Appendices

CONTENTS

Appendix 1
DA GHGI Estimation Methodology

CONTENTS

1.1 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 2009, presents UK greenhouse gas emission estimates for the period 1990 to 2007 (Jackson *et al*, 2009).

This report presents separate inventories of greenhouse gas emissions for England, Scotland, Wales and Northern Ireland for the years 1990, 1995 and 1998 to 2007 that are consistent with the 1990 to 2007 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).

1.1.1 Reporting Format

Emissions are reported according to the Sector Tables in the IPCC Common Reporting Format with some modifications.

Where it is not possible to allocate emissions from certain sources to any one constituent country of the United Kingdom, such emissions are calculated and reported as “Unallocated”. This only applies to emissions from the offshore oil and gas industry. Emissions from domestic and military aviation and shipping, which were previously unallocated, have now been allocated to the country from which the aircraft or shipping movements originated.

The UK Inventory also reports emissions from international marine and aviation bunkers separately, as required by the Intergovernmental Panel on Climate Change (IPCC). Emission estimates for each of the constituent countries of the UK are presented separately from the main inventory data. For more details, see Appendix 3.

1.1.2 General Approach

The UK Inventory is based on UK statistics for activities producing greenhouse gas emissions. These include fuel consumption, industrial production, agriculture and land use change and forestry. 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:

$$E_i = \frac{d_i Ae}{\sum_{j=1}^{5} d_j}$$ [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 2007 inventories, over 130 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 A1.1 to A1.10. The IPCC classification is used throughout (IPCC, 1997a), and the following section provides a description of the abbreviations used throughout the Appendix 1 discussion.

1.1.3 Improvements to DA Inventory Datasets

In the derivation of the 1990-2007 DA GHGI datasets, the AEA inventory team have aimed to improve disaggregation methodologies and data sources for several GHG emission source sectors, including:

- Methane from waste landfills
- DECC regional energy statistics for gas, solid and liquid fuels used in domestic, commercial, public administration and small-scale industrial sectors
- Domestic aircraft
- Oil & Gas sector
- Road transport
- Forest land (LULUCF)

Data and methodological improvements and revisions within the latest DA GHG inventories are summarised in Chapter 7 of the main report, with detailed estimation methods presented in this appendix.

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
DECC	Department for Energy and Climate Change
DETI	Department of Enterprise, Trade and Investment (Northern Ireland)
DETR / DEFRA	Department of Environment, Transport & the Regions / Department for Environment, Food and Rural Affairs
DTLR	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)
MSW	Municipal Solid Waste
NA	Not Available
NAEI	National Atmospheric Emissions Inventory
NI DoE	Northern Ireland Department of Environment
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
SPRU	Science Policy Research Unit
UKOOA	UK Offshore Operators Association, now called “Oil & Gas UK”
UKPIA	United Kingdom Petroleum Industry Association
WO	Welsh Office
WS	Welsh Statistics

1.2 ENERGY INDUSTRIES

The drivers used for the energy industries are summarised in Table A1.2. 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 2007. The derivation of drivers sometimes differs between years depending on data availability.

1.2.1 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, 2008a) the Scottish Pollution Release Inventory (SEPA, 2008a) and the Inventory of Statutory Releases (Northern Ireland Department of Environment, 2008a) has been used to estimate DA emissions. For emissions in 2005 onwards, fuel use and emissions data reported within the EUETS (Environment Agency, 2008b; SEPA, 2008b; Northern Ireland DoE, 2008b) 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 and UK fuel use reported in DUKES. Country-specific electricity generation data (DECC, 2008b) 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 the EA and SEPA.

A small number of plants generate heat rather than electricity and these are categorised as 1A4a commercial and institutional. Some 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 (see Waste, Section 1.11).

1.2.2 Petroleum Refining

UKPIA have provided a site-by-site breakdown of UK refining emissions for 1997 and 1999 – 2007 (UKPIA, 2008), and have advised that refinery throughput did not vary significantly between 1990 and 1997. The CO_2 emissions data are used as a surrogate for all fuel consumption. Emissions for 1998 are based on CO_2 emissions reported in the Pollution Inventory (EA: 1999a). Note that there is ongoing research to resolve data reporting inconsistencies between EUETS data for refineries and the UK fuel use for the sector reported within DUKES.

Table A1.2a: Energy Industries (Base Year – 1990)[1]

IPCC Category	NAEI Sources	Activity: Fuel Consumption	1990
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
		Other fuels	Arrivals of natural gas, DTI
	Offshore Own Gas Use / Gas Separation Plant	Unrefined natural gas, LPG, OPG	Extrapolated from 1995 on oil and gas arrivals, DTI
	Nuclear Fuel Prod.	natural gas	All plant in England.

[1] See Section 1.1.3 for abbreviations

Table A1.2b: Energy Industries (1995; 1998 to 2007)

IPCC Category	NAEI Sources	Activity: Fuel Consumption	Data Sources / 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. Emission totals are always held consistent with the UK GHGI and DUKES fuel use totals.
		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.
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 and (since 1999) PI data.
		Coke	Coke breeze consumption, ISSB.
		Blast Furnace gas	Coke Consumed in Blast Furnaces, ISSB**.**
	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.
		Other fuels	Arrivals of natural gas, DECC
	Offshore Own Gas Use / Gas Sepn.	Unrefined natural gas, LPG, OPG	(1995 – current) Oil & Gas UK EEMS CO_2 estimates for terminals, DECC activity data.
	Nuclear Fuel Prod.	natural gas	(1995 – current) Data not available.

1.2.3 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 (2009). 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, 2000-2008). The Welsh statistics are only available to 1993, so this data is used as an estimate of the Welsh non-iron and steel coking coal consumption in 1995. For 1998 to 2007, the non-iron and steel coking coal consumption data is apportioned between England and Wales using CO_2 emissions for the particular sites reported in the Pollution Inventory and EUETS (EA: 2008).

The generic driver for coke oven fuel consumption is the regional consumption of coking coal (ISSB, 2009). This driver is also used for natural gas consumption and coke oven gas consumption. Some coke ovens use blast furnace gas as fuel and the availability depends on blast furnace gas capacity (see Industrial Processes). 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, 2008a) 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.

1.2.4 Other Energy Industries

This category consists of a number of small emissions from collieries, the gas industry, the nuclear fuel industry and a large emission from offshore natural gas use. In the DA inventories, emissions from oil and gas terminals are based on data provided by Oil & Gas UK (2008). Installation-specific data are only available for post-1995. Emissions for 1990 are extrapolated based on 1995 Oil & Gas UK data and the arrivals of crude oil and natural gas in Scotland and England (DTI, 1991; 1996). The category of “gas separation plant” is assumed to be a subset of the gas used in oil and gas terminals and is treated in the same way as “offshore own gas use”, with emissions allocated based on the Oil & Gas UK data on gas consumption in terminals. A driver is estimated for the category of “gas production” based on the arrivals of natural gas in England and Scotland (DECC: 2008d). Other sources are minor and are covered in Table A1.2.

1.3 MANUFACTURING INDUSTRIES AND CONSTRUCTION

The drivers used to estimate DA-specific fuel consumption from these sectors are summarised in Table A1.3.

1.3.1 Iron and Steel

The ISSB (2009) provides annual reports of the detailed regional consumption of fuel by the steel industry. 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 regional figures for coal feed to coke ovens, whilst the consumption of blast furnace gas is distributed as proportional to 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.

1.3.2 Other Industry

DECC (2008a) reports regional sales of solid and liquid fuels, but only as totals for England and Wales (combined), Scotland and Northern Ireland, based on reported sales data from refineries and collieries. These data have previously been used to provide estimates for other industrial fuel use, by difference from consumption data from specific sources (e.g. road transport, heavy industry). In recent years, however, DECC has started to produce more detailed regional energy use data (DECC, 2008b), based on new data that has become available on local electricity and gas consumption patterns, as part of a project to develop Local Authority CO_2 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 A1.3a: Manufacturing Industry and Construction (Base Year – 1990)[1]

IPCC Category	NAEI Sources	Activity: Fuel Consumption	1990
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
		Fuel oil, gas oil, LPG, natural gas, coal	Consumption of specified fuel, ISSB
Other Industry	Other Industry	Burning oil, fuel oil, gas oil	Regional oil consumption, DECC
		OPG	All such plant are located in Scotland, DECC
		LPG	Regional energy statistics, DECC
		Lubricants	Regional 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	Regional energy statistics, DECC
		Coke oven gas	Coal feed to coke ovens, ISSB, WO, WS
		SSF	Regional 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	GDP data.

1 See Section 1.1.3 for abbreviations

Table A1.3b: Manufacturing Industry and Construction (1995; 1998 to 2007)

IPCC Category	NAEI Sources	Activity: Fuel Consumption	Data Sources / 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
		Fuel oil, gas oil, LPG, natural gas, coal	Consumption of specified fuel, ISSB
Other Industry	Other Industry	Burning oil, fuel oil, gas oil	Regional oil consumption, DECC
		OPG	All such plant are located in Scotland, DECC
		LPG	Regional energy statistics, DECC
		Lubricants	Regional 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). Regional energy statistics (DECC) and AEA point source data, analysed to minimise double-counting.
		Colliery Methane	Deep mined coal production, British Coal Authority
		Coal, coke	Regional energy statistics, DECC; Coal consumption, WO, NIO
		Coke oven gas	Coal feed to coke ovens, ISSB, WO, WS
		SSF	Regional energy statistics, DECC
		Wood	GDP data.
	Cement	Coal, oil, gas, petrocoke, tyres, waste oil	Regional cement capacity, BCA; For 2002 onwards, based on emissions reported to EUETS, EA, DoE 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	GDP data.

The DECC regional 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; data gaps and inconsistencies have previously been addressed by making “expert judgement” assumptions over the time series.

The DECC regional energy statistics are therefore regarded as a more accurate indication of other industrial fuel use for recent years, and have been used to derive estimates for 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. In this latest inventory compilation cycle, significant additional work has been undertaken to analyse the available point source emissions data from the EUETS and other pollution inventories 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. In future it is hoped that gradually more of the point source data can be researched, assessed, allocated to a specific source and country, and that the uncertainty of the emissions data from this source sector can continue to be reduced.

