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 2006, presents UK greenhouse gas emission estimates for the period 1990 to 2004 (Baggott *et al*, 2006).

This report presents separate inventories of greenhouse gas emissions for England, Scotland, Wales and Northern Ireland for the years 1990, 1995 and 1998 to 2004 that are consistent with the 1990 to 2004 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 off-shore oil and gas industry. Emissions from domestic and military aviation and shipping, which were previously unallocated, have now been allocated to the country from which the aircraft or shipping movements originated.

The UK Inventory also reports emissions from international marine and aviation bunkers separately, as required by the Intergovernmental Panel on Climate Change (IPCC). 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 2004 inventories, 108 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 1990-2004 DA GHGI datasets, the Netcen team have aimed to improve disaggregation methodologies and data sources for many GHG emission source sectors, including:

- Through consultation with Statistics Wales, Northern Ireland DETI Statistics & Economic Research and Scottish Executive Statistics, the Netcen team have accessed more "bottom-up" datasets for sectors such as: fishing & coastal shipping, agricultural employment, energy import and export data.

Note that there have also been some problems with access to regional datasets, including the late publication of the ONS annual Regional Trends (#39), which was not published until May 2006. This was not published in time for use in the compilation of the 2004 inventories, so the split was based on data for 2003. This will be revised for the 2005 inventories.

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
DAs	Devolved Administrations
DTI	Department of Trade and Industry
DEFRA	Department for Environment, Food and Rural Affairs
DETR	Department of Environment, Transport & the Regions (now DEFRA)
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)
GB	Great Britain
IPCC	Intergovernmental Panel on Climate Change
ISR	Inventory of Statutory Releases (refers to NI DoE's inventory of emissions from regulated industries)
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 2004. In some cases the derivation of the drivers differs between years depending on the availability of data.

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), Bell (2004), Innogy (2004), PowerTech (2004), AES Drax (2004). From 2000 onwards, emissions data reported in the Pollution Inventory (Environment Agency, 2005) and to SEPA and the Northern Ireland Department of Environment has been used rather than the fuel consumption data.

Emissions from plant generating electricity from municipal solid waste combustion are less certain for pre-1999, but all the plant are known to be in England for 1990-98 and so the emissions will correspond to the UK emissions. Since 1999, two plants have been commissioned in Scotland, at Lerwick and Dundee and emissions estimations are based on emissions data reported to SEPA.

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 was 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 – 2004 (UKPIA: 2005), 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). Scottish emissions are based on CO_2 emissions data from Grangemouth Refinery (BP: 2004).

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 2004)

IPCC Category	NAEI Sources	Activity: Fuel Consumption	Data Sources / Comments
Electricity Production	Power Stations	Coal, oil, natural gas	Consumption data from Power Generators, plus PI, EPER & ISR data from 2000 onwards
		Unrefined natural gas	Some power facilities have used this fuel since 1995. Data provided by plant operators. Some sour gas also now used in one plant England (was previously only used in Scottish power stations)
		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 1999-2003. BP Grangemouth data for Scottish emissions data.
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 / SCOPEC CO_2 estimates for terminals.
	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 (2005). 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, 2000-2005). 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 2004, 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 (EA: 2005).

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, 2000-2005) 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, 2002-2004). 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, 2000-2005). 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 (2005) 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. Moreover, the emissions from the secondary plant are considerably lower than the primary plant.

1.3.2 Other Industry

DTI (2000-2005, 1996 & 1991) reports regional consumption of liquid fuels, but only as totals for England and Wales (combined), Scotland and Northern Ireland. WO (1998) reports liquid fuel consumption up to 1993. The total consumption for Wales has been extrapolated from 1993 to provide the England-Wales split.

Burning oil is mainly consumed in the residential sector, but there is also a significant use by industry. Hence industrial consumption of burning oil was distributed according to the remaining consumption after domestic consumption had been deducted.

Fuel oil is consumed widely across industry, and the regional distribution of miscellaneous industry consumption is calculated by difference, when fuel oil use identified for specific uses is deducted from the DTI total. The consumption of fuel oil within specific uses is initially estimated through the calculation of other drivers, as discussed in other sections of this report.

