Appendix 2: Devolved Administrations' Greenhouse Gas Inventory Compilation Methods and Data Sources

This appendix describes the methodology used to derive the by source Devolved Administrations' (DA) greenhouse gas (GHG) emission estimates for each source.

Introduction

The UK Greenhouse Gas Inventory compiles national estimates of greenhouse gas emissions for submission to the UN Framework Convention on Climate Change under the requirements of the Kyoto Protocol. The most recent version of the inventory, published in April 2013, presents UK greenhouse gas emission estimates for the period 1990 to 2011 (Webb *et al*, 2013).

This report presents separate inventories of greenhouse gas emissions for England, Scotland, Wales and Northern Ireland for the years 1990, 1995 and 1998 to 2011 that are consistent with the 1990 to 2011 UK Greenhouse Gas Inventory.

The six direct greenhouse gases are considered:

- Carbon dioxide (CO_2);
- Methane (CH_4);
- Nitrous oxide (N_2O);
- Hydrofluorocarbons (HFCs);
- Perfluorocarbons (PFCs); and
- Sulphur hexafluoride (SF_6).

By source inventories allocate GHG emissions in the country that they are emitted, regardless of the end use of any fuel output or product that creates the demand for the emitting activity. The by source estimates for each DA include emissions from fuel combustion (Energy), industrial processes, agricultural practices (Agriculture), Land Use, Land Use Change and Forestry (LULUCF) and waste disposal (Waste). National totals for DAs exclude emissions from international aviation and shipping (which are presented as memo items) and of carbon dioxide from the burning of biofuels (which are considered to be renewable fuels from recently sequestered carbon). In addition, emissions of GHGs from offshore oil and gas exploration and production are classified within this report as "Unallocated" emissions and not attributed to any of the DAs.

Reporting Format

The DA GHG inventories are presented in National Communication reporting format, in order that emissions align with policy analysis requirements of the DA Governments. Within the discussion of inventory compilation methodology, source data and trends, the IPCC sector nomenclature is used, as this enables information to be presented at a much greater level of detail, aligned with specific emission sources. The mapping between National Communication and IPCC sector format reporting is summarised in the table in Appendix 5.

The UK Inventory also reports emissions from international marine and aviation bunkers separately, as memo items to the main UK inventory dataset, in line with the reporting requirements of the United Nations Framework Convention on Climate Change (UNFCCC). DA emission estimates for these international transport sources are not included within the DA totals in this report, but are available within the supporting spreadsheet tables; the estimation methodology is described in the Transport section of this Appendix.

General Approach

The UK Inventory is based on UK statistics for activities producing greenhouse gas emissions. These include fuel consumption, industrial production, agriculture, land use change and forestry and waste. In principle, it would be ideal to obtain a complete set of equivalent statistics for each constituent country to compile each inventory.

Such a set of statistics is not available for all sources and for all constituent countries and hence it is necessary to disaggregate UK emissions into the four constituent countries by an estimation procedure.

For most sources in the UK Inventory, the emission of a pollutant from a source is calculated from the general equation:

$$E = Ae \qquad \text{[Equation 1]}$$

where

E = Emission of pollutant (tonnes)
A = Activity (unit activity)
e = Emission Factor (tonnes pollutant/unit activity)

The activity unit may be fuel combustion (tonnes), or production of product (tonnes) or numbers of animals. A modified equation is used in the compilation of the Devolved Administration GHG inventories:

$$E_i = \frac{d_i Ae}{\sum_{j=1}^{5} d_j} \qquad \text{[Equation 2]}$$

where

E_i = Emission (in tonnes) from either England (1),Scotland (2), Wales (3), Northern Ireland (4) or "Unallocated" (5)
d_i = A driver representing the contribution of the region to UK emissions
i = 1, 2, 3, 4, 5

The driver, d_i can be any one of:

1. The value of the activity data for the region. [For example, consumption of specific fuels or industrial production figures for the region.];
2. The fraction of the UK activity in the region;
3. The value of a surrogate activity data statistic in the region. Where the required activity is unavailable on a regional basis, a surrogate value may be used. [For example, employment statistics or manufacturing output of a specific product, used as a surrogate for consumption data of a given fuel.]; and

4. In cases where the emissions are derived from a complex model, the driver will be the actual emission for the region calculated from the model.

The modified equation [2] ensures that the sum of the emissions from England, Scotland, Wales and Northern Ireland, plus any "unallocated" (i.e. offshore) emissions, equals the total UK emission reported within the national inventory.

Where the driver is fuel consumption, then the sum of the drivers should add up to the UK consumption. However, in practice this may not be the case if the data are taken from different sources or may be based on the financial rather than the calendar year. The estimation procedure removes such discrepancies.

Thus the compilation of the greenhouse gas inventories for the constituent countries of the UK reduces to the estimation of a set of drivers, each appropriate to emissions from a specific source. In compiling the 2011 inventories, over 230 drivers have been calculated.

Subsequent sections discuss the estimation of the drivers for each source category. Most of the detailed discussion is concentrated on the more complex categories, whilst simpler sources are summarised in Tables A2.1 to A2.10. The IPCC classification is used throughout (IPCC, 1997a), and the following section provides a description of the abbreviations used throughout the Appendix 2 discussion.

Improvements to DA Inventory Data

In the derivation of the 1990-2011 DA GHGI datasets, the inventory methods and data sources for several GHG emission source sectors have been revised and improved, including:

- ***New Source***: Recalculations in the UK GHGI for the use of Other Petroleum Gases in the industrial sector have led to increases across the times series for Other Industrial Combustion (1A2f) emissions for Scotland and England, and increases in the early part of the time series for Wales. This reflects research at UK level to identify where chemical and petrochemical sites utilise process off-gases as a combustion fuel where the carbon in the fuels is derived ultimately from petroleum feedstock that within the UK energy statistics are assumed to be applied to non-energy uses only. The inventory agency has addressed this previous under-report for a number of sites in England and Scotland that are operating, and also for a site in Wales that closed in the early 1990s. The annual estimates for these sites are based on operator-reported emission totals through EUETS and IPPC during the 2000s, back-cast across the time series using plant capacity data. Estimates for the plant in Wales were also based on plant capacity information, assuming an emissions-per-unit-production performance and plant utilisation equivalent to the other UK production plant;
- ***New Source***: Emissions from charcoal production and use within the residential sector have been added to the UK and DA inventories within the 1990-2011 compilation cycle. The DA driver to estimate the share of emissions from charcoal sources is based on the mapping grid used for domestic wood;
- ***New Source***: The estimates for gas leakage at point of use, within the residential, commercial and public sectors have been revised to include new estimates for releases of gas from cooking appliances and domestic gas fires. The DA share of these new UK estimates assumes that each DA follows the UK trend and has a similar level of leakage per unit gas consumed in the residential, public and commercial sectors;
- ***New Source***: Emissions from industrial waste water treatment have been included in the UK GHG inventory based on a new estimation method in the 1990-2011 inventory cycle. The DA

emissions from this source are estimated using the data reported by UK water companies from the waste water treatment and disposal in the municipal system;

- ***New Source***: LULUCF emissions of non-CO2 gases from drainage of organic soils and wetlands have been added to the UK and DA inventories in the 1990-2011 cycle, based on new activity data.
- EUETS data has been used to inform sector fuel allocations where EUETS data are inconsistent with UK energy statistics; specifically, gas use in the downstream gas transmission and distribution network has been increased through use of EUETS data, with an equal and opposite reduction in gas use in the unclassified other industrial combustion to compensate, maintaining the overall national gas use balance;
- Revisions to the road transport emission estimation methods, especially due to revisions to the approach for minor roads, at UK level have impacted on the DA estimates for the sector, with variable impacts that reflect the different fleet compositions and activities within the DAs. (*See the Road Transport sector methodological text later in this Appendix for details*.)
- Emission estimates from combustion, flaring, fugitive and process sources in the upstream oil and gas sector have been revised following an overhaul of UK GHG inventory estimates to address outlier emission factors and reconcile data from DUKES with the EEMS dataset. Research to align energy use against emissions data and consultation with the DECC DUKES team identified under-reports in the UK activity data for the sector from 1990-2001 (natural gas use) and for 2003 onwards (LPG, OPG use in terminals). These have been revised and updated to use EEMS and EUETS data, leading to a much more realistic time series of implied emission factors for the combustion and flaring of gaseous fuels used in this sector. The UK and DA inventory time series have therefore been revised, with the DA methods revised for several sources in the early part of the time series, where the operator-reported data from 1998 is now regarded as a better indicator of the share of DA activity for earlier years. In addition, there have been re-allocations between “upstream oil” and “upstream gas” to correct previous allocations for a couple of installations, although these only impact upon the offshore (i.e. unallocated) inventory estimates. Gap-filling for process and fugitive sources has in some cases led to small increases in the DA inventories within the time series, predominantly leading to higher methane and VOC emission estimates in some years.
- Industrial combustion emissions from fuel oil and waste oils have been revised for 2009-10 to correct a mis-allocation in the inventory agency point source database. This correction slightly increases the allocation of industrial emissions in Northern Ireland in those years;
- Methane emissions from deep coal mines have been revised for recent years within the UK GHG inventory, and these revised data are reflected in the 1990-2011 DA GHGI estimates;
- For those sources where population data are used as the driver to estimate the DA share of UK emissions (including several F-gases sources), the ONS has revised its population statistics from 2002 onwards, leading to small revisions in DA emission estimates.
- Primary Aluminium emission estimates for 2010 have been revised, as within the UK GHG inventory there was a correction to previous assumptions about the share of production in light of the closure of the Anglesey Aluminium plant during 2010. It was assumed that some production continued at that site into 2010, but this was incorrect; further research indicated that Pollution Inventory emissions reported for 2010 were evidently for ancillary processes covered in other source categories, so these primary aluminium estimates have been removed from the Wales 2010 inventory, to remove a small double-count.
- Emissions from agricultural soils have been revised across all DAs due to updates to historical crop area data based on new information from Defra, DARDNI and Welsh Government. Furthermore, the area of cultivated histosols has been corrected to align with the value reported in the LULUCF inventory.
- In the derivation of emission estimates from livestock enteric fermentation and waste management, a number of revisions have been implemented in the UK and DA GHG inventory

this year including: update of cattle ash value to use IPCC default, revision to feed digestibility percentages, revised assumptions regarding the life-span of lambs and the applicable emission factors for enteric fermentation, waste management and N excretion rates from lambs and ewes.

- Revisions to deforestation and wildfire activity data and method improvements to apply country-specific biomass densities to analysis for sources in 5B, 5C and 5E have led to revisions of the LULUCF inventories for each DA.
- New emissions data from water companies led to a revision of the default methane emission factors for waste water treatment, sludge treatment and disposal of sewage sludge to land. The main impact of these revisions is an increase in (UK-wide) methane estimates in source 6B1 in the early part of the time series. The increase affects the DAs to a differing degree based on the DA-specific activity data for sludge treatment and disposal fate.

Data recalculations within the latest DA GHG inventories are summarised in Appendix 6, with detailed estimation methods presented in this appendix. Where EU ETS data have been used to improve the emission estimates for high emitting source sectors such as power stations, refineries, cement kilns and other industrial combustion sources, the details are provided within Annex 11 of the National Inventory Report 2013 (Webb *et al*, 2013).

Summary of Abbreviations

AEAT	AEA Technology plc
BCA	British Cement Association
BERR	Department for Business Enterprise & Regulatory Reform
BGlass	British Glass
CA	Coal Authority
CAA	Civil Aviation Authority
DAs	Devolved Administrations
DARD	Department of Agriculture and Rural Development (Northern Ireland)
DTI	Department of Trade and Industry (now DECC)
DfT	Department for Transport
DECC	Department for Energy and Climate Change
DEFRA	Department for Environment, Food and Rural Affairs
DETI	Department of Enterprise, Trade and Investment (Northern Ireland)
DETR	Department of Environment, Transport & the Regions
DFPNI	Department of Finance and Personnel, Northern Ireland
DLTR	Department for Local Government, Transport and the Regions
E	England
EA	The Environment Agency of England & Wales
EAF	Electric Arc Furnace
EM	Enviros March
EPER	European Pollutant Emissions Register
EUETS	EU Emission Trading Scheme
IPCC	Intergovernmental Panel on Climate Change
ISR	Inventory of Statutory Releases (NI DoE)
ISSB	Iron and Steel Statistics Bureau
LPG	Liquefied petroleum gas
LRC	London Research Centre
MAFF	Ministry of Agriculture, Fisheries and Food (now DEFRA)
MPA	Mineral Products Association
MSW	Municipal Solid Waste
NA	Not Available
NAEI	National Atmospheric Emissions Inventory
NI DoE	Northern Ireland Department of Environment
NIEA	Northern Ireland Environment Agency
NIO	Northern Ireland Office
NO	Not occurring
OFMDFM	Office of the First Minister and the Deputy First Minister (Northern Ireland)
ONS	Office for National Statistics
OPG	Other petroleum gas
PI	Pollution Inventory of the Environment Agency of England & Wales
S	Scotland
SEPA	The Scottish Environment Protection Agency
SPRI	Scottish Pollution Release Inventory
SSF	Solid smokeless fuel
UKOOA	UK Offshore Operators Association, now called “Oil & Gas UK”
UKPIA	United Kingdom Petroleum Industry Association
WO	Welsh Office
WS	Welsh Statistics

Energy Industries

The drivers used for the energy industries are summarised in Table A2.2. This shows the base sources used in the National Atmospheric Emissions Inventory (NAEI) database, which correspond to the IPCC sources. The activity data used in the UK Inventory are shown together with the drivers used in the inventories for the constituent countries for 1990, 1995 and 1998 to 2011. The derivation of drivers sometimes differs between years depending on data availability.

Electricity Production

Emissions are based on fuel consumption data provided by the major power generators in Great Britain and the Northern Ireland Office for 1990 to 1999: Scottish Power (2004), Scottish and Southern Energy (2004), Innogy (2004), PowerTech (2004), AES Drax (2004). From 2000 onwards, emissions data from the Pollution Inventory (Environment Agency, 2012a) the Scottish Pollution Release Inventory (SEPA, 2012a) and the Inventory of Statutory Releases (Northern Ireland Environment Agency, 2012a) has been used to estimate DA emissions. For emissions in 2005 onwards, fuel use and emissions data reported within the EUETS (Environment Agency, 2012b; SEPA, 2012b; Northern Ireland Environment Agency, 2012b) have been used to revise and update the annual fuel emission factors that are applied within the UK GHGI, and the DA GHGI. The emissions data reported via the EUETS are used to estimate DA share of UK emissions, whilst maintaining the emission totals consistent with the UK GHGI data. Country-specific electricity generation data (DECC, 2012b) are then used as a comparator against reported emissions, as a quality check for the power station emissions data.

Emissions from plant generating electricity from municipal solid waste combustion are less certain for pre-1999, but all the plant are known to be in England for 1990-98 and so the emissions will correspond to the UK emissions. Since 1999, two plants have been commissioned in Scotland, at Lerwick and Dundee and emissions estimations are based on emissions data reported to SEPA. In the 1990-2011 inventory, the fossil carbon content of MSW has been revised by new research into trends in MSW composition by Defra, and the revised factor now better represents the waste composition and the impacts of recycling and recovery waste management policies across the UK.

A small number of plants generate heat rather than electricity; some of these generating plant burn poultry litter, or meat and bone meal, and these are all located in England. The distribution of landfill gas and sewage gas generation is assumed to correspond to the distribution of landfill sites and sewage treatment plant.

