with GHGI data (kilotonnes CO_2) 2018

Source Name	GHGI	Points	Points total as percentage of GHGI total
Autogenerators	1,996	121	6%
Blast furnaces	2,853	2,558	90%
Iron and steel - combustion plant	5,992	6,116	102%
Non-Ferrous Metal (combustion)	697	262	38%
Chemicals (combustion)	8,330	8,024	96%
Pulp, Paper and Print (combustion)	1,433	1,725	120%
Food & drink, tobacco (combustion)	4,365	3,395	78%
Lime production - non decarbonising	368	371	101%
Cement production - combustion	2,135	2,144	100%
Other industrial combustion	17,679	4,755	27%
Railways - stationary combustion	2.35	2.37	101%
Public sector combustion	7,988	1,928	24%
Miscellaneous industrial/commercial combustion	11,713	225	2%
Agriculture - stationary combustion	250	127	51%
Cement - decarbonising	4,364	4,364	100%
Lime production - decarbonising	1,089	1,064	98%
Glass - general	360	365	101%
Brick manufacture - all types	333	322	97%
Ammonia production - combustion	540	502	93%
Ammonia production - feedstock use of gas	799	819	102%
Chemical industry - titanium dioxide	182	182	100%
Chemical industry - soda ash	133	133	100%
Electric arc furnaces	25	61	245%
Basic oxygen furnaces	68	178	260%
Sinter production	1,261	1,310	104%
Primary aluminium production - general	68	64	93%
Incineration - clinical waste	81	60	75%
Incineration - chemical waste	157	43	27%

Table 9 compares the summed emissions for point sources and the national (GHGI) emission for sectors other than energy suppliers and other excluded sectors.

Figures for many source sectors are in good agreement; the point source emissions are all within a few percent of the GHGI figures for **iron and steel – combustion plant**, **cement – decarbonising, lime production – non decarbonising, glass – general, cement production – combustion, lime production – decarbonising, incineration - clinical waste, incineration – chemical waste, ammonia production – feedstock use of gas, ammonia production – combustion, chemical industry – soda ash** and **chemical industry - titanium dioxide.**

In many other cases, the point source emission is lower than the national emission and this is to be expected since many smaller processes will not be included in the point source data. For example, the point source emissions for **miscellaneous industrial/commercial combustion, other industrial combustion**, and **public sector 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 or IPPC data sets.

The figures for **autogenerators** reflect the fact that we are largely unable to distinguish between autogenerators and industrial combustion plants in the EU ETS and IPPC data. Therefore, there are few point source data for autogenerators, and emissions that would be classified in the GHGI as from autogeneration are instead listed in the point source data as from industrial combustion processes. This means that the percentage given in Table 9 for autogenerators underestimates the coverage of autogeneration emissions, while overestimating the level of reporting in sectors such as **pulp, paper and print (combustion).**

In the case of combustion in the paper industry, the point source data actually exceed the national total. This demonstrates the impact of the autogeneration issue – because autogeneration within the paper sector cannot be separately identified and split out, the point source emissions in these sectors then exceed the GHGI totals, while the point source data for autogeneration are too low. In the case of the chemical and food sectors, this problem is not so severe, so the points data are below but still fairly close to the national total, and for **other industrial combustion**, the points figure is well below the GHGI figure. A more realistic comparison of GHGI and points data can be made by combining the figures for autogeneration and the 4 industrial source categories, thus avoiding differences in scope. Taken as a group in this way, the points data for autogenerators and the 4 industrial source categories are 53% of the GHGI total (18,019 ktonnes CO_2, out of 33,802) which does not seem unreasonable, since in all four sectors, one would expect a significant quantity of fuel to be used by small plants not included in the points data. The figures for **iron and steel (combustion)** are as expected – the sector is dominated by fuel combustion at a small number of very large steelworks, but a small proportion of sector emissions occur at foundries and other small sites. Figures for **non-ferrous metals (combustion)** show a higher proportion of emissions outside the points data and this can be explained by the fact that this sector is less dominated by large plants – the UK has relatively few large non-ferrous metal processes, and most of the sector is small-scale, foundries, galvanisers, alloys production or similar.

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.

The point sources database figure for **basic oxygen furnaces** is much higher than in the GHGI. The points data are based on operator's own estimates, while the GHGI figures are derived using DUKES energy data and a carbon-balance type approach. There are also some differences in the way in which the GHGI emissions are allocated to the different stages of the steelmaking process, compared with the way in which the operators do it, and the different basic methodology, together with the differences in allocation, account for the large difference for basic oxygen furnaces (and also for flaring at steelworks which is not included in **Table 9**).

Similarly, **Electric arc furnace** emissions are higher in the points data. Some of the points data are based on site-specific emission estimates reported by operators, whereas the GHGI data are estimates based on published steel production and an emission factor, and this difference in methodology is probably the main reason for the difference.

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

Table 10: Comparison of Estimates of Point Source CO_2 Emissions by Fuel with GHGI data (emissions in kilotonnes CO_2) 2018

Fuel category	Fuel	GHGI	Points	% points
Natural gas	Colliery methane	1	2	143%
	Natural gas	101,936	19,247	19%
Oils	Burning oil	9,505	83	1%
	Fuel oil	1,311	207	16%
	Gas oil	12,181	301	2%
	LPG	2,689	77	3%
	OPG	2,936	2,835	97%
Process gases	Blast furnace gas	8,446	8,200	97%
	Coke oven gas	311	120	39%
Solid fuels	Coal	4,972	1,890	38%
	Anthracite	616	0	0%
	Coke oven coke	855	817	96%
	Petroleum coke	737	373	51%
	Other Smokeless	695	0	0%
Wastes and bio fuels	Scrap tyres	201	190	94%
	Waste oils	1.06	0.94	89%

Table 10 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, petroleum coke and coal. Burning oil and LPG are very much lower, as these fuels are almost exclusively used in small equipment, but for emissions from fuels such as OPG, coke and blast furnace gas, which are all expected to be burnt almost exclusively in larger plants, the points figures for these fuels are a significant proportion of the GHGI total. Natural gas, fuel oil, gas oil and coal, on the other hand, are assumed to be used in plant of all sizes, and so the points data would be expected to cover a lower proportion of emissions. The points data for colliery methane significantly exceed the GHGI figure but emissions are still trivial and the inconsistency probably reflects differences in allocation rather than a real difference in fuel consumption.