Note that the regional energy statistics have only been produced by DECC since 2003, and complete data (i.e. all fuels) are only available up to 2006 (with gas and electricity data available up to 2007). The regional 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 1A2f “other industry” sources 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 regional energy statistics (DECC, 2008b) 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, 2008a) with England and Wales being disaggregated based on regional manufacturing employment statistics (ONS, 2008a).

DECC (DECC, 2008c) 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 (2008) for 1999 onwards, and now also Firmus Energy (2008), a new gas supplier in Northern Ireland. 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 aseries of assumptions are made to estimate the gas use at these “missing” sites. There remains, therefore, a degree of uncertainty in the overall gas use data for each country.

The gas use within each economic sub-sector at country-level is then analysed based on the available data from the DECC Regional Energy Statistics, supplemented by estimates of major point source gas use derived from analysis of the EU ETS 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 Phoenix Gas for gas use in 2005 has provided 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 have been used to disaggregate UK emissions (EA: 2008a, SEPA: 2008a, NIDoE: 2008a).

"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 not considered a large source and has therefore been distributed according to the other natural gas "other industry" driver, as discussed above.

1.4 TRANSPORT

The drivers used for transport are summarised in Table A1.4.

1.4.1 Aviation and Navigation

Emissions from domestic aviation and navigation were allocated across the DAs for the first time in the 1990-2004 DA GHG inventories. The disaggregation of the domestic aviation emissions has been revised in the latest inventory using a database of aircraft movement data from the Civil Aviation Authority (CAA: 2008), 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 have been included in the DA GHG inventory data. 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.

The DA GHG inventory method has been amended slightly in this latest publication. In the 1990-2006 DA GHGI, the emissions from flights originating in the UK Crown Dependencies (i.e. the Channel Islands, Isle of Man) were allocated to the England inventory. The UK inventory database has since been overhauled to enable separate reporting of emissions from the Crown Dependencies. The detailed flight information within the CAA database includes information pertinent to flights from / to the Crown Dependencies and hence the inventory method has been revised to exclude these emissions from Crown Dependency flights from the England GHGI dataset.

The driver for emissions from aircraft support vehicles is calculated based on aircraft movement data from the UK's major airports (DfT, 2008d).

The disaggregation of emissions from navigation, fishing and coastal shipping is based on port movement data in each constituent country (DfT: 2008b).

[See Appendix 3 for details of the recent research to estimate the DA share of the UK emissions from international shipping and international aviation, which are not directly part of the UK GHGI but are reported as "memo items" in the UK submission to the UNFCCC.]

1.4.2 Road Transportation

Carbon dioxide, methane and nitrous oxide are emitted from the exhaust of all road vehicles with internal combustion engines. CO_2 is the principal product of combustion and emissions are directly related to the fuel efficiency of the vehicle.

Methane is a hydrocarbon 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.

Table A1.4a: Transport (Base Year – 1990)[1]

IPCC Category	NAEI Sources	Activity: Fuel Consumption	1990
Civil Aviation	Domestic cruise; Domestic Take-off & Landing	Aviation Gasoline, Jet Gasoline	CAA database of flight information (CAA, 2008)
Road Transportation	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	Gas oil consumption, Railtrack & NIR
Navigation	Coastal shipping	Gas oil, Fuel oil	Port movement data, DfT Maritime Statistics
Other	Aircraft Support	Gas oil	Regional aircraft movements, DfT

See Section 1.1.3 for abbreviations

Table A1.4b: Transport (1995; 1998 to 2007)[1]

IPCC Category	NAEI Sources	Activity: Fuel Consumption	Data Sources / Comments
Civil Aviation	Domestic cruise; Domestic Take-off & Landing	Aviation Gasoline, Jet Gasoline	CAA database of flight information (CAA, 2008)
Road Transportation	Road Transport	Petrol, Diesel oil, LPG	Vehicle km, DfT, NI DRD Emission factors: COPERT III (EEA, 2000), Barlow et al. (2001), COPERT 4 (EEA, 2007) Fuel efficiency: Road Freight Statistics, DfT (1990-2007) Composition of fleet: Vehicle Licensing Statistics Report, DfT (GB) Dept of Regional Development (NI). Traffic data: National Traffic Census, DfT (England, Scotland, Wales: 1990-2007) 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 2007 (NI: 2002-2007) Fuel consumption: Digest of UK Energy Statistics (1990-2007), Welsh Office fuels data (WO, 1998)
Railways	Railways	Gas oil	Gas oil consumption, Railtrack, ATOC, Translink & NIR
Navigation	Coastal shipping	Gas oil, Fuel oil	Port movement data, DfT Maritime Statistics
Other	Aircraft Support	Gas oil	Regional aircraft movements, DfT

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 N_2O, 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 do show a consistent growth in traffic across all the regions.

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 CO_2 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 guidance.

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.

The emission factors and methodology used for the DA GHG inventory of emissions from road transport are those used for the UK National Atmospheric Emissions Inventory (NAEI).

These are largely taken from the European COPERT III/4 databases, recommended for CORINAIR and forming the basis of the IPCC Guidelines (EEA, 2000, 2007) and from the compilation of exhaust emission factors provided by TRL based on recent tests carried out on vehicles in the UK fleet (Barlow *et al*, 2001).

1.4.2.1 Emission factors

All the emission factors were those used in the latest UK Greenhouse Gas Emissions Inventory (Jackson *et al*., 2009). Methane emissions factors are unchanged and are the same as those used in the last DA GHG inventory compilation; the emission factors are taken from COPERT III (EEA, 2000).

The emission factors for N_2O for all vehicle types have been updated with the latest recommendation of the Emissions Inventory Guidebook (EEA, 2007) derived from the COPERT 4 methodology "*Computer Programme to Calculate Emissions from Road Transport*". 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, buses and motorcycles are unchanged and make no distinction between different Euro standards and road types. Previously, the inventory assumed that petrol car emission factors for all Euro standards from Euro 1-4 were the same and larger than those for pre-Euro 1 cars, leading to an increase in the N_2O inventory since the introduction of three-way catalysts in the 1990s. The latest compilation of emission factors now shows that emission factors have been declining with successive Euro standards since the first generation of catalysts for Euro 1, presumably due to better catalyst formulations as well as reductions in fuel sulphur content.

The uncertainties in the factors for CH_4 and N_2O can be expected to be quite large. However, the emission factors used reflect the fact that three-way catalysts are less efficient in removing methane from the exhausts than other hydrocarbons and that early generation catalyst cars (Euro 1 and 2) have higher N_2O emissions than non-catalyst cars (pre-Euro 1), but with emissions significantly improving for more recent generation catalyst technologies (Euro 3 and 4).

Fuel consumption factors are unchanged and are the same as those used in the last DA GHG inventory compilation. They are based on emission-speed equations developed by TRL (Barlow *et al*, 2001) and they are used in conjunction with fleet-average fuel efficiency and vehicle CO_2 factors from other sources. For heavy-good vehicles, DfT provide statistics from a survey of haulage companies on the average miles per gallon fuel efficiency of different sizes of lorries. A time-series of mpg figures from 1989 to current year is provided by the Continuing Survey of Road Goods Transport, CSRGT (DfT, 2008), and these can be converted to g fuel per kilometre fuel consumption factors.

The figures reflect the operations of haulage companies in the UK in terms of vehicle load factor and typical driving cycles, e.g. distances travelled at different speeds on urban, rural and motorways. These data for HGVs from CSRGT have preference over the research-based speed-emission equations developed by TRL as they are based on a larger sample of vehicles and reflect actual operations. However, the TRL speed-related functions based on test-cycle emission measurements have been used to define the variation in fuel consumption with speed and hence road type. Further details on fuel consumption factors for other vehicle types can be found in the UK GHGI report for 2007 (Jackson *et al*, 2009).

Tables A1.4.1 to A1.4.3 show the emission and fuel consumption 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. Table A1.4.4 presents the fleet-averaged fuel consumption factors for rigid and articulated HGVs from 1990-2007 for urban, rural and motorway conditions. It should be noted that DfT has revised the average miles per gallon fuel efficiency for HGVs between 1993 and 2007 from the figures used in the DA inventory last year. 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 A1.4.1 to A1.4.3. The average speeds used were modified from the values used in the last DA inventory as described below.

The emission factors shown in Tables A1.4.1-A1.4.3 refer to hot exhaust emissions, that is the emissions occurring from the vehicle when the engine and catalyst are at their normal operating temperatures. For the first time this year, 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, 2007). Details of the cold start method are given in he latest UK Greenhouse Gas Emissions Inventory (Jackson *et al*., 2009), 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. The cold start distances are based on GB-averaged trip length information (assumed to be the same in each DA region) and ambient temperature. 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.

1.4.2.2 Age and composition of the fleet

Information on the age and composition of the vehicle fleet in the regions from 1990 to 2007 are taken from vehicle licensing statistics. For England, Scotland and Wales, the data are taken from the Vehicle Licensing Statistics Report published for Great Britain each year by DfT (2008a); this is based on the DVLA files of vehicles licensed in Great Britain at the end of each year.

Additional information is obtained directly from DfT, including the post-town where the vehicles are registered and the year of first registration of vehicles currently licensed in 1995 (DoT, 1996). By grouping together the post-town data into the regions, the average age of the fleet by DA can be estimated, based on registrations in England, Scotland and Wales. This indicates that the age of the fleet is very similar in England and Wales, but somewhat newer in Scotland. However, because vehicles are not necessarily used on the roads in the regions where they are registered (this would be particularly true for company cars and commercial vehicles), the licensing data by post-town is not used for the DA inventories and it is assumed that the age of the fleet and petrol/diesel mix for Great Britain as a whole applied equally to England, Scotland and Wales.

For Northern Ireland, the situation is slightly different. Vehicle licensing statistics for private and light goods vehicles (PLG) are available in Northern Ireland Transport Statistics from the Central Statistics and Research Branch of the Department of Regional Development in Northern Ireland. These show a newer fleet of cars than in Great Britain (DoRDNI, 2009a). It is likely that most of the light duty vehicles on the road in Northern Ireland will be those licensed in Northern Ireland and *vice versa*. This means that a newer licensed fleet should result in a higher proportion of cars fitted with three-way catalysts on the road in Northern Ireland during 1995-2007 than in England, Scotland and Wales.

1.4.2.3 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 UK national inventory (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, 2008b). These estimates are based on traffic counts from the rotating census and core census surveys.