Table A2.2a: Energy Industries (Base Year – 1990)

IPCC Category	NAEI Sources	Activity: Fuel Consumption	Data used for deriving DA estimates from UK totals / Comments
Electricity Production	Power Stations	Coal, oil, natural gas	Consumption data from Power Generators
		Unrefined natural gas	NO
		Sewage gas	Sewage methane recovered
		Landfill gas	As landfill methane
		Orimulsion, MSW, poultry litter and tyres	All plant in England
Petroleum Refining	Refineries	All fuels	UKPIA CO_2 emission estimates for pre-1997
Manufacture of Solid Fuels	Coke Production	Colliery Methane	All such plant assumed to be in England
		Coke Oven gas, natural gas	Coal feed to coke ovens, ISSB, WS, DTI
		Coke	Coke breeze consumption, ISSB
		Blast Furnace gas	Coke consumed in blast furnaces, ISSB
	SSF Production	All fuels	Coal feed to SSF plant, DTI, WS
Other Energy Industries	Collieries	All other fuels	Deep mined coal production, data from British Coal Authority
		Coke oven gas	All such plant assumed to be in England
	Gas Production	Colliery methane	Deep mined coal production, data from British Coal Authority
		LPG and Natural gas	DA share of aggregate data from EUETS installations for natural gas use from 2005
	Upstream oil and gas / Gas Separation Plant	Unrefined natural gas, LPG, OPG	Estimates for terminals extrapolated from operator estimates within EEMS data in 1998
	Nuclear	natural gas	All plant in England

Table A2.2b: Energy Industries (1995; 1998 to 2011)

IPCC Category	NAEI Sources	Activity: Fuel Consumption	Data used for deriving DA estimates from UK totals / Comments
Electricity Production	Power Stations	Coal, oil, natural gas	Emissions data and fuel consumption data from Power Generators; PI, EPER & ISR data from 2000 onwards; EUETS data from 2005 onwards.
		Unrefined natural gas	Some power facilities have used this fuel since 1995. Data provided by plant operators.
		Sewage gas	Sewage methane recovered
		Landfill gas	As landfill methane
		Orimulsion, MSW, poultry litter	From 1999, some MSW plant now also in Scotland.
Petroleum Refining	Refineries	All fuels	UKPIA CO_2 emission estimates for pre-1997. Pollution Inventory CO_2 emission estimates for 1998. UKPIA data for 1999 onwards. EUETS data from 2008 onwards. Deviations from DUKES fuel use allocations have been made for petroleum coke and Other Petroleum Gases (OPG), using EUETS activity data instead.
Manufacture of Solid Fuels	Coke Production	Colliery Methane	All such plant assumed to be in England.
		Coke oven gas	Coal feed to coke ovens, ISSB, WS, DTI and (since 1999) PI data. 2005 onwards: EUETS, CCA and PI data analysis
		Natural gas	Coal feed to coke ovens, ISSB, WS, DTI and (since 1999) PI data
		Coke	Coke breeze consumption, ISSB.
		Blast Furnace gas	Coke Consumed in Blast Furnaces, ISSB. 2005 onwards: EUETS, CCA and PI data analysis
	SSF Production	All fuels	Coal feed to SSF plant, DECC, WS.
Other Energy Industries	Collieries	All other fuels	Deep mined coal production, data from British Coal Authority.
		Coke oven gas	(1995 – current) No such plant operating.
	Gas Production	Colliery methane	Deep mined coal production, data from British Coal Authority.
		LPG and Natural gas	EUETS installation data for natural gas use from 2005-2011. All other years estimated based on the aggregate DA share from the 2005 EUETS data.
	Upstream oil and gas	Unrefined natural gas, LPG, OPG	(1995 – current) Oil & Gas UK EEMS CO_2 estimates for terminals, DECC activity data. EUETS data for terminals.
	Nuclear	Natural gas	(1995 – current) Data not available.

Petroleum Refining

UKPIA have provided a site-by-site breakdown of UK refining emissions for 1997 and 1999 – 2011 (UKPIA, 2012), presenting the emissions of a range of pollutants from combustion, process and fugitive sources. In addition, UKPIA have advised that refinery throughput did not vary significantly between 1990 and 1997. The EUETS data also provides (from 2008 onwards) a comprehensive scope of refinery emissions broken down by process and fuel, and these data are used to derive emission factors for fuel oil, natural gas and other petroleum gases (OPG) use in refineries within the UK and DA GHG inventories.

In the 1990-2011 GHG inventory, the activity data reported in the EUETS (EA, 2012b) for petroleum coke and other petroleum gases (OPG) use in refineries has been used in preference to activity data reported in DUKES. Small revisions to 2010 allocations for two sites (Grangemouth and North Tees) were made based on confirmation of PI/SPRI data for emissions not included in EUETS. Emissions for 1998 are based on carbon dioxide emissions reported in the Pollution Inventory (EA: 1999a).

Manufacture of Solid Fuels

This category comprises the production of coke and solid smokeless fuel (SSF). Country-specific data on coke ovens in the iron and steel industry are reported in detail by ISSB (2012), and emissions data for integrated steel works are reported via the PI and EUETS (Environment Agency, 2012b). Two coke ovens in England and Wales are not attached to an integrated iron and steel facility, and the consumption of coal by these ovens is estimated from WO (1998) and UK data (DECC: 1991, 2000-2012). The Welsh statistics are only available to 1993, so these data are used as an estimate of the Welsh non-iron and steel coking coal consumption in 1995. For 1998 to 2011, the non-iron and steel coking coal consumption data is apportioned between England and Wales using carbon dioxide emissions for the particular sites reported in the Pollution Inventory (EA: 2012a) and EUETS (EA: 2012b).

The generic driver for coke oven fuel consumption is the regional consumption of coking coal (ISSB, 2012). This driver is also used for natural gas consumption through the time series and coke oven gas consumption until 2004, and from 2005 data on coke oven gas emissions from the EUETS are used (EA, 2012b). Some coke ovens use blast furnace gas as fuel and the availability depends on blast furnace gas capacity (see Industrial Processes); emissions from blast furnace gas use are apportioned across DAs using regional data on coke consumption in blast furnaces (ISSB, 2012) until 2004 and from 2005 data on BFG emissions from the EUETS (EA, 2012b).Small amounts of colliery methane are consumed in the manufacture of solid fuels and this was judged to occur entirely in England where coking occurs in close proximity to deep mining. Small amounts of coke breeze are also used, and this has been disaggregated using data on other coke consumption from ISSB.

The estimation of emissions from SSF production is rather uncertain, as limited fuel use data are available from processes across the UK. Moreover, many of these are the new briquetting processes rather than coking processes and produce negligible emissions. For SSF plant operating in England and Wales, it is possible to estimate regional consumption using UK data (DECC, 2012a) and Welsh data (WO, 1998). Welsh data for 1995 has been estimated, whilst all SSF coking plant still operating since 1998 are known to be in England. Thus the driver used is coal consumed by SSF plant.

Other Energy Industries

This category consists of a number of small emissions from collieries, the gas industry, the nuclear fuel industry and emissions from the upstream oil and gas exploration and production sector which comprises offshore rigs and vessels as well as onshore terminals. In the DA inventories, emissions from oil and gas terminals and offshore rigs and vessels are based on data provided by DECC (2012e). Installation-specific data are only available for post-1995, and until 1998 these data are incomplete and inconsistent across the time series, so are disregarded. Emissions for 1990 are extrapolated based on 1998 operator-reported data; previous use of data from the mid-1990s has now been disregarded, due to new research in the UK GHGI to address outlier implied emission factors for combustion and flaring of gaseous fuels. Emissions from gas separation plant are from combustion of process off-gases (mainly ethane) in terminals, which are reported by facility operators within emission estimates under EEMS (DECC 2012e); the emission factor for these emissions has been revised to reflect that the "OPG" in these terminals is predominantly ethane rather than the mixture of gases derived from refineries that is also known as "OPG". Data on LPG and OPG use at oil and gas terminals is reported within EUETS (SEPA 2012b and EA 2012b) and these data are used to directly inform the DA GHGI estimates from 2005 onwards, with the DA split for earlier years is extrapolated back from EUETS data.

Emissions from gas combustion at installations linked to the gas supply network comprise activities at compressor stations, LNG terminals and other above ground installations. The UK GHGI estimates were previously based on the sector natural gas allocation in DUKES. However, a large number of the larger sites (compressor sites, LNG terminals) report their fuel use and emissions to the EUETS. Since 2008, the reported fuel use and emissions from these large sites in EUETS exceeds that reported within DUKES and the UK GHGI, indicating that there is a small gas mis-allocation within DUKES. Therefore in the 1990-2011 UK GHGI, the gas use data from EUETS have been used to estimate the UK sector emissions, and the DA split has been derived directly from the data in EUETS (EA 2012b, SEPA 2012b); to retain the overall natural gas use energy balance for the UK, an equal and opposite reduction in gas use in "unclassified industry" (which is reported within IPCC 1A2f) was applied. The EUETS data are used for each year from 2005 onwards. For 1990-2004, the DA share of the gas use is estimated based on the 2005 EUETS totals. These estimates are uncertain: the UK data are an under-report; the EUETS data only cover the larger sites on the network and may not be representative of the overall DA split of activity; the 1990-2004 data are extrapolated from more recent data, assuming that the DA trends follow the UK-wide trend.

Other sources are minor and are covered in Table A2.2.

Manufacturing Industries and Construction

The drivers used to estimate DA-specific fuel consumption from these sectors are summarised in Table A2.3.

Iron and Steel

The ISSB (2012) provides annual report of detailed regional consumption of fuel by the steel industry and these data are used to inform regional iron and steel sector consumption of fuels such as natural gas which is used across many of the smaller production sites in the UK. Access to the detailed data for the steel sector from the Climate Change Agreement reporting system (Personal Communication:

Hodges, 2012), has provided clarifications on fuel use and site allocations within the Ricardo-AEA point source dataset, to complement the EUETS dataset (EA, 2012b) which provides details for the highest-emitting sources in the iron and steel sector including the integrated steelworks.

Energy use and emissions data for the integrated steelworks has been used to derive the DA estimates from 2005 onwards for the combustion of coke, blast furnace gas and coke oven gas in blast furnaces, sinter plant, iron and steel combustion plant and in iron and steel flaring sources. Prior to 2005, the ISSB regional energy statistics are used for those sources and fuels.

The consumption of coke by sinter plant is estimated as the non-blast furnace coke consumption (as this is the main other use of coke). The consumption of coke oven gas is distributed as proportional to ISSB regional figures for coal feed to coke ovens, whilst the consumption of blast furnace gas is distributed as proportional to ISSB regional figures for coke feed to blast furnaces. (The production of these gases is estimated to be proportional to the fuel used as feedstock.)

The ISSB reports the general consumption of coal, fuel oil, gas oil, LPG and natural gas by the primary iron and steel industry. This is a narrower definition than that used by DECC, which includes foundries and finishing plant, and therefore the DECC data used in the UK GHGI is higher than the ISSB data. Nevertheless, the regional ISSB data is used as a surrogate, since the distribution of the wider steel industry is directly linked to that of the primary industry, and the emissions from the secondary plant are considerably lower than the primary plant.

Other Industry

DECC sub-national energy use data (DECC, 2012b), are based on local electricity and gas consumption patterns, as part of a project to develop Local Authority carbon dioxide emissions data. These statistics use local electricity and gas use data from the National Grid and the gas supply network operators (formerly Transco). Solid and liquid fuel use is calculated using point source consumption data (for major industrial sites), and a complex modelling process to distribute remaining UK fuel allocations that uses employment and population data, and takes account of smoke control zones and the patterns of gas and electricity consumption.

Table A2.3a: Manufacturing Industry and Construction (Base Year – 1990)

IPCC Category	NAEI Sources	Activity: Fuel Consumption	Data used for deriving DA estimates from UK totals / Comments
Iron & Steel	Sinter Plant	Coke-breeze	Other coke consumption, ISSB
	Iron & Steel	Blast furnace gas	Coke consumed in blast furnaces, ISSB, WO
		Coke oven gas	Coal feed to coke ovens, ISSB, WS
		Coke	Coke consumed in blast furnaces, ISSB, WO
		Other fuels	Regional fuel use data (ISSB): fuel oil, gas oil, LPG, coal, natural gas.
Other Industrial combustion	Non-ferrous metals	All fuels	Emissions analysis for 2011: Pollution Inventory (EA, SEPA, NIEA 2012a), EUETS (EA, SEPA, NIEA 2012b) IDBR and employment data (ONS, 2011). Overall analysis of the 1A2b,c,d,e and f sectors used to constrain the DA totals to previous 1A2 DA estimates, using 1A2f Other Industry as residual.
	Chemicals	All fuels	
	Paper and Pulp	All fuels	
	Food and drink	All fuels	
	Other Industry	All oils	Sub-national oil consumption, DECC
		OPG	Petrochemical plant capacity, emissions per unit capacity on site-specific data from PI/SPRI data, applying UK average to Welsh estimates.
		LPG	Sub-national energy statistics, DECC
		Lubricants	Sub-national energy data, DECC, less estimate of road transport use.
		Natural gas	Natural gas consumed, data from Transco
		Colliery Methane	Deep mined coal production, British Coal Authority
		Coal, coke	Sub-national energy statistics, DECC
		Coke oven gas	Coal feed to coke ovens, ISSB, WO, WS
		SSF	Sub-national energy statistics, DECC
		Wood	GDP data.
	Cement	Coal, oil, gas, petrocoke, tyres, waste oil	Regional cement capacity, BCA
	Ammonia (combustion)	Natural Gas	All such plant are located in England
	Autogenerators	Coal	All such plant are located in England
		Natural gas	(Data sources exactly as per “Other Industry” above)
	Other-Industry: Off-road	Gas oil, petrol	Industrial employment data (ONS)

Table A2.3b: Manufacturing Industry and Construction (1995; 1998 to 2011)

IPCC Category	NAEI Sources	Activity: Fuel Consumption	Data used for deriving DA estimates from UK totals / Comments
Iron & Steel	Sinter Plant	Coke-breeze	To 2004: Other coke consumption, ISSB. 2005 onwards: EUETS data
	Iron & Steel	Blast furnace gas	To 2004: Coke use in blast furnaces, ISSB, WO. 2005 onwards: EUETS data
		Coke oven gas	To 2004: Coal feed to coke ovens, ISSB, WS. 2005 onwards: EUETS data
		Coke	To 2004: Coke use in blast furnaces, ISSB, WO. 2005 onwards: EUETS data
		Other fuels	Regional fuel use data (ISSB): fuel oil, gas oil, LPG, coal, natural gas.
Other Industrial combustion	Non-ferrous metals	All fuels	Emissions analysis for 2011: Pollution Inventory (EA, SEPA, NIEA 2012a), EUETS (EA, SEPA, NIEA 2012b) IDBR and employment data (ONS, 2011). Overall analysis of the 1A2b,c,d,e and f sectors used to constrain the DA totals to previous 1A2 DA estimates, using 1A2f Other Industry as residual.
	Chemicals	All fuels	
	Paper and Pulp	All fuels	
	Food and drink	All fuels	
	Other Industry	All oils	Sub-national oil consumption, DECC
		OPG	Petrochemical plant emissions from PI/SPRI and EUETS. DECC data on Natural Gas Liquid deliveries used to interpolate where no emissions data.
		LPG	Sub-national energy statistics, DECC
		Lubricants	Sub-national energy data, DECC, less estimate of road transport use.
		Natural gas	Natural gas consumed, data from Transco (now UK National Grid) & (since 1995) from Phoenix Gas (NI). Sub-national energy statistics (DECC) and Ricardo-AEA point source data, analysed to minimise double-counting.
		Colliery Methane	Deep mined coal production, British Coal Authority
		Coal, coke	Sub-national energy statistics, DECC; Coal consumption, WO, NIO
		Coke oven gas	Coal feed to coke ovens, ISSB, WO, WS
		SSF	Sub-national energy statistics, DECC
		Wood	GDP data.
	Cement	All fuels	Regional cement capacity, BCA; For 2002 onwards, based on emissions reported to the EUETS, PI, SPRI and ISR (EA, NIEA and SEPA).
	Ammonia (combustion)	Natural Gas	All such plant are located in England
	Autogenerators	Coal	All such plant are located in England
		Natural gas	(Data sources exactly as per “Other Industry” above)
	Other-Industry: Off-road	Gas oil, petrol	Industrial employment data. (ONS)

The DECC sub-national energy statistics are revised and improved each year through targeted sector research aimed at reducing uncertainties in the modelling approach, and are now National Statistics. Previously the regional fuel use in these sectors has been developed using a complex balance approach based on limited source data. The lack of consistent and comprehensive fuel use or fuel sales data from across the DAs (especially for solid and liquid fuels) leads to significant potential errors in the distribution of UK fuel use across the regions. Expert judgement and proxy data are used to address data gaps and inconsistencies in DA energy use data over the time series; the DA emission estimates for earlier years in the inventory time series and the reported inventory trends are associated with higher uncertainty than the data and trends reported in the UK GHG inventory, due to the lack of detailed DA energy balance data.

The DECC sub-national energy statistics are used to derive estimates for industry sector combustion of fuels such as fuel oil, gas oil and coal. These data are based predominantly on analysis of available point source data, supplemented by production and employment surveys. Several industry sectors are now 100% covered under EUETS, such as the cement sector, and hence uncertainties in the DA GHGI estimates are much lower than previously for such sources. To supplement EUETS data, additional information from other pollution inventories (PI, SPRI, ISR) are used to improve the accuracy of the allocation of industrial combustion sources. To reduce the risk of double-counting emissions, the mapping of area sources has been revised to remove the proxy data (i.e. employment or production indices) associated with those major point sources that can be accurately allocated. The revision of mapping grids for the area sources is conducted periodically as part of the NAEI work programme, with the industry data typically revised every 3-4 years. In 2011, new analysis was conducted to revise the grids for the emissions in year 2010, and these data are retained in the latest DA GHG inventory. This revision to the DA estimates for industry sectors enables a more accurate representation of the emissions in recent years following the recession, compared to the data presented in the 1990-2009 DA GHGI report which was based on area source analysis for the year 2006. Furthermore in the 2010 mapping update, the industry sector was analysed at a greater level of detail to enable DA-specific estimates to be derived for the non-ferrous metal (1A2b), chemicals (1A2c), paper and pulp (1A2d) and food, drink and tobacco (1A2e) sectors.

Note that the sub-national energy statistics have only been produced by DECC since 2003, and complete data (i.e. all fuels) are only available up to 2010, with gas and electricity data available up to 2011 within the DECC publication *Energy Trends December 2012* (DECC 2012b). The sub-national data are used to extrapolate estimates back across the time-series (assuming UK trends across all DAs) in many instances where more detailed data for the earlier years is absent. Hence the emission estimates & trends from solid and liquid fuels within the industrial combustion categories remain amongst the more uncertain estimates within the DA inventories, due to uncertainties from the modelling approach to derive the source activity data and the back-casting of emission estimates for the earlier years.