In summary, there is very good agreement between in the CO_2 emission and fuel consumption estimates derived from the GHGI and the point source data in many areas, but differences in other areas. Often, those differences are small, and in nearly all cases the difference is to be expected and therefore acceptable because the point source data are not designed to cover all UK sources in a given sector, or because of differences in the scope of the figures in the two data sets. The comparisons indicate some areas where one or other data set could be improved, however these improvements would have a trivial impact on overall agreement.

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 – 2018 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 the 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 IPPC 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 IPPC data sets. 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 were revised this year using updated employment and energy statistics. The method used is described in more detail in the document **Employment based energy consumption mapping in the UK** (Tsagatakis, 2018) on the gov.uk 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[14].
- Energy Consumption in the UK (ECUK) 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.
- Xoserve's Off-Gas Postcode dataset[16]
- Business Register and Employment Survey (BRES) annual employment estimates for the UK split by Region and Broad Industry Group (SIC2007)[17]

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 and therefore estimate the total residual energy which needs to be distributed using the employment data. 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.

The employment data by SIC codes in the IDBR database were matched with the BEIS energy consumption 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. Energy consumption data were available for coal, gas oil, fuel oil and natural gas. These were combined to calculate industry specific fuel intensities for coal, oil and gas.

[13] Residual emission is the national total minus the point source emission total for the relevant sector
[14] http://www.ons.gov.uk/ons/about-ons/products-and-services/idbr/index.html
[15] https://www.gov.uk/government/statistics/energy-consumption-in-the-uk (Industrial and Services tables)
[16] www.xoserve.com/wp-content/uploads/Off-Gas-Postcodes.xlsx
[17] http://www.ons.gov.uk/ons/rel/bus-register/business-register-employment-survey/index.html

The IDBR employment data at local unit level were aggregated to 2-digit SIC codes at Local Authority resolution using postcodes and 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 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);
- Where evidence of areas with natural gas availability, Xoserve's Off-Gas Postcode dataset has been used to identify sites with no gas;
- 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.

In order to produce time-series statistics the following ECUK tables where used:

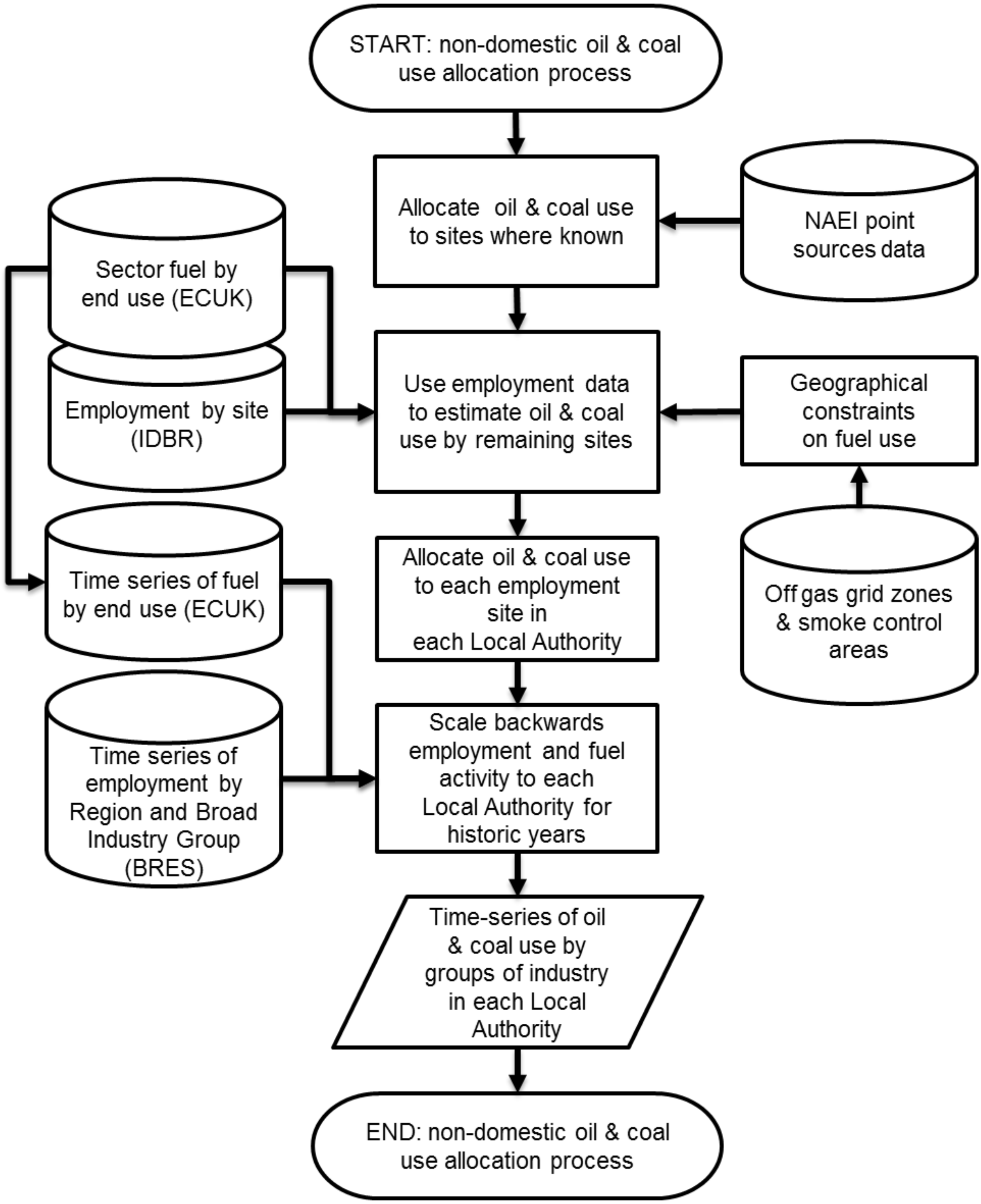
- Industrial final energy consumption at two digit SIC2007 level by fuel type, for the years 2009-2016[18];
- Service sector final energy consumption by sub-sector, for the years 2005-2016

The employment activity was also back-calculated with the use BRES annual employment estimates and applied to each Region and by Broad Industry Group. This was available for the years 2008-2016[19].

Figure 3 shows the process to convert industrial & commercial fuel usage from individual employment sites into emissions.

[18] Pre-2009 ECUK tables were only available at SIC2003 level
[19] Pre-2008 activity has been estimated from earlier NAEI studies

Figure 3 Non-domestic oil and coal use allocation process



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.

6 Agricultural Emissions

Electricity and gas consumption in the agriculture sector are included in the BEIS 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 for each year 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** (Tsagatakis, 2018).

