Appendices

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Appendix 1
Estimation Methodology

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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 2007, presents UK greenhouse gas emission estimates for the period 1990 to 2005 (Baggott *et al*, 2007).

This report presents separate inventories of greenhouse gas emissions for England, Scotland, Wales and Northern Ireland for the years 1990, 1995 and 1998 to 2005 that are consistent with the 1990 to 2005 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)
- sulphur hexafluoride (SF_6).

1.1.1 Reporting Format

Emissions are reported according to the Sectoral 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 and domestic aircraft emissions from the UK Crown Dependencies. 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). These emissions have not been allocated within the inventories for the constituent countries of the UK.

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 for the regional inventories:

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

where

E_i = Emission (in tonnes) from either England (1), Scotland (2), Wales (3), Northern Ireland (4) or “Unallocated” (5)

d_i = A driver representing the contribution of the region to UK emissions

i = 1, 2, 3, 4, 5

The driver, d_i can be any one of:

1. The value of the activity data for the region. [For example, consumption of specific fuels or industrial production figures for the region.]
2. The fraction of the UK activity in the region.
3. The value of a surrogate activity data statistic in the region. Where the required activity is unavailable on a regional basis, a surrogate value may be used. [For example, employment statistics or manufacturing output of a specific product, used as a surrogate for consumption data of a given fuel.]
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” (e.g. 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 is 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 2005 inventories, 133 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 1990-2005 DA GHGI datasets, the AEA Energy & Environment inventory team have aimed to improve disaggregation methodologies and data sources for many GHG emission source sectors, including:

- Methane emissions from closed coal mines
- Peat consumption data
- DTI regional energy statistics for solid and liquid fuels used in domestic, commercial, public administration and small-scale industrial sectors
- Domestic aircraft emissions
- Road transport (Northern Ireland)

For further details regarding improvements & revisions to DA inventory data, see Chapter 7 of the main report.

Summary of Abbreviations used in Tables A1.1 to A1.10

AEAT	AEA Technology plc
BCA	British Cement Association
BGlass	British Glass
CA	Coal Authority
CAA	Civil Aviation Authority
DAs	Devolved Administrations
DTI/BERR	Department of Trade and Industry / Department for Business Enterprise & Regulatory Reform
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 previously MCG
EPER	European Pollutant Emissions Register (refers to SEPA's inventory of emissions from regulated industries)
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)
MCG	March Consulting Group (now EM)
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
ONS	Office for National Statistics
OPG	Other petroleum gas
PI	Pollution Inventory
S	Scotland
SEPA	The Scottish Environmental Protection Agency
SSF	Solid smokeless fuel
SPRU	Science Policy Research Unit
UKOOA	UK Offshore Operators Association
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 2005. 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. These include Scottish Power (2004), Scottish and Southern Energy (2004), Innogy (2004), PowerTech (2004), AES Drax (2004). From 2000 onwards, emissions data reported in the Pollution Inventory (Environment Agency, 2006) the Scottish Pollution Release Inventory (SEPA, 2006) and the Inventory of Statutory Releases (Northern Ireland Department of Environment, 2006) has been used rather than the fuel consumption data. For emissions in 2005, fuel use and emissions data reported within the EUETS have also been used, mainly as a verification of the CO_2 emissions data reported under IPPC.

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 – 2005 (UKPIA: 2006), 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).

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 2005)

IPCC Category	NAEI Sources	Activity: Fuel Consumption	Data Sources / Comments
Electricity Production	Power Stations	Coal, oil, natural gas	Consumption data from Power Generators, plus EUETS, PI, EPER & ISR data from 2000 onwards
		Unrefined natural gas	Some power facilities have used this fuel since 1995. Data provided by plant operators.
		Sewage gas	Sewage methane recovered
		Landfill gas	As landfill methane
		Orimulsion, MSW, poultry litter	From 1999, some MSW plant now also in Scotland.
Petroleum Refining	Refineries	All fuels	UKPIA CO_2 emission estimates for pre-1997. PI CO_2 emission estimates for 1998. UKPIA data for 1999-2005.
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, DTI, 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, DTI
	Offshore Own Gas Use / Gas Sepn.	Unrefined natural gas, LPG, OPG	(1995 – current) UKOOA EEMS CO_2 estimates for terminals, DTI 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). Regional data on coke ovens in the iron and steel industry are reported in detail by ISSB (2007). 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 (DTI: 1991, 2000-2006). 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 2005, 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: 2006).

The generic driver for coke oven fuel consumption is the consumption of coking coal, which is in effect the regional capacity of coke ovens. 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 (DTI: 1991, 2000-2006) 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 UKOOA (1999, 2002-2006). Installation-specific data are only available for post-1995. Emissions for 1990 are extrapolated based on 1995 UKOOA 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 UKOOA 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 (DTI: 1991, 1996, 2000-2006). Other sources are minor and are covered in Table A1.2.

1.3 MANUFACTURING INDUSTRIES AND CONSTRUCTION

The drivers calculated to disaggregate regional fuel consumption from these sectors are summarised in Table A1.3.

1.3.1 Iron and Steel

The ISSB (2007) 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 DTI, which includes foundries and finishing plant, and therefore the DTI 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

DTI (2000-2006, 1996 & 1991) 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, the DTI has started to produce more detailed regional energy use data (DTI, 2006b), 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, DTI
		OPG	All such plant are located in Scotland, DTI
		LPG	Regional energy statistics, DTI
		Lubricants	Regional energy data, DTI, 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, DTI
		Coke oven gas	Coal feed to coke ovens, ISSB, WO, WS
		SSF	Regional energy statistics, DTI
		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 2005)

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, DTI
		OPG	All such plant are located in Scotland, DTI
		LPG	Regional energy statistics, DTI
		Lubricants	Regional energy data, DTI, less estimate of road transport use.
		Natural gas	Natural gas consumed, data from Transco (now UK National Grid) & (since 1995) from Phoenix Gas (NI)
		Colliery Methane	Deep mined coal production, British Coal Authority
		Coal, coke	Regional energy statistics, DTI; Coal consumption, WO, NIO
		Coke oven gas	Coal feed to coke ovens, ISSB, WO, WS
		SSF	Regional energy statistics, DTI
		Wood	GDP data.
	Cement	Coal, oil, gas, petrocoke, tyres, waste oil	Regional cement capacity, BCA; For 2002-2005, 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 resulting DTI regional energy statistics are regarded as experimental for use at local level, but at DA-level the fuel use patterns will be subject to less error. 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 new DTI 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. However, these data are based on surveys and proxy activity data from the early 2000s, and have only been produced for 2003 onwards and hence their use to extrapolate estimates back across the time-series presents other limitations to the inventory data usefulness. Hence, despite the new DTI regional energy statistics, 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.

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 DTI regional energy statistics (DTI: 2006).

The driver for emissions from lubricant use is based on regional lubricant sales (DTI: 1991, 1996, 2001-2006) with England and Wales being disaggregated based on regional manufacturing employment statistics (ONS: 2006).

The DTI (DTI: 2006c) has supplied 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 (2006) for 1999 onwards.