Vehicle kilometre data for 1990-2007 are available from DfT separated into the road networks in England, Scotland and Wales. However, the breakdown in figures by vehicle type and road class (major and minor roads) varies somewhat for different years and assumptions have to be made to derive vehicle kilometre data with a consistent breakdown by vehicle and road type for the emission calculations across all years. The vehicle kilometre data used for England, Scotland and Wales in 2007 are taken from the DfT Road Traffic Statistics Bulletin (DfT, 2008c).

Vehicle kilometre data in Northern Ireland for different road classes and vehicle categories are available from the Traffic and Travel Information 2007: Vehicle Kilometres of Travel Annual Report produced for the Department for Regional Development (DoRDNI, 2008b). Additional information was provided by DoRDNI for the first time this year which gave a better indication of the split between cars and vans in the vehicle kilometres figures and a better indication of the fuel split between petrol and diesel vehicles within the car and van vehicle kilometre data.

This information is based on more detailed licensing data according to vehicle body type and was provided for years 2002-2007 via direct communication with DoRDNI (2009); these figures are believed to give a more accurate picture of the car and van activity data in Northern Ireland for these years than previously used, but confirm the higher proportion of diesel cars in the Northern Ireland fleet compared with the car fleet in GB.

The vehicle speed data used to calculate emission factors from the emission factor-speed relationships were updated and applied to all previous years. Average speed data for traffic in a number of different areas were taken from the following main sources: Transport Statistics Great Britain (DfT, 2008b) provided averages of speeds in Central, Inner and Outer London surveyed at different times of day during 1990 to 2007. Speeds data from other DfT's publications such as 'Road Statistics 2007: Traffic, Speeds and Congestion' (DfT, 2008c) and 2008 national road traffic and speed forecasts (DfT, 2008e) were used to define speeds in other urban areas, rural roads and motorways. Where new information is not available, previous NAEI assumptions were maintained or road speed limits used for the vehicles expected to observe these on the type of road concerned.

1.4.2.4 Estimation of Emissions of Methane and Nitrous Oxide

Emissions of CH_4 and N_2O 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.

Table A1.4.1: Fuel Consumption Factors for Road Transport (in g fuel/km)

g fuel/km		Urban	Rural	Motorway
Petrol cars	ECE 15.04	59.4	49.5	58.4
	Euro I	58.3	51.9	60.5
	Euro II	58.1	54.8	66.2
	Euro III	54.6	51.4	62.2
	Euro IV	48.7	45.9	55.5
Diesel cars	Pre-Euro I	57.6	45.5	54.1
	Euro I	56.5	49.4	64.2
	Euro II	55.2	50.3	66.6
	Euro III	49.2	44.9	59.4
	Euro IV	44.7	40.8	54.0
Petrol LGVs	Pre-Euro I	65.1	54.2	87.9
	Euro I	82.1	73.2	96.4
	Euro II	86.8	77.8	102.6
	Euro III	82.8	74.2	97.8
	Euro IV	76.2	68.3	90.0
Diesel LGV	Pre-Euro I	84.0	84.0	122.3
	Euro I	83.8	72.4	117.1
	Euro II	84.8	73.2	118.5
	Euro III	77.9	67.3	108.9
	Euro IV	72.7	62.8	101.7
Buses	Pre-1988	399	178	229
	88/77/EEC	386	174	224
	Euro I	319	195	213
	Euro II	288	191	208
	Euro III	288	191	208
	Euro IV	279	185	202
	Euro V	271	179	196
Mopeds, <50cc, 2st	Pre-2000	25	25	25
	Euro I	11	11	11
	Euro II	11	11	11
Motorcycles, >50cc, 2st	Pre-2000	30.6	32.9	38.0
	Euro I	24.2	27.1	29.3
	Euro II	24.2	27.1	29.3
Motorcycles, >50cc, 4st	Pre-2000	30.9	30.0	36.9
	Euro I	26.9	27.2	33.3
	Euro II	26.9	27.2	33.3

Table A1.4.2: Methane Emission Factors for Road Transport (in mg/km)

mg/km	Standard	Urban	Rural	Motorway
Petrol cars	ECE 15.01	105	33	48
	ECE 15.02	106	33	49
	ECE 15.03	106	33	49
	ECE 15.04	85	26	39
	Euro 1	37	17	23
	Euro 2	26	11	7
	Euro 3	15	7	4
	Euro 4	12	5	3
Diesel cars	Pre-Euro 1	8	10	18
	Euro 1	4	5	11
	Euro 2	3	4	7
	Euro 3	2	2	5
	Euro 4	2	2	5
Petrol LGVs	Pre-Euro 1	150	40	25
	Euro 1	36	17	27
	Euro 2	22	11	18
	Euro 3	13	6	11
	Euro 4	10	5	8
Diesel LGV	Pre-Euro 1	5	5	5
	Euro 1	2	3	3
	Euro 2	2	3	3
	Euro 3	2	3	2
	Euro 4	1	1	1
Rigid HGVs	Pre-1988	241	91	79
	88/77/EEC	120	45	39
	Euro I	44	15	12
	Euro II	35	13	11
	Euro III	24	9	8
	Euro IV	17	6	6
Artic HGVs	Pre-1988	441	201	176
	88/77/EEC	175	80	70
	Euro I	187	97	96
	Euro II	154	86	92
	Euro III	108	60	64
	Euro IV	75	42	45
Buses	Pre-1988	722	330	289
	88/77/EEC	175	80	70
	Euro I	130	69	58
	Euro II	94	59	53
	Euro III	66	41	37
	Euro IV	46	29	26
Mopeds, <50cc, 2st	Pre-Euro 1	219		
	Euro 1	48		
	Euro 2	48		
	Euro 3	48		
Motorcycles, >50cc, 2st	Pre-Euro 1	150	150	
	Euro 1	104	107	
	Euro 2	40	41	
	Euro 3	14	14	
Motorcycles, >50cc, 4st	Pre-Euro 1	200	200	200
	Euro 1	84	79	59
	Euro 2	32	30	23
	Euro 3	11	11	8

Table A1.4.3: N_2O Emission Factors for Road Transport (in mg/km)

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
Diesel cars	Pre-Euro 1	0	0	0
	Euro 1	2	4	4
	Euro 2	4	6	6
	Euro 3	9	4	4
	Euro 4	9	4	4
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
Diesel LGV	Pre-Euro 1	0	0	0
	Euro 1	2	4	4
	Euro 2	4	6	6
	Euro 3	9	4	4
	Euro 4	9	4	4
Rigid HGVs	Pre-1988	30	30	30
	88/77/EEC	30	30	30
	Euro I	30	30	30
	Euro II	30	30	30
	Euro III	30	30	30
	Euro IV	30	30	30
Artic HGVs	Pre-1988	30	30	30
	88/77/EEC	30	30	30
	Euro I	30	30	30
	Euro II	30	30	30
	Euro III	30	30	30
	Euro IV	30	30	30
Buses	Pre-1988	30	30	30
	88/77/EEC	30	30	30
	Euro I	30	30	30
	Euro II	30	30	30
	Euro III	30	30	30
	Euro IV	30	30	30
Mopeds, <50cc, 2st	Pre-Euro 1	1		
	Euro 1	1		
	Euro 2	1		
	Euro 3	1		
Motorcycles, >50cc, 2st	Pre-Euro 1	2	2	
	Euro 1	2	2	
	Euro 2	2	2	
	Euro 3	2	2	
Motorcycles, >50cc, 4st	Pre-Euro 1	2	2	2
	Euro 1	2	2	2
	Euro 2	2	2	2
	Euro 3	2	2	2

Table A1.4.4: Fuel Consumption Factors for HGVs (in g fuel/km)

g fuel/km	Rigid			Artic		
	Urban	Rural	Motorway	Urban	Rural	Motorway
1990	239	224	261	399	322	367
1991	244	227	266	398	321	366
1992	244	228	266	395	319	363
1993	234	219	255	373	303	345
1994	227	212	248	357	300	339
1995	231	216	252	340	296	330
1996	228	213	249	328	291	324
1997	226	211	247	323	292	323
1998	217	203	237	304	278	307
1999	222	207	242	304	281	309
2000	221	207	242	302	282	309
2001	231	216	253	305	286	313
2002	225	210	246	301	284	310
2003	234	219	256	305	287	314
2004	226	211	247	293	277	302
2005	222	207	242	289	273	298
2006	228	213	249	291	275	300
2007	234	219	256	295	280	305

1.4.2.5 Estimation of Road Transport CO_2 Emissions

Road transport is a very significant and growing source of CO_2 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 CO_2 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 CO_2 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 CO_2 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 are 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 CO_2 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 is collected across the UK.

Therefore, in recent years AEA has moved away from using regional fuel sales data and instead has either directly used regional vehicle km data to estimate road transport CO_2 emissions in each DA or has used regional vehicle km data as a means to proportion the total UK road transport CO_2 emissions between each DA region. This is believed to provide a more representative assessment of transport emission trends of CO_2 within the constituent countries of the UK. The two methods for calculating CO_2 emissions based on regional vehicle km data are described in the following sections.

Disaggregation of UK CO_2 Emissions by DA: Constrained Method:

In this method the sum of the DA inventories for CO2 are constrained to meeting the total of the UK inventory for road transport which for CO2 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 CO2 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, CO2 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 CO_2 emissions from the constrained and unconstrained approaches. The disparity has been changed across the 1990 – 2007 time series. Calculated petrol consumption in 1990 is 7% lower than petrol sales; in 2007, it is 5% lower. Calculated diesel consumption in 1990 is 1% higher than diesel sales; in 2007, it is 7% higher.

The trend in road transport CO_2 emissions for each DA and the UK calculated by the constrained and unconstrained methods across the time series is shown in Table A1.4.5 and Figure A1.4.1. Note that in the table, figures labelled “vkm” refer to the unconstrained method; figures labelled “Fuel sales” refer to the constrained method.

Table A1.4.5: Comparison between methods of CO_2 emissions for each DA (kt CO_2)[2]. Vkm refer to the unconstrained method. Fuel sales refer to the constrained method.