Liquid Petroleum Gas (LPG) has a number of uses, primarily in sectors such as domestic use and the growing sector of LPG use in road transport applications. Industrial use of LPG has been disaggregated based on DECC sub-national energy statistics (DECC, 2012b) for recent years, maintaining the mass balance approach for the earlier years where complete data are available.

The driver for emissions from lubricant use is based on regional lubricant sales (DECC, 2012a) with England and Wales being disaggregated based on regional manufacturing employment statistics (ONS, 2012a).

DECC (2012c) provides data on natural gas sales to consumers categorised by consumer size and region in Great Britain, excluding consumption by large industrial users and power generators. Consumption data for gas use in Northern Ireland is supplied by Phoenix Natural Gas Ltd (2012) for 1999 onwards, Firmus Energy (2012) and Vayu Ltd. (2012). These data sources are used to assess the overall gas use data for each country. Note however, that the DECC data are incomplete due to issues of commercial confidentiality for several large gas using sites, and a series of assumptions are made to estimate the gas use at these "missing" sites. Furthermore, the local authority gas use estimates do not cover a calendar year and are weather-corrected and are therefore not directly consistent with the annual fuel use data by sector that are reported in DUKES, which are used to underpin the UK and DA GHG inventory emission estimates from gas combustion. The overall gas use data for each country are uncertain as a result of these scope and reporting limitations.

The gas use within each economic sub-sector at country-level is then analysed based on the available data from the DECC sub-national energy statistics, supplemented by estimates of major point source gas use derived from analysis of the EUETS and pollution inventory emissions data. Similar to the approach adopted for gas oil, fuel oil and coal, the analysis of point source data enables greater direct allocation of gas use to industry or commercial sectors, reducing allocation uncertainties. Note that the driver determined for "other industry" is also used for "autogenerators". In Northern Ireland, supplementary information from gas suppliers provides a slightly more detailed breakdown of gas use by end-user sector, and this has been used to revise the allocations between industrial and commercial sectors across recent years.

Drivers for fuel consumption in cement kilns are based on annual regional clinker capacity data for 1990, 1995, 1998-2001 supplied by the British Cement Association (BCA: 2004). These are applied to all fuels, with a correction factor applied to Northern Ireland to account for the absence of natural gas. Where the UK estimate of fuel consumed in cement kilns has been revised for a given year, the regional consumptions have also been revised. From 2002 onwards the emissions data reported to the PI, SPRI and ISR are used to disaggregate UK emissions (EA: 2009a, SEPA: 2009a, NIDoE: 2009a), until 2008 where the EUETS Phase II reporting scope covers all UK cement kiln sites. For 2008 to 2011 therefore, the EUETS data (EA: 2012b, SEPA: 2012b, NIEA: 2012b) are used to derive the DA estimates, in order that local fuel use patterns and emission factors are fully reflected within the DA inventory data, and to maintain consistency between the EUETS and DA GHGI.

"Autogeneration" refers to electricity generation by industry for its own use. In the case of coal, the key autogenerators are Alcan and Brunner Mond, both of which are located in England. Gas autogeneration is distributed according to the other natural gas "other industry" driver.

Transport

The drivers used for transport are summarised in Table A2.4.

Aviation

The disaggregation of the domestic aviation emissions uses a database of aircraft movement data from the Civil Aviation Authority, also used in the compilation of the UK GHG inventory.

The CAA database includes details of individual flights (airport origin, destination, fuel type, plane type, engine type), covering both domestic and international flights. Only domestic UK flights are included in the core DA GHG inventory data, as the DA inventory is aligned with the territorial coverage of the UK statistical release, which excludes international aviation and flights to Crown Dependencies, Overseas Territories and Gibraltar; however, for the purposes of reporting data to match the scope of Scottish Government GHG mitigation targets, estimates of the DA share of these international flights are also made using the same method, i.e. allocating emissions from flights to the DA of flight origin, using the CAA database. For England, Wales and Northern Ireland, these data are retained merely as memo items, accounted separately from the by source inventory totals.

Estimates of emissions from take-off and landing cycles and aircraft cruise have been calculated. The protocol adopted for disaggregating emissions across DAs is to assign all emissions from a flight to the DA of flight origin. In the 1990-2011 DA inventories, the method for disaggregating the flights to Crown Dependencies, Overseas Territories and Gibraltar has been improved to take proper account of available information on flights to these destinations rather than merging the analysis with the UK-international flight data. This has an almost negligible impact on all of the DA aviation estimates, but removes inconsistencies where it is known that there are no direct flight routes between, for example, Scotland and Gibraltar.

Details of the aviation methodology can be found in the NIR. The driver for emissions from aircraft support vehicles is calculated based on aircraft movement data from the UK's major airports (CAA, 2012). Emission estimates for both domestic and international aviation are constrained at UK level by the fuel use data reported within the annual publication of DUKES. Annual aviation fuel sales in the UK therefore define the overall aviation emissions, in accordance with UNFCCC, UNECE and IPCC inventory guidance.

The DA emission estimates for domestic and international aviation are associated with low uncertainty; the emission estimates are based on a database of UK flight movements and detailed calculations of emissions from different phases of flights (take off, cruise, landing cycles).

Navigation

Emissions from navigation (coastal shipping and fishing) are based on emission estimates within the UK GHGI that do not use the shipping fuel use data reported within DUKES (DECC 2012a), but instead uses data from a research study by AMEC (formerly Entec) under contract to Defra. The study calculated fuel consumption and emissions from shipping activities around UK waters using a bottom-up procedure based on detailed shipping movement data for different vessel types, fuels and journeys (Entec, 2010). The total fuel delivery statistics given in DUKES (marine bunker plus national navigation) are believed to be an accurate representation of the amount of fuel made available for marine consumption, but there is more uncertainty in the ultimate distribution and use of the fuels for domestic and international shipping consumption and hence the AMEC study data are used.

The overall approach can be summarised as follows:

- Fuel consumption and emissions for domestic journeys are taken from the AMEC study based on detailed movement data for 2007 in which AMEC provided an uplift to their bottom-up estimates to take account of missing vessel movements ;
- Fuel consumption and emissions for fishing vessels are taken from the AMEC study and reported separately under 1A4ciii;
- Estimates for domestic coastal shipping fuel consumption and emissions back-cast to 1990 and forecast to 2011 are used, which are derived from applying trends in port movement data as proxies for changes in activities of different types of vessels;
- Fuel consumption and emissions are calculated separately for naval shipping from data provided by the MoD;
- Fuel consumption and emissions are calculated separately for inland waterways from estimates of vessel population and activities;
- Fuel consumption and emissions are calculated separately for fishing which takes place in non-UK waters by UK vessels;
- Fuel consumption and emissions are calculated separately for shipping movements between the UK and Overseas Territories;
- A reconciliation with fuels data in DUKES is made whereby the difference between the sum of the currently reported fuel deliveries for marine bunkers and national navigation in DUKES and the sum of the fuel consumption estimate for domestic coastal shipping taken from AMEC, and the fuel consumption estimates for naval shipping, the UK's inland waterways, fishing outside UK waters and shipping movements between the Overseas Territories, is assigned to international shipping.

From the UK inventory for domestic navigation, the disaggregation of emissions between each constituent country is based on port movement data (DfT, 2012). The same approach is taken for the allocation of the international shipping emissions to each DA. As with the international aviation data, the Scottish Government GHG reduction targets take account of the Scottish share of international shipping, whereas for England, Wales and Northern Ireland the international shipping data are merely a memo item that are accounted for separate to the main DA by source dataset.

The DA emission estimates derived for domestic and international shipping are regarded as indicative, as there is limited data availability for regional marine shipping fuel use.

No detailed dataset of domestic and international shipping movements is currently available, and hence emissions are assigned based on the assumption that the total mass of port traffic per DA is a representative proxy to estimate shipping fuel sales and use in the ports and waters around the DAs. Note that the sum of the DA shipping emission allocations are constrained by the UK fuel use data for the sector; this method of estimation is therefore consistent with the principles of international inventory guidance, whereby emissions are allocated to the country at the point of fuel sale.

[Note that in the reporting of the UK GHGI, the emission estimates for international aviation and shipping are reported as "memo items" to the UK submission to the UNFCCC, and hence the approach taken for England, Wales and Northern Ireland is fully consistent with the UK reporting commitments.]

Road Transport

Carbon dioxide, methane and nitrous oxide are emitted from the exhaust of all road vehicles with internal combustion engines. Carbon dioxide is the principal product of combustion and emissions are directly related to the fuel efficiency of the vehicle.

Methane is emitted as a result of the incomplete combustion of the fuel. Nitrous oxide is a by-product of the combustion process and emitted from partial oxidation of nitrogen present in the air.

All these pollutants are emitted by different amounts from vehicles of similar size running on petrol and diesel fuel. For example, diesel cars tend to be more fuel-efficient than petrol cars of a similar size, so their carbon emissions are lower. None of these pollutants are subject to regulatory type-approval emission limits as are those which have an impact on air quality. However, emissions of GHGs are affected by technologies introduced to reduce emissions of the regulated air quality pollutants. Methane emissions are lower from petrol vehicles fitted with a three-way catalyst, although the reduction in emissions of this pollutant by the catalyst is not as efficient as it is for other hydrocarbons. Measurements also suggest that a three-way catalyst, which is efficient at reducing NO_x emissions, can actually increase emissions of nitrous oxide, formed as a by-product of the catalyst NO_x reduction process, but evidence suggests that this is mainly a problem only for early generation catalyst cars.

Disaggregation of UK emissions across the DAs is based on local data from road traffic surveys run by the UK Department for Transport and the Department for Regional Development in Northern Ireland. Vehicle kilometre figures for different vehicle types and road types are combined with fuel consumption or emission factors. The vehicle kilometre data are also subject to uncertainty, but have shown a consistent growth in traffic across all the regions up to 2007. Traffic levels have gone down slightly in general between 2007 and 2011.

It is worth noting that the IPCC Reference Manual states that “the CORINAIR (programme), with a view to the input requirements of atmospheric dispersion models, applies the principle of territoriality (emission allocation according to fuel consumption) whereas the IPCC is bound to the principle of political responsibility (allocation according to fuel sale). For the IPCC, countries with a big disparity between emissions from fuel sales and fuel consumption have the option of estimating true consumption and reporting the emissions from consumption and trade separately.” (IPCC, 1996).

UK emissions of carbon dioxide from road transport are reported to IPCC on the basis of fuel sales. However, basing road transport emissions on fuel sales in each constituent country of the UK does not provide a representative picture of trends in road transport emissions at regional level, due to issues of cross-border fuel sales (especially between Northern Ireland – Republic of Ireland) and sales data accounting issues within the UK (e.g. “supermarket sales” in Scotland allocated to original point of sale in northern England). Estimates based on fuel consumption calculated from traffic data in each DA are therefore regarded as a more representative approach, and are consistent with the CORINAIR (now EMEP/EEA) guidance.

Table A2.4a: Transport (Base Year – 1990)

IPCC Category	NAEI Sources	Activity: Fuel Consumption	Data used for deriving DA estimates from UK totals / Comments
Civil Aviation	Domestic cruise; Domestic Take-off & Landing	Aviation Gasoline, Jet Gasoline	CAA database of flight information (CAA, 2012) Fuel consumption: Digest of UK Energy Statistics (1990)
Road Transport	Road Transport	Petrol, Diesel oil	Road fuel sales, DECC; vehicle km, DfT Traffic data: National Traffic Census, DfT Dept of Regional Development (NI: 1990) Fuel consumption: Digest of UK Energy Statistics (1990)
Railways	Railways	Gas oil	The DfT Rail Emissions Model, calibrated against total train kilometres figures for 2009/10 taken from ORR's National Rail Trends Yearbook. DA estimates from 2010 back-cast to 1990, assuming DAs follow UK trend. Fuel consumption: Digest of UK Energy Statistics (1990-2012).
Navigation	Coastal shipping	Gas oil, Fuel oil	Back calculated from 2007 estimates by Entec based on detailed shipping movements. Backcasting done from 2007 using trends in port movement data, DfT Maritime Statistics Fuel consumption: Digest of UK Energy Statistics (1990)
Other	Aircraft Support	Gas oil	Regional aircraft movements, DfT Fuel consumption: Digest of UK Energy Statistics (1990)

Table A2.4b: Transport (1995; 1998 to 2011)

IPCC Category	NAEI Sources	Activity: Fuel Consumption	Data used for deriving DA estimates from UK totals / Comments
Civil Aviation	Domestic cruise; Domestic Take-off & Landing	Aviation Gasoline, Jet Gasoline	CAA database of flight information (CAA, 2012) Fuel consumption: Digest of UK Energy Statistics (1990-2012)
Road Transport	Road Transport	Petrol, Diesel oil, LPG	Vehicle km, DfT, NI DRD Emission factors: Boulter et al. (2009) COPERT 4 (EEA, 2010) Fuel efficiency: Road Freight Statistics, DfT (1990-2012) Composition of fleet: Vehicle Licensing Statistics Report, DfT (GB) Dept of Regional Development (NI). Traffic data: National Traffic Census, DfT (England, Scotland, Wales: 1990-2012) Dept of Regional Development (NI: 1990-1999), Traffic Census Report (NI: 2000), Vehicle Kilometres of Travel Survey of Northern Ireland Annual Report (NI: 2001), Traffic and Travel Information, DRDNI (NI: 2002- 2012) Fuel consumption: Digest of UK Energy Statistics (1990-2012), Welsh Office fuels data (WO, 1998)
Railways	Railways	Gas oil	The DfT Rail Emissions Model, calibrated against total train kilometres figures for 2009/10 taken from ORR's National Rail Trends Yearbook. Fuel consumption: Digest of UK Energy Statistics (1990-2012)
Navigation	Coastal shipping	Gas oil, Fuel oil	Back calculated from 2007 estimates by Entec based on detailed shipping movements. Backcasting and forewardcasting done from 2007 using trends in port movement data, DfT Maritime Statistics Fuel consumption: Digest of UK Energy Statistics (1990-2012)
Other	Aircraft Support	Gas oil	Regional aircraft movements, DfT Fuel consumption: Digest of UK Energy Statistics (1990-2012)

Total emissions from road transport in each region are calculated from the following information:

- Emission factors for different types of vehicles. In the case of carbon emissions, fuel consumption factors can be used because the mass of carbon emitted is proportional to the mass of fuel consumed. Emission factors (g/km) and fuel consumption factors depend on the vehicle type and fuel type (petrol or diesel) and are influenced by the drive cycle or average speeds on the different types of roads;
- Traffic activity, including distance and average speed travelled by each type of vehicle on each type of road;
- Fleet composition in terms of the age of the fleet and the petrol/diesel mix. The age of the fleet determines the proportion of vehicles manufactured in conformity with different exhaust emission regulations (which have been successively tightened over the past 30 years); and
- One of the defining factors for the inventories is the proportion of petrol cars fitted with a three-way catalyst since this became mandatory for all new cars first registered in the UK from around August 1992, in accordance with EC Directive 91/441/EEC. The proportion of cars and vans running on diesel fuel is also an important factor. The sensitivity to the age of the fleet will be much less for the 1990 inventory because there were very few cars then fitted with catalysts and the difference in emissions from cars made to the earlier emission standards was much smaller.

There are a number of improvements made to the 2011 UK road transport inventory and thus affecting the DA inventories. One of the main changes is the revision of minor road traffic estimates between 2000 and 2010 for England and Wales as a result of a benchmarking exercise planned in 2010. The improvements that have been made are discussed further in the following sections.

Emission factors

All the emission factors were consistent with those used in the latest UK Greenhouse Gas Emissions Inventory (Webb *et al*., 2013). Emission factors for methane are unchanged and they are developed by TRL on behalf of DfT (Boulter et al., 2009), expressed as speed-related functions for cars and LGVs and single average factors for HGVs, buses and motorcycles for urban, rural and motorways.

Nitrous oxide emission factors remain the same as those used in the last DA GHG inventory (except corrections have been made for coaches, London buses and HGVs 3.5-7.5t and 7.5-12t weight classes). They are based on factors obtained from the Emissions Inventory Guidebook (EEA, 2012). For petrol cars and LGVs, emission factors are provided for different Euro standards and driving conditions (urban, rural, highway) with adjustment factors that take into account the vehicle's accumulated mileage and the fuel sulphur content; both of these tend to increase emission factors. For diesel cars and LGVs, bulk emission factors are provided for different Euro standards and road types, with no fuel and mileage effects. The factors for HGVs and buses are provided for different Euro standards, weight classes and driving conditions. The factors for motorcycles make no distinction between different Euro standards and road types.

The uncertainties in the CH_4 and N_2O factors can be expected to be quite large. However, the relative differences between emission factors used for different technologies, Euro standards and fuels are likely to reflect realistic trends.

Fuel consumption factors are also unchanged and are based on the fuel consumption-speed relationships for detailed categories of vehicles compiled by TRL on behalf of DfT. They are used in conjunction with fleet-average fuel efficiency and vehicle CO_2 factors from other sources. These include fuel efficiency factors for HGVs and buses from sources in DfT. Further details on fuel consumption factors for other vehicle types can be found in the UK GHGI report (Webb *et al*., 2013).