Off-road mobile machinery 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.

The agriculture non-fuel sector includes CO_2 emissions from urea application and liming of soils. Prior to the 2017 release of LA CO_2 dataset, emissions from liming had been included in the LULUCF (Land Use, Land-Use Change and Forestry) sector, but having been reallocated in the 2006 IPCC guidelines for GHG inventory compilation, are now included in the Agriculture sector. Emissions from urea application and liming are distributed using data on land use provided by The UK Centre for Ecology & Hydrology (UKCEH) and Rothamsted Research respectively.

7 Domestic Electricity Consumption

Electricity consumption data for 2005 to 2018 published on the gov.uk website[20] has 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 factor for the relevant year in terms of kt CO_2 per GWh. This average allocates equal shares of coal, gas, oil, nuclear and renewable powered generation to all the electricity consumers and is derived from the UK inventory for 2018. The factors used are described in **Section 2**.

Electricity consumption reported in the sub-national dataset does not match exactly with DUKES. This is partly due to the inclusion of some non-domestic users within this dataset as described in **Section 2.1**. Other reasons for the differences (BEIS 2019b) are that:

- the sub-national consumption data covers Great Britain and DUKES covers the United Kingdom;
- the sub-national consumption data are aggregated from the bottom-up meter point level and the DUKES statistics are produced using a top-down approach;
- DUKES contains a wider sector breakdown than the simple domestic and non-domestic split;
- the sub-national consumption data are not for exactly a calendar year whereas DUKES data are based on a calendar year;
- the sub-national data excludes some Central Volume Allocation (CVA) users – these are very large industrial consumers receiving electricity via the high voltage system;
- some consumption is estimated as opposed to actual metered consumption.

The BEIS 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 in late 2007, consumers were able to choose their electricity supplier and confidentiality restrictions on the data were reduced. Figures for domestic electricity consumption in 2008-2017 at District Council level in Northern Ireland are available on the gov.uk website alongside the Great Britain statistics. These statistics are produced by BEIS using aggregated meter point data derived from Northern Ireland Electricity's Distribution Use of System (DUoS) Billing system.

As Northern Ireland electricity consumption 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 2017 has been used for 2018.

Data on total electricity sales as reported by NI suppliers are available in the sub-national electricity and gas summary report (e.g. BEIS 2019a). However, in 2016, an extrapolated value was used in preference to the report due to concerns over time-series consistency. The total electricity consumption in Northern Ireland for 2015 was 7,610 GWh. For all years, there is a statistical difference between the total electricity sales and the published meter point data (BEIS 2019d). Published meter point data provides electricity consumption disaggregated by domestic and non-domestic sources, and it is the year-specific ratio of domestic to non-domestic consumption from this source which is used to split total electricity consumption. The statistical difference between total electricity sales and meter point data is distributed across all local authorities in Northern Ireland, including the unallocated sector, on the basis of the year-specific relative consumption within each.

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

[20] https://www.gov.uk/government/collections/sub-national-electricity-consumption-data

8 Domestic Gas Consumption

The gas consumption data published by BEIS provides estimates of gas consumption by the domestic sector and the industrial and commercial sector for each LA in Great Britain for 2005-2018, and for each LA in Northern Ireland for 2015-2017; these are published on the gov.uk website[21,22]. The gas consumption estimates for the domestic sector have been used to calculate CO_2 emissions for the domestic gas sector using the implied emission factor for Northern Ireland shown in **Table 6** and for Great Britain shown in **Table 7**. More information about how emissions estimates from gas consumption data were produced is provided in **Section 3.**

Gas consumption reported in the sub-national dataset does not match exactly with DUKES for the following reasons (BEIS 2019b):

- the sub-national consumption data covers Great Britain and DUKES covers the United Kingdom;
- the sub-national consumption data are aggregated from the bottom-up meter point level and the DUKES statistics are produced using a top-down approach;
- DUKES contains a wider sector breakdown than the simple domestic and non-domestic split;
- the gas data is based on the gas year whereas DUKES in based on the calendar year;
- the sub-national gas data is weather corrected, whereas DUKES is not weather corrected.

21 https://www.gov.uk/government/collections/sub-national-gas-consumption-data
22 https://www.gov.uk/government/statistics/sub-national-gas-consumption-statistics-in-northern-ireland-2019-2017-data

9 Domestic 'Other Fuels'

Domestic oil and solid fuel use distributions were created by spatially resolving detailed local information on central heating and house type data from the 2011 census with data from the BEIS National Household Model (NHM), which provides average household energy consumption estimates across the 13 regions of England, Wales and Scotland. Regions within England and Wales follow the regional classification scheme[23], with Scottish regions abiding by the Met Office 3-tier regional (Northern, Eastern and Western) classification so as to represent the spatial shifts in climate[24]. The census data were combined with full-address matched dwelling locations from Ordnance Survey data to give a more accurate distribution of households at LA level.

Solid fuel use was assigned to solid fuel burnt in boilers and non-boiler appliances (such as open fireplaces, closed stoves). It was assumed that solid fuel activity for boilers was used in properties which, according to Census 2011, had Solid Fuel Central Heating. Solid fuel activity for non-boiler appliances was assumed to be used in houses and bungalows with No Central Heating. Supplementary heating from the same technologies was considered more likely to be located in houses and bungalows only. Apartments were excluded for solid fuel use to be consistent with BEIS NHM assumptions on wood use. The number of supplementary heating users for wood was calibrated at Regional level by comparing the total wood user count (as derived from all the above assumptions) against the regional count from the BEIS Residential wood survey[25].

Further information on the datasets and methodology used to develop the domestic model can be found in the *UK Emission Mapping Methodology* (Tsagatakis, et al., 2019).

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[23] http://www.ons.gov.uk/ons/guide-method/geography/beginner-s-guide/maps/index.html
[24] http://www.metoffice.gov.uk/climate/uk/regional-climates
[25] https://www.gov.uk/government/publications/summary-results-of-the-domestic-wood-use-survey (Table 1.1)

10 Road Transport

Road transport fuel use estimates for 2018 at LA level were compiled by Ricardo Energy & Environment for BEIS. The method used is described in this section, with improvements for 2018 summarised at the end of the section.