Methodology	vkm	Fuel Sales	Vkm	Fuel Sales	vkm	Fuel Sales	vkm	Fuel Sales	vkm	Fuel Sales
DA	England		Scotland		Wales		Northern Ireland		UK	
1990	86,537	91,115	8,644	9,071	5,261	5,538	3,098	3,224	103,539	108,949
1995	89,358	92,338	8,758	9,030	5,345	5,524	3,421	3,512	106,881	110,404
1998	95,321	96,468	9,319	9,396	5,693	5,758	3,708	3,742	114,042	115,363
1999	97,701	97,405	9,293	9,204	5,791	5,762	3,911	3,896	116,695	116,267
2000	97,850	96,471	9,509	9,315	5,775	5,678	4,063	4,014	117,199	115,478
2001	99,216	96,348	9,604	9,266	5,839	5,651	4,176	4,076	118,835	115,341
2002	100,093	97,953	9,803	9,534	5,965	5,819	4,438	4,373	120,299	117,679
2003	100,708	97,402	9,936	9,552	6,016	5,800	4,701	4,602	121,361	117,357
2004	101,268	98,386	9,990	9,666	6,102	5,918	4,625	4,547	121,985	118,516
2005	100,167	98,789	9,907	9,738	6,036	5,946	4,602	4,581	120,713	119,053
2006	100,698	98,876	10,077	9,863	6,154	6,017	4,730	4,690	121,659	119,445
2007	101,290	99,697	10,284	10,085	6,238	6,122	4,787	4,795	122,600	120,700

Note that emissions of CH_4 and N_2O 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.

1.4.2.6 : 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 actually declined in 2007 from levels reached in 2006.

1.4.2.7 Trends in GHG Emissions from Road Transport

Table A1.4.6 below sets out the CO_2 and GHG emissions from 1990 to the latest inventory year (2007) from the two methods of estimating road transport emissions of CO_2.

[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.

Table A1.4.6: Emissions of GHGs from UK road transport, according to fuel type consumed, and percentage changes from 1990 to the latest inventory year (kt CO_2 equivalent).

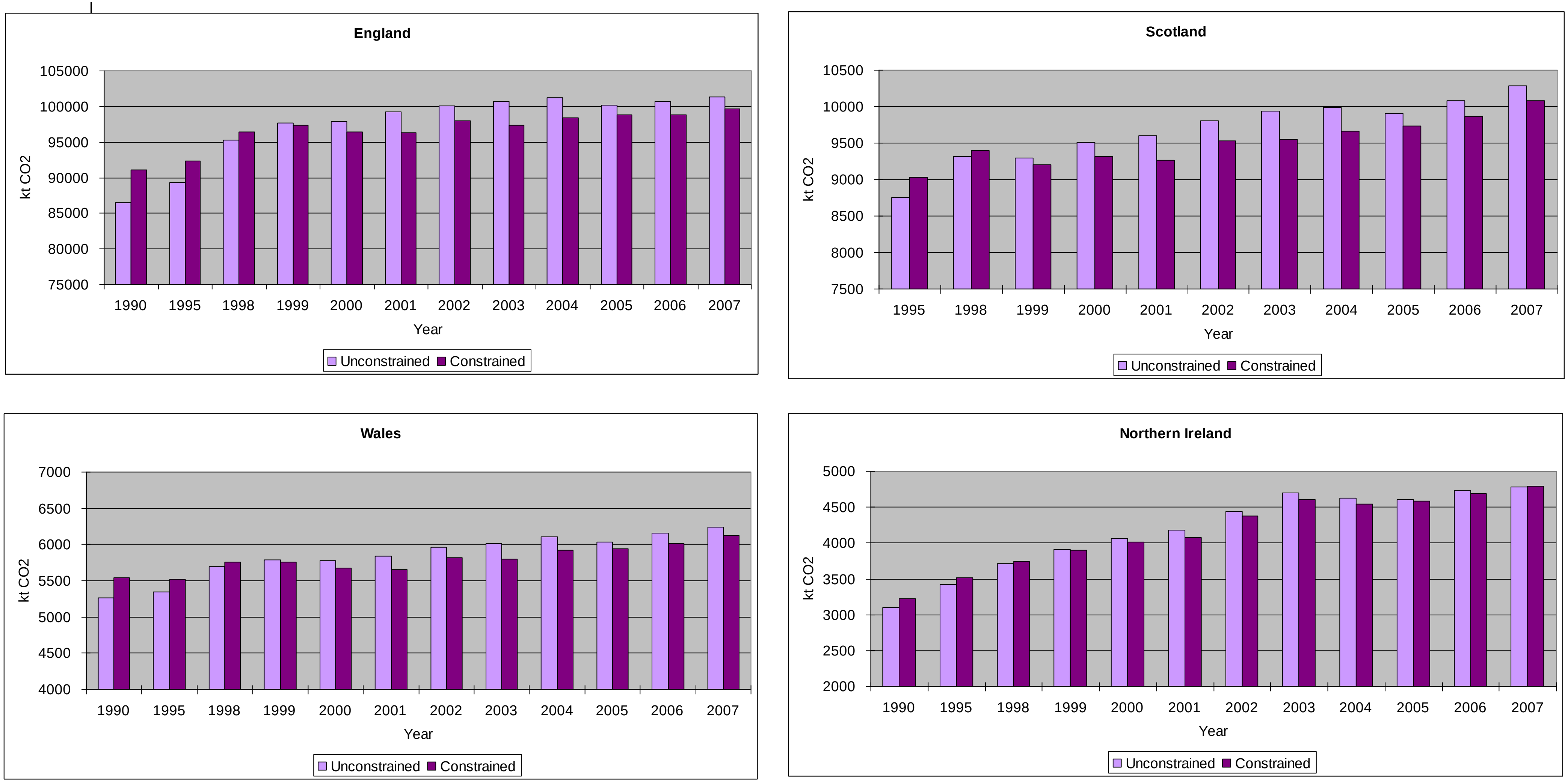
Calculation method	GHG	Fuel used	1990	2007	Percentage change 1990-2007
Constrained	Carbon	LPG	-	351.44	
		Petrol and DERV	108,948.82	120,699.76	
		Lubricants	262.77	160.69	
	CH_4	Petrol and DERV	687.34	144.11	
	N_2O	Petrol and DERV	1,172.89	1,245.23	
		Sum	**111,071.82**	**122,601.23**	**10.38%**
Unconstrained	Carbon	LPG	-	351.44	
		Petrol and DERV	103,539.45	121,658.58	
		Lubricants	262.77	160.69	
	CH_4	Petrol and DERV	687.34	144.11	
	N_2O	Petrol and DERV	1,172.89	1,245.23	
		Sum	**105,662.45**	**123,560.05**	**16.94%**

The emissions of CH_4 and N_2O are estimated using vkm data in both of the calculation methods, and 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.

1.4.3 Railways

Emissions from railway locomotives in Great Britain are disaggregated based on diesel oil consumption data supplied by ATOC (2008) for passenger services and NAEI estimates for freight services. The data from ATOC includes fuel use data for each passenger railway company, whose area of operation can in most cases be allocated to one of the four regions. Emissions from railways in Northern Ireland are based on fuel consumption data supplied by Translink (2008).

Figure A1.4.1: Road transport CO_2 emission trends 1990-2007 calculated by constrained and unconstrained methodologies



1.5 OTHER SECTORS

1.5.1 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 error than well-documented sectors (i.e. energy-intensive industries).

The DECC regional energy statistics (DECC, 2008b), 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 1.3.2). 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 regional energy statistics.

Regional 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 (2008a). This data is 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, 2008), with a new supplier, Firmus Energy, also providing sales data for 2005 onwards (Firmus Energy, 2008). 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 2005 has previously been provided by Phoenix Gas (Phoenix Gas, 2007).

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 (2008a) 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 A1.5a: Other Sectors (Base Year – 1990)[1]

IPCC Category	NAEI Sources	Activity: Fuel Consumption	1990
Commercial & Institutional	Miscellaneous, Public service	Coal	DECC Regional energy statistics
		SSF	DECC Regional energy statistics
		Natural gas	Commercial Sales, DECC.
		Landfill gas	Landfill methane emissions
		Sewage gas	Sewage methane recovered
		fuel oil, gas oil	DECC Regional energy statistics
		MSW	As MSW incinerators
		Burning oil	DECC Regional energy statistics
	Railways (Stationary)	fuel oil, burning oil, coal	Regional oil consumption, DECC
		Natural gas	Assumed as all England
Residential	Domestic	Wood	Domestic wood mapping grid
		Peat	Domestic peat consumption data, CEH
		SSF, coke, LPG	Regional energy statistics (SSF), DECC & Housing Condition Survey data, NI HECA
		Natural gas	Domestic Gas, DECC
		Burning oil, gas oil,	Regional energy statistics (oil), DECC & Housing Condition Survey data, NI HECA
		Coal, anthracite	Regional energy statistics (coal, anthracite), DECC & Housing Condition Survey data, NI HECA
		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 Regional energy statistics
		straw	Wheat production, MAFF
	Agricultural mobile machinery	Gas oil, petrol	Agricultural off-road mapping grid

1 See Section 1.1.3 for abbreviations

Table A1.5b: Other Sectors (1995; 1998 to 2007)

IPCC Category	NAEI Sources	Activity: Fuel Consumption	Data Sources / Comments
Commercial & Institutional	Miscellaneous, Public service	Coal	DECC Regional energy statistics, analysis of point source data and energy modelling data
		SSF	DECC Regional energy statistics
		Natural gas	Natural gas consumed, Transco (now UK National Grid), Phoenix, Firmus
		Landfill gas	Landfill methane emissions
		Sewage gas	Sewage methane recovered
		fuel oil, gas oil	DECC Regional energy statistics, analysis of point source data and energy modelling data
		MSW	As MSW incinerators
		Burning oil	DECC Regional energy statistics
	Railways (Stationary)	fuel oil, burning oil, coal	Regional gas oil consumption, Network Rail (GB) and Translink (NI)
		Natural gas	Assumed as all England
Residential	Domestic	Wood	Domestic wood mapping grid
		Peat	Domestic peat consumption data, CEH
		SSF, coke, LPG	Regional energy statistics (SSF), DECC & Housing Condition Survey data, NI HECA
		Natural gas	Domestic Gas, DECC, Transco & UK gas network operators, Phoenix Gas and Firmus Energy (NI)
		Burning oil, gas oil,	Regional energy statistics (oil), DECC & Housing Condition Survey data, NI HECA
		Coal, anthracite	Regional energy statistics (coal, anthracite), DECC & Housing Condition Survey data, NI HECA
		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 Regional energy statistics
		straw	Wheat production, MAFF/Defra
	Agricultural mobile machinery	Gas oil, petrol	Agricultural off-road mapping grid

1.5.2 Residential

DECC regional energy statistics (DECC, 2008b) have been used in conjunction with information drawn from Housing Condition Surveys to provide estimates of domestic solid and liquid fuel use patterns across the DAs. (See Section 1.3.2 for more details regarding the DECC regional energy statistics source data.)