Tables A2.4.1 to A2.4.3 show the fuel consumption and emission factors used for the inventory broken down by vehicle type, road type and emission standard which the vehicle was compliant with when manufactured and first registered. Tables A2.4.4 and A2.4.5 present the fleet-averaged fuel consumption factors for rigid and articulated HGVs, buses and coaches respectively from 1990-2011 for urban, rural and motorway conditions. For the other vehicle types and pollutants, CH_4 and N_2O, where the original source of the factors provided them as speed-emission factor equations, emission factors are calculated at average speeds typical of the road types shown in the tables A2.4.1 to A2.4.3. The average speeds used were same as those used in the last DA inventory as described below.

The emission factors shown in Tables A2.4.1-A2.4.3 refer to hot exhaust emissions that is the emissions occurring from the vehicle when the engine and catalyst are at their normal operating temperatures. The excess emissions occurring when the vehicle is started with the engine and catalyst cold was taken into account for calculating N_2O emissions from petrol cars and vans using the methodology given in COPERT 4 (EEA, 2010). Details of the cold start method are given in the latest UK Greenhouse Gas Emissions Inventory (Webb et al., 2013), but essentially it uses mg/km "cold start" emission factors for each Euro standard in combination with the distances travelled with the vehicle not fully warmed up. DA-specific data on trip lengths were gathered in the previous DA improvement programme and no significant difference in passenger car trip lengths were found for Scotland and Wales compared with the GB average, but trip lengths are shorter in Northern Ireland and this information has been incorporated in the DA inventory. Data for estimating cold start effects on methane emissions are not available, but the effects are considered to be probably smaller and within the range of uncertainty in the hot exhaust methane emission factors.

Age and composition of the fleet

Automatic Number Plate Recognition (ANPR) data provided by DfT (2012b, pers comm) are used to define the UK's vehicle fleet composition on the road. The ANPR data has been collected annually (since 2007) over 256 sites in the UK on different road types (urban and rural major/minor roads, and motorways) and regions. Measurements are made at each site on one weekday and one half weekend day in June, capturing approximately 1.4-1.7 million observations from all the sites each year. The data cover various vehicle and road characteristics such as fuel type, age of vehicle (which can be associated with its Euro standard), engine sizes, vehicle weight and road types.

The ANPR data is used to define fleet composition in two aspects:

- ***Petrol and diesel mix in the car fleet on different road types (urban, rural and motorway).*** The ANPR data confirmed that there is a preferential use of diesel cars on motorways, as was previously assumed in the inventory, but that preferential usage of diesel cars also extended to urban roads as well, although not to the extent as seen on motorways. The net result was an increase in diesel car km on urban roads, but less on motorways than had been previously assumed. For Northern Ireland, the ANPR data for 2010 and 2011 show that there was no

major difference in the proportion of diesel cars observed on different road types and that the proportion was similar to that implied by the licensing data; as a result, it is assumed that there is no preferential use of diesel cars, and the petrol/diesel mix in car km should follow the proportion as indicated by the licensing statistics provided by DRDNI (2012a).

- ***Variations in age and Euro standard mix on different road types.*** The ANPR data tended to show that the diesel car, LGV and HGV fleet observed on the road was rather newer than inferred from the licensing records and mileage surveys.

The results from above are then further combined with regional licensing statistics provided by DfT from their Driver and Vehicle Licensing Agency database (hereafter referred to as DVLA data) to define regional variation (DfT, 2010a). The DVLA data were introduced in the 2009 DA inventories and show that there are some regional differences in the composition of fleet, including:

- The proportion of diesel cars in the fleet is similar in England and Scotland, but is consistently slightly highly in Wales.
- Scotland and Wales have a slightly higher proportion of smaller engine-size petrol cars compared with England and the GB average;
- Scotland has a newer petrol car fleet than England and Wales, while Wales appears to have an older diesel car fleet than England and Scotland.
- The van fleet in Scotland is newer then the GB average, while in Wales the van fleet is older

It should be noted that the application of the ANPR and DVLA data is dependent on the vehicle, pollutant and region combination. For instance, when calculating fuel consumption and CO_2 emissions, data on the average mpg fuel efficiency of different sizes of lorries from the Road Freight Statistics and the BSOG data for buses take precedence over the ANPR data, and they are continued to be used to define the fuel consumption/ CO_2 emissions for HGVs and buses respectively, without any adjustment to account for variations in the age of the HGV or bus fleets. Further details on the methodology of defining fleet composition are given in Webb et al., 2013.

Traffic data

The preferred indicators for road transport activity in emission inventories are traffic data in terms of vehicle kilometres travelled per year disaggregated by vehicle and road type. For the NAEI, vehicle kilometre data for the road network in Great Britain are provided by DfT for each vehicle type on roads classified as trunk, principal and minor roads in built-up areas (urban) and non-built-up areas (rural) and motorways (DfT, 2012c). These estimates are based on traffic counts from the rotating census and core census surveys.

A consistent time series of vehicle km data for 1993 to 2011 by road type and vehicle type for England, Wales and Scotland was made available by DfT for the first time (DfT, 2012c). Vehicle km data for 1993 was scaled to derive the 1990 values for England, Wales and Scotland, based on the GB trend between 1990 and 1993. As mentioned previously, the minor traffic estimates have been revised between 2000 and 2010 for England and Wales as a result of a planned benchmarking exercise. The revision does not affect minor road estimates for Scotland.

Vehicle kilometre data for Northern Ireland by vehicle type and road class were provided by the Department for Regional Development (DRD), Northern Ireland, Road Services (DRDNI, 2011a).

These provided a consistent time-series of vehicle km data for all years up to 2010. Data for 2011 was not available for this year's inventory and were derived using change factors provided by DRDNI (2012a). Data for 2010 has been revised slightly upward for artic HGVs and buses and downward for LGVs, however, the changes were within 1%. Motorcycle vehicle km data were not available from the DRDNI and so they were derived based on the ratio of motorcycles registered in Northern Ireland relative to the GB each year. The ratios were then applied to the motorcycle vehicle km activity data for the GB. There has been a downward revision to the motorcycle vehicle km data for Northern Ireland across the time series as updated GB licensing statistics have been used in 2011 inventory.

Estimation of Emissions of Methane and Nitrous Oxide

Emissions of methane and nitrous oxide from road transport in the regions are calculated by combining the vehicle emission factors, fleet composition data and vehicle kilometre data for the different vehicle, fuel and road types. The emissions from petrol and diesel vehicles in each DA are normalised so that the totals across all DAs equal the UK emissions calculated for the pollutant and fuel type.

Estimation of Road Transport Carbon Dioxide Emissions

Road transport has been a very significant and growing source of carbon dioxide across all of the constituent countries of the UK.

For the purposes of the UK's reporting to the UNFCCC on greenhouse gas emissions under the Kyoto Protocol, the UK is required to use estimation and reporting methodologies that comply with IPCC guidance. The recommended methodology for estimation of carbon dioxide emissions from road transport sources applies the principle of political responsibility for emissions, whereby fuel sales data are used as the basis for the estimates. In this way, across a group of countries such as the Member States of the EU, there is no risk of double-counting road transport carbon dioxide emissions due to the use of different estimation methodologies[1].

Therefore, for the purposes of reporting to the UNFCCC and the determination of progress towards Kyoto Protocol emission reduction targets, the UK uses fuel sales data as the basis for carbon dioxide emission estimates from road transport in the National Inventory Report. However, for the purposes of compiling the Devolved Administration GHG inventories, the use of regional fuel sales data is problematic due to a couple of key issues:

- **Cross-border fuel sales** - This factor is especially evident in Northern Ireland, where the price differential between fuel in the UK and the Republic of Ireland may have encouraged purchase of fuel from outside of the UK (BERR: Personal Communication, 2004); and

- **Supermarket fuel sales** - Where a supermarket chain purchases its fuel from storage facilities in England and then sells the fuel in other parts of the UK, the emissions from that fuel sold will be incorrectly attributed to England. Although this is known to be a potential source of inconsistency in the reporting of regional fuel sales from supermarkets, it is also likely to be evident across other economic sectors too (BERR: Personal Communication, 2004).

[1] Note that the UK methodology for estimating emissions of methane and nitrous oxide from road transport sources is based on vehicle kilometre data, in accordance with IPCC guidance.

Adopting the IPCC estimation method of using fuel sales data in each DA produces carbon dioxide emission trends from road transport in Northern Ireland and Scotland that buck the UK trend of increasing emissions with time, contrary to vehicle kilometre data that are collected across the UK.

Table A2.4.1: Fuel Consumption Factors for Road Transport (in g fuel/km)

g fuel /km		Urban	Rural	Motorway
Petrol cars	Pre-Euro 1	66.4	62.8	69.1
	Euro 1	61.4	57.9	64.1
	Euro 2	58.8	55.3	61.5
	Euro 3	55.0	51.4	57.6
	Euro 4	50.8	47.2	53.4
	Euro 5	44.7	41.2	47.4
Diesel cars	Pre-Euro 1	60.3	55.0	61.2
	Euro 1	58.5	53.2	59.4
	Euro 2	54.9	49.6	55.8
	Euro 3	50.2	44.9	51.1
	Euro 4	47.7	42.4	48.7
	Euro 5	42.0	36.7	42.9
Petrol LGVs	Pre-Euro 1	68.7	64.1	70.0
	Euro 1	63.6	59.0	64.8
	Euro 2	60.9	56.3	62.1
	Euro 3	57.1	52.5	58.3
	Euro 4	52.3	47.7	53.6
Diesel LGV	Pre-Euro 1	61.9	68.4	91.9
	Euro 1	76.7	84.4	110.1
	Euro 2	71.5	77.5	106.0
	Euro 3	63.2	69.8	104.0
	Euro 4	63.2	69.8	104.0
Mopeds, <50cc, 2st	Pre-Euro 1	25.5		
	Euro 1	15.3		
	Euro 2	12.3		
	Euro 3	10.7		
Motorcycles, >50cc, 2st	Pre-Euro 1	27.5	30.2	
	Euro 1	25.3	27.8	
	Euro 2	25.3	27.8	
	Euro 3	25.3	27.8	
Motorcycles, >50cc, 4st	Pre-Euro 1	35.3	35.1	53.9
	Euro 1	33.5	33.2	46.9
	Euro 2	31.6	31.9	49.3
	Euro 3	31.6	31.9	49.3

Table A2.4.2: Methane Emission Factors for Road Transport (in mg/km)

mg CH_4/km		Urban	Rural	Motorway
Petrol cars	Pre-Euro 1	73.0	21.8	57.7
	Euro 1	15.0	5.2	20.9
	Euro 2	15.8	9.6	9.7
	Euro 3	5.0	4.1	7.2
	Euro 4	1.3	1.0	1.8
	Euro 5	1.3	1.0	1.8
Diesel cars	Pre-Euro 1	12.3	10.2	10.0
	Euro 1	6.1	6.3	6.2
	Euro 2	2.9	1.7	1.2
	Euro 3	1.4	1.1	1.1
	Euro 4	1.0	0.8	0.7
	Euro 5	1.0	0.8	0.7
Petrol LGVs	Pre-Euro 1	73.0	21.8	57.7
	Euro 1	15.0	5.2	20.9
	Euro 2	15.8	9.6	9.7
	Euro 3	5.0	4.1	7.2
	Euro 4	1.3	1.0	1.8
	Euro 5	1.3	1.0	1.8
Diesel LGV	Pre-Euro 1	11.8	4.0	22.0
	Euro 1	6.7	1.7	5.8
	Euro 2	2.9	1.7	1.2
	Euro 3	2.2	0.6	1.0
	Euro 4	1.5	0.4	0.7
	Euro 5	1.5	0.4	0.7
Rigid HGVs	Pre-Euro I	185.5	50.2	43.6
	Euro I	85.0	23.0	20.0
	Euro II	54.4	20.0	18.6
	Euro III	47.6	21.4	18.2
	Euro IV	2.6	1.6	1.2
	Euro V	2.3	1.4	1.1
Artic HGVs	Pre-Euro I	381.8	174.5	152.7
	Euro I	175.0	80.0	70.0
	Euro II	112.0	69.6	65.1
	Euro III	98.0	74.4	63.7
	Euro IV	5.3	5.6	4.2
	Euro V	4.7	5.0	3.8
Buses & coaches	Pre-Euro I	381.8	174.5	152.7
	Euro I	175.0	80.0	70.0
	Euro II	113.8	52.0	45.5
	Euro III	103.3	47.2	41.3
	Euro IV	5.3	5.6	4.2
	Euro V	4.7	5.0	3.8
Mopeds, <50cc, 2st	Pre-Euro 1	219.0		
	Euro 1	43.8		
	Euro 2	24.1		
	Euro 3	19.7		
Motorcycles, >50cc, 2st	Pre-Euro 1	150.0	150.0	
	Euro 1	99.0	106.5	

mg CH_4/km		Urban	Rural	Motorway
	Euro 2	30.0	31.5	
	Euro 3	12.0	13.5	
Motorcycles, >50cc, 4st	Pre-Euro 1	200.0	200.0	200.0
	Euro 1	127.9	138.6	148.7
	Euro 2	126.7	93.1	107.1
	Euro 3	76.2	32.6	31.8

Table A2.4.3: N_2O Emission Factors for Road Transport (in mg/km)

N_2O(mg/km)	Standard	Urban	Rural	Motorway
Petrol cars	Pre-Euro 1	10.0	6.5	6.5
	Euro 1	21.3	13.8	6.9
	Euro 2	10.7	3.4	1.8
	Euro 3	1.4	0.6	0.5
	Euro 4	1.8	0.6	0.5
	Euro 5	1.8	0.6	0.5
Diesel cars	Pre-Euro 1	0.0	0.0	0.0
	Euro 1	2.0	4.0	4.0
	Euro 2	4.0	6.0	6.0
	Euro 3	9.0	4.0	4.0
	Euro 4	9.0	4.0	4.0
	Euro 5	9.0	4.0	4.0
Petrol LGVs	Pre-Euro 1	10.0	6.5	6.5
	Euro 1	22.0	13.8	6.9
	Euro 2	16.3	9.3	5.8
	Euro 3	10.5	4.6	4.6
	Euro 4	0.8	1.3	1.3
	Euro 5	0.8	1.3	1.3
Diesel LGV	Pre-Euro 1	0.0	0.0	0.0
	Euro 1	2.0	4.0	4.0
	Euro 2	4.0	6.0	6.0
	Euro 3	9.0	4.0	4.0
	Euro 4	9.0	4.0	4.0
	Euro 5	9.0	4.0	4.0
Rigid HGVs	Pre-Euro I	30.0	30.0	30.0
	Euro I	10.4	8.6	6.1
	Euro II	10.0	8.6	5.7
	Euro III	4.9	4.9	3.7
	Euro IV	10.6	12.9	10.6
	Euro V	27.6	37.1	31.3
Artic HGVs	Pre-Euro I	30.0	30.0	30.0
	Euro I	17.6	14.7	10.8
	Euro II	17.6	14.7	9.8
	Euro III	8.8	8.8	6.8
	Euro IV	18.6	22.9	18.8
	Euro V	47.9	65.1	54.5

N_2O(mg/km)	Standard	Urban	Rural	Motorway
Buses	Pre-Euro I	30.0	30.0	30.0
	Euro I	11.7	11.2	7.0
	Euro II	11.7	11.2	6.0
	Euro III	5.7	5.7	4.0
	Euro IV	12.4	13.1	11.4
	Euro V	32.2	35.2	33.6
Mopeds, <50cc, 2st	Pre-Euro 1	1.0		
	Euro 1	1.0		
	Euro 2	1.0		
	Euro 3	1.0		
Motorcycles, >50cc, 2st	Pre-Euro 1	2.0	2.0	
	Euro 1	2.0	2.0	
	Euro 2	2.0	2.0	
	Euro 3	2.0	2.0	
Motorcycles, >50cc, 4st	Pre-Euro 1	2.0	2.0	2.0
	Euro 1	2.0	2.0	2.0
	Euro 2	2.0	2.0	2.0
	Euro 3	2.0	2.0	2.0

Table A2.4.4: Fuel Consumption Factors for HGVs (in g fuel/km)

g fuel/km	Rigid HGVs			Artic HGVs		
	urban	rural	m-way	urban	rural	m-way
1990	272.4	217.7	231.5	438.8	337.1	343.6
1991	276.6	221.0	235.1	437.2	335.9	342.4
1992	277.0	221.4	235.4	433.9	333.3	339.8
1993	266.9	213.5	227.0	412.1	316.7	322.8
1994	259.0	207.8	221.1	405.1	311.6	317.6
1995	263.3	212.2	225.9	395.5	304.6	310.5
1996	258.2	209.0	222.8	388.1	299.3	305.1
1997	256.3	208.4	222.3	387.2	299.2	304.9
1998	245.1	200.5	214.1	370.8	287.2	292.7
1999	249.8	205.4	219.6	370.3	287.3	292.8
2000	247.8	204.8	219.2	370.2	287.7	293.2
2001	259.8	214.2	228.8	375.5	292.0	297.6
2002	252.9	208.4	222.3	373.2	290.0	295.6
2003	262.8	216.1	230.1	378.3	293.7	299.4
2004	253.9	208.6	221.8	365.0	283.2	288.7
2005	250.7	205.0	217.4	360.9	279.7	285.2
2006	261.9	213.1	225.5	363.4	281.4	286.9
2007	270.1	218.5	230.7	365.9	283.1	288.7
2008	279.6	226.0	238.5	379.8	293.5	299.3

g fuel/km	Rigid HGVs			Artic HGVs		
	urban	rural	m-way	urban	rural	m-way
2009	281.8	228.0	240.8	381.1	294.3	300.1
2010	285.3	229.9	242.5	384.9	296.9	302.7
2011	284.8	229.2	241.7	384.1	296.0	301.8

Table A2.4.5: Average fuel consumption factors for buses and coaches (in g fuel/km) in the fleet based on DfT's BSOG data

g fuel/km	Urban	Rural	Motorway
1990	268.9	167.8	190.9
1991	268.9	167.8	190.9
1992	268.9	167.8	190.9
1993	268.2	167.5	190.5
1994	265.0	165.7	189.0
1995	260.8	163.3	187.0
1996	255.9	160.7	184.8
1997	255.3	160.9	185.8
1998	255.1	161.5	187.4
1999	264.5	168.2	195.9
2000	277.0	176.7	206.4
2001	278.3	177.9	208.4
2002	290.0	186.1	219.0
2003	303.9	195.0	229.8
2004	309.5	198.6	234.1
2005	324.4	208.1	245.6
2006	319.2	204.7	241.6
2007	327.6	209.7	247.7
2008	340.7	217.8	257.3
2009	341.6	217.9	257.7
2010	338.0	215.2	254.8
2011	337.8	214.8	254.4

In order to provide a more representative assessment of transport emission trends of carbon dioxide within the constituent countries of the UK, the approach is either directly using regional vehicle km data to estimate road transport carbon dioxide emissions in each DA or using regional vehicle km data as a means to proportion the total UK road transport carbon dioxide emissions between each DA region.