10.1 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. The methodology combines traffic activity data (from DfT's national traffic census) with fleet composition data and fuel consumption/emission factors. The vehicle fleet composition data are based on licensing statistics and evidence from Automatic Number Plate Recognition (ANPR) data from DfT; these provide an indication of the vehicle mix by engine size, vehicle size, age, engine and exhaust treatment technology, Euro emission standards, and fuel type as observed on different road types. Fuel consumption factors are based on a combination of published compilations of factors derived from vehicle emission test data from European sources and factors from industry on the fuel efficiency of cars sold in the UK. In the former case, representative samples of vehicles are tested over a range of drive cycles associated with different average speeds on different road conditions: there are many parameters that affect the amount of fuel a vehicle uses and average vehicle speed is one of them, so the NAEI uses functions that relate fuel consumption to average speed.

In previous versions of the inventory, these functions were developed by Transport Research Laboratory (TRL) on behalf of DfT in 2009. However, the source of fuel consumption factors changed this year and factors for all vehicle types are now derived from the fuel consumption-speed relationships given in the COPERT 5 source. COPERT 5 "*Computer Programme to Calculate Emissions from Road Transport*" is a model and database of vehicle emission factors developed on behalf of the European Environment Agency and is used widely by other Member States to calculate emissions from road transport. It is a source of factors recommended for national inventory reporting in the EMEP/EEA Emissions Inventory Guidebook (2016). This included a method for passenger cars which applies a year-dependent 'real-world' correction to the average type-approval CO_2 factor weighted by new car sales in the UK from 2005-2018. The new car average type-approval CO_2 factors for cars in different engine size bands were provided by the Society of Motor Manufacturers and Traders (SMMT, 2015). The real-world uplift uses empirically-derived equations in the Guidebook that take account of average engine capacity and vehicle mass. Previous versions of the inventory calibrated speed-fuel consumption curves for HGVs and buses with independent data from DfT on the fuel efficiencies of these vehicles in the UK obtained from surveys of haulage companies and bus operators' fuel returns. However, DfT have recently found the data to be less complete than was previously considered and therefore less suitable for use in the inventory.

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 and activity data sourced at a national level from the NAEI end user inventory.

NAEI petrol and diesel vehicle fuel consumption and emissions are estimated for individual vehicle types from a bottom-up approach using an array of traffic statistics and exhaust emission and fuel consumption factors representing the real-world performance of vehicles. These estimates are reconciled to national energy consumption statistics from DUKES. Further details of the NAEI reconciliation methodology and the effect of this across the timeseries may be found in section 3.4 MS 8 of the UK NIR.

The emission factors applied for road transport in LA CO_2 statistics are provided below in **Table 11**. These are derived from NAEI by-source emission factors, calculated from the carbon content of the fuel used, adjusted to an end user basis to account for emissions from the production and processing of fuels. NAEI CO_2 emission factors per unit of fuel for road transport are different for petrol and diesel vehicles, but do not vary according to vehicle type.

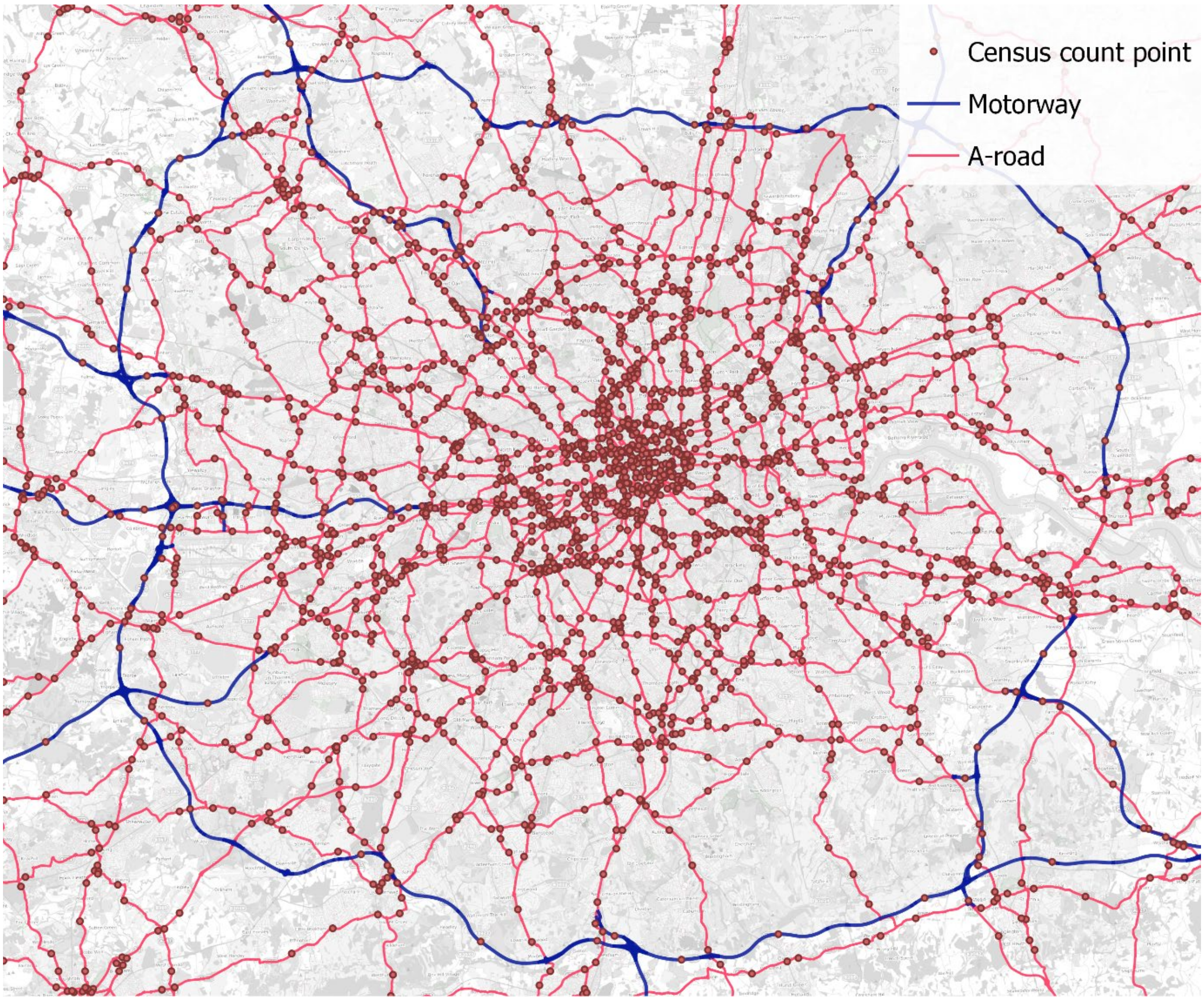
Table 11 Emission factors applied for road transport in LA CO_2 statistics