DECC regional energy use estimates for 2003 to 2007 have been extrapolated using data from Housing Condition Surveys in 1996, 2001 and 2004 (HECA NI, 2005), 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 during the late 1990s - early 2000s. This approach is used for coal, anthracite, gas oil and burning oil. 2005 regional estimates are available from more recent housing surveys, notably in Northern Ireland, and these data have been used and extrapolated backwards using the periodic Housing Condition Survey reports.

Domestic natural gas consumption data is available for 1990, 1995 and 1998-2007 (DECC: 2008a), with additional information from Transco and other GB gas supply network operators (2008) and Phoenix Gas (2008) and Firmus Energy (2008) for Northern Ireland. However, the accuracy of the domestic estimates is subject to uncertainty, as gas companies use scale of annual consumption to allocate users to the domestic sector, which implies that small-scale commercial users will also be reported in the domestic sector.

The consumption of fuel oil by the domestic sector is a very small amount, and is distributed simply according to population (ONS, 2008a). Domestic use of wood is estimated across the time-series using the latest mapping grid information on wood use (NAEI maps, 2008). Domestic peat use estimates by DA are provided by the Centre for Ecology & Hydrology (Personal Communication: Mobbs, 2008).

1.5.3 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, and hence emissions from these sources are allocated on the basis of regional employment figures from DEFRA (2008a).

Recent work by AEA (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 develop a new agricultural off-road mapping grid. These data have been used to estimate DA GHG emissions from agricultural mobile machinery in preference to using Defra regional agricultural employment data that were used in previous inventories.

1.6 MILITARY

Emissions from military aircraft and naval vessels have been allocated based on regional GVA data (ONS, 2008a). Army vehicle emissions are included within road transport data and other army emissions are included within public service categories but are not clearly defined.

1.7 FUGITIVE EMISSIONS FROM FUELS

1.7.1 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 (2008), BGS (2008), 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, 2008).

Emissions of methane from closed coal mines are based on research that provides emission estimates on a site-by-site basis, and therefore DA-specific totals can be calculated (White Young Green, 2005). Note, however, that this research has not been updated for a number of years and hence the latest emission estimates available for use stem from analysis of closed coal mine emissions in 2004.

1.7.2 Solid Fuels 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 discussed in Section 1.2.3.

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 1.2.3). 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.

1.7.3 Oil and Natural Gas

All emissions from the oil & gas exploration and production industry that occur offshore have been classified as unallocated. Emissions from on-shore 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 Oil & Gas UK (2008) data for 1995, 1998-2007. Data is unavailable for 1990, so these are extrapolated based on flaring volumes for Scottish Terminals and natural gas arrivals to gas terminals in England (DTI, 1991, 1996).

The 2000-2007 UK GHG inventories include a correction to account for flaring on onshore oil and gas fields excluded by the Oil & Gas UK (offshore) emissions inventory. Onshore flaring volumes are obtained from DECC sources (DECC, 2008d). 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 Oil & Gas UK EEMS inventory data provides data for fugitive emissions of CO_2 and methane from terminals for 1998-2007. Methane emissions arise from venting, oil storage and tanker loading and unloading, whilst CO_2 emissions arise from venting and processes. A more aggregated set of data for 1995 has been provided by UKOOA (1999), whilst estimates for 1990 have been calculated by extrapolation of data of oil and gas arrivals in England and Scotland (DTI, 1991, 1996) split across the sources and regions based on the 1995 dataset.

Note that analysis of the dataset from Oil & Gas UK has indicated several areas of inconsistency in the annual reporting by operators. Inconsistencies have been identified through comparison of the Oil & Gas UK inventory submissions against emissions data reported within the SPRI and via the EUETS. This had led to a process of ongoing consultation with DECC and Oil & Gas UK contacts to resolve these areas of uncertainty, which impact most significantly upon methane and NMVOC (not a direct GHG) inventories. Through consultation with DECC Oil & Gas and UK Oil & Gas industry representatives, some revisions to recent data were made to address data reporting gaps and inconsistencies.

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 (2008) and the other gas network operators: Northern Gas Networks (2008), Scotia Gas Networks (2008), Phoenix Gas (2008) and Wales & West Utilities (2008). Estimates are provided by Local Distribution Zones, enabling direct allocation to each of the constituent countries.

Table A1.7a: Fugitive Emissions from Fuels (Base Year – 1990)[1]

IPCC Category	NAEI Sources	Activity: Fuel Consumption	1990
Coal Mining	Deep mined coal Coal storage & transport	Deep mine coal production	Regional deep mine production, British Coal Authority. CH_4 from closed coal mines from WYG 2005
	Open cast coal	Open cast mine coal production.	Regional open cast mine production, British Coal Authority CH_4 from closed coal mines from WYG 2005
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	Offshore Oil & Gas	NA	Fugitive emissions from Terminals (extrapolated from 1995)
	Oil Terminal Storage	NA	1998 driver
	Onshore Loading	Oil loaded	1998 driver
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

1 See Section 1.1.3 for abbreviations

Table A1.7b Fugitive Emissions from Fuels (1995; 1998 to 2007)

IPCC Category	NAEI Sources	Activity: Fuel Consumption	Data Sources / Comments
Coal Mining	Deep mined coal Coal storage & transport	Deep mine coal production	Regional deep mine production, British Coal Authority. CH_4 from closed coal mines from WYG 2005
	Open cast coal	Open cast mine coal production.	Regional open cast mine production, British Coal Authority CH_4 from closed coal mines from WYG 2005
Solid Fuel transformation	Coke production	Coke production	Coal feed to coke ovens, ISSB, WS, DECC and (1999-current) PI
	Flaring	Coke oven gas	Coal feed to coke ovens, ISSB, WS, DECC and (1999-current) PI
	SSF production	Coal, Petrocoke	Coal feed to SSF plant, DECC, WS
Oil	Offshore Oil & Gas	NA	Oil & Gas UK Process emissions from Terminals
	Oil Terminal Storage	NA	Data from storage emissions, Oil & Gas UK inventory
	Onshore Loading	Oil loaded	Data from loading emissions, Oil & Gas UK inventory.
Venting & Flaring	Flaring	Volume gas flared	Flaring at terminals and onshore fields, Oil & Gas UK, DECC
	Venting	NA	Data from venting emissions, Oil & Gas UK inventory.
Natural Gas	Gas Leakage	Natural gas leakage	National Grid (Transco), Northern Gas Networks, Scotia Gas Networks, Wales & West Utilities, Phoenix Gas

1.8 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 A1.2 covers combustion emissions.) The drivers used for process and fugitive industrial releases are summarised in Table A1.8.

1.8.1 Minerals Industries

Large emissions of CO_2 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[3] (2004) for 1990 to 2001. From 2002 onwards, the regional split is based on reported emissions from the PI, SPRI and ISR. 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. Corus suggest 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, 2009).

Limestone, dolomite and soda ash are also used in glass production. Emissions were previously disaggregated using plant capacity and CO_2 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, 2008a) 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 inventory also reports CO_2 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.

1.8.2 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.

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

Table A1.8a: Industrial Processes (Base Year – 1990)[1]

IPCC Category	NAEI Sources	Activity Data	1990
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

1. See Section 1.1.3 for abbreviations

Table A1.8a: Industrial Processes (Base Year – 1990) (continued)

IPCC Category	NAEI Sources	Activity Data	1990
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 A1.8b: Industrial Processes (1995; 1998 to 2007)

IPCC Category	NAEI Sources	Activity Data	Data Sources / Comments
Cement Production	Cement (decarbonising)	Clinker production	Point source data from PI/SPRI/ISR, EA, SEPA & NIDoE
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, BGlass
	Blast Furnaces	Limestone and dolomite consumption	Iron production, ISSB
Soda Ash Production and Use	Glass production	Soda Ash Consumption	Regional glass production, BGlass
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. Since 2002, all such 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
Chemical Industry: Other	Chemical Industry	NA	PI 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

Table A1.8b: Industrial Processes (1995; 1998 to 2007) (continued)

IPCC Category	NAEI Sources	Activity Data	Data Sources / Comments
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, 2008a), SPRI (SEPA, 2008a) 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.

1.8.3 Metal Production

In the iron and steel industry, emissions of CO_2 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, 2009).

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, 2009).

Emissions of CO_2 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 (2009). These include regional data on coke consumed in blast furnaces, pig iron production and crude steel production.

The electrolytic process used to produce aluminium results in a CO_2 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, 2008a; SEPA, 2008a). There have been some significant changes in the aluminium industry in recent years, with the closure of the Kinlocheven plant in 2000, and the expansion of the Lynmouth 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, 2008).

1.8.4 Use of Halocarbons and SF_6

The UK emissions of halocarbons and sulphur hexafluoride were based on estimates from a model prepared initially by Enviros March (1999). This model has now been updated by AEAT (Haydock et al, 2003). 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 GDP estimates, which have been obtained from ONS (2008a).

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).

1.9 AGRICULTURE

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

The UK inventory is disaggregated into England, Scotland, Wales and Northern Ireland, with all default factors and emission factors carried over from the national inventory. In the 1990-2007 UK GHG inventory compilation, nitrogen excretion factors have been modified across all the UK using data from Ken Smith and Bruce Cottrill (ADAS, 2008).

Regional crop areas are obtained from the Defra June Agricultural Census for 1990, 1995, 1998 - 2007 (Defra, 2008), SEERAD (SEERAD, 2008) and DARD (DARD, 2008). Crop production data is taken from Agriculture in the UK and Basic Horticultural Statistics for the UK. The Welsh Assembly Government also provides crop area data in Wales for this inventory.

Fertiliser applications are derived from regional crop areas and average application rates published in the British Survey of Fertiliser Practice for 1990, 1995, 1998 - 2007 (BSFP, 2008), which presents data for England and Wales, Scotland and Great Britain. Application rates in Northern Ireland are assumed to be the same as Scottish applications. 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.