Regional gas consumption is estimated by matching the UK National Grid and Phoenix totals with the NAEI UK total. Northern Ireland gas consumption is estimated directly from the Phoenix data. Gas consumption by "other industry" and "autogenerators" in GB is disaggregated based on a mass balance, after all other defined sector uses have been deducted from the totals. Determination of drivers for gas consumption by other defined sectors is discussed in other sections of this appendix. The driver determined for "other industry" is also used for "autogenerators".

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: 2006, SEPA: 2006, NIDoE: 2006).

"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 approach to the disaggregation of the domestic aviation emissions has been revised in the latest inventory to utilise a new data-source: a database of aircraft movement data from the Civil Aviation Authority (CAA: 2006), also used in the compilation of the UK GHG inventory.

The 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 use of the CAA database has enabled us to also present separate emission estimates for flights that originate in the Crown Dependencies of the UK (i.e. the Channel Islands, Isle of Man). Emissions from these flights have been accounted within the "Unallocated" inventory.

The driver for emissions from aircraft support vehicles is calculated based on aircraft movement data from the UK's major airports (DfT, 2006).

The disaggregation of emissions from navigation, fishing and coastal shipping is derived based on port movement data in each constituent country (DfT: 2006b).

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.

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, their emissions are affected by technologies introduced to reduce emissions of the regulatory 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, actually increases emissions of N_2O, formed as a by-product of the catalyst NO_x reduction process.

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

IPCC Category	NAEI Sources	Activity: Fuel Consumption	1990
Civil Aviation	NA	Aviation Gasoline, Jet Gasoline	CAA database of flight information
Road Transportation	Road Transport	Petrol, Diesel oil	Road fuel sales, DTI; 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	Gas oil, Fuel oil	Port movement data, DfT Maritime Statistics
Other	Aircraft Support	Gas oil	Regional aircraft movements, DfT

1 See Section 1.1.3 for abbreviations

Table A1.4b: Transport (1995; 1998 to 2005)[1]

IPCC Category	NAEI Sources	Activity: Fuel Consumption	Data Sources / Comments
Civil Aviation	NA	Aviation Gasoline, Jet Gasoline	CAA database of flight information
Road Transportation	Road Transport	Petrol, Diesel oil, LPG	Road fuel sales, DTI; vehicle km, DETR / DLTR Emission factors: COPERT III (European Environment Agency, 2000), Barlow et al. (2001) Composition of fleet: Vehicle Licensing Statistics Report, DfT (GB) Dept of Regional Development (NI). Traffic data: National Traffic Census, DfT (GB: 1990-2006) 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 2004, 2005 (DRDNI: 2002-2006) Fuel consumption: Digest of UK Energy Statistics (1990-2006), Welsh Office fuels data (WO, 1998)
Railways	Railways	Gas oil	Gas oil consumption, Railtrack, Translink & NIR
Navigation	Coastal	Gas oil, Fuel oil	Port movement data, DfT Maritime Statistics
Other	Aircraft Support	Gas oil	Regional aircraft movements, DfT

Regional disaggregation is based on traffic data in the regions as the driver for allocating UK emissions between each region. The traffic data used originated from 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 were 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. One of the remaining problems is receiving data each year in the same form and the coverage of traffic data on minor roads on a regional basis.

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) In this context, the decision to base emissions for the regions on fuel consumption derived from traffic data rather than fuel sales, is consistent with CORINAIR.

Total emissions from road transport in each region were 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). 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 followed for the regional inventory of emissions from road transport were those used for the UK National Atmospheric Emissions Inventory (NAEI). These are largely taken from the European COPERT III program and database, recommended for CORINAIR and forming the basis of the IPCC Guidelines (European Environment Agency, 2000), and from the more recent 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 (Baggott *et al*., 2007). 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 (European Environment Agency, 2000).

The factors for N_2O are also unchanged (COPERT III), with emissions data for this pollutant remain sparse and only those for petrol cars and LGVs with catalysts (Euro I and on) able to reflect a dependence on vehicle speed. The uncertainties in these 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 also lead to higher N_2O emissions than non-catalyst vehicles.

Fuel consumption factors for different vehicle types and speeds are unchanged and are based on emission-speed equations developed by TRL (Barlow *et al*, 2001).

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. Where the original source of the factors provided them as speed-emission factor equations, emission factors were calculated at average speeds typical of the road types shown in the tables.

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 2005 were taken from vehicle licensing statistics. For England, Scotland and Wales, the data were taken from the Vehicle Licensing Statistics Report published for Great Britain each year by DfT (2006a); this is based on the DVLA files of vehicles licensed in Great Britain at the end of each year.

Additional information had been obtained directly from DfT which showed the post-town where the vehicles were 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, it was possible to estimate the average age of the fleet based on registrations in England, Scotland and Wales. This tended to show that the age of the fleet was 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 was not used for the DA inventories and it was 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 was slightly different. Vehicle licensing statistics for private and light goods vehicles (PLG) were available in Northern Ireland Transport Statistics from the Central Statistics and Research Branch of the Department of Regional Development in Northern Ireland. These showed a newer fleet of cars than in Great Britain (DoRDNI, 2006a). 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 1995-2005 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, 2006b). These estimates are based on traffic counts from the rotating census and core census surveys.

Vehicle kilometre data for 1990-2005 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 2005 are taken from the DfT Road Traffic Statistics Bulletin (DfT, 2006c).

Vehicle kilometre data in Northern Ireland for different road classes and vehicle categories were available from the Traffic and Travel Information 2005: Vehicle Kilometres of Travel Annual Report produced for the Department for Regional Development (DoRDNI, 2006b).

1.4.2.4 Estimation of emissions

Emissions of CH_4 and N_2O from road transport in the regions were calculated by combining the vehicle emission factors, fleet composition data and vehicle kilometre data for the different vehicle, fuel and road types. Fuel consumption was calculated in the same way using fuel consumption factors and converted to CO_2 emissions. The summed emissions for petrol and diesel vehicles in each region were normalised so the total equalled the emissions from road transport calculated for the UK for each pollutant and fuel type.

1.4.2.5 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 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 estimate DA emissions. This is the first time that we have used this approach, and hopefully in future years, actual LPG sales data by DA may become available to provide a more accurate methodology.