	By-source CO_2 Factor (kt CO_2 per ktoe gross)		End-user CO_2 Factor (kt CO_2 per ktoe gross)	
Year	Petrol	DERV	Petrol	DERV
2005	2.790	2.895	3.154	3.255
2006	2.788	2.897	3.128	3.232
2007	2.787	2.903	3.117	3.230
2008	2.787	2.903	3.105	3.217
2009	2.787	2.900	3.115	3.224
2010	2.787	2.903	3.122	3.234
2011	2.787	2.901	3.112	3.223
2012	2.784	2.900	3.079	3.192
2013	2.784	2.902	3.077	3.191
2014	2.784	2.901	3.073	3.187
2015	2.784	2.901	3.077	3.191
2016	2.784	2.901	3.069	3.182
2017	2.787	2.901	3.078	3.189
2018	2.790	2.901	3.078	3.187

10.2 Road transport mapping methodology

The base map of the UK road network used for calculating hot exhaust road traffic emissions has been developed from two mapping datasets. The Ordnance Survey Open Roads (OSOR) dataset (see **Figure 4**) provides locations of all roads (motorways, A-roads, B-roads and unclassified roads) in Great Britain (GB). For Northern Ireland (NI) a dataset of roads was obtained from Ordnance Survey of Northern Ireland, part of Land & Property Services Northern Ireland.

Figure 4: Illustration of OSOR road network and DfT count point data for the Greater London area.



10.2.1 Mapping traffic on major roads

Traffic flow data for major roads (A-roads and motorways) are available on a census count point basis for both GB (DfT, 2018) and NI (DfI NI, 2018). The data comprise counts of each type of vehicle as an Annual Average Daily Flow (AADF), aggregated up to annual flows by multiplying by 365. These AADF statistics take account of seasonal variation using 'expansion factors' applied to single day counts based on data from automatic counts for similar roads and vehicle types. Differences between GB and NI datasets should be noted. Coverage of roads in GB is considerably denser than that for NI. Additionally, in NI, some count points record total vehicles, rather than a split of different vehicle types. An average vehicle split has been applied to these records.

For NI, traffic counts were allocated according to the proximity of the point where the count was made and major roads with the same road number – i.e. each link has the nearest count point with the same road number assigned to it -- using a computer script.

For GB, the OSOR network is more complex than the NI road network, and count point allocation required a different approach. Here, count points were allocated to a section of the major road network according to shared road number and spatial proximity to the stretch of road that each count point covers (**Figure 5**). This was done by using a highly simplified, straight line, Department for Transport (DfT) representation of the start and end of each count points' coverage ('count point lines'). A series of computer-based processes were used to automatically perform this allocation. Where count point lines overlapped Local Authority boundaries, OSOR roads were split at that boundary and each split assigned to the relevant LA. Automated allocation was followed up with manual checking and verification.

Figure 5: Traffic flows are assigned to the road network (Ordnance Survey Open Roads) by selecting OSOR sections that fall between the start and end points of traffic census count point coverage (DfT road line).

10.2.2 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. 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 DfT.

For NI vehicle-specific minor road flows have been calculated from 2014 data (DfI NI, 2017) which provides information on vehicle kilometres travelled for vehicle types and by road types.

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

10.2.3 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 continues to be used in two aspects for the 2018 NAEI 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 (Richmond *et al.*, 2020).

10.2.4 Fuel consumption calculations

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

The urban or rural classification of a section of OSOR road covered by a count point (here called a 'count point road') was determined through the following logic:

1. Count point roads that have at least two-thirds of their DfT defined length within an urban area: classify as urban.

2. Count point roads that have at least two-thirds of their DfT defined length outside an urban area: classify as rural.

Count point roads not captured by cases 1 or 2 were split at the urban boundary and urban or rural classification of these splits were classed as urban or rural if they were within or outside an urban area. Count point roads intersecting urban areas more than twice were classed based on the majority urban or rural length of the whole road section. Splits of less than 100m were given the urban or rural classification of their counterpart, and splits of less than 15% of the total count point road length were manually inspected for validity. Each major road link has been assigned an area type using definitions of urban area types shown in **Table 12** 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 12: 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 BEIS.

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.

10.3 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.

11 Railways

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

Emissions from railways in the national inventory also include emissions from combustion of coal which have been included in DUKES. These emissions make up 2% of all railway emissions in the Local CO_2 data. The method used is described in the 'Transport – Other' section as this is where the emissions are reported.

The UK total diesel rail emissions are compiled for three journey types: freight, intercity and regional. The rail mapping methodology has been updated for the 2011 emission maps. The emissions have been spatially disaggregated using data from the Department for Transport's Rail Emissions Model (REM). This provides emission estimates for each strategic route in Great Britain for passenger and freight trains. 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. The most recent year in REM is 2009/10 and therefore the 2011 emissions for each strategic route have had to be scaled using emission totals for 2011. These were then distributed across Great Britain with the use of GIS data provided by Network Rail, containing the Strategic Routes Sections (SRS) as those have been defined in 2012 (Network Rail, 2012).

Rail emissions are distributed across Northern Ireland using data from Translink (Translink, 2012) 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.

Coal based rail emissions have been accounted for by extracting station, line and operating information from the latest version of the 'UK Heritage Railways' website[26]. This information was then verified against two additional independent UK heritage railway guides[27],[28] and dedicated webpages for specific lines. National coal based rail emissions have been proportionally allocated based on the number of days a line operated per year (consistent across all sections of a lines track). In total, 86 operational heritage lines were identified and their main station coordinates plotted. Those stations with track lengths >5 miles were mapped with the assistance of route schematics alongside the aerial imagery and OS Open Background map services provided by ESRI (Environmental Systems Research Institute). For the remaining 48 stations activity was assigned to a single 1x1km grid.

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[26] http://www.heritage-railways.com/index.php
[27] http://www.heritagerailwaysmap.co.uk/
[28] http://www.steamrailwaylines.co.uk/index.htm

12 Other Transport Emissions

Two other small sources of emissions from road traffic are included in the inventory. These are emissions from combustion of lubricants and from vehicles which run on LPG. The 'Other Transport' sector also includes emissions from inland waterways, coal combustion in the rail sector and aircraft support vehicles.

12.1 Other Road Transport Emissions

Combustion of lubricants and LPG in road vehicles use estimates of total vehicle kilometres calculated from the NAEI maps of traffic flows.