Livestock numbers are obtained from the Defra, SEERAD, the Welsh Assembly and DARD Agricultural Census data for 1990, 1995, 1998 – 2007. Cattle weights are estimated following the trend for the previous 5 years. In the compilation of the UK inventory for 1990-2007, the 2007 cattle data for Wales were erroneous in the NIR and national inventory submission. In the derivation of the DA GHG inventories these Welsh cattle statistics have been corrected, although the DA total is still kept consistent with the UK GHGI.
As in the national inventory, the area of cultivated histosols (soils of high organic content) is assumed to be equivalent to the area of Eutric Histosols, and is disaggregated according to a percentage split estimated by the Soil Survey and Land Research Centre (personal communication).

Any small differences in national-regional census data are removed by normalising the DA inventories such that the sum of England, Scotland, Wales and Northern Ireland equals the UK emission. (For details of the normalisation procedure, see Section 1.1.2.) In particular, for census years prior to 2001, the supply of data for the constituent countries from different sources (MAFF, DANI and the Scottish Office) was not concurrent with obtaining the UK data and submitting the UK inventory. This lack of synchronicity was not conducive to ensuring that there was good agreement between the sum of country data and the UK figure, and consequently the UK and disaggregated inventory estimates. This problem was rectified in some recent years by the supply of all required land use and livestock data directly from DEFRA statistics. As this is no longer possible, the current protocol is to obtain data from constituent countries prior to submission of the UK inventory, altering UK figures where necessary.

1.10 LAND USE, LAND USE CHANGE & FORESTRY (LULUCF)

The Land Use, Land Use Change and Forestry (LULUCF) sector is different from other sectors in the Greenhouse Gas Inventory in that it contains both sources and sinks of greenhouse gases (principally carbon dioxide). The sources, or emissions to the atmosphere, are given as positive values; the sinks, or removals from the atmosphere, are given as negative values.

The estimates for the LULUCF sector within the DA emissions inventories are made by the Centre for Ecology and Hydrology. The methods for estimating removals and emissions of carbon dioxide from this sector are described in the latest contract report to Defra (Dyson, 2009) and Annex 3 of the UK National GHG Inventory 1990-2007 (Jackson et al., 2009).

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

The reporting categories for the sector are defined by the IPCC Good Practice Guidance for LULUCF framework (IPCC 2003). This framework is based on six broad categories of land use: 5A Forest Land, 5B Cropland, 5C Grassland, 5D Wetlands, 5E Settlements, 5F Other Lands, and 5G Other (used for LULUCF activities that do not fall within any of the other categories). Inventory calculations of changes in carbon stocks (and hence emissions or removals of CO_2 from the atmosphere) are based on whether land remains in a land use category or changes to another land use category during a time period. A land use change matrix captures all these transitions in a compact manner. Activities that do not directly cause changes in carbon stocks, e.g. non-CO_2 GHGs, are reported in separate tables, but emissions from these activities are combined into a summary table for the Sector.

The 2007 inventory has been updated using the most recent figures, but this has not significantly changed the net emissions/removals as reported within the previous inventory. Deforestation associated with harvested wood products is included in this year’s inventory; the removal of timber from harvesting or thinning operations is considered as deforestation and therefore should be reported. Deforestation is the result of either a land use change or thinning. It is assumed that a change in land use will be to Grasslands or Settlements and will be reported in Sector 5.C.2 and 5.E.2 respectively.

1.10.1: 5A Forest Land

The Forest Land category is divided into *Category 5.A.1 Forest remaining Forest Land* and *Category 5.A.2 Land converted to Forest Land*. Three activities are reported under 5.A.2: carbon stock changes on land converted to Forest Land, N_2O emissions from N fertilization of forests, and biomass burning emissions from wildfires on forest land.

Forest Land remaining Forest Land

There are 811,000 ha (811 kha) of land that has been under forest land use since before 1922 (504 kha in England, 194 kha in Scotland, 111 kha in Wales and 2 kha in Northern Ireland). This forest is assumed to be in overall carbon balance because of its age, and hence has a carbon stock change of zero. Forest land which is thinned will undergo a reduction in area; these changes are reported in 5.A.1. Forest Land remaining Forest Land.

Land converted to Forest Land

Carbon stock changes
Changes in carbon stocks in forest standing biomass, litter and soils are calculated with the C-Flow forest carbon model (Dewar and Cannell 1992, Cannell and Dewar 1995, Milne *et al.* 1998). The model is driven by records of annual forest planting in each DA on previously unforested land (available from 1922 onwards). Forests accumulate carbon (removing it from the atmosphere) in their biomass and soils as they grow, but timber harvesting and planting activities disturb this accumulation and result in emissions of carbon to the atmosphere. The net carbon stock change at any one time depends on the balance between these different activities. Forestry management cycles operate over long time scales (50 years+) so the rate of carbon removal in the present day is driven by the rate of forest planting in previous decades.

In 2007 around 52% of the area under forest land use in the UK had been planted since 1922 (412 kha in England, 1027 kha in Scotland, 162 kha in Wales and 81 kha in Northern Ireland). The activity data for annual forest planting (private and state) for the C-Flow model are provided by the Forestry Commission (for England, Scotland and Wales) and the Northern Ireland Department of Agriculture. The data is sub-divided into conifer and broadleaf planting and is time-consistent and reliable. There are differences in trends between conifer and broadleaf planting since 1990.

All DAs have seen a decline in annual conifer planting rates 1990-2007, however, annual broadleaf planting has on average increased in all DAs (Table A1.10.1).

Table A1.10.1: Forest planting rates since 1990

Annual planting, kha a^{-1}	England	Scotland	Wales	Northern Ireland
Conifer				
1990-1994	0.827	9.529	0.216	0.988
1995-1999	0.547	6.504	0.091	0.521
2000-2004	0.556	3.536	0.084	0.210
2005	0.190	1.865	0.013	0.036
2006	0.082	1.007	0.008	0.043
2007	0.064	2.000	0.037	0.044
Broadleaf				
1990-1994	3.828	3.384	0.312	0.298
1995-1999	4.016	4.997	0.420	0.316
2000-2004	4.507	5.180	0.368	0.450
2005	4.522	3.817	0.521	0.320
2006	3.030	2.968	0.452	0.563
2007	2.573	4.579	0.388	0.505

The C-Flow model also requires input data on the stemwood growth rate and harvesting pattern, which come from standard management and yield tables used by the Forestry Commission (Edwards and Christie 1981). Following work by Milne *et al.* (1998) DA-specific growth patterns are used for conifers but the same growth pattern is used for all new broadleaf planting in the UK. Milne *et al.* (1998) have shown that different yield class assumptions for conifer and broadleaf planting have an effect of less than 10% on estimated carbon uptakes for the country as a whole. CEH and Forest Research are undertaking research to characterise forest planting (including species mix) and management in greater spatial and temporal detail. Comparisons of forest census data have already indicated that there is non-standard management (shorter rotations) in England and Wales during the mid-20th century. These variations in management have been incorporated into the forest model but they have only a small impact on net carbon stock change.

The C-Flow method is a Tier 3 modelling approach, so there are no explicit emission factors. Instead parameter values for either conifer or broadleaf trees are required to estimate (i) stemwood, foliage, branch and root masses from the stemwood volume, and (ii) the decomposition rates of litter soil carbon and wood products. Losses of soil carbon due to the disturbance by planting activity are also considered on a DA-specific basis. From these values and the activity data C-Flow calculates the net changes in the pools of standing trees, litter and soil carbon.

The overall uncertainty in emissions/removals from 5A Forest Land is estimated to be 25% but a full analysis of uncertainties is planned for future inventories.

N_2O emissions from N fertilization of forests

Emissions of nitrous oxide from direct nitrogen fertilisation of forests are included. Information on forest fertilisation was gathered from a search of the relevant literature and discussion with private chartered foresters and the Forestry Commission (Skiba 2007). In the UK the general recommendation is not to apply fertiliser to forests unless it is absolutely necessary: it is not applied to native woodlands, mature forest stands or replanted forests. The instances where N fertiliser is applied to forests are first rotation (afforestation) forests on 'poor' soil, e.g. reclaimed slag heaps, impoverished brown field sites, upland organic soils. In terms of the inventory, this means that N fertilisation is assumed for Settlement converted to Forest land and Grassland converted to Forest Land on organic soils. A Tier 1 approach is used with the amount of N fertiliser calculated using a fixed application rate and the areas of relevant forest planting for each DA from the same datasets used in the CFlow model for 5.A.2. Land converted to Forest land.

An application rate of 150 kg N ha^{-1} is assumed based on Forestry Commission fertilisation guidelines (Taylor 1991). The guidelines recommend applying fertiliser on a three-year cycle until canopy closure (at c. 10 years), but this is thought to be rather high (Skiba 2007) and unlikely to occur in reality, so two applications are adopted as a compromise. These applications occur in year 1 and year 4 after planting. As a result, emissions from N fertilisation since 1990 include emissions from forests that were planted before 1990 but received their second dose of fertiliser after 1990. The emission factor for N_2O of applied nitrogen fertiliser is the default value of 1.25%. Emissions of N_2O from N fertilisation of forests have fallen since 1990 due to reduced rates of new forest planting.

Emissions from wildfires on forest land

Estimates of emissions from wildfires on forest land are included in the inventory. The approach is Tier 2, using country-specific activity data and default emission factors. There is no information as to the age and type of forest that is burnt in wildfires, so all wildfire emissions are recorded under 5.A.2.

Estimates of the area burnt in wildfires 1990-2007 are published for Great Britain (data from the Forestry Commission) and Northern Ireland (data from the Forest Service). No data on areas burnt in wildfires has been collected or published since 2004, although this is under review. Activity data for 2005 to 2007 is extrapolated using a Burg regression equation based on the trend and variability of the 1990-2004 dataset. These areas refer only to fire damage in state forests; no information is collected on fire damage in privately owned forests. The area of private-owned forest that was burnt each year was assumed to be in proportion to the percentage of the state forest that was burnt each year. The Great Britain total forest estimate was split between the individual countries in proportion to their forest areas. An estimated 957 ha of forest is burnt on average every year (361 ha in England, 431 ha in Scotland, 92 ha in Wales and 72 ha in Northern Ireland) between 1990 and 2007, although there is high inter-annual variability.