They are described in the following sections:

Disaggregation of UK Carbon Dioxide Emissions by DA: Constrained Method:

In this method the sum of the DA inventories for carbon dioxide are constrained to meeting the total of the UK inventory for road transport which for carbon dioxide is derived from UK fuel sales data for petrol and DERV from DECC. The vehicle km data for each region are used to provide an estimated allocation of the total UK road transport emissions across the constituent countries. In constraining

to sum to the national totals, this approach is consistent with that adopted across every other source sector in the DA GHG inventories.

However, the criticism of this method is that the presentation of results does not always provide a carbon dioxide emission trend for the DAs that is directly consistent with the vehicle kilometre trend data, as the fluctuations in UK fuel data (from DECC) have a more significant impact on the resultant emission trends.

Direct Calculation of DA Emissions: Unconstrained Method:

In this method, carbon dioxide emissions from constituent countries are derived directly from the regional vehicle km data and are not constrained to the UK totals based on national fuel consumption data. This method removes any year to year fluctuations caused by the normalisation process and enables the emission trends to mirror the smooth trends in vehicle km.

The difference in results between the constrained and unconstrained methods at DA level largely reflects the difference in the results at UK level between bottom-up calculated fuel consumption using vehicle km data and fuel consumption factors and the fuel sales data in DUKES. The reason for a disparity has previously been attributed to cross-border fuel sales ("fuel tourism") although model uncertainty was always emphasised as an additional, and probably a major explanation for the differences.

Any change in the methodologies or the factors used to calculate fuel consumption will affect the magnitude of the difference between calculated fuel consumption at national level and sales figures from DUKES and so, in turn, it will affect the disparity between the DA carbon dioxide emissions from the constrained and unconstrained approaches. The disparity has been changed across the 1990 – 2011 time series. At UK level, the calculated petrol consumption in 1990 is -0.01% lower than petrol sales; in 2011, it is 4.5% lower. Calculated diesel consumption in 1990 is -2.5% lower than diesel sales; in 2011, it is -1.2% higher.

The trend in road transport carbon dioxide emissions for each DA and the UK calculated by the constrained and unconstrained methods across the time series is shown in Table A2.4.6 and Figure A2.4.1. Note that in the table, figures labelled "vkm" refer to the unconstrained method; figures labelled "Fuel sales" refer to the constrained method.

Further details on the fuel consumption vs. fuel sales reconciliation issue and normalisation procedure applied at UK level are given in Webb et al., 2013.

Note that emissions of methane and nitrous oxide both at UK level and for the DAs are calculated directly from vehicle km data and emission factors, with no normalisation to fuel sales data involved.

Table A2.4.6: Comparison between methods of Carbon Dioxide emissions for each DA (kt CO_2)[2] by vehicle type. Vkm refer to the unconstrained method. Fuel sales refer to the constrained method.

England		1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
CO_2 (vkm)	Cars	59,415	60,235	61,984	62,634	61,872	61,838	62,232	61,241	61,123	60,179	59,687	58,488	56,723	55,372	52,686	51,622
	LGVs	7,902	8,958	10,390	10,525	10,699	10,991	11,118	11,568	12,075	12,309	12,675	13,106	12,706	12,346	12,390	12,588
	HGVs	19,305	18,784	19,378	19,888	19,968	20,446	20,301	20,807	20,688	20,092	20,459	20,743	20,557	18,801	19,083	18,671
	Buses	2,718	2,911	3,073	3,211	3,244	3,251	3,384	3,686	3,680	3,818	3,858	4,006	3,788	3,739	3,721	3,455
	Motorcycles	534	366	430	474	470	491	512	565	518	540	515	547	498	504	446	444
	TOTAL	89,875	91,253	95,255	96,733	96,253	97,017	97,548	97,867	98,084	96,937	97,195	96,890	94,272	90,762	88,326	86,780
CO_2 (fuel sales)	Cars	59,421	59,074	61,387	62,620	62,406	62,159	63,130	61,928	62,147	61,491	60,983	60,504	58,974	56,673	54,127	53,169
	LGVs	7,903	8,875	10,355	10,524	10,721	11,003	11,146	11,587	12,101	12,338	12,705	13,150	12,753	12,372	12,417	12,617
	HGVs	19,990	20,430	20,553	19,705	18,949	18,774	19,239	19,092	19,310	19,962	20,138	20,718	18,617	17,976	19,466	19,309
	Buses	2,718	2,911	3,073	3,211	3,244	3,251	3,384	3,686	3,680	3,818	3,858	4,006	3,788	3,739	3,721	3,455
	Motorcycles	535	358	425	474	475	494	521	573	529	556	531	573	527	521	465	466
	TOTAL	90,567	91,646	95,793	96,535	95,795	95,681	97,421	96,865	97,767	98,164	98,215	98,953	94,659	91,280	90,196	89,015

Scotland		1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
CO2 (vkm)	Cars	5,670	5,714	5,820	5,849	5,776	5,774	5,890	5,821	5,827	5,732	5,795	5,686	5,533	5,402	5,127	5,003
	LGVs	786	891	1,080	1,103	1,089	1,108	1,137	1,184	1,225	1,256	1,311	1,378	1,352	1,318	1,331	1,343
	HGVs	1,985	1,894	1,919	1,951	1,945	1,970	1,937	2,064	2,071	2,057	2,160	2,228	2,240	2,078	2,091	2,038
	Buses	374	385	407	428	436	441	476	514	486	506	511	555	544	543	552	517
	Motorcycles	29	22	25	28	28	29	33	37	35	35	34	36	35	35	31	32
	TOTAL	8,844	8,905	9,251	9,359	9,274	9,322	9,472	9,620	9,644	9,586	9,811	9,883	9,704	9,377	9,132	8,933
CO2 (fuel sales)	Cars	5,670	5,606	5,766	5,848	5,824	5,803	5,973	5,885	5,923	5,855	5,918	5,877	5,746	5,524	5,262	5,148
	LGVs	786	883	1,076	1,103	1,091	1,109	1,140	1,186	1,228	1,259	1,314	1,383	1,357	1,321	1,334	1,346
	HGVs	2,056	2,060	2,036	1,933	1,846	1,809	1,835	1,894	1,933	2,044	2,126	2,225	2,029	1,987	2,133	2,108
	Buses	374	385	407	428	436	441	476	514	486	506	511	555	544	543	552	517
	Motorcycles	29	21	24	28	28	30	33	37	36	36	35	38	37	36	33	33
	TOTAL	8,915	8,955	9,309	9,340	9,226	9,192	9,458	9,517	9,606	9,699	9,904	10,078	9,713	9,412	9,314	9,152

[2] The totals in this table include emissions from Diesel and Petrol use, but do not include the small emissions from LPG and lubricants. These figures are therefore not directly comparable with the road transport emissions presented in Appendix 2, which include emissions from all fuel use.

Wales		1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
CO2 (vkm)	Cars	3,638	3,675	3,742	3,774	3,722	3,725	3,802	3,781	3,819	3,735	3,755	3,698	3,588	3,473	3,293	3,216
	LGVs	510	578	668	684	694	711	735	767	800	817	841	866	853	833	843	851
	HGVs	1,057	1,001	1,044	1,024	995	1,002	986	995	998	985	996	1,033	1,030	933	927	892
	Buses	172	172	178	189	193	193	202	220	214	223	231	239	231	229	227	207
	Motorcycles	25	18	21	23	24	24	26	28	26	28	26	28	27	27	23	24
	TOTAL	5,402	5,444	5,653	5,694	5,627	5,654	5,752	5,790	5,857	5,786	5,849	5,864	5,730	5,495	5,313	5,190
CO2 (fuel sales)	Cars	3,638	3,605	3,708	3,773	3,752	3,743	3,854	3,821	3,879	3,811	3,832	3,818	3,721	3,549	3,378	3,306
	LGVs	510	573	666	684	696	712	737	768	802	819	843	869	856	835	845	853
	HGVs	1,095	1,088	1,107	1,015	944	920	934	913	932	978	980	1,032	933	892	945	923
	Buses	172	172	178	189	193	193	202	220	214	223	231	239	231	229	227	207
	Motorcycles	25	17	20	23	24	25	26	28	27	28	27	29	28	28	24	25
	TOTAL	5,440	5,456	5,679	5,684	5,609	5,592	5,754	5,750	5,853	5,859	5,913	5,987	5,770	5,533	5,419	5,314

Northern Ireland		1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
CO2 (vkm)	Cars	2,275	2,458	2,589	2,684	2,758	2,778	2,733	2,735	2,823	2,805	2,786	2,822	2,701	2,769	2,664	2,611
	LGVs	116	136	152	159	165	169	240	246	230	227	261	254	294	235	217	231
	HGVs	490	519	541	578	600	635	737	933	811	811	836	850	844	738	747	746
	Buses	30	34	36	39	43	45	42	43	44	46	38	48	48	55	50	48
	Motorcycles	7	6	8	9	9	10	11	15	13	14	14	16	14	14	12	12
	TOTAL	2,918	3,152	3,326	3,470	3,576	3,637	3,763	3,971	3,921	3,903	3,935	3,990	3,900	3,811	3,691	3,647
CO2 (fuel sales)	Cars	2,275	2,413	2,566	2,683	2,779	2,790	2,766	2,760	2,862	2,855	2,835	2,901	2,790	2,822	2,724	2,676
	LGVs	116	135	152	159	165	170	241	246	230	227	261	254	295	235	217	231
	HGVs	508	564	573	572	570	583	698	856	757	805	823	849	764	706	762	771
	Buses	30	34	36	39	43	45	42	43	44	46	38	48	48	55	50	48
	Motorcycles	7	6	8	9	9	10	11	15	14	15	15	16	14	14	13	12
	TOTAL	2,936	3,153	3,336	3,464	3,567	3,597	3,758	3,920	3,907	3,948	3,972	4,069	3,912	3,833	3,766	3,738

Disaggregation of Emissions from LPG fuel Use

All emissions from LPG-fuelled vehicles are disaggregated based on the supply infrastructure that has developed in recent years to provide for this relatively new market. Information on LPG fuel supply stations was obtained from the Energy Saving Trust website, and the number of stations per DA has been used as an activity parameter to distribute UK-based emission figures for LPG consumption across each DA. It is hoped that in future years, actual LPG sales data by DA may become available to provide a more accurate methodology, though it should be noted that consumption of LPG as a transport fuel is still very small in comparison with consumption of petrol and diesel and has been declining from levels reached in 2008.

Emissions of methane and nitrous oxide from LPG consumption are calculated based on an estimate of the number of vehicles and distances travelled using this fuel.

Trends in GHG Emissions from Road Transport

Table A2.4.7 below sets out the carbon dioxide and GHG emissions from 1990 to the latest inventory year (2011) from the two methods of estimating road transport emissions of carbon dioxide.

Table A2.4.7: Emissions of GHGs from UK road transport, according to fuel type and percentage changes from 1990 to the latest inventory year (kt CO_2 equivalent).

Calculation method	GHG	Fuel used	1990	2011	Percentage change 1990-2011
Constrained	Carbon	LPG	-	289.75	
		Petrol and DERV	107,857.74	107,219.48	
		Lubricants	262.77	117.47	
	CH_4	LPG	-	0.59	
		Petrol and DERV	628.06	59.55	
	N_2O	LPG	-	2.22	
		Petrol and DERV	1,173.69	842.13	
		Sum	109,922.25	108,531.19	-1.27%
Calculation method	GHG	Fuel used	1990	2011	Percentage change 1990-2011
Unconstrained	Carbon	LPG	-	289.75	
		Petrol and DERV	107,039.35	104,550.74	
		Lubricants	262.77	117.47	
	CH_4	LPG	-	0.59	
		Petrol and DERV	628.06	59.55	
	N_2O	LPG	-	2.22	
		Petrol and DERV	1,173.69	842.13	
		Sum	109,103.86	105,862.44	-2.97%

The emissions of methane and nitrous oxide are estimated using vkm data in both of the calculation methods, thus the total emissions of these GHGs from the two methods are identical. Carbon emissions of LPG and lubricants burnt in engines are very small relative to emissions from the combustion of petrol and DERV. For convenience, the emissions from LPG and lubricants have not been constrained to fuel sales, and, have been assumed equal in magnitude in both calculation methods in the comparison above. The emissions are quoted to 0.01 ktonne purely for convenience, to avoid the risk of rounding errors. The number of decimal places used should not be taken as indicative of the accuracy of the estimates.

Railways

In accordance with the UK inventory, diesel rail emissions are compiled for three journey types: freight, intercity and regional for the DA regions. The allocation to different areas has been much improved for the 2011 inventory, due to data becoming available from DfT's Rail Emissions Model (REM). This information was provided to the inventory team by direct communication with DfT.[3]

The REM covers all passenger train movements on the Great Britain rail network and provides engine kilometres by train class and by strategic route and is based on detailed information from published passenger rail timetables and Network Rail. The passenger rail movements cover 25 different train operating companies and have been calibrated against total train kilometres figures for 2009/10 taken from ORR's National Rail Trends Yearbook (NRTY)[4]. Work is currently in progress in calibrating passenger rail movements against 2010/11 and 2011/12 data from NRTY.

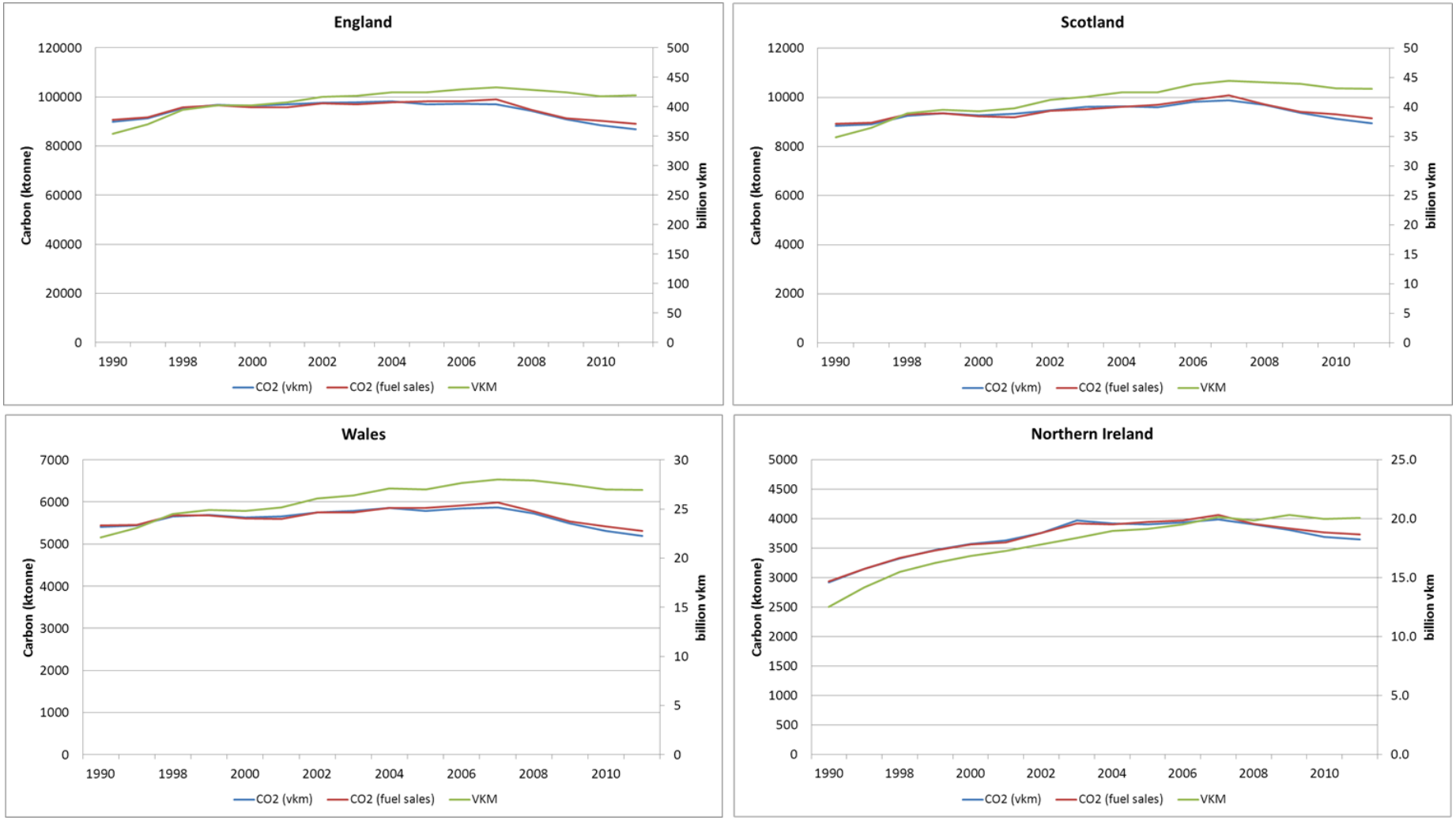
The fuel consumption and emission factors were supplied to the REM by WS Atkins Rail.
REM combines the passenger train activity data with the emission factor information to provide emission estimates for each strategic route in Great Britain, which have then been allocated by the inventory team to England, Scotland and Wales. As outlined above, the most recent year in REM is currently 2009/10 and it has been assumed that the same split between the regions applies to other years. The passenger rail sector is fairly static and there are no large changes in emissions year to year and therefore in the absence of other data, this is a reasonable assumption. With the current rail electrification programme, this will not however be appropriate going forward.