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

g/km	Standard	Urban	Rural	Motorway
Petrol cars	ECE 15.01	77.9	65.1	76.8
	ECE 15.02	73.1	61.0	72.0
	ECE 15.03	73.1	61.0	72.0
	ECE 15.04	66.7	55.7	65.7
	Euro I	65.4	58.2	68.2
	Euro II	63.0	59.7	72.2
	Euro III	59.2	56.1	67.8
	Euro IV	52.8	50.0	60.5
Diesel cars	Pre-Euro I	64.5	51.0	60.5
	Euro I	63.4	55.8	71.6
	Euro II	61.1	56.0	74.3
	Euro III	54.5	49.9	66.3
Petrol LGVs	Pre-Euro I	73.9	61.5	99.8
	Euro I	93.3	83.2	109.6
	Euro II	95.3	85.5	112.6
	Euro III	90.9	81.5	107.4
Diesel LGV	Pre-Euro I	95.1	95.1	138.4
	Euro I	94.9	81.9	132.6
	Euro II	95.1	82.1	132.9
	Euro III	87.4	75.5	122.1
Rigid HGVs	Pre-1988	241	225	263
	88/77/EEC	241	225	263
	Euro I	241	225	263
	Euro II	241	225	263
	Euro III	241	225	263
Artic HGVs	Pre-1988	393	317	362
	88/77/EEC	393	317	362
	Euro I	348	330	360
	Euro II	321	304	332
	Euro III	321	304	332
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
Mopeds, <50cc, 2st	Pre-2000	25.0	25.0	25.0
	97/24/EC	11.0	11.0	11.0
	EU 2003	11.0	11.0	11.0
Motorcycles, >50cc, 2st	Pre-2000	30.1	33.1	38.2
	97/24/EC	24.4	27.1	29.2
	EU 2003	24.4	27.1	29.2
Motorcycles, >50cc, 4st	Pre-2000	28.5	30.7	38.8
	97/24/EC	24.9	27.8	34.9
	EU 2003	24.9	27.8	34.9

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

g/km	Standard	Urban	Rural	Motorway
Petrol cars	ECE 15.01	0.105	0.033	0.048
	ECE 15.02	0.106	0.033	0.049
	ECE 15.03	0.106	0.033	0.049
	ECE 15.04	0.085	0.026	0.039
	Euro I	0.037	0.017	0.023
	Euro II	0.026	0.011	0.007
	Euro III	0.015	0.007	0.004
	Euro IV	0.012	0.005	0.003
Diesel cars	Pre-Euro I	0.008	0.010	0.018
	Euro I	0.004	0.005	0.011
	Euro II	0.003	0.004	0.007
	Euro III	0.002	0.002	0.005
Petrol LGVs	Pre-Euro I	0.150	0.040	0.025
	Euro I	0.036	0.017	0.027
	Euro II	0.022	0.011	0.018
	Euro III	0.013	0.006	0.011
Diesel LGV	Pre-Euro I	0.005	0.005	0.005
	Euro I	0.002	0.003	0.003
	Euro II	0.002	0.003	0.003
	Euro III	0.002	0.003	0.002
Rigid HGVs	Pre-1988	0.241	0.091	0.079
	88/77/EEC	0.120	0.045	0.039
	Euro I	0.044	0.015	0.012
	Euro II	0.035	0.013	0.011
	Euro III	0.024	0.009	0.008
Artic HGVs	Pre-1988	0.441	0.201	0.176
	88/77/EEC	0.175	0.080	0.070
	Euro I	0.187	0.097	0.096
	Euro II	0.154	0.086	0.092
	Euro III	0.108	0.060	0.064
Buses	Pre-1988	0.722	0.330	0.289
	88/77/EEC	0.175	0.080	0.070
	Euro I	0.130	0.069	0.058
	Euro II	0.094	0.059	0.053
	Euro III	0.066	0.041	0.037
Mopeds, <50cc, 2st	Pre-2000	0.219	0.219	0.219
	97/24/EC	0.048	0.048	0.048
	EU 2003	0.048	0.048	0.048
Motorcycles, >50cc, 2st	Pre-2000	0.150	0.150	0.150
	97/24/EC	0.104	0.107	0.091
	EU 2003	0.040	0.041	0.035
Motorcycles, >50cc, 4st	Pre-2000	0.200	0.200	0.200
	97/24/EC	0.084	0.079	0.059
	EU 2003	0.032	0.030	0.023

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

g/km	Standard	Urban	Rural	Motorway
Petrol cars	ECE 15.01	0.005	0.005	0.005
	ECE 15.02	0.005	0.005	0.005
	ECE 15.03	0.005	0.005	0.005
	ECE 15.04	0.005	0.005	0.005
	Euro I	0.053	0.016	0.035
	Euro II	0.053	0.016	0.035
	Euro III	0.053	0.016	0.035
	Euro IV	0.053	0.016	0.035
Diesel cars	Pre-Euro I	0.027	0.027	0.027
	Euro I	0.027	0.027	0.027
	Euro II	0.027	0.027	0.027
	Euro III	0.027	0.027	0.027
Petrol LGVs	Pre-Euro I	0.006	0.006	0.006
	Euro I	0.053	0.016	0.035
	Euro II	0.053	0.016	0.035
	Euro III	0.053	0.016	0.035
Diesel LGV	Pre-Euro I	0.017	0.017	0.017
	Euro I	0.017	0.017	0.017
	Euro II	0.017	0.017	0.017
	Euro III	0.017	0.017	0.017
Rigid HGVs	Pre-1988	0.030	0.030	0.030
	88/77/EEC	0.030	0.030	0.030
	Euro I	0.030	0.030	0.030
	Euro II	0.030	0.030	0.030
	Euro III	0.030	0.030	0.030
Artic HGVs	Pre-1988	0.030	0.030	0.030
	88/77/EEC	0.030	0.030	0.030
	Euro I	0.030	0.030	0.030
	Euro II	0.030	0.030	0.030
	Euro III	0.030	0.030	0.030
Buses	Pre-1988	0.030	0.030	0.030
	88/77/EEC	0.030	0.030	0.030
	Euro I	0.030	0.030	0.030
	Euro II	0.030	0.030	0.030
	Euro III	0.030	0.030	0.030
Mopeds, <50cc, 2st	Pre-2000	0.001	0.001	0.001
	97/24/EC	0.001	0.001	0.001
	EU 2003	0.001	0.001	0.001
Motorcycles, >50cc, 2st	Pre-2000	0.002	0.002	0.002
	97/24/EC	0.002	0.002	0.002
	EU 2003	0.002	0.002	0.002
Motorcycles, >50cc, 4st	Pre-2000	0.002	0.002	0.002
	97/24/EC	0.002	0.002	0.002
	EU 2003	0.002	0.002	0.002

1.4.3 Development of the Estimation Methodology of Road Transport CO_2 Emissions in the UK

Road transport is a very significant and growing sector as regards emissions of greenhouse gases 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 greenhouse gas emissions inventories for the Devolved Administrations in the UK, 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 (DTI: Personal Communication, 2004).

- **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 (DTI: Personal Communication, 2004).

Adopting the IPCC estimation method of using fuel sales data 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 Energy & Environment has moved away from using regional fuel sales data and instead have used regional vehicle kilometre data to disaggregate the UK road transport CO_2 total to provide a more representative assessment of transport emission trends of CO_2 within the constituent countries of the UK.

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[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.

1.4.3.1 Current Disaggregation Method: Road Transport

The current method used to estimate emissions of CO_2, CH_4 and N_2O from road transport is based on vehicle kilometre travelled data for the constituent countries of the UK, *with the sum of the DA-level inventories constrained to meeting the total of the UK inventory for the road transport sector* which for CO_2 is derived from UK fuel sales data of petrol and DERV from the DTI.