There is no information on the type (conifer or broadleaf) or age of forest that is burnt in wildfires in the UK. Therefore, the amount of biomass burnt is estimated from the mean forest biomass density in each country of the UK, as estimated by the C-Flow model. These densities vary with time due to the different afforestation histories in each country. A combustion efficiency of 0.5 is used with a carbon fraction of dry matter of 0.5 to estimate the total amount of carbon released, and hence emissions of CO_2 and non-CO_2 gases (using the IPCC emission ratios).

The uncertainty for the wildfire activity data is estimated to be 50% for the activity data 1990-2004, but 100% for the 2005 to 2007 values, as these have been extrapolated from previous years. The IPCC default of 70% uncertainty is used for the emission factors.

1.10.2 5B Cropland

This category is disaggregated into Cropland remaining Cropland and Land converted to Cropland.

Cropland remaining Cropland

Three activities contribute to this sub-category: the effect on non-forest biomass due to crop yield improvements, the effect of fenland drainage on soil carbon stocks (which occurs only in England) and carbon dioxide emissions from soils due to agricultural lime application to Cropland (which is also disaggregated into application of Limestone ($CaCO_3$) and Dolomite ($CaMg(CO_3)_2$)).

Changes in non-forest biomass resulting from yield improvements
This activity results in a carbon sink. The activity data on cropland area is DA-specific and the emission factor is fixed at 2% p.a. (Sylvester-Bradley *et al.* 2002).

Application of lime
The second activity is the application of 'lime' (limestone, chalk and dolomite) to Cropland (and Grassland) which produces emissions of CO_2. Data on the use of limestone, chalk and dolomite for agricultural purposes is reported in the Business Monitor of Mineral Extraction in the UK (Office of National Statistics 2007), the data for 2008 were unavailable for inclusion in this year's inventory; figures were assumed to be equal to the values estimated for 2007 at the time of the 2006 inventory. Estimates of the individual materials are provided by the British Geological Survey each year as only the totals are published because of commercial confidentiality rules for small quantities. The amount of lime applied is variable from year to year but generally reducing over time. The area that receives lime is calculated from the regional agricultural censuses, the Fertiliser Statistics Report (Agricultural Industries Confederation, 2006) and the British Survey of Fertiliser Practice (BSFP, 2007). This data is DA-specific from 2000 onwards for England, Scotland and Wales and estimated from GB rates before that. There is no specific information on the % area limed in Northern Ireland, which is therefore assumed to be the same as that in England. Fixed emission factors (for limestone/chalk and dolomite) are used to estimate emissions. The uncertainty in the activity data and emission factors are judged to be low and consistent over time. The inclusion of more precise figures for the % area receiving lime (AIC, 2006) resulted in some regional adjustments in the allocation of lime to Cropland or Grassland. The 2007 numbers were also not available in time for the 1990-2007 inventory, so those values were estimated from the previous years.

Lowland drainage
The third activity is past drainage of lowland peatlands in England, which produces an ongoing change in soil carbon stocks and therefore carbon emissions. The baseline (1990) area of drained peatland is taken as 150,000 ha (Bradley 1997) with an assumption of no further drainage since that time. The annual loss decreases in proportion to the amount of carbon remaining (there are different implied emission factors for 'thick' and 'thin' peat).

Land converted to Cropland
Emissions and removals in this category result from (i) changes in soil carbon stocks, and (ii) changes in non-forest biomass carbon stocks due to land use change to Cropland. The methodology also applies to land converted to Grassland and to Settlement. Changes in carbon stocks from land use change to Forest land are calculated by the C-Flow model, as described above.

Changes in soil carbon stocks due to land use change to Cropland
Land use change results in soil carbon stock change because soil carbon density generally differs under different land uses and the land use change initiates a transition from one density value to another. The change in vegetation cover and management affects the amount of carbon that goes into the soil from biomass decomposition and the initial disturbance of the soil releases carbon to the atmosphere. An increase in soil carbon density results in a removal of CO_2 from the atmosphere, and vice versa. The rate of loss or gain of carbon depends on the type of land use transition. For transitions where carbon is lost, e.g. Grassland conversion to Cropland, the rate is "fast" (50-150 years), but for transitions where carbon is gained the rate is much slower.

The method used for this activity links a land use change matrix to a dynamic model of carbon stock change. Matrices of land use change have been constructed back to 1950 for each DA using country-specific land surveys (MLC 1986, Haines-Young *et al* 2000, Cooper and McCann 2002).

Areas of land use were assigned to the IPCC GPG categories – Forest land, Cropland, Grassland, Settlements and Other Land. The data available for the UK does not distinguish Wetlands from other land use types so this category is not used. Area change data exists up to 1998 and extrapolated from there to the latest inventory year (2007). Since 1990 an estimated 63.5 kha yr^{-1} have been converted to Cropland in England, 21.7 kha yr^{-1} in Scotland, 8.0 kha yr^{-1} in Wales and 3.7 kha yr^{-1} in Northern Ireland. Updates to the Countryside Surveys for Great Britain and Northern Ireland took place in 2007 and the new data from these will be used to update the matrices in due course.

A database of soil carbon density, based on information on soil type, land cover and carbon content, is available at 1km scale for the UK (Bradley *et al.* 2005): this gives the soil carbon densities under the different land use categories for each UK country. DA-specific times, from the initial to the new soil carbon density following a land use change, are used with the core differential equation to calculate carbon fluxes per unit area (hence the implied emission factors will change over time).

Changes in non-forest biomass stocks resulting from land use change to Cropland
Changes in carbon stocks in non-forest biomass due to land use change are based on the same area matrices used for estimating changes in carbon stocks in soils. The biomass carbon densities for five basic land use types are then weighted by their occurrence in each DA to calculate mean biomass densities for Cropland, Grassland and Settlements. The mean biomass carbon densities for each land type were then weighted by the relative proportions of change occurring between land types, in the same way as the calculations for changes in soil carbon densities. Changes between these equilibrium biomass carbon densities were assumed to happen in a single year.

A Monte Carlo approach is used for both activities to vary the inputs for the core equation, and also give an estimate of uncertainty. The uncertainty in changes in soil carbon from the initial to the final equilibrium value is up to ±11% of the mean value. The uncertainty of the areas of land use change in each land use transition is assumed to be ±30% of the mean. Independent estimates of the uncertainty for each DA are not currently available.

1.10.3 5C Grassland

Grassland remaining Grassland
Emissions resulting from the application of lime (described in the Cropland remaining Cropland section) and from peat extraction are reported in this sub-category. Peat extraction for horticultural use is reported for England, Scotland and Northern Ireland (it is negligible in Wales). Peat extraction for fuel use is now reported in the Energy sector of the inventory. The annual volume of peat extraction in Scotland and England is obtained from the Business Monitor of Mineral Extraction in Great Britain (ONS, 2008b), the data for 2008 were unavailable for inclusion in this year's inventory; figures were assumed to be equal to the values estimated for 2007 at the time of the 2006 inventory. Extraction in Northern Ireland is estimated from a 1997 survey (Cruikshank and Tomlinson 1997). The volume extracted is variable in England (800,000 – 1,600,000 m^3 yr^{-1}) and Scotland (100,000-700,000 m^3 yr^{-1}) but constant in Northern Ireland (628,000 m^3 yr^{-1}). Rates of peat extraction in Northern Ireland are currently being re-assessed (see chapter 19 in Dyson 2009). Fixed DA-specific emission factors (Cruickshank and Tomlinson 1997) are used to estimate emissions from this activity.

Land converted to Grassland
Methods for estimating changes in non-forest biomass and soils due to land use change to Grassland are described in the Land converted to Cropland section. Since 1990 an estimated 58.6 kha yr^{-1} have been converted to Grassland in England, 17.8 kha yr^{-1} in Scotland, 8.1 kha yr^{-1} in Wales and 5.9 kha yr^{-1} in Northern Ireland.

When Forest land is converted to Grassland (i.e. deforestation) it is assumed that 60% of the standing biomass is removed as timber products and the remainder is burnt. This burning of forest biomass produces emissions of CO_2, CH_4 and N_2O.

Activity data on deforestation to Grassland in the UK is estimated from Forestry Commission unconditional felling licence data where there is no requirement to restock by replanting or regeneration (see Levy and Milne 2004). The most recent data from the Forestry Commission has been collated: these are estimates for England for 1990-2002 and estimates for GB in 1999-2001.

Estimates for Scotland and Wales are extrapolated from the England estimates using the GB:England ratios in 1999-2001. Areas of deforestation for 2003-2005 are estimated by extrapolation from earlier years. There are no data currently available for Northern Ireland.

Annual rates of deforestation to Grassland were low and stable from 1990 to 1998 (E: 0.16 kha yr^{-1}, S: 0.05 kha yr^{-1}, W: 0.01 kha yr^{-1}) when they increased rapidly to a peak in 2001 (E: 0.8 kha yr^{-1}, S: 0.25 kha yr^{-1}, W: 0.06 kha yr^{-1}). There is anecdotal evidence from the Forestry Commission that this was due in part to felling of exotic conifers for heathland restoration. Since 2001 rates of deforestation have declined slightly.

Emissions from biomass burning are estimated using the rates described in the IPCC 1996 guidelines (IPCC 1997a, b, c), based on a mature broadleaf forest stand. Only immediate losses are considered because sites are normally cleared completely for development, leaving no debris to decay. Changes in soil carbon stocks after deforestation are estimated with the other land use transitions.

This method is also used to estimate biomass burning emissions from Forest land converted to Settlements. Deforestation to Cropland in the UK since 1990 is negligible.

1.10.4 5D Wetlands

No data are included for this category as Wetlands will either fall within the Grassland category or open water, which is included in the Other Land category, due to the classifications in the land surveys used to construct the land use change matrix.

1.10.5 5E Settlements

No changes in carbon stocks are reported for land In Settlements remaining Settlements. Methods for estimating changes in non-forest biomass and soils due to land use change to Settlements are described in the Land converted to Cropland section. Since 1990 an estimated 11.2 kha yr^{-1} have been converted to Settlements in England, 2.5 kha yr^{-1} in Scotland, 2.1 kha yr^{-1} in Wales and 1.1 kha yr^{-1} in Northern Ireland.