Activity data for Northern Ireland is provided directly by Translink (Stewart, 2012[5]) and the emissions arising are calculated separately and therefore this data is directly available from the UK inventory. Since 2002, the data provided covers passenger trains only as there has been no freight activity in Northern Ireland since this date.

Limited freight data is currently available from REM and work is currently in progress to calibrate freight rail movements against 2010/11 data from the NRTY. In the meantime, data from a previous version of REM has been used to calculate the split in emissions by DA using the same approach as undertaken for passenger trains and then these figures have been applied to the 2011 UK inventory data.

[3] Personal communication with Alberto Pompermaier, Department for Transport, 2012
[4] http://dataportal.orr.gov.uk/displayreport/report/html/df2ac230-682c-4041-9b29-8f4d4d732af7
[5] Data provided to Ricardo-AEA by David Stewart at Translink in October 2012.

Figure A2.4.1: Road transport CO_2 emission trends calculated by constrained and unconstrained methodologies and vehicle kilometres trends, 1990-2011.



Other Sectors

Commercial & Institutional

Emissions estimates for the source categories "public administration" and "miscellaneous and commercial" have previously been based on regional proxy activity data including GVA (as a broad indicator of economic activity across the DAs) or regional employment statistics. Similar to the source categories for small-scale industry and the domestic sector, there is very little detailed solid or liquid fuel use data for these sectors and hence the estimates are subject to greater uncertainty than well-documented sectors (i.e. energy-intensive industries).

The DECC sub-national energy statistics (DECC, 2012b), provide estimates of fuel use by Local Authority for each of these sectors, split by solid fuel types and "oil". These data are estimates that are based on (i) local electricity and gas meter data, and (ii) modelled estimates of the distribution of solid and liquid fuels using proxy data, concessionary coal data and information on smoke control zones. The estimation methodology has been developed for the latest inventory cycle and now follows a similar method to that described for other industrial combustion (see section A2.3.2). For gas oil, coal and gas, the available point source emissions data and fuel use data from EUETS and the pollution inventories have been analysed to allocate emissions to the DAs. The remaining emissions are allocated to the DAs using the energy modelling approach consistent with the DECC sub-national energy statistics.

National gas sales data for the commercial sector were previously reported by DTI (1992), but for later years (1995 to date) UK National Grid has provided data for regional gas use in the 73-732 MWh range. The UK National Grid source provides the closest data available for commercial and institutional consumers, but the total is lower than UK data reported by DECC (2012a). These data are used to distribute miscellaneous and public service gas use in GB.

Natural gas use data for Northern Ireland are supplied by Phoenix Gas for 1999 onwards (Phoenix Gas, 2012), Firmus Energy providing sales data for 2005 onwards (Firmus Energy, 2012), and Vayu Ltd providing sales data for 2010 onwards (Vayu, 2012). The commercial consumption is used as an estimate for Northern Ireland miscellaneous and public service gas consumption. A more detailed split of gas use across the domestic, commercial and industrial sectors in Northern Ireland in recent years has been provided by Phoenix Gas, and expert judgement has been used to estimate the overall allocation of gas use to these sectors from the total gas sales data for Northern Ireland.

Consultation with DFPNI has led to the provision of detailed new energy data from public sector energy reports from 2002 to 2009 and 2011, covering all fuels (including electricity) used in public sector buildings in Northern Ireland. The Public Sector Energy Campaign (PSEC) data have been used to replace previous estimates of fuel use in that sector, for most (but not all) fuels. The data scope covers building energy use and is a close match to the DUKES category description, and therefore the data have been used directly to inform gas and solid fuel use within the public sector in Northern Ireland. The reported gas oil use in the PSEC report is significantly higher than that currently reported for the UK as a whole; in the UK GHGI programme, the limited data on gas oil has been identified as problematic and these data from PSEC should now also be taken into consideration to help inform future gas oil allocations to the public sector. In the current NI inventory, therefore,

there is a small under-report in public sector emissions due to this discrepancy. However, for other fuels the use of the PSEC data provides a more accurate estimate of sector emissions and trends.

Stationary combustion by the railway sector is classified as a commercial source. Consumption of burning oil, fuel oil, and coke is relatively insignificant, and has therefore been allocated according to the diesel oil driver used for locomotives. Natural gas consumption for electricity generation refers to the London Underground (Lotts Road power station – closed in 2001).

DECC (2012a) reports a small amount of solid waste (municipal, industrial & hospital) consumption for energy production in the commercial and miscellaneous sectors. Little is known about the distribution of these installations, but the emissions have been distributed using the split derived for MSW incinerators.

Table A2.5a: Other Sectors (Base Year – 1990)

IPCC Category	NAEI Sources	Activity: Fuel Consumption	Data used for deriving DA estimates from UK totals / Comments
Commercial & Institutional	Miscellaneous, Public service	Coal	DECC Sub-national energy statistics
		SSF	DECC Sub-national energy statistics
		Natural gas	Commercial Sales, DECC.
		Landfill gas	Landfill methane emissions
		Sewage gas	Sewage methane recovered
		fuel oil, gas oil	DECC Sub-national energy statistics
		MSW	As MSW incinerators
		Burning oil	DECC Sub-national energy statistics
	Railways (Stationary)	Oils and coal	Sub-national oil consumption, DECC
		Natural gas	Assumed as all England
Residential	Domestic	Wood[6]	Domestic wood mapping grid
		Peat	Domestic peat consumption data, CEH
		SSF, coke, LPG	Sub-national energy statistics, NI HECA, DECC & Housing Condition Survey data, census data
		Natural gas	Domestic Gas data, DECC
		Burning oil, gas oil,	Sub-national energy statistics (oil), DECC & Housing Condition Survey data, NI HECA, census data
		Coal, anthracite	Sub-national energy statistics (coal, anthracite), DECC & Housing Condition Survey data, NI HECA, census data
		Fuel oil	Regional population, ONS
	House & Garden	DERV, petrol	Regional dwellings, ONS
Agriculture, Forestry & Fishing	Agriculture – stationary combustion	coal, coke, natural gas	Agricultural employment, MAFF
		burning oil, gas oil, fuel oil	DECC Sub-national energy statistics
		Straw[6]	Wheat production, MAFF
	Agricultural mobile machinery	Gas oil, petrol	Agricultural off-road mapping grid

[6] Used to calculate non-CO_2 emissions

Table A2.5b: Other Sectors (1995; 1998 to 2011)

IPCC Category	NAEI Sources	Activity: Fuel Consumption	Data used for deriving DA estimates from UK totals / Comments
Commercial & Institutional	Miscellaneous, Public service	Coal	DECC Sub-national energy statistics, point source data and energy modelling data, including EUETS data and PI/SPRI/ISR data, PSEC data.
		SSF	DECC Sub-national energy statistics
		Natural gas	Natural gas consumed, Transco (now UK National Grid), Phoenix, Firmus, Vayu, PSEC data.
		Landfill gas	Landfill methane emissions
		Sewage gas	Sewage methane recovered
		Fuel oil, gas oil	DECC Sub-national energy statistics, analysis of point source data and energy modelling data, including EUETS, PI/SPRI/ISR data, PSEC data
		MSW	As MSW incinerators
		Burning oil	DECC Sub-national energy statistics, PSEC data (DFPNI, 2012)
	Railways (Stationary)	Oil and coal	Regional gas oil consumption, Network Rail (GB) and Translink (NI)
		Natural gas	Assumed as all England
Residential	Domestic	Wood[7]	Domestic wood mapping grid
		Peat	Domestic peat consumption data, CEH
		SSF, coke, LPG	Sub-national energy statistics (SSF), DECC, 2009 mapping grid, using Housing Condition Survey data, NI HECA, DEMScot model, census data
		Natural gas	Domestic Gas sub-national split for GB from DECC, Transco & UK gas network operators, Data from Phoenix Gas, Vayu Ltd. and Firmus Energy (NI)
		Burning oil, gas oil,	Sub-national energy statistics (oil) from DECC, 2009 mapping grid using Housing Condition Survey data, NI HECA, DEMScot model, census.
		Coal, anthracite	Sub-national energy statistics (coal, anthracite), DECC, 2009 mapping grid using Housing Condition Survey data, NI HECA, DEMScot model, census.
		Fuel oil	Regional population, ONS
	House & Garden	DERV, petrol	Regional dwellings, ONS
Agriculture, Forestry & Fishing	Agriculture – stationary combustion	coal, coke, natural gas	Agricultural employment, MAFF/Defra
		burning oil, gas oil, fuel oil	DECC Sub-national energy statistics
		Straw[7]	Wheat production, MAFF/Defra
	Agricultural mobile machinery	Gas oil, petrol	Agricultural off-road mapping grid

[7] Used to calculate non-CO_2 emissions

Residential

Energy and emissions mapping analysis for the combustion of solid and liquid fuels in the residential sector was completed in 2011 and integrated into the 1990-2009 DA GHG inventory estimates; the DA share of UK fuel use totals for solid and liquid fuels are unchanged in the latest DA GHG inventory estimates. Annual gas use data estimates for the residential sector are provided by the gas suppliers in Northern Ireland (Phoenix Gas: 2012; Firmus Energy: 2012; Vayu Ltd.: 2012) and these data have been used to estimate the residential emissions in 2010. The gas use estimates for Scotland, Wales and England are derived from the DECC sub-national energy statistics (DECC, 2012a) which presents a breakdown of gas use by Local Authority for the domestic and non-domestic sectors. Whilst the DECC sub-national energy statistics data are not directly consistent with the published UK gas use statistics for the sector, the DA share from these GB data are used to inform the gas use and emissions in Scotland, Wales and England corrected to the DUKES annual domestic gas data minus the Northern Ireland gas supplier estimates. Domestic natural gas consumption data is estimated for GB using the split presented in the DECC sub-national energy statistics for 2005 onwards (DECC, 2012a) whilst data for earlier years draws upon regional data obtained from Transco and other GB gas supply network operators.

The domestic sector DA method for the non-gas fuels does introduce uncertainty to the overall sector estimates, especially for Northern Ireland where the gas grid is limited and hence a higher proportion of the sector relies upon solid and liquid fuels. The maps and peat data only provide snapshots of analysis for the latest year and where large revisions to previous mapping grid data are evident, the DA inventory compilation must consider the impacts on time-series consistency for the sector as a whole. In order to enable a sector-wide quality check on the time-series data for the sector, estimates of the energy allocations in the sector across all fuels were derived (including estimated electricity use in each DA in the domestic sector).

Using the time series of population data, the energy use estimates per capita were calculated, in order to review the relative energy intensity per head across the time series for each DA. This is a quality check of limited usefulness given the variability in housing stock, fuel availability (e.g. on gas grid or not) climatic considerations and inter-annual variations of factors such as fuel price and average temperature which will all affect the local energy use in the sector. Further research is recommended to further develop the domestic sector dataset for each of the DAs, as this is a sector where DA policy levers can have a large impact and currently the evidence base for the energy use in the sector is uncertain.

The domestic sector emission estimates have been extrapolated back from recent mapping grid estimates, drawing on data on primary fuels used in the sector from Housing Condition Surveys in 1996, 2001 and 2006 (HECA NI, 2008), which provide a summary of fuel-switching trends away from solid fuels due to the development of the gas network and use of burning oil in Northern Ireland since the late 1990s. This approach is used for coal, anthracite, gas oil and burning oil. The Scottish Housing Condition Survey, census data and DEMScot model were considered within the domestic sector energy mapping work for 2009, which also considered more recent (2009) housing post-code level data for Great Britain, retaining some assumptions on the DA share of housing types from the 2001 census. (Personal Communication: Tsagatakis, 2010)

The consumption of fuel oil by the domestic sector is a very small amount, and is distributed simply according to population (ONS, 2012a). Domestic use of wood is estimated across the time-series using the latest mapping grid information on wood use (NAEI mapping, 2011). Domestic peat use estimates by DA are provided by the Centre for Ecology & Hydrology (Personal Communication: Thomson, 2012).

Agriculture, Forestry & Fisheries

Emissions from solid fuel use in the agriculture sector are not very significant, whilst regional gas use data in this sector are not available for Great Britain; in Northern Ireland the gas suppliers do provide an estimate of gas use in the agriculture sector and these data are used directly to inform Northern Ireland emission estimates for gas use, whilst in GB the emissions from agricultural sources are allocated on the basis of regional employment figures from DEFRA (2012a).

Work by AEAT (NAEI, 2008) to derive a more detailed split of regional off-road fuel use (i.e. mainly gas oil use in tractors and other mobile machinery) has utilised research to determine the regional distribution of different land uses and farm types (pasture, arable, forestry). These data have been combined with data on the intensity of mobile machinery use by farm type (tractor hours per hectare of arable land, tractor hours per head of livestock), to derive an agricultural off-road mapping grid to estimate geographical distribution of fuel use in the sector. These data have been used to estimate DA GHG emissions from agricultural mobile machinery.

Military

Emissions from military aircraft and naval vessels are allocated across the DAs based on regional GVA data (ONS, 2012a). Army vehicle emissions are included within road transport data and other army emissions are included within public service categories but are not clearly defined.

Fugitive Emissions from Fuels

Coal Mining

Methane emissions arise from coal mining activities. Emissions from operating mines are estimated based on the amounts of deep mined and open cast coal produced. DA inventory estimates are based on regional coal production derived from a number of sources: Coal Authority (2012), BGS (2012), WO (1998), SO (1999), BERR (1996). A small emission occurs from coal storage and transport, which is based on deep mined coal production. Data suggests that only small amounts of coal are transported outside of the region of production and no attempt has been made to allow for this. Hence coal storage and transport emissions are distributed according to deep-mined production (Coal Authority, 2012).

DA estimates of methane emissions from abandoned coal mines are based on research undertaken by WSP (2011) on behalf of DECC, which uses a site-specific approach to estimating the methane content of seams, and rates of water ingress and methane emissions.

Solid Fuel Transformation

For coke ovens, three fugitive emissions are estimated:

1. A 'residual' emission of CO_2 which reflects the difference between the carbon input to the coke oven and the carbon content of the coke and coke-oven gas produced;
2. Emissions from the flaring of coke-oven gas;
3. Emissions of methane from the process.

These are disaggregated based on the regional consumption of coking coal and site-specific fuel use data from EUETS (for 2005 onwards), as discussed in Section A2.2.3. For solid smokeless fuel (SSF) plant, the only fugitive emissions estimated are the 'residual' CO_2 emission and some process methane. The driver used is that for regional consumption of coal by SSF plant (see Section A2.2.3). It is known that some petroleum coke is used in SSF production but the amount is uncertain. The same driver is applied to the petroleum coke consumption.

Oil and Natural Gas

All emissions from the oil & gas exploration and production industry that occur offshore are reported within the DA GHGI data as unallocated. Emissions from onshore oil and gas terminals in England, Wales and Scotland and from a small number of on-shore oil and gas fields, are based on operator reported data.

The estimates of terminal flaring and venting emissions are based on DECC (2012e) EEMS data for 1995, 1998-2012. Data is unavailable for 1990, so these are extrapolated based on flaring volumes reported in 1998 as the earliest year of EEMS where data are complete and consistent.

The 2000-2011 UK GHG inventories include a correction to account for flaring on onshore oil and gas fields excluded by the DECC EEMS inventory. Onshore flaring volumes are obtained from DECC sources (DECC, 2012d). Their significance in the UK national GHG inventory is minimal, but the data is more significant for the DA GHG inventories. Wytch Farm, which lies a few miles off the south coast of England, is classified as on-shore for this purpose.