The vehicle kilometre data for each region is used to provide an estimated allocation of the total UK road transport emissions across the constituent countries, but this method essentially constrains the sum of regional CO_2 emissions to the national totals. (This approach is consistent with that adopted across every other source sector in the Devolved Administration GHG inventories.)

However, the criticism of this method is that the presentation of results does not always provide a CO_2 emission trend for the DAs that is directly consistent with the vehicle kilometre trend data, as the fluctuations in UK fuel data (from DTI) have a more significant impact on the resultant emission trends. This is illustrated in **Figure A1.4.4.1** below.

1.4.3.2 Alternative Disaggregation Method: Road Transport

As an alternative to the current method, road transport CO_2 emissions from the constituent countries of the UK may be estimated *solely by vehicle kilometre data unconstrained to the UK total derived from fuel consumption data*.

In 1990, the estimated CO_2 emissions from these two methods agreed closely. However, this agreement has deteriorated during the 1990s, and now the estimated CO_2 emissions using the vehicle kilometre approach, when summed over all constituent countries, are greater than those estimated using UK fuel sales data. In 2005, the estimated UK CO_2 emissions from the unconstrained vehicle kilometre approach are 7% greater than the estimates based on DTI fuel sales. The pattern in the trend of CO_2 emissions using the two methods also differs.

The likely reason for this disparity in both total emissions and the trend in CO_2 emissions is the growth in cross-border fuel sales (“fuel tourism”), although there is inevitably a degree of uncertainty associated with both of the estimation methods considered.

The DA-level trends in road transport CO_2 emissions from this method are presented below in **Figure A1.4.4.2**, whilst the disparity in total UK CO_2 emissions using the current method and this alternative method are detailed in **Table 1.4.4** and **Figure A1.4.4.3** below.

Table 1.4.4a Comparison between methods of CO_2 emissions for each DA (kt CO_2)[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.

Methodology	vkm	Fuel Sales	vkm	Fuel Sales	vkm	Fuel Sales	vkm	Fuel Sales	vkm	Fuel Sales
DA	England		Scotland		Wales		Northern Ireland		UK	
1990	91889	91422	9061	9009	5525	5500	3244	3216	109719	109147
1995	96151	92455	9469	9105	5759	5538	3648	3511	115027	110609
1998	102132	96589	10053	9512	6123	5789	3940	3734	122248	115625
1999	104478	97486	10027	9356	6227	5813	4158	3877	124890	116533
2000	104737	96580	10235	9434	6205	5723	4328	3981	125505	115718
2001	105729	96481	10288	9388	6248	5703	4437	4043	126703	115615
2002	106651	98095	10495	9653	6378	5864	4716	4342	128239	117954
2003	106982	97558	10614	9682	6425	5860	4974	4545	128995	117645
2004	108207	98489	10746	9783	6558	5969	5021	4581	130532	118822
2005	106160	98887	10567	9851	6442	5990	4925	4632	128093	119360

Table 1.4.4b below sets out the CO_2 and GHG emissions from 1990 to the latest inventory year from the two methods of estimating road transport emissions.

Table 1.4.4b 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	2005	Percentage change
Constrained to fuel sales data **See text below**	Carbon	LPG	-	353.85	
		Petrol and DERV	109,146.91	119,360.09	
		Lubricants	262.77	179.34	
	CH_4	Petrol and DERV	613.31	165.62	
	N_2O	Petrol and DERV	1,023.60	5,082.55	
		Sum	111,046.59	125,141.44	12.7%
Unconstrained to fuel sales data (by using vkm) **See text below**	Carbon	LPG	-	353.85	
		Petrol and DERV	109,718.70	128,093.00	
		Lubricants	262.77	179.34	
	CH_4	Petrol and DERV	613.31	165.62	
	N_2O	Petrol and DERV	1,023.60	5,082.55	
		Sum	111,618.38	133,874.36	19.9%

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.

Figure A1.4.4.1 Road Transport CO_2 Emission Trends 1990-2005: Current Methodology