12.2 Aircraft support vehicles

The locations of airports and their air support activity were mapped for the 2012 inventory with the use of satellite imagery. The emissions were allocated to the individual airports on the basis of the number of movements of aircraft using data provided by the Civil Aviation Authority.

12.3 Coal combustion in railways

Coal based rail emissions have been accounted for by extracting station, line and operating information from the latest version of the 'UK Heritage Railways' website[29]. This information was then verified against two additional independent UK heritage railway guides[30] and dedicated webpages for specific lines. National coal based rail emissions were proportionally allocated based on the number of days a line operated per year (consistent across all sections of a lines track). In total, 86 operational heritage lines were identified, and their main station coordinates plotted. Those stations with track lengths >5 miles were mapped with the assistance of route schematics alongside the aerial imagery and OS OpenData basemap services provided by ESRI UK. For the remaining stations, activity was assigned to a single 1km grid.

12.4 Inland Waterways

Emissions from inland waterways were first included nationally in the 2010 inventory and were first included in the 2011 LA CO_2 inventory.

Details of the approach used to estimate emissions are given in the GHGI improvement programme report Walker et al. (2011). A bottom-up approach was used based on estimates of the population and usage of different types of craft and the amounts of different types of fuels consumed. Estimates of both population and usage were made for the baseline year of 2008 for each type of vessel used on canals, rivers and lakes and small commercial, service and recreational craft operating in estuaries / occasionally going to sea. For this, data were collected from stakeholders, including the British Waterways, DfT, Environment Agency, Maritime and Coastguard Agency (MCGA), and Waterways Ireland.

Sparse data were available to estimate the distribution of emissions from this sector. As a result, total emissions from the inland waterways sector were mapped using datasets of vessel activity for a limited number of Great Britain and Northern Ireland's waterways. Lock passage information for NI were provided by Waterways Ireland (Waterways Ireland, 2012) for the Shannon Erne Waterway and the five Locks on the Lower Bann Navigation as well as a geospatial dataset. Data for GB, including geospatial data, were provided by the British Waterways (British Waterways, 2012). Where data gaps were identified, additional activity data were taken from the 'Members' area of the Association of Inland Navigation Authorities website (AINA, 2012).

[29] http://www.heritage-railways.com/index.php
[30] http://www.heritagerailwaysmap.co.uk/

The activity data were used in combination with geospatial information to calculate the product of boat activity and distance. This was subsequently combined with the UK's emissions data.

13 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 conversion of land to cropland and settlements, and are removed through forest growth and conversion of cropland to grassland. Currently in the UK, LULUCF activities are a net sink resulting in the removal of emissions from the atmosphere.

Forest Research and the UK Centre for Ecology & Hydrology (UKCEH) in Edinburgh annually prepares estimates of the uptake (removal from atmosphere) of CO_2 by afforestation and net loss or gain of CO_2 from soils (emissions to or removals from the atmosphere) for inclusion in the UK GHGI. These emissions are classified as the LULUCF sector for inclusion in the UK GHGI.

The estimates are reported according to IPCC classification of sources and removals. Estimates for 2018 are shown in **Table 13**. 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 national inventory. The emissions to the atmosphere are given as positive values; the removals from the atmosphere are given as negative values.

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. Overall net removals across the UK (excluding Harvested Wood Products, which is not mapped) have increased in magnitude by 45.3% since 2005. The most significant impacts on the time-series for total net emissions are associated with the emission of carbon from cropland soil (4B) and the carbon sink grassland soil (4C). 74.3% of the total trend is accounted for by land converted to and/or remaining cropland (4B), which decreases in magnitude as a source by around 1.4% per year as soil carbon fluxes due to conversion take many decades to reach equilibrium. Land converted to and/or remaining grassland (4C) increases in magnitude as an emissions sink across the time series by an average of around 1.6% per year, accounting for 57.1% of the total trend in net emissions.

Large changes in carbon stock in forest living biomass for some local authorities, particularly in Scotland, are due to forest management. The forest carbon model assumes standard forest management practice where plantations are harvested and replanted once they reach a certain age. Many conifer plantations in Scotland were planted in the mid-20th century and are now starting to come to maturity and being harvested. This loses a large stock of living biomass in the mature trees which is replaced with a much smaller stock in the young tree.

The most significant recalculations have been made to estimates of emissions from sectors 4A, 4B, 4C and 4E which have been revised due to;

- reconciliation of harvest volume and forest age data,
- change in soil carbon density for crop management,
- revision of deforestation activity data.

Full details of the methodology used by UKCEH to estimate emissions and removals by LA for 2018 are provided in a separate document supporting this report: **Mapping Carbon Emissions & Removals for the Land Use, Land-Use Change & Forestry Sector**[31]

[31] https://www.gov.uk/government/publications/local-authority-carbon-dioxide-emissions-methodology-notes

Table 13: Emissions of CO_2 from Land-Use Change and Forestry 2018 (kt CO_2)

Category*	Activity	2018 UK total ktCO_2 emission (+) or removal (-)
4A	Forest Land	-18,360.22
4C	Grassland (soil)	-10,201.52
4B	Cropland (soil)	+10,010.96
4E	Settlement (soil)	+6,061.81
4G*	Harvested Wood Products	-2,329.82
4B1	Cropland remaining Cropland (drainage of histosols)	+1,701.88
4C2	Land converted to Grassland (deforestation to Grassland)	+532.72
4C2	Land converted to Grassland (non-forest biomass)	+460.80
4E2	Land converted to Settlement (deforestation to Settlement)	+425.30
4B1	Cropland remaining Cropland (cropland management soils)	-379.66
4D1	Wetlands remaining Wetlands	+334.99
4B2	Land converted to Cropland (non-forest biomass)	-288.57
4C1	Grassland remaining Grassland (drainage of histosols)	+176.80
4E2	Land converted to Settlements (non-forest biomass)	+67.75
4C1	Grassland remaining Grassland (grassland management biomass)	+54.88
4A1	Forest Wildfires	+29.65
4B1	Cropland remaining Cropland (cropland management biomass)	+2.31
	Total	-11,699.94

* Sector 4G (Harvested Wood Products) is not included in the LA estimates because of insufficient data for distributing the emissions and removals

14 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; and
- The proportion that each sector contributes to emissions in each LA.

Overall uncertainties in the 2018 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.

Uncertainties on LULUCF net emissions are excluded from this analysis since they are very high and would mask other variations in uncertainty. Further information on LULUCF uncertainties may be found in the separate National Inventory Report (Brown et al., 2020) and Mapping Carbon Emissions & Removals for the Land Use, Land-Use Change & Forestry Sector (UKCEH, 2020).