The DECC EEMS inventory data provides data for fugitive emissions of carbon dioxide and methane from terminals for 1998-2011. Methane emissions arise from venting, oil storage and tanker loading and unloading, whilst carbon dioxide emissions arise from venting and processes. The DA estimates from operator reporting in 1998 are used to back-cast the DA share of UK emission totals for fugitive sources including: oil terminal storage, onshore oil loading, process emissions. Estimates provided by the trade association in 1999 (UKOOA, 1999) are used to derive the DA share of UK emissions from venting sources in 1995, with the 1995 DA share used to back-cast to 1990. Flaring volumes at oil and gas terminals and onshore production fields are available from DECC back to 1990.

UK inventory estimates of emissions of methane due to leakage from the gas transmission system are based on UK National Grid data of leakage from the high-pressure network, Above Ground Installations and the low-pressure networks. Estimates are provided by National Grid (2012) and the other gas network operators: Northern Gas Networks (2012), Scotia Gas Networks (2012), Phoenix Gas (2012) and Wales & West Utilities (2012). Estimates are provided by Local Distribution Zones, enabling direct allocation to each of the constituent countries.

Table A2.7a: Fugitive Emissions from Fuels (Base Year – 1990)

IPCC Category	NAEI Sources	Activity: Fuel Consumption	Data used for deriving DA estimates from UK totals / Comments
Coal Mining	Deep mined coal Coal storage & transport	Deep mine coal production	Regional deep mine production, British Coal Authority.
	Open cast coal	Open cast mine coal production.	Regional open cast mine production, British Coal Authority
	Closed coal mines	NA	CH_4 from closed coal mines from WSP 2011
Solid Fuel transformation	Coke production	Coke production	Coal feed to coke ovens, ISSB, WS, DECC
	Flaring	Coke oven gas	Coal feed to coke ovens, ISSB, WS, DECC
	SSF production	Coal, Petrocoke	Coal feed to SSF plant, DECC, WS
Oil and gas production	Offshore Oil & Gas	NA	Fugitive emissions from Terminals (extrapolated from 1995)
	Oil Terminal Storage	NA	1998 operator reported emissions, EEMS
	Onshore Loading	Oil loaded	1998 operator reported emissions, EEMS
Venting & Flaring	Offshore Flaring	Volume gas flared	Flaring at terminals and onshore fields, UKOOA, DECC
	Offshore Venting	NA	Fugitive emissions from Terminals (extrapolated from 1995)
Natural Gas	Gas Leakage	Natural gas leakage	National Grid (Transco), Northern Gas Networks, Scotia Gas Networks, Wales & West Utilities
	Gas leakage	Leakage at point of use	Aggregate activity data by DA for residential, public and commercial gas

Table A2.7b Fugitive Emissions from Fuels (1995; 1998 to 2011)

IPCC Category	NAEI Sources	Activity: Fuel Consumption	Data used for deriving DA estimates from UK totals / Comments
Coal Mining	Deep mined coal Coal storage & transport	Deep mine coal production	Regional deep mine production, British Coal Authority.
	Open cast coal	Open cast mine coal production.	Regional open cast mine production, British Coal Authority
	Closed coal mines	NA	CH_4 from closed coal mines from WSP 2011
Solid Fuel transformation	Coke production	Coke production	Coal feed to coke ovens, ISSB, WS, DECC and (1999-2004) PI. 2005 onwards: EUETS (EA, SEPA, NIEA 2011b)

IPCC Category	NAEI Sources	Activity: Fuel Consumption	Data used for deriving DA estimates from UK totals / Comments
	Flaring	Coke oven gas	Coal feed to coke ovens, ISSB, WS, DECC and (1999-2004) PI. 2005 onwards: EUETS (EA, SEPA, NIEA 2011b)
	SSF production	Coal, Petrocoke	Coal feed to SSF plant, DECC, WS
Oil and gas production	Offshore Oil & Gas	NA	Oil & Gas UK GHG emissions from Terminals, DECC EEMS
	Oil Terminal Storage	NA	Data from storage emissions, DECC EEMS
	Onshore Loading	Oil loaded	Data from loading emissions, DECC EEMS
Venting & Flaring	Flaring	Volume gas flared	Flaring at terminals and onshore fields, Oil & Gas UK, DECC
	Venting	NA	Data from venting emissions, DECC EEMS
Natural Gas	Gas Leakage	Natural gas leakage	National Grid (Transco), Northern Gas Networks, Scotia Gas Networks, Wales & West Utilities, Phoenix Gas
	Gas leakage	Leakage at point of use	Aggregate activity data by DA for residential, public and commercial gas

Industrial Processes

These sources report process and fugitive emissions from industrial processes as opposed to the emissions from fuel combustion used to provide energy to these processes. (Table A2.2 covers combustion emissions.) The drivers used for process and fugitive industrial releases are summarised in Table A2.8.

Minerals Industries

Large emissions of carbon dioxide arise from the degradation of limestone used in cement and lime kilns. Cement emissions are estimated from the production of cement clinker, with regional emission estimations based on plant capacity data supplied by the British Cement Association[8] (2004) for 1990 to 2001. From 2002 to 2007, the regional split is based on reported emissions from the PI, SPRI and ISR, whereas in 2008 to 2011 all cement sites now report under EUETS and hence the emissions from combustion and process sources by site are derived from EUETS data. Through discussions with environmental regulators it has been determined that lime calcination only occurs in England.

Limestone and dolomite are also used in iron and steel production. Information from operators indicates that it would be impossible to identify all the different uses of limestone and dolomite in iron and steel making. The major use is in blast furnaces, and so emissions have been disaggregated based upon regional iron production figures (ISSB, 2012).

[8] Production capacity data are used for cement emissions as the actual annual production data from cement plant are commercially confidential.

Limestone, dolomite and soda ash are also used in glass production. Emissions were previously disaggregated using plant capacity and carbon dioxide emissions data from British Glass for 1990, 1995, 1998 and subsequently extrapolated for 1999 and 2000. However, the improvement of data supplied via the Pollution Inventory (Environment Agency, 2012) has enabled more accurate disaggregation for the years 2000 and 2001. Historic data has therefore been revised where appropriate and the Pollution Inventory data now provides a more accurate methodology for regional disaggregation of UK data from 2002 onwards.

The 2009 to 2011 EUETS datasets contain a much greater coverage of sites and emission sources (combustion and process) from the glass industry, which are now used to inform time series estimates of DA activity and emissions. Previously the DA allocation of emissions from the glass sector was based on site information on production capacity, but access to fuel use data for 2009 to 2011 has enabled these assumptions to be over-written with fuel-specific DA allocations.

The inventory also reports carbon dioxide and methane emissions from Fletton brick production, as introduced in 2000. These bricks are made from Fletton clay which contains a significant amount of naturally occurring carbonaceous material and all such production occurs in England.

Chemical Production

The UK Inventory reports emissions of carbon dioxide from ammonia production; nitrous oxide from adipic acid production and nitrous oxide from nitric acid production. Following the closure of a (nitric acid) fertiliser plant in Belfast in late 2001, all of the nitric acid, ammonia and adipic acid plants are within England. Prior to that, plant capacities for nitric acid production facilities were used to estimate the split in UK chemical production GHG sources. The adipic acid plant in England ceased production in 2009.

Table A2.8a: Industrial Processes (Base Year – 1990)

IPCC Category	NAEI Sources	Activity Data	Data used for deriving DA estimates from UK totals / Comments
Cement Production	Cement (decarbonising)	Clinker production	Regional cement production capacity, BCA
Lime Production	Lime (decarbonising)	Limestone consumption	All such plant located in England
Limestone and Dolomite Use	Glass production	Limestone and dolomite consumption	Regional glass production, British Glass
	Blast Furnaces	Limestone and dolomite consumption	Iron production, ISSB
Soda Ash Production and Use	Glass production	Soda Ash Consumption	Regional glass production, British Glass
Mineral Products: Other	Fletton Brick Production	Fletton Brick Production	All such plant located in England
Ammonia Production	Ammonia feedstock	Natural gas feedstock	All such plant located in England
Nitric Acid Production	Nitric Acid Production	Plant capacity	Regional plant capacity
Adipic Acid Production	Adipic Acid Production	Adipic acid made	All such plant located in England
Chemical Industry: Other	Methanol Production	Production of Methanol	All such plant located in England
Chemical Industry: Other	Ethylene Production	Production of Ethylene	Plant capacities
Chemical Industry: Other	Chemical Industry	NA	Extrapolated from PI data
Iron and Steel	Electric Arc Furnace	EAF steel production	Regional EAF production, ISSB
	Flaring	Blast furnace gas	Coke consumed in blast furnaces, ISSB, WO
Aluminium Production	Aluminium production	Primary aluminium produced	Regional aluminium plant capacity, ALCAN
SF_6 Used in Aluminium and Magnesium Foundries	SF_6 Cover gas	NA	Regional consumption & sales data, EM industry report 1999
Halocarbon & SF6 By-Product Emissions	Halocarbon Production	NA	All such plant are located in England.
Refrigeration and Air Conditioning	Refrigeration	NA	Regional population, ONS
	Supermarket Refrigeration	NA	Regional GDP, ONS
	Mobile Air conditioning	NA	Vehicle Registration data, AEAT industry report 2003
Foam Blowing	Foams	NA	Regional population, ONS
Fire Extinguishers	Fire fighting	NA	Regional population, ONS
Aerosols	Metered Dose Inhalers	NA	Regional population, ONS
	Aerosols (halocarbons)	NA	Regional population, ONS
Other	Electronics	NA	Regional electronics plant consumption, EM industry report 1999
	Training shoes	NA	Regional population, ONS
	Electrical Insulation	NA	Regional electrical capacity, AEAT industry report 2003

Table A2.8b: Industrial Processes (1995; 1998 to 2011)

IPCC Category	NAEI Sources	Activity Data	Data used for deriving DA estimates from UK totals / Comments
Cement Production	Cement (decarbonising)	Clinker production	Point source data from EUETS (2008 onwards), and the PI/SPRI/ISR (EA, SEPA & NIEA).
Lime Production	Lime (decarbonising)	Limestone consumption	All such plant located in England.
Limestone and Dolomite Use	Glass production	Limestone and dolomite	Regional glass production, BGlass. EUETS (2009 onwards)
	Blast Furnaces	Limestone and dolomite	Iron production, ISSB
Soda Ash Production and Use	Glass production	Soda Ash Consumption	Regional glass production, BGlass. EUETS (2009 onwards)
Mineral Products: Other	Fletton Brick Production	Fletton Brick Production	All such plant located in England
Ammonia Production	Ammonia feedstock	Natural gas feedstock	All such plant located in England
Nitric Acid Production	Nitric Acid Production	Plant capacity	Regional plant capacity, PI/SPRI/ISR. Since 2002, all plant located in England.
Adipic Acid Production	Adipic Acid Production	Adipic acid made	All such plant located in England
Chemical Industry: Other	Methanol Production	Production of Methanol	All such plant located in England
Chemical Industry: Other	Ethylene Production	Production of Ethylene	Plant Capacities, PI/SPRI/ISR
Chemical Industry: Other	Chemical Industry	NA	PI/SPRI/ISR data, or extrapolated from PI data
Iron and Steel	Electric Arc Furnace	EAF steel production	Regional EAF production, ISSB
	Flaring	Blast furnace gas	Coke Consumed in blast furnaces, ISSB, WO
Aluminium Production	Aluminium production	Primary aluminium produced	UK plant production & emissions data, Alcan, Rio-Tinto, EA, SEPA
SF_6 Used in Aluminium and Magnesium Foundries	SF_6 Cover gas	NA	Regional consumption & sales data from industry reports compiled by EM & AEAT
Halocarbon & SF6 By-Product Emissions	Halocarbon Production	NA	All such plant are located in England.
Refrigeration and Air Conditioning	Refrigeration	NA	Regional population, ONS
	Supermarket Refrigeration	NA	Regional GDP, ONS
	Mobile Air conditioning	NA	Vehicle Registration data, AEAT industry report 2003
Foam Blowing	Foams	NA	Regional population, ONS
Fire Extinguishers	Fire fighting	NA	Regional population, ONS
Aerosols	Metered Dose Inhalers	NA	Regional population, ONS
	Aerosols (halocarbons)	NA	Regional population, ONS
Other	Electronics	NA	Regional electronics plant consumption, EM industry report 1999 & AEAT industry report 2003
	Training shoes	NA	Regional population, ONS
	Electrical Insulation	NA	Regional electrical capacity, AEAT industry report 2003

The UK inventory reports emissions of methane from methanol production, ethylene production and the other chemical industry. The methanol plant is located in England, whilst ethylene production occurs in England, Scotland and Wales. These emissions are distributed based on data reported in the PI (Environment Agency, 2012a), SPRI (SEPA, 2012a) and plant capacity. Emissions are extrapolated to 1990 and 1995 based on plant capacities.

The emissions from the "other chemical industry" sector are disaggregated to England and Wales based on the site data in the Pollution Inventory. Data on emissions from other chemical processes are not available for Scotland.

Metal Production

In the iron and steel industry, emissions of carbon dioxide arise from electric arc furnaces through the consumption of the graphite anodes. Regional data on steel production from electric arc furnaces is used to determine the regional drivers for this activity (ISSB, 2012).

The flaring of waste blast furnace gas is disaggregated according to the distribution of blast furnaces, using the driver derived for coal consumption by blast furnaces (ISSB, 2012) up to 2004, and then using plant-specific data from the EUETS for 2005 onwards (EA, SEPA, NIEA 2012b) verified using data from operators (Tata, 2012).

Emissions of carbon dioxide from iron and steel making are estimated from a mass balance on the coke consumed in blast furnaces; the blast furnace gas produced; the pig iron produced; the pig iron used in steel making and the crude steel produced. The emissions are distributed using appropriate drivers for each source and sink taken from ISSB (2012) and on site-specific information for the integrated steelworks taken from the EUETS for 2005 onwards.

The electrolytic process used to produce aluminium results in a carbon dioxide emission as the petroleum coke anode is consumed. Emission estimations are based on plant capacity data provided by Alcan (2004), for years up to 2002. The DA emissions data for 2003 onwards are based on PI and SPRI data (EA, 2012a; SEPA, 2012a). There have been some significant changes in the aluminium industry in recent years, with the closure of the Kinlochleven plant in 2000, and the expansion of the Lynemouth plant, and hence there has been a swing in emissions from this sector from Scotland to England.

The anode baking process within aluminium production also results in emissions of PFCs, and estimates are provided by plant operators (Alcan, 2012).

Use of Halocarbons and Sulphur Hexafluoride

The UK emissions of halocarbons and sulphur hexafluoride (SF_6) were based on estimates from a model prepared initially by Enviros March (1999). This model was updated by AEAT (Haydock et al, 2003), with further updates at UK level for the refrigeration and air conditioning sectors during 2008-9 (Personal Communication: MacCarthy, 2010) and again during 2011 (Brown et al, 2012). For some sources, the emission is equal to the consumption of fluid (e.g. aerosols). For other sources the emissions occur during product manufacture, leakage during product lifetime, and at product disposal (e.g. refrigerators). In these cases emissions are estimated from a time dependent model of the bank of fluid held in products, accounting for unit production and disposal.

Data for HFC emissions from metered dose inhalers in the UK are also taken from the EM & AEAT predictive models. The National Asthma Campaign's National Asthma Audit (1999-2000) concluded that:

"There is little variation in asthma prevalence among children or adults throughout Great Britain."

Therefore, the regional split of emissions is proportional to population.

Supermarket refrigeration is regarded as sufficiently different from other refrigeration to warrant a separate study. Emissions are based on a market review of the number and size of supermarkets in the regions, combined with discussions with gas manufacturers on the sales into this sector. Discussions with supermarket owners also suggest that regional use could be approximately equated to sales volume, which in turn could be approximated by regional GVA estimates, which have been obtained from ONS (2012a). The DA GVA data are therefore used to estimate the share of refrigeration emissions within the UK.

Air conditioning systems in cars began to use HFC134a from around 1993. Data is supplied by SMMT on regional sales of new cars. Initially, installation of air conditioning was skewed towards company cars, which are broadly distributed according to population.

PFCs and SF_6 are used to cushion the soles of some training shoes. Data have previously been gathered from discussions with Nike. Sales figures for the devolved regions of the UK were not available, and therefore the regional split is made according to population.

Sulphur hexafluoride is used in electrical switchgear within the electricity transmission system. UK estimates are based on discussions with industry sources and summarised within the EM & AEAT model. Regional estimates are determined through consultation with power supply companies (NIE, Scottish Power & Scottish Electric, National Grid) and the Electricity Association.

For aerosols, the split by region is made on the basis of population, although use of these gases often have industrial applications. Making the split using population has the advantage of making the data directly comparable with the figures for the baseline years of 1990 and 1995.

Other sources such as fire extinguishers are very small and are likely to be distributed with the general population.

Emissions of SF_6 cover gas from magnesium production is based on regional sales and consumption data. This stable market is assessed within the AEAT model (2003), with all production located in England & Wales.

Emissions data for regional emissions from semiconductor wafer manufacture are estimated from manufacturing data and consultation with relevant trade associations, and incorporated within the AEAT model (2003).