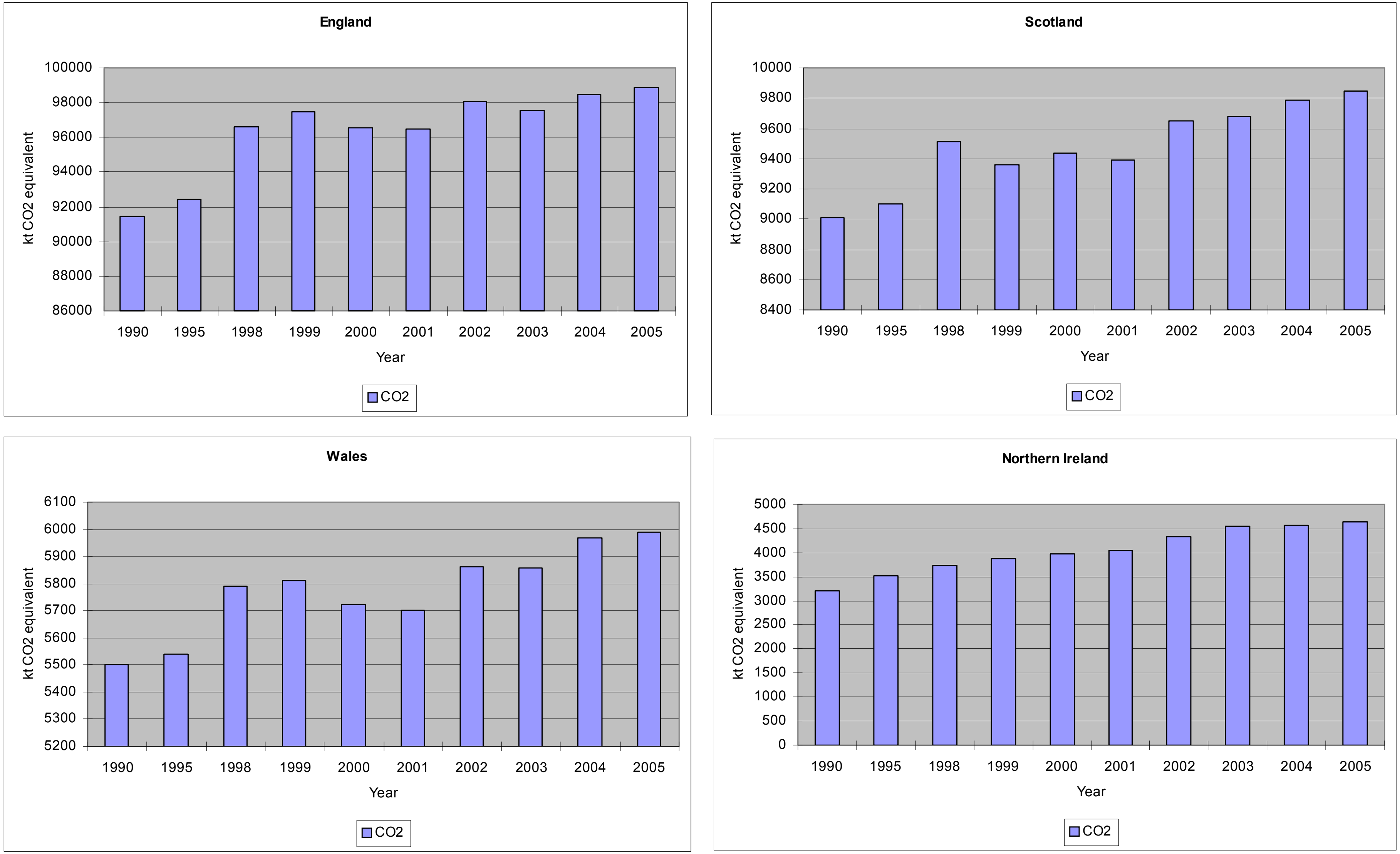
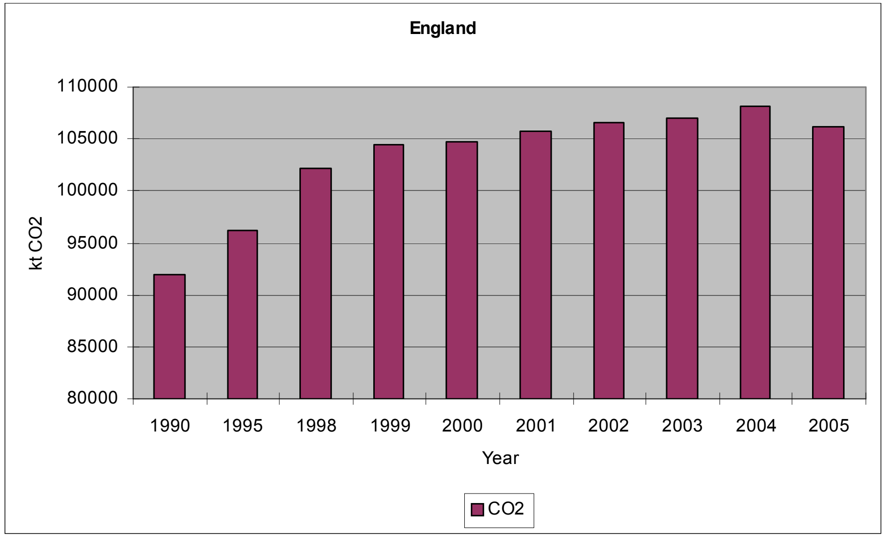
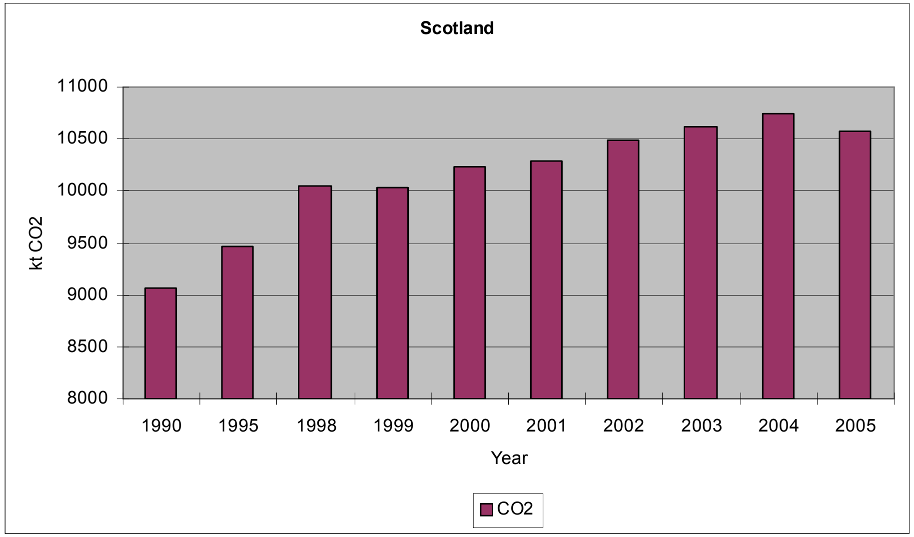
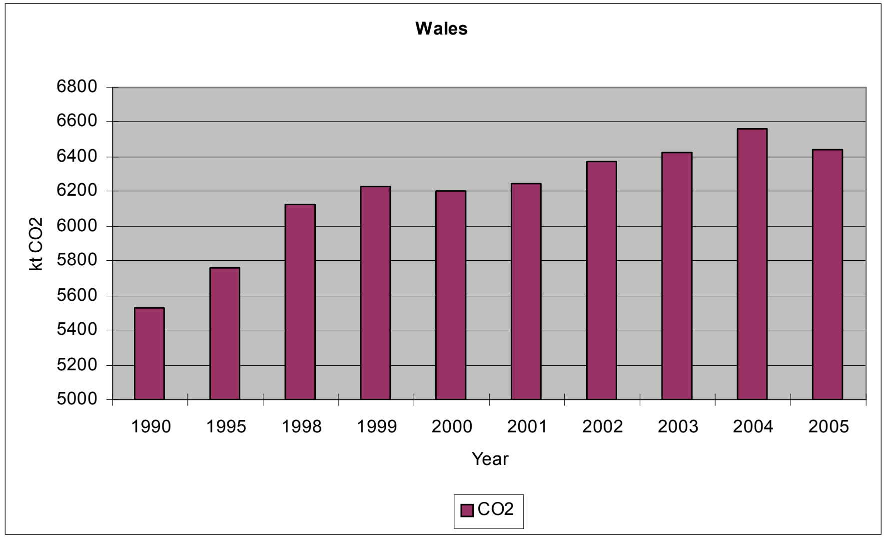


Figure A1.4.4.2 Road Transport CO_2 Emission Trends 1990-2005: Alternative Methodology