The method used for estimating emissions from biomass burning from Forest land converted to Settlements (deforestation) is the same as that used for Forest land converted to Grassland. The activity data comes from the Ordnance Survey's annual assessment of land use change for map updates (collected on behalf of the Department of Communities and Local Government) (DCLG 2007). Deforestation to Settlements is estimated to be the area that has moved from the forest land-use class to the non-rural land use class (see Levy and Milne 2004 for more details). At present, this data is only available for England for 1990-2004 (smoothed using a five-year moving average); estimates for Scotland and Wales are made by extrapolation from the English rates, assuming that England accounted for 72 per cent of deforestation, based on the distribution of licensed felling between England and the rest of GB in 1999 to 2001. Annual rates of deforestation to Settlements are variable but stable, with an average of 0.38 kha yr^{-1} for England, 0.11 kha yr^{-1} for Scotland and 0.03 kha yr^{-1} for Wales. Deforestation is not currently estimated for Northern Ireland.

The activity data for deforestation to Settlements come from a continuous rolling survey programme and were updated this year. This revision had a knock-on effect on other parts of the land use change matrix but the overall impact on emissions/removals was relatively small..

1.10.6 5F Other Land

No emissions or removals are reported in this category. It is assumed that there are very few areas of land of other types that become bare rock or water bodies, which make up the majority of this type.

1.10.7 5G Other Activities

Changes in stocks of carbon in harvested wood products (HWP) are reported here. The C-Flow model (described in the Forest land section) estimates changes in stocks of HWP produced from the management and harvesting of conifer and broadleaf forests planted since 1922. The activity data used for calculating this activity is the annual forest planting rates. For a given forest stand, carbon enters the HWP pool when thinning is undertaken (depending upon the species thinning first occurs c. 20 years after planting) and when harvesting takes place.

According to this method the total HWP pool from UK forests is presently increasing, driven by historical expansion of the forest area and the resulting history of production harvesting (and thinning). The stock of carbon in HWP (from UK forests planted since 1921) has been increasing since 1990 but this positive stock change rate recently reversed, reflecting a severe dip in new planting during the 1940s. The net carbon stock change in the HWP pool has returned to a positive value (i.e. an increasing sink) in 2007, and is forecast to increase sharply as a result of the harvesting of the extensive conifer forests planted between 1950 and the late 1980s. Different DAs have different patterns depending on their forest planting history.

1.11 WASTE

1.11.1 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 AEA Technology model of methane generation from landfill sites initially used for 1996-2000 data (Brown *et al*., 1999) has been updated and revised for DEFRA by various consultants including Land Quality Management (LQM, 2003) and Golder Associates (Golder, 2005). The AEA waste team has most recently updated the UK-level data for the 1990-2007 UK GHGI submission. Specific research has recently been commissioned to review the UK waste model and clarify the referencing and traceability of the calculations.

In previous DA inventories, the DA emission estimates from the landfill waste sector were calculated based on regional municipal waste arisings data available from the Defra waste team. Up until 1995, waste arisings data was assumed to be the same as in Brown *et al.* (1999). After 1995, data are available from the England and Wales National Waste Production Survey (Environment Agency, 1999b), the Scottish Waste Data Digest (SEPA: 2001) and the Waste Management Strategy Northern Ireland (DoE NI: 2001). The Golder (2005) model revised MSW arisings from 2001 based on the Local Authority Waste Recycling and Disposal (LAWRRD) model (AEA Technology, 2005). The LAWRRD model provides arisings for England, with UK arisings calculated by scaling upwards, assuming England represents 83% of the UK's total. Comparison between the LAWRRD data and actual waste arisings for 2002 and 2003 showed a discrepancy of 2% and 4%, respectively. These differences are considered insignificant and the LAWRRD model data were taken to be representative of the current situation.

The Brown *et al*. (1999) study adjusted the proportion of waste landfilled for each region to reflect regional data on waste disposals. For Scotland and Northern Ireland, this meant higher percentage disposals to landfill than for England and Wales. However the LQM and Golder approaches were based only on the national waste arisings data; no adjustment was made for different proportions of waste disposal to landfill in each region. Due to a lack of detailed local data, it has also had to be assumed that the composition of waste in each region is the same, and that the degree of methane recovery is the same in each region.

In this latest inventory, however, a more detailed dataset has been identified from the www.WasteDataFlow.org website, which 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.

Hence this source of data (which has limited data back to 1999) has been used to derive regional drivers for emissions of methane from landfill waste. Note that this method is still limited in its accuracy, as the lack of detailed local data necessitates that average UK waste composition and average UK methane recovery is still assumed within each DA.

1.11.2 Waste Water Handling

Emissions from waste-water handling are based on population statistics for the UK. These are taken from the Office of National Statistics (ONS, 2008a) and assume that the application of different sludge treatment and disposal options are uniform across the UK.

1.11.3 Waste Incineration

The UK Inventory reports emissions from the incineration of sewage sludge, municipal solid waste and some chemical waste. Regional estimates are based on DEFRA (2008a) which reports data for the amount sewage 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, 2008a).

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, 2008a), 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.

1.12 UNCERTAINTIES

1.12.1 Summary of improvements to the DA uncertainty model

A number of improvements and additions have been made to the DA Uncertainty model this year. These are summarised in the list below, and described in more detail in the relevant sections that follow.

- Inclusion of improvements made to UK model over the last few years;
- Review of DA weighting factors;
- Estimation of uncertainty in base year emissions;
- Estimation of trend uncertainty ; and
- Sectoral estimation of uncertainties in F-gas emission estimates.

1.12.2 Introduction

The uncertainties in the UK Inventory are estimated using a Monte Carlo simulation. Eggleston et al (1998) and Salway et al (2001) describe this in detail. In general this involves estimating the uncertainties in the activity data and the emission factors for all the emission source categories and then using a Monte Carlo simulation package to calculate the uncertainty in the emission totals. In order to apply a similar approach to the DA GHG inventories, it is necessary to estimate uncertainties for the DA activity data (i.e. fuel consumption, production data). The same emission factors are used in the DA inventories as in the UK Inventory, so their uncertainties are known. In the UK Inventory uncertainties in the activity data for fuel use are estimated on the basis of the statistical differences between fuel supply and demand data reported in the energy statistics. However, such data is not available for the DA-specific activity data used. Moreover, for some sources, no direct activity data is available at all, and it has been necessary to distribute the UK data using surrogate data (e.g. employment statistics). In such cases, it is impossible to say whether the surrogate statistics are an accurate indicator of fuel consumption.

1.12.3 DA GHGI Uncertainty Estimation

The uncertainties in the DA GHG inventories are also estimated using a Monte Carlo simulation. In order to simplify the calculations, the source categories are far broader than those used in the UK GHG Inventory simulation. In the DA inventory simulation, the combustion categories are effectively the total consumption of a particular fuel. This contrasts with the UK simulation where there is a further disaggregation into sectoral categories (e.g. power stations, refineries). The rationale for this is that it is more practicable to estimate the uncertainty in the total consumption of a fuel in a region than to attempt to estimate uncertainties in diverse sectors where in some cases surrogates have been used.

For each of the broad source categories, an estimate of the activity uncertainty has been made for Scotland, Wales, Northern Ireland, and Unallocated emissions. The approach adopted was to estimate a factor to scale the UK uncertainty with, based on knowledge of the relative uncertainties of the DA estimates to each other, and to the UK total.

The factors used to weight the uncertainties for each of the DAs have been reviewed as part of the model updates made this year. The DA inventories have evolved since the uncertainty model was set up, and so some of the assumptions that were previously used are now no longer relevant. For example, different methods used to be used for fuel sales data in Northern Ireland and therefore the Northern Ireland estimate was assumed to be less uncertain than the other DAs. Now that DECC regional energy statistics are used across all four DAs, this difference in uncertainty is no longer assumed.

It is important to note that the uncertainties in the inventories for the UK, England, Scotland, Wales, Northern Ireland, Unallocated are inter-dependent, because:-

UK Emissions = [England + Scotland + Wales + Northern Ireland + Unallocated]
Therefore uncertainties from the UK, Scotland, Wales, Northern Ireland, and Unallocated emissions are estimated using the model, and uncertainty in the English emissions are calculated.

In many of the non-combustion sources (e.g. industrial processes, coal mines) the overall uncertainty is dominated by the emission factor and the uncertainty in the activity data is not a determining factor. Therefore, there is unlikely to be any significant variation in uncertainties between DAs. In these cases, a low uncertainty for the activity data (say 1%) may be assumed for each DA, whilst the UK uncertainty for the emission factor is applied.

For sources where the UK total is made up as a sum of the DA totals, such as agriculture or LULUCF, no additional uncertainty is introduced in the process of deriving the UK split, and therefore the UK uncertainty parameters are applied directly to the DA estimates.

In the case of halocarbons and SF_6 emissions it is not considered feasible to attempt to assume varying uncertainties across the DAs. However, this year the uncertainties have been considered at a sector level. This means that the uncertainty for each sector emission at UK level has been applied to the DA estimates, so that the overall uncertainty for each of the F-gases reflects the mix of sources that are the most significant for each of the DAs, and their relative uncertainties.

1.12.4 Trend Uncertainty Analysis

The DA uncertainty model has been extended this year to provide estimates of the uncertainty in the emissions trend. The model uses, where possible, the same principles as the UK uncertainty model, however, these estimates are currently indicative since it will take further improvement work to refine the estimates fully.

In order to estimate the uncertainty on the trend, it was necessary to make an estimate of the uncertainty in the base year (1990 for CO_2, CH_4 and N_2O, and 1995 for the F-gases). This estimate is made for the UK Inventory, as part of the analysis presented in the National Inventory Report (Jackson *et al*., 2009). Therefore, it was possible to make the DA uncertainty estimates using the method described above in conjunction with the UK estimates for the base year. The DA weighting factors were reviewed as part of this process, because changes to the source data and methods used across the time series mean that it is not always appropriate to apply the same weighting factor in the latest year as in the base year.

In addition to the estimation of the uncertainty in each year, it was also necessary to consider correlations between sources across years. The UK uncertainty model considers correlations in the estimates of

- N_2O from agriculture;
- CH_4 from landfills;
- CH_4 from leakage from the gas distribution network; and

- N_2O from waste water treatment.

These correlations have been replicated in the DA model. The uncertainty in the trend is particularly sensitive to the correlation in emissions from agricultural soils.

The uncertainty in the trend between 2006 and 2007 has been considered. However, the correlations between activity data and emission factors between adjacent years are not currently well understood, and it has therefore not been possible to produce a meaningful estimate at this time.