14.1 Uncertainty in the national sectoral GHG emissions

Uncertainty estimates for the national total GHG emissions, according to IPCC sector[32], are calculated in the UK's GHGI. This analysis is published in the UK's National Inventory Report, which is updated annually, most recently published for the 2016 inventory (Brown et al., 2020).

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 GHGI are expressed as half the difference between 2.5 and 97.5 percentiles, equivalent for normal distributions to $1.96s/E$, 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 14**.

14.2 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 local CO_2 estimates were compiled. With the exception of the BEIS data on gas and electricity, no quantitative estimates of uncertainty for the individual components exist. Therefore, numerical uncertainties have been estimated using 'expert judgment' through a process of 'expert elicitation' as described in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006b). **Table 14** 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 BEIS. They are based on the amount of the consumption that was located correctly

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

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 14** are used.

The mapping of emissions has been divided into point and area sources. In general, mapped point source data are 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[33].

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.

High uncertainties are assigned to some sectors. In particular, the combustion of coal and liquid fuels in small industry, commercial and public service sectors. 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 combined heat & power and does not attempt to correct or fill gaps in the BEIS electricity use or gas use datasets.

Table 14 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.

14.3 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.

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

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.

[33] https://www.eea.europa.eu/publications/emep-eea-guidebook-2019

Table 14: Summary of information used in uncertainty analysis and comments on data quality

Sector	Percentage of 2018 UK emissions excluding LULUCF	National emission error	Geographical Estimated error	Comment on estimated geographical error
A. Industry and Commercial Electricity	12.00%	4.2%	3%	97.7% 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	10.15%	4.5%	3%	BEIS geographical allocation for gas is good. However the BEIS definition of domestic gas consumers includes some small commercial users. But there is no numerical estimate of this uncertainty
C. Large Industrial Installations (non-EU ETS)	0.06%	7.7%	5%	Good location information for point sources but still some emissions modelled
C. Large Industrial Installations (EU ETS)	8.76%	1.0%	1%	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	4.74%	14.6%	30%	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. Agriculture	1.67%	35.9%	30%	Modelled estimates using fuel and employment distributions for stationary combustion; land-use data used to distribute liming and machinery emissions.
F. Diesel Railways	0.53%	19.3%	20%	Modelled estimates using known rail link locations. Emissions along each rail link are assumed to be uniform along the length of the rail link
G. Domestic Electricity (GB)	5.79%	4.2%	3%	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)	1.18%	4.2%	8%	Based on 92.4% of postcodes being located correctly.
H. Domestic Gas	17.09%	4.7%	3%	BEIS geographical allocation for gas is very good. However the BEIS definition of domestic gas consumers includes some small commercial users. There is a 3% difference between domestic/non-domestic categories in LA CO_2 and national inventory.
I. Domestic 'Other Fuels'	2.99%	8.8%	10%	Estimates made using complex modelling of household energy demand compared with known gas usage. New distributions of domestic fuel use has been achieved by combining very detailed spatially resolved data on central heating and house type data from the 2011 census. This provides a much better indication of where different fuels are burnt, but

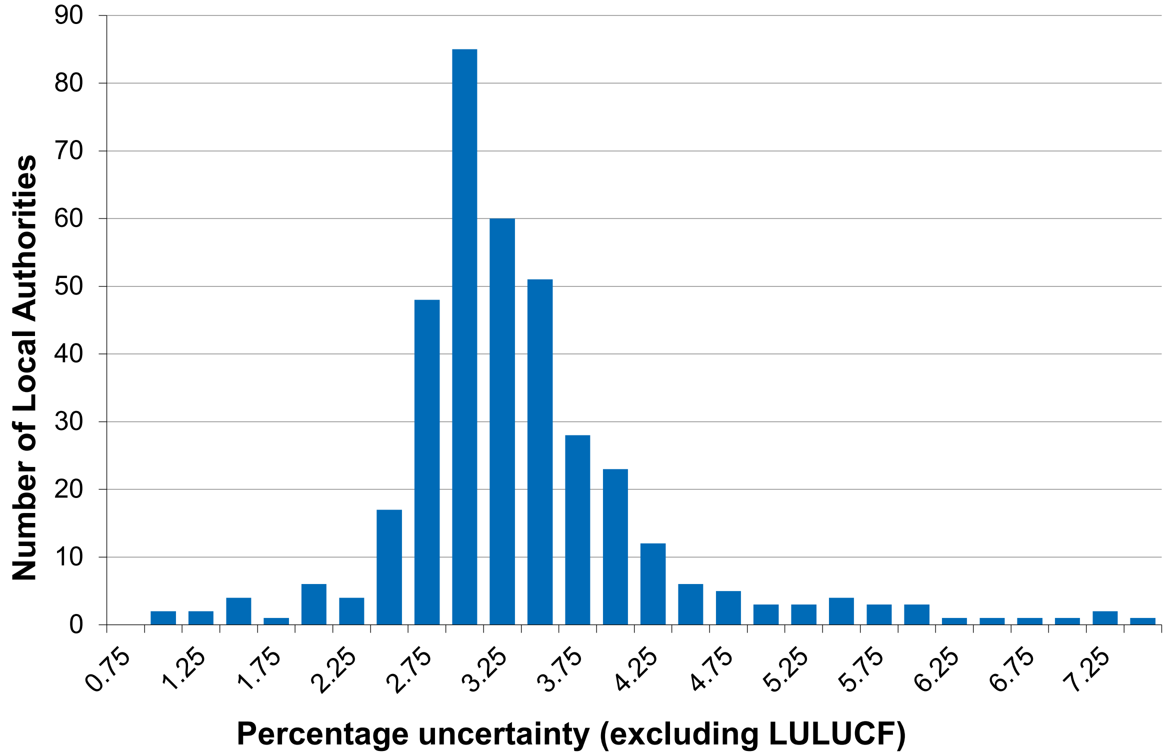
Sector	Percentage of 2018 UK emissions excluding LULUCF	National emission error	Geographical Estimated error	Comment on estimated geographical error
				still uncertain because of average regional fuel consumption data.
J. Road Transport (A roads)	15.21%	3.3%	5%	Activity data are good quality annual average traffic count points. Emissions calculated using complex modelling of fleet mix and average speeds on different roads.
K. Road Transport (Motorways)	8.40%	3.3%	5%	Activity data are good quality annual average traffic count points. Emissions calculated using complex modelling of fleet mix and average speeds on different roads.
L. Road Transport (Minor roads)	10.79%	3.3%	20%	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. Transport Other	0.63%	28.5%	30%	Locations of LPG use and burning of engine oil are not known and are therefore distributed across all road traffic activity. Aircraft support vehicle emissions based on aircraft movements out of airports. Sparse data available for distribution of emissions for inland waterways. Coal combustion from railways has been modelled using information on heritage railways, but the uncertainty remains high.