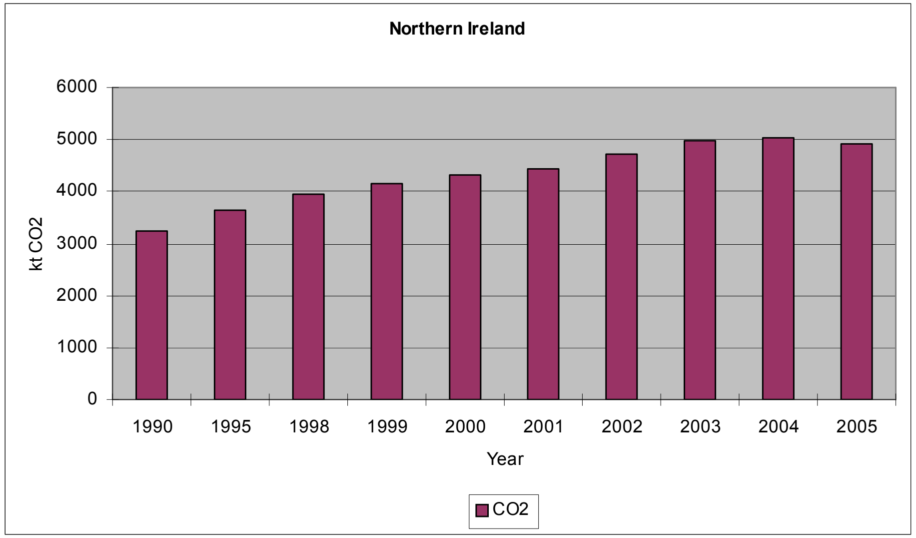
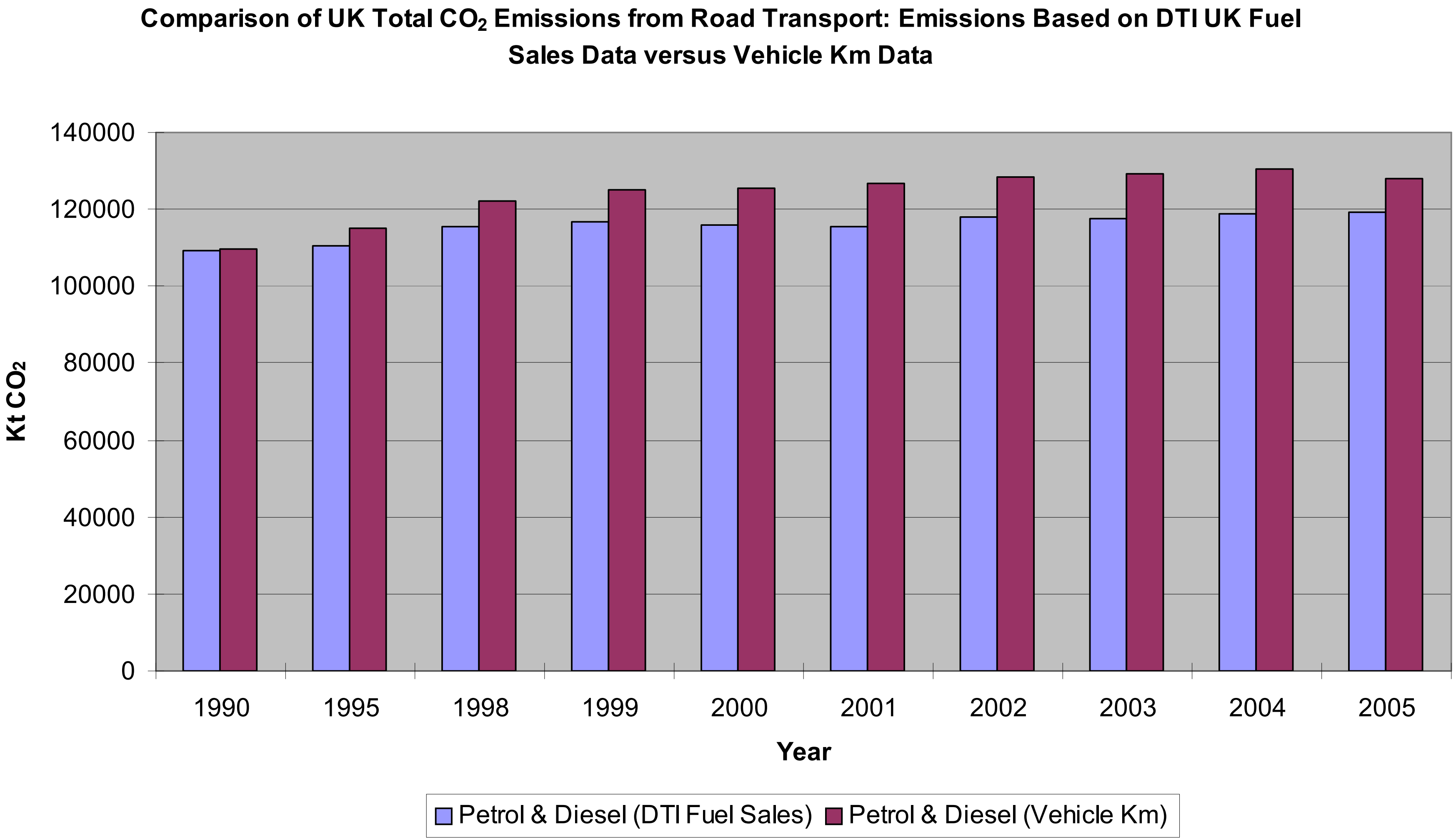


Figure A1.4.4.3 Road Transport CO_2 Emission Trends 1990-2005: UK Comparison between methods



1.4.4 Railways

Emissions from railway locomotives in Great Britain are disaggregated based on diesel oil consumption data supplied by ATOC (2006) 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 (2006).

1.5 OTHER SECTORS

1.5.1 Commercial & Institutional

Emissions estimates for the source categories “public administration” and “miscellaneous” 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 (“other”) 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 DTI regional energy statistics (DTI: 2006b), however, do now provide regional estimates of fuel use in these sectors, based on the use of local electricity and gas use data and a modelling approach to the distribution of solid and liquid fuels.

Regional gas sales for the commercial sector have previously been reported by the DTI (1992), but for later years (1995 to date) the key source has been UK National Grid 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 DTI (2001-2006). 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 Natural Gas for 1999 onwards. The commercial consumption is used as an estimate for Northern Ireland miscellaneous and public service gas consumption.

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).

DTI (2006a) 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	DTI Regional energy statistics
		SSF	DTI Regional energy statistics
		Natural gas	Commercial Sales, DTI.
		Landfill gas	Landfill methane emissions
		Sewage gas	Sewage methane recovered
		fuel oil, gas oil	DTI Regional energy statistics
		MSW	As MSW incinerators
		Burning oil	DTI Regional energy statistics
	Railways (Stationary)	fuel oil, burning oil, coal	Regional oil consumption, DTI
		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), DTI & Housing Condition Survey data, NI HECA
		Natural gas	Domestic Gas, DTI
		Burning oil, gas oil,	Regional energy statistics (oil), DTI & Housing Condition Survey data, NI HECA
		Coal, anthracite	Regional energy statistics (coal, anthracite), DTI & Housing Condition Survey data, NI HECA
		Fuel oil	Regional population, ONS
	House & Garden	DERV, petrol	Regional dwellings, ONS
Agriculture, Forestry & Fishing	Agriculture	coal, coke, fuel oil, gas oil, natural gas	Agricultural employment, MAFF
		burning oil	Regional burning oil, DTI
		straw	Wheat production, MAFF
	Agric. Power Units	Gas oil, petrol	Agricultural employment, MAFF

1 See Section 1.1.3 for abbreviations

Table A1.5b Other Sectors (1995; 1998 to 2005)