Agriculture

Rothamsted Research provides all data and information pertaining to agricultural sources within the Devolved Administration emission inventories.

The UK inventory is disaggregated into the Devolved Administrations of England, Scotland, Wales and Northern Ireland, with all default factors and emission factors carried over from the national inventory. The compilation of the emissions is carried out at DA level and added up to national level.

Agricultural Soils

DA-specific crop areas and crop production data for years previously only reported at UK, and not DA, level (1991-1994, 1996-1997) have been sourced from official statistical data sources where available and where not available have been interpolated from existing data (this especially applied to crop production data). As part of this process all historical crop area data has been updated and revised with current published statistics. Crop areas for Northern Ireland were updated with data supplied by DARDNI (Personal communication, Paul Caskie, DARDNI, 2012). Welsh crop area data for 1998-2011 updated with data provided by the Welsh Government (Personal communication, Stuart Neil, Welsh Government, 2012)). Some crop areas and production for England also updated (Defra, 2012).

Fertiliser applications are derived from regional crop areas and average application rates published in the British Survey of Fertiliser Practice (BSFP, 2012), which presents data for England and Wales, Scotland and Great Britain. Application rates in Northern Ireland were supplied by Paul Caskie in DARDNI. In many cases, the sample size used to estimate fertiliser use in Scotland is considered too small to be sufficiently robust and in these cases, the Great Britain data are used. Where application rates are not available for particular crop types, the crop area is amalgamated with a similar crop with a known fertiliser application rate. Where annual applications are not available, fertiliser application for a different year are used.

The area of cultivated histosols (soils of high organic content) has been corrected to be consistent with the value reported under LULUCF. The UK total updated from 392 km^2 to 1500 km^2 is now reported under England only (UK GHG Inventory, 1990 to 2011 Report, Table A.3.7.27; total area of peat 150,000 ha).Data sources for the annual production of sewage sludge (as dry matter) for 2011 values were unavailable at the time of data compilation so it was extrapolated from previous years. Data from E&W is no longer supplied by OFWAT but by the EA; revised data has been supplied for 2008 and 2009 which has been input along with the 2010 data. Additional data was provided by the Water Commission for Scotland (WICS, 2012)[9] and by UREGNI [10]for Northern Ireland.

Estimation method corrections in the 1990-2011 DA GHGI cycle include: N-C ratio value of 0.012 for oats, barley and linseed replaced with the wheat default value of 0.015 (IPCC 1996).

Livestock Enteric Fermentation and Manure Management

Livestock numbers are obtained from Defra, Scottish Government, the Welsh Assembly and DARD Agricultural Census data for all years. Other data such as milk production and fat in milk are obtained from Agriculture in the UK (Defra, 2012), with common values used across the DAs. Provisional data for 2009-2010 was updated.

Dairy cattle weight is from slaughter weight data provided by Sarah Thompson, Defra, with common values used across the DAs. Dairy cattle weights due to weight anomalies from the 30 month rule

[9] WICS, Scotland, http://www.watercommission.co.uk/view_Regulatory_data.aspx
[10] http://www.uregni.gov.uk/publications/show/category/water_and_sewerage/P40/

were corrected for years 1997-2005 by interpolating via linear regression. A Tier 2 methodology is used for the calculation of the enteric emissions from beef cattle, but a time series of cattle weights are not available, and so a constant weight of 500 kg has been assumed. A UK-specific emission factor is used, assuming a weight of 500 kg. A Tier 2 methodology is used for the calculation of the emissions from other cattle but weight is not changed from year to year.

N excretion factors are kept in agreement with the UK NH_3 inventory (Cotteril and Smith, 2006), with common values used across the DAs.

Tier 2 methodology has been adopted for estimating CH_4 emission from manure management ensuring that we reflect much better the UK-specific data we have on manure management practices (as we do for the N_2O emission estimate). Previously, Tier 2 methodology was only applied to dairy and beef cows. Tier 2 methodology is now applied to all livestock categories with the exception of deer because of the lack of VS excretion and Bo values for this livestock category.

For dairy cows the Tier 2 methodology for calculating enteric methane was revised from the 1996 Guidelines to the IPCC 2000 Good Practice Guidance. A number of additional cattle categories have been introduced to allow for more accurate source apportionment of emissions to the 'dairy' and 'beef' sectors.

In addition, the cattle ash value was updated from 7.90 to 8.0 to agree with the IPCC (1996) default. Feed digestibility was changed from 73.588% to 75%.

Emissions of N_2O and CH_4 from poultry litter AWMS for that proportion of poultry litter which goes to incineration are included in the inventory. Direct losses from incineration are not reported here, as they are reported in the Energy sector of the inventory.

The N excretion factor of 56 kg N animal place per year, is retained for beef heifers (Cotteril and Smith, 2006).

Emission factors for lamb enteric and waste management were also revised. Previously lambs were assumed to have a 6 month life-span; this has been revised to 8.1 months based on new evidence on the average age of UK lambs at slaughter (Wheeler, Wright & Phillips, 2012.). The report only gives data from one year and so the same value of age is used for the whole time series. The enteric EF has changed from 3.2 to 2.2 accordingly. A correction and a revision have been made to the waste EF: the lamb EF should have been 40% of the adult EF of 0.19; this has now been applied and the lamb lifespan revised from 6 to 8.1 months. The waste EF has therefore changed from 0.19 to 0.05. Other sheep are assumed to live for 6 months. N excretion for ewes was revised to 9 kg/year (from 10.5/9.9 kg/year for lowland/upland ewes) and for lambs 2.4 kg/year (from 0.6/0.7 kg/6 months) (Smith & Frost, 1999). The EF's were revised because the previous value for ewes incorrectly included lambs and the lamb value was not applicable to the lamb whole lifespan (only after weaning). Other sheep are assumed to live 6 months, lambs lifespan 8.1 months (same reference as above).

There are no regional differences in the parameters currently used to calculate emissions (except for activity data).

Planned improvements to the inventory

UK emission factors are currently under review for:

- EF1, emission factor for direct soil emissions; from a literature review and a field measurement programme.
- EF3, emission factor from manure management systems; from a literature review and a field measurement programme and,
- EF5, nitrogen leaching/runoff factor; from a field measurement programme

The UK aims to improve the spatial disaggregation of the inventory by calculating emissions using parameters specific at DA level.

The UK is improving the link between the NH_3 and GHG inventories, and incorporating NOx in a study (desk/experimental) which will review the current value of 20% of N lost as NH_3 and NOx.

A large programme of improvements to the UK inventory is underway, as a platform of projects to provide country specific data has been funded by Defra. Improvements include analysis of available data from the literature, and specific experimental work to improve the estimates of emissions of N_2O and CH_4.

Land Use, Land Use Change & Forestry (LULUCF)

The Land Use, Land Use Change and Forestry (LULUCF) sector includes carbon stock changes, emissions of greenhouse gases (carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O)) by sources and removals of CO_2 by sinks from land use, land use change and forestry activities. Removals of CO_2 are conventionally presented as negative quantities. Total greenhouse gas emissions are described as carbon dioxide equivalents (CO_2e), using Global Warming Potentials (GWP) of 21 for CH_4 and 310 for N_2O (as used in the inventories submitted to the UNFCCC).

Detailed information on the data and methods used in the LULUCF inventory is available in the 1990-2011 UK Greenhouse Gas Inventory Report, available on the National Atmospheric Emissions Inventory website http://naei.defra.gov.uk/. Chapter 7 and Annex 3.7 contain information on the LULUCF sector, and Chapter 11 contains additional information on the reporting of LULUCF activities for the Kyoto Protocol. Additional information on LULUCF and KP-LULUCF inventory reporting has been made available at http://ecosystemghg.ceh.ac.uk/. The description of the DA GHG inventory methodology and emission estimates are included in a report published in April 2013[11], available on the NAEI website at:

http://uk-air.defra.gov.uk/reports/cat07/1304150833_DA_LULUCF_GHG__Inventory_report_2013_final_version.pdf

The current LULUCF inventory methods use a combination of top-down and bottom-up approaches, based on activity data for each of the Devolved Administrations and the UK as a whole. As a result of

[11] "*Emissions and Removals of Greenhouse Gases from Land Use, Land Use Change and Forestry (LULUCF) for England, Scotland, Wales and Northern Ireland: 1990-2011*". Heath Malcolm, Stephen Hallsworth and Amanda M. Thomson, Centre for Ecology & Hydrology, 15th April 2013

this approach, estimates of emissions and removals from LULUCF activities are automatically produced at the DA and UK scale.

Net emissions and removals in greenhouse gases are summarised for each country and the reasons for differences from the previous inventory are provided. Summary tables for 1990, 1995, 2000, 2005, 2010 and 2011 are given in for each country in Appendix 1, and for LULUCF emissions and removals under the Kyoto Protocol in Appendix 2.

The 1990-2011 LULUCF inventory

There are small differences in net emissions from the 2010 inventory due to the inclusion of new activity data and other minor revisions. These are described separately for each country, but comprise:

- **5A Forest Land**: Revisions to activity data for wildfires and inclusion of carbon from dead organic matter in biomass burning;
- **5B Cropland**: Method revision to use country-specific biomass densities in the estimation of biomass and dead organic matter losses from deforestation. Corrections to activity data in allocation to Settlements converted to Cropland have affected some DA totals;
- **5C Grassland**: Revisions to activity data for Forest Land converted to Grassland, and the use of country-specific biomass densities to estimate biomass and dead organic matter losses;
- **5D Wetlands**: Revision to assumptions concerning emissions from extraction sites that are no longer active, and the use of newly published activity data;
- **5E Settlements**: Revisions to activity data for Forest Land converted to Settlements, and the use of country-specific biomass densities to estimate biomass and dead organic matter losses;
- **5G Harvested Wood Products**: Revisions to deforestation activity data have affected the pool of harvested wood products.

Waste

Solid Waste Disposal on Land

In the UK Inventory, emissions are estimated based on a model of methane production in landfill sites. The generation of methane is assumed to follow a first order model with different decay rates for different types of waste. The model requires data on waste disposals and waste composition from 1945 onwards.

The UK GHGI waste model was revised and updated during the 1990-2010 inventory cycle to correct a number of errors in the model from the previous inventory cycle, and incorporating a range of DA-specific data on waste composition, MSW arisings. These revisions have been retained.

The AEAT team provided a suite of DA-specific waste sector datasets that were incorporated into the landfill model revision funded by Defra during the 1990-2009 UK GHGI cycle. Consultation with waste sector experts during 2010 led to the collation of new information from recent waste survey and compositional studies including: MSW composition (Scotland WRAP study, Wales WRAP study), public sector waste arisings survey (Wales), Commercial & Industrial & Agricultural waste fate studies (Wales), Northern Ireland waste compositional study and Commercial & Industrial waste sector report.

The current model retains much of the design and functionality of the previous GHGI waste model; due to a lack of detailed local data, it is assumed that the level of methane recovery is the same in each region.

Data from the www.WasteDataFlow.org website are used to estimate DA landfill activity. The Waste Data Flow website is used by Local Authorities to track progress towards waste sector objectives. Reports from the Waste Data Flow organisation have been reviewed, and these provide a more detailed split of waste disposal options undertaken in the DAs, with ultimate fate of municipal waste recorded against numerous options, primarily: recycling, landfill and incineration.

The detailed methodology for determining DA emission estimates from landfills was revised by Defra in the 1990-2010 inventory cycle to derive estimates of landfill methane emissions by country. The method makes use of disaggregated waste arising and compositional analysis data to reflect better the individual country emissions, rather than taking UK aggregate emission estimates and scaling.

Following the update to MELMod (released in the 2011 inventory submission), we now have a much more disaggregated understanding of the waste quantity assumptions fed into different MELMod categories. The underlying data, as well as references, that fed into the 2011 revision is discussed in depth in a separate report.[12] Estimates of country-specific landfill tonnages are derived by:

- Using the data on Local Authority Collected Waste (**LACW**, previously known as MSW). There is not annual data on the quantity and composition of landfilling. For each country, however, there are periodic surveys of waste composition, as well as quarterly/annual data on quantity of waste landfilled, and the quantity/composition of recycling.

  These sources are combined to produce a best estimate of the quantity of different types of waste landfilled. The data are uncertain due to the limited nature and frequency of compositional surveys; however, the data on landfilling and recycling of materials is considered to be associated with low uncertainty.

  Country-specific data were revised back to 1995 within the UK model update in the 1990-2010 inventory. Data for 2011 are derived based on a projection from 2010.

- Data are less frequent and complete for commercial and industrial (C&I) waste; DA-specific data have been used where available, whilst UK average data have been used to fill data gaps in other DAs.

  The quantity of different types of landfilling was computed from compositional data, landfill site returns, landfill tax data and data on the composition and destination of construction and demolition (which is required to determine what element of construction and demolition waste is methane-producing).

  The overall input to MELMod was not done on a country-by-country basis due to the data limitations.

[12] http://randd.defra.gov.uk/Document.aspx?Document=9887_WR1124Finalreportincludingappendices.pdf

The DA estimates are based on available data that were used within the UK MELMod model used in the 1990-2011 UK GHGI (Brown et al, 2012). The following section explains the method.

Local Authority Collected Waste (LACW)

- LACW estimates of landfilling by waste type are available for each country from 1995 to 2020.
- The time series of data were extrapolated back from 1995 and forward to 2010;
- The data time series was extrapolated back from 1995 for each country by applying the UK figures in Melmod pre-1995 to each country's share of overall LACW landfilling in 1995.
- The data time series was projected forward to 2010 by flatlining.

Commercial and Industrial Waste (C&I[13])

- DA-specific C&I waste data is very limited or not available at all; the method uses the available estimates of overall UK compositions of C&I (and C&D) waste landfilled in different years, based on waste surveys, and combines the UK-wide data with DA-specific estimates of total landfilling of commercial, and industrial, waste for given years (interpolated from the available survey evidence).
- Using the estimates over country-specific landfilling of both commercial and industrial waste, and applying the estimated UK C&I landfill composition allows a calculation of country specific estimates of the quantity and type of waste landfilled.
- Due to data limitations, the Eunomia revision only went as far back as 1997. A similar backwards extrapolation to that for LACW was performed, according to each country's relative share of combined commercial and industrial landfilling in 1997.
- As the C&I estimates are not country-specific in the revision, forward projections to 2010 are estimated on a country basis by taking the most recent year's data (at the time of the revision) – 2008/09 – for each country's share of commercial, and industrial, landfilling, and multiplying by the assumed overall UK composition for that year.
- The estimation of country-specific C&D landfilling (which feeds into the 'C&I' section of MELMod) followed the same process as set out above for C&I.

The method applies the current UK assumptions on methane capture and oxidation to the country-specific emission estimates.

Waste Water Handling

Nitrous oxide emissions from waste-water handling are based on population statistics for the UK (ONS, 2012a) whilst methane emission estimates are based on operator reported data on treatment activities from water companies in England and Wales within the June Returns to OFWAT (OFWAT,

[13] Also includes C&D waste in MELMod.

2012), and from Scottish Water (Personal Communication: Jacques-Turner, 2012) and Northern Ireland Water Service directly (Personal communication: Pollock, 2012). Methane emission factors for water treatment and sewage sludge treatment and disposal options are derived from operator information provided for the UK GHGI compilation process (Scottish Water 2011, Northern Ireland Water 2011, Thames Water 2011, Yorkshire Water 2011, Anglian Water 2011, South West Water 2011). There has been some improvement to the UK GHGI methodology for this source during the 1990-2011 cycle, but there is incomplete reporting from the water industry to the NAEI/GHGI work programme and hence there remains a high level of uncertainty in the current estimates.

New estimates of emissions from industrial waste water treatment were included in the UK GHG inventory in the 1990-2011 cycle and were distributed across the DAs based on the dataset from water companies outlined above.

Waste Incineration

The UK Inventory reports emissions from the incineration of sewage sludge, municipal solid waste and some chemical waste. DA estimates are based on DEFRA (2012a) which reports data for the amount waste incinerated for Scotland, Northern Ireland and England & Wales.

Emission drivers from MSW Incinerators for 1990-1995 are based on capacity data for individual incinerators taken from RCEP (1993). It is assumed there were no significant changes between 1990 and 1995. Estimates for recent years are based on plant capacity data (Patel, 2000). All of the larger MSW incinerator plant have been re-fitted during the late 1990s to generate electricity and are therefore reported as power stations in the regional inventories. A handful of smaller waste incinerators (municipal, industrial and clinical) are used for district heating and are reported as commercial or miscellaneous. The disaggregation of these smaller heat-generating plant is based on the same driver as for larger MSW incinerators, as there is no specific source of information that provides a more satisfactory estimation of the regional split. The total consumption of these incinerators is reported within the Digest of UK Energy Statistics (DECC, 2012a).

Emissions from clinical waste incineration are allocated to the regions based on a set of plant capacity data for 1998. Emissions data from chemical waste incineration are available for England and Wales only, based on data taken from the Pollution Inventory (Environment Agency, 2012a), and these data are used for the DA estimates also. Some chemical waste incineration takes place in Scotland but no emissions data are available, and hence the emissions contributed from this source are currently omitted from the Scottish inventory data. No chemical incinerators have been identified in Northern Ireland.