14.4 Results of the uncertainty analysis

Figure 7 shows how the errors calculated from the sum of the squares method vary across the UK. The percentage error is 3 or lower for 44% of LAs. This proportion is broadly unchanged from the assessment for 2017 carried out in 2019 but has fallen substantially over time since as emissions from the more certain sources reduce the overall uncertainty levels increase.

There were no significant revisions to uncertainty factors. Most changes to overall uncertainty have resulted from revisions to the relative contribution of sources to the emission uncertainty.

Figure 6: Uncertainty distribution



The limited spread around the mean may seem surprising given the size of some of the uncertainties in **Table 14**, 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 North Lincolnshire in Yorkshire and the Humber (±0.76%). This LA has a significant level of emissions from large EU ETS installations. The largest spread is for Orkney Islands in Scotland (±11.6%) because of the lack of gas supply, little industry and high dependence on oil and solid fuels.

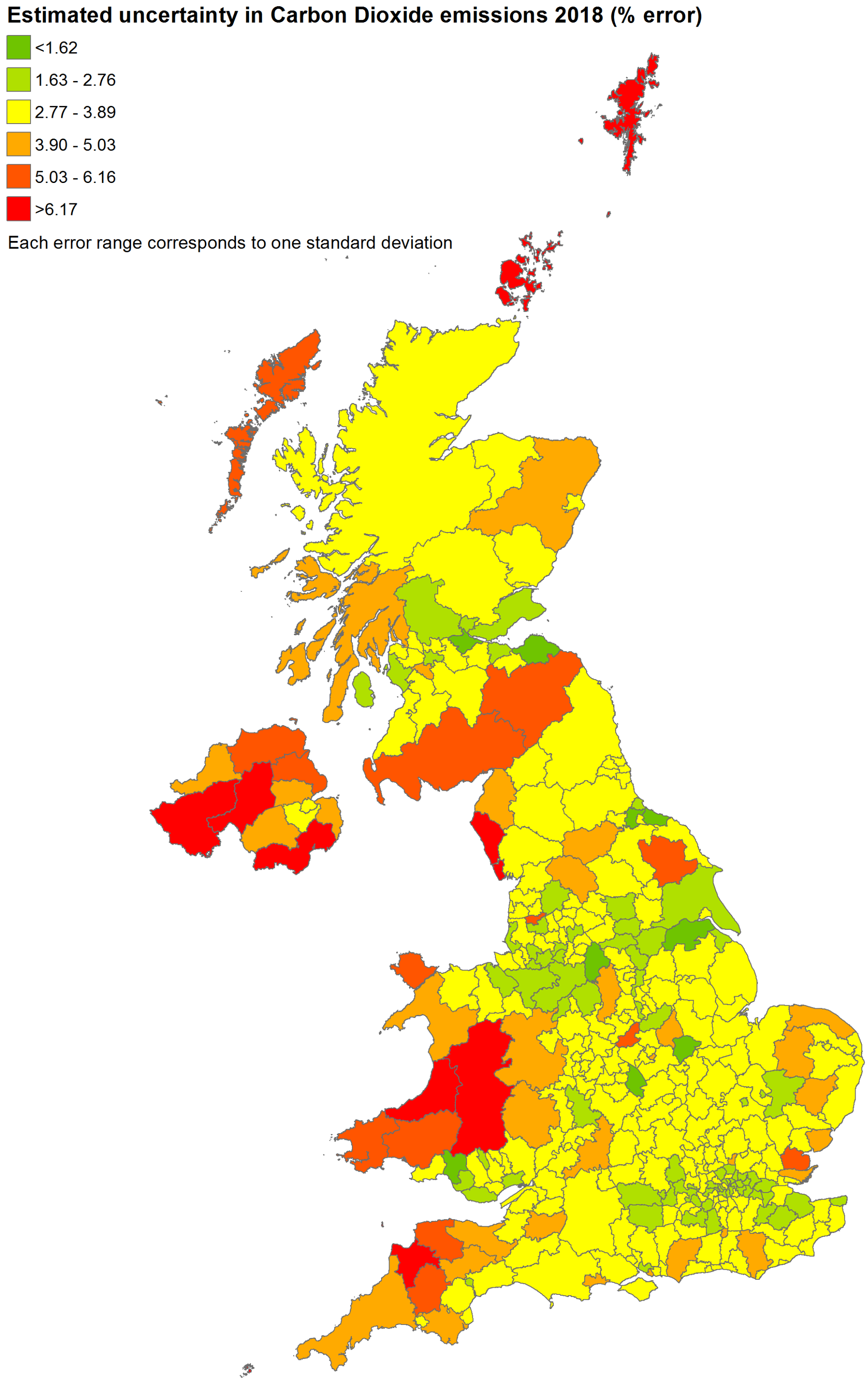
The median uncertainty across all Local Authorities, and in each of the Devolved Administrations, is presented in Table 15 below.

Table 15: Median uncertainty for all UK Local Authorities and in each Devolved Administration

	Median uncertainty	
	Excluding LULUCF	Including LULUCF
England	±3.0%	±3.2%
Scotland	±3.4%	±3.6%
Wales	±3.2%	±3.2%
Northern Ireland	±4.9%	±4.8%
UK	±3.1%	±3.2%

By comparison the National GHG Inventory uncertainty on total UK carbon dioxide emissions for 2018 was ±2.6%. In the Devolved Administration GHG Inventory, for England, Scotland, Wales and Northern Ireland, the uncertainty estimates for CO_2 were ±2%, ±12%, ±3% and ±9% respectively. In both cases these inventories include LULUCF in the estimates of uncertainty. Emissions & removals from LULUCF tend to be concentrated in a small number of LAs, so the impact of LULUCF uncertainty does not noticeably impact on the figures in **Table 15**: Median uncertainty for all UK Local Authorities and in each Devolved Administration.

Figure 7: Estimated uncertainty in the CO_2 emissions 2018 (not including LULUCF emissions)



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The Gemini Building
Fermi Avenue
Harwell
Didcot
Oxfordshire
OX11 0QR
United Kingdom

t: +44 (0)1235 753000
e: enquiry@ricardo.com