IPCC Category	NAEI Sources	Activity: Fuel Consumption	Data Sources / Comments
Commercial & Institutional	Miscellaneous, Public service	Coal	DTI Regional energy statistics
		SSF	DTI Regional energy statistics
		Natural gas	Natural gas consumed, Transco (now UK National Grid) & Phoenix
		Landfill gas	Landfill methane emissions
		Sewage gas	Sewage methane recovered
		fuel oil, gas oil	DTI Regional energy statistics
		MSW	As MSW incinerators
		Burning oil	DTI 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), DTI & Housing Condition Survey data, NI HECA
		Natural gas	Domestic Gas, DTI, Transco & UK gas network operators
		Burning oil, gas oil,	Regional energy statistics (oil), DTI & Housing Condition Survey data, NI HECA
		Coal, anthracite	Regional energy statistics (coal, anthracite), DTI & Housing Condition Survey data, NI HECA
		Fuel oil	Regional population, ONS
	House & Garden	DERV, petrol	Regional dwellings, ONS
Agriculture, Forestry & Fishing	Agriculture	coal, coke, fuel oil, gas oil, natural gas	Agricultural employment, MAFF / DEFRA
		burning oil	Regional burning oil, DTI
		straw	Wheat production, MAFF / DEFRA
	Agric. Power Units	Gas oil, petrol	Agricultural employment, MAFF / DEFRA

1.5.2 Residential

In previous inventories, domestic coal consumption was estimated using data reported in NIO (2005) up to the present and in WO (1998) to 1993. These data were not very detailed as they also included anthracite and (for NI) other solid smokeless fuels. In addition, published data for Scotland and England were not available, and hence estimates were uncertain. Solid fuel sales data were obtained from major coal producers and a complex mass balance was used to provide estimates, but this method was becoming untenable due to lack of source data leading to considerable data gaps and inconsistencies with DUKES domestic fuel totals.

A very similar approach was adopted for petroleum-based fuels using sales data that was limited in detail (i.e. no split between different oil grades) and incomplete, drawing on sales data from refiners. The complex balance approach was again adopted, but data gaps and inconsistencies were apparent across the time-series.

In this latest inventory, the DTI regional energy statistics (DTI: 2006b) have been used in conjunction with information drawn from Housing Condition Surveys to provide new estimates of domestic solid and liquid fuel use patterns across the DAs. (See Section 1.3.2 for more details regarding the DTI regional energy statistics source data.)

DTI regional energy use data for 2003 and 2004 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 data is available from more recent surveys for LPG and Solid Smokeless Fuel use, and hence these data have been used and extrapolated backwards using the HCS data.

Domestic natural gas consumption data is available for 1990, 1995 and 1998-2005 (DTI: 1991, 1996, 1999-2006), with additional information from Transco and other GB gas supply network operators (2006) and Phoenix Gas for NI (2006).

The consumption of fuel oil by the domestic sector is a very small amount, and is distributed simply according to population (ONS: 2006). Domestic use of wood is estimated across the time-series using the latest mapping grid information on wood use (NAEI maps: 2007). New data on domestic peat use was provided via a recent study by the Centre for Ecology & Hydrology (Mobbs: 2006)

1.5.3 Agriculture, Forestry & Fisheries

Regional fuel consumption by agriculture is not available. Emissions are allocated on the basis of employment figures from DEFRA (2006a).

1.6 MILITARY

Emissions from military aircraft and naval vessels have been allocated based on regional GVA data (ONS, 2005). 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 (2001-2005), BGS (1991, 1996, 2002-2005), WO (1998), SO (1999), DTI (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. 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 (WYG: 2005).

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 offshore industry have been classified as unallocated. However some emissions occur from on-shore oil and gas terminals in England, Wales and Scotland and from a small number of on-shore oil and gas fields.

The estimates of terminal flaring and venting emissions are based on UKOOA (2006) data for 1995, 1998-2005. 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 2000-2005 UK GHG inventories include a correction to account for flaring on onshore oil and gas fields excluded by the UKOOA (offshore) emissions inventory. Onshore flaring volumes are obtained from DTI sources (DTI: 2006b).

Their significance in the UK national GHG inventory is minimal, but the data is more significant for the regional inventories. Wytch Farm, which lies a few miles off the south coast of England, was classified as on-shore for this purpose.

The UKOOA inventory data (2006) provides data for fugitive emissions of CO_2 and methane from terminals for 1998-2005. 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.

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 (formerly Transco) (2006) and the other gas network operators: Northern Gas Networks (2006), Scotia Gas Networks (2006) and Wales & West Utilities (2006). Estimates are provided by Local Distribution Zones, enabling allocation to the specific DA.

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 2006
	Open cast coal	Open cast mine coal production.	Regional open cast mine production, British Coal Authority CH_4 from closed coal mines from WYG 2006
Solid Fuel transformation	Coke production	Coke production	Coal feed to coke ovens, ISSB, WS, DTI
	Flaring	Coke oven gas	Coal feed to coke ovens, ISSB, WS, DTI
	SSF production	Coal, Petrocoke	Coal feed to SSF plant, DTI, 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, DTI
	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 2005)

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 2006
	Open cast coal	Open cast mine coal production.	Regional open cast mine production, British Coal Authority CH_4 from closed coal mines from WYG 2006
Solid Fuel transformation	Coke production	Coke production	Coal feed to coke ovens, ISSB, WS, DTI and (1999-current) PI
	Flaring	Coke oven gas	Coal feed to coke ovens, ISSB, WS, DTI and (1999-current) PI
	SSF production	Coal, Petrocoke	Coal feed to SSF plant, DTI, WS
Oil	Offshore Oil & Gas	NA	UKOOA Process emissions from Terminals
	Oil Terminal Storage	NA	Data from storage emissions, UKOOA inventory
	Onshore Loading	Oil loaded	Data from loading emissions, UKOOA inventory.
Venting & Flaring	Offshore Flaring	Volume gas flared	Flaring at terminals and onshore fields, UKOOA, DTI
	Offshore Venting	NA	Data from venting emissions, UKOOA inventory.
Natural Gas	Gas Leakage	Natural gas leakage	National Grid (Transco), Northern Gas Networks, Scotia Gas Networks, Wales & West Utilities

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, EPER 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, 2007).

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: 2006) 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 to 2005.

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.

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 Pollution

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

Inventory (Environment Agency, 2006) 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.

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 2005)

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 2005) (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

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, 2007).

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, 2007).

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 (2007). 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. 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 regional splits for 2003 onwards are based on PI and SPRI data (EA, SEPA: 2006)

The anode baking process within aluminium production also results in emissions of PFCs.

1.8.4 Use of Halocarbons and SF6

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 (2006).

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

All data and information pertaining to agricultural sources within the regional emissions inventories are provided by the Institute of Grassland and Environmental Research.

The UK inventory was disaggregated into England, Scotland, Wales and Northern Ireland. No methodological alterations were made in terms of emissions calculations, with defaults and emission factors carried over from the national inventory.

Regional crop areas were obtained from the Defra (previously MAFF) June Agricultural Census for 1990, 1995, 1998 - 2005 (MAFF: 1991,1996, 1999, 2000;

DEFRA: 2001 - 2006), SEERAD (Scottish Office: 1991, 1996, 1999, 2000; SEERAD 2000-2006) and DARDNI (DANI: 1991, 1996, 1998; DARDNI 1999, 2000-2006). Crop production data is taken from Agriculture in the UK and Basic Horticultural Statistics for the UK. The Welsh Assembly Government has also provided crop area data in Wales for this inventory.

Fertiliser applications were derived using regional crop areas and average application rates published in the British Survey of Fertiliser Practice for 1990, 1995, 1998 - 2005 (BSFP, 1991; 1996; 1999-2006), which presents data for England and Wales, Scotland and Great Britain. Application rates in Northern Ireland were assumed to be the same as Scottish applications. In many cases, the sample size used to estimate fertiliser use in Scotland was considered too small to be sufficiently robust and in these cases, the Great Britain data were used. Where application rates were not available for particular crop types, the crop area was amalgamated with a similar crop with a known fertiliser application rate. Where annual applications were not available, fertiliser application for a different year was used.

Livestock numbers were obtained from the Defra (previously MAFF), SEERAD (previously Scottish Office), the Welsh Assembly and DARDNI (previously DANI) Agricultural Census data for 1990, 1995, 1998 – 2006. Cattle weights have been updated for this inventory based on data supplied by Defra.

As in the national inventory, the area of cultivated histosols (soils of high organic content) was assumed to be equivalent to the area of Eutric Histosols. This was disaggregated according to a percentage split estimated by the Soil Survey and Land Research Centre (personal communication).

In general, the UK totals in the disaggregated inventory match well with those submitted in the national inventory. Any small differences are due to the derivation of disaggregated data that was not readily available. These small differences have been removed by normalising the regional inventories so 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 landuse and livestock data directly via 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 regional 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 contract reports to Defra (e.g. Thomson and van Oijen, 2007) and Annex 3 of the UK National GHG Inventory 1990-2005 (Baggott et al. 2007).

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 are combined into the totals for the Sector summary table.

There has been some revision of the data used for the 2005 Inventory, but the picture of net emissions/removals has not changed significantly from the previous Inventory. The small differences are due to revision of the data on conversion of Forestland to Settlement, which affected the land use transition matrix, and other minor data revisions and corrections.

1.10.1 5A Forest Land

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.

There are 822,000 ha (822 kha) of land that has been under forest land use since before 1922 (512 kha in England, 196 kha in Scotland, 112 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.

In 2005 around 67% of the area under forest land use in the UK had been planted since 1922 (402 kha in England, 1010 kha in Scotland, 161 kha in Wales and 80 kha in Northern Ireland). The activity data of annual forest planting (private and state) for the C-Flow model is 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 more or less variable decline in annual conifer planting rates 1990-2005 (E: 0.9-0.2 kha, S: 12.8-1.9 kha, W: 0.4-0.01 kha, NI: 1.3-0.04 kha). However, broadleaf planting has increased in England 1990-2005 (2.6 to 4.5 kha) but there is no clear trend in the other countries: planting in Scotland has varied between 2.5 and 7.8 kha, and Northern Ireland and Wales between 0.2 and 0.5 kha per year.

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 Forestland is estimated to be 25% but a full analysis of uncertainties is planned for future inventories.

1.10.2 5B Cropland

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

Cropland remaining Cropland

There are three activities that contribute to this sub-category. The first is the annual increase in the biomass of cropland vegetation as a result of yield improvements (resulting 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).

The second activity is the application of 'lime' (limestone, chalk and dolomite) to Cropland (and Grassland) which produces emissions of CO_2. The British Geological Survey report the amount of lime used for agricultural purposes in GB each year (BGS 2006): this amount is variable from year to year but generally reducing over time. The area that receives lime is calculated from the regional agricultural censuses and the Fertiliser Statistics Report (Agricultural Industries Confederation 2006). 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. Minor revisions in the agricultural census dataset resulted in some regional adjustments in the allocation of lime to Cropland or Grassland (> 0.01 Mt CO_2 for Cropland, >0.02 Mt CO_2 for Grassland).

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 Forestland are calculated by the C-Flow model, as described above.

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 – Forestland, 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 (2005). 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 are taking place this year (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 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 to vary the inputs for the core equation, and also gives 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. A full description of this method is available in the latest CEH inventory contract report (Thomson and van Oijen 2007).

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 UK Minerals Handbook (BGS 2006), while 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 Thomson and van Oijen 2007). 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 59.0 kha yr^{-1} have been converted to Grassland in England, 17.6 kha yr^{-1} in Scotland, 6.1 kha yr^{-1} in Wales and 5.9 kha yr^{-1} in Northern Ireland.

When Forestland 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 Forestland 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 11.0 kha yr^{-1} have been converted to Settlements in England, 2.5 kha yr^{-1} in Scotland, 2.0 kha yr^{-1} in Wales and 1.0 kha yr^{-1} in Northern Ireland.

The method used for estimating emissions from biomass burning from Forestland converted to Settlements (deforestation) is the same as that used for Forestland 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 2006). 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 1990-2003 (smoothed using a five-year moving average); estimates for Scotland and Wales are made by extrapolation from the English rates. Annual rates of deforestation to Settlements are variable but stable, with an average of 0.38 kha yr^{-1} for England, 0.12 kha yr^{-1} for Scotland and 0.03 kha yr^{-1} for Wales.

The activity data for deforestation to Settlements were completely revised this year (by the Ordnance Survey). 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 Forestland section) estimates changes in stocks of HWP produced from the management and harvesting of conifer and broadleaf forests planted since 1922.

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 the consultants Land Quality Management (LQM, 2003) in the provision of data for the 2001 –2003 inventories. The model was been modified again by Golder Associates (Golder, 2005) and emission estimates from that revision have been incorporated into the 2005 inventory.

The regional estimates have been calculated based on updated waste arisings data for the regions. Up until 1995, waste arisings data is assumed to be the same as in Brown *et al.*. (1999). After 1995, data are taken 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 has 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 and so the data has been scaled upwards, assuming England represents 83% of the UK's total. A 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 approach is based only on the national waste arisings data. There is no adjustment for different proportions of waste disposal to landfill in each region. It is also 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.

The LQM study provides regional estimates for Scotland and Northern Ireland but only a total aggregated figure for England and Wales. The aggregated emissions estimate provided by LQM has therefore been split between England and Wales assuming that the same ratio applies as for the 2000 estimates based on the Brown *et al.* (1999) model (94% England, 6% Wales). The Golder study did not provide a regional split and so it has been assumed that the same regional split for the devolved administrations used by LQM still applies.

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) and assume the split of sludge treatment 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 (2006a) 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 (DTI: 2006a).

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: 2006), and these data are used for the regional 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 regional figures. No chemical incinerators have been identified in Northern Ireland.

1.12 UNCERTAINTIES

1.12.1 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 regional 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 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 regional 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.

Given the difficulties inherent in estimating the uncertainties in the DA estimates, it is evident that such estimates are likely to be tentative and should be treated as indicative rather than a precise estimate of uncertainties.

1.12.2 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, with the aim of obtaining a factor of a similar scale to the uncertainty within the UK national inventory data.

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]

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

In the case of halocarbons and SF_6 emissions it is not considered feasible to attempt to assume varying uncertainties across the regions. Hence it is assumed that the uncertainty of each regional emission is the same as that of the UK. This is equivalent to assuming that the emissions are correlated or that the uncertainty in the regional activity data is very small. This is clearly not the case, but given that these emissions make a small contribution to the total GWP, this seems a reasonable working approximation.