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, WO (Remainder calculated after other uses)
		OPG	All such plant are located in Scotland, DTI
		LPG	Mass balance, DTI
		Lubricants	Regional sales, DTI
		Natural gas	Natural gas consumed, data from Transco
		Colliery Methane	Deep mined coal production, British Coal Authority
		Coal, coke	Coal consumption, WO, NIO
		Coke oven gas	Coal feed to coke ovens, ISSB, WO, WS
		SSF	NAEI spatial inventory
		Wood	SPRU database: non-traded fuel
	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	Employment in construction, ONS

1 See Section 1.1.3 for abbreviations

Table A1.3b Manufacturing Industry and Construction (1995; 1998 to 2004)

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, WO (Remainder calculated after other uses)
		OPG	All such plant are located in Scotland, DTI
		LPG	Mass balance, DTI
		Lubricants	Regional sales, DTI
		Natural gas	Natural gas consumed, data from Transco (now UK National Grid) & (since 1995) from Phoenix
		Colliery Methane	Deep mined coal production, British Coal Authority
		Coal, coke	Coal consumption, WO, NIO
		Coke oven gas	Coal feed to coke ovens, ISSB, WO, WS
		SSF	NAEI spatial inventory
		Wood	SPRU database: non-traded fuel
	Cement	Coal, oil, gas, petrocoke, tyres, waste oil	Regional cement capacity, BCA. For 2002-2004, the split is based on emissions reported to the EA 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	Employment in construction, ONS

DTI (2005) reports total fuel oil sales for England & Wales (combined), Scotland and Northern Ireland. However, these are not consistent with the totals used in the inventory because they include fishing and navigation but exclude refineries. Other industrial fuel oil consumption is derived by correcting these totals for shipping and refineries, and then subtracting the fuel used for all known sources.

The driver for **industrial gas oil consumption** is calculated in a similar manner to the fuel oil driver. DTI reports gas oil consumption on a similar basis to fuel oil, and the other industrial combustion is derived by calculation the difference between the corrected totals and the fuel used in all known sources.

Some gas oil and petrol is used for off-road machinery mainly in the construction industry. The UK estimates themselves are uncertain, and regional drivers are therefore based on regional GVA data (ONS: 2006).

Liquid Petroleum Gas (LPG) has a number of uses, which can be more precisely characterised in other sectors such as domestic use and the growing sector of LPG use in road transport applications. Hence, industrial use of LPG has been disaggregated based on a mass balance, using total regional sales (DTI: 2005) less consumption by all other sources.

The driver for emissions from lubricant use is based on regional lubricant sales (DTI: 1991, 1996, 2001-2005) with England and Wales being disaggregated based on regional manufacturing employment statistics (ONS: 2004).

UK National Grid (2005) supplies 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 (2005) 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".

Regional **coal** data is difficult to obtain, and hence estimates are very uncertain. Sectoral data is available for Northern Ireland (NIO, 2004) up to the present and Wales (WO, 1998) to 1993, but published data for coal use across industry in Scotland and England are not evident.

Industrial coal consumption for 1995 and 1998 to 2004 are estimated from sales data, gathered from all major coal producers. Using a mass balance approach, considering production, imports, stock-changes and imports, it is possible to estimate the amount of British coal not included in the sales data. This 'unknown' coal and anthracite is allocated to industrial consumption in proportion to the 'known' sales data. English and Welsh sales data are quite comprehensive but since 1995, Scottish data has been somewhat incomplete. Hence the allocation of consumption has been estimated for Scotland through extrapolation of the 1995 England-Scotland coal use figures.

To provide an estimated regional split for coal use in 1990, figures have been extrapolated back from data from the WO (1998) and NIO (1996) and the 1995 England-Scotland split.

Coal import data split by sector has recently been provided to Netcen by DOENI, and will be incorporated into the DA Inventories next year, in order to improve the accuracy of estimates in this sector.

Drivers for fuel consumption in **cement kilns** are based on annual regional clinker capacity data for 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. For 2002-2004, drivers have been derived from PI, SPRI and EPER data.

"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 have previously been reported as "unallocated." A decision has been made this year to allocate these emissions.

The driver for emissions from domestic aviation is calculated based on aircraft movement data from the UK's major airports (DLTR, 2005). The total number of domestic flights from each of the DAs has been calculated, and based on this, a fraction of the total UK emission has been allocated to each constituent country. This driver is also used to allocate emissions from aircraft support vehicles.

The disaggregation of emissions from navigation, fishing and coastal shipping has been derived in a similar way to the driver for aviation, based on port movement data in each constituent country (DfT, 2005).

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	Regional aircraft movements
Road Transportation	Road Transport	Petrol, Diesel oil	Road fuel sales, DTI; vehicle km, DETR / DLTR 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

[1] See Section 1.1.3 for abbreviations

Table A1.4b: Transport (1995; 1998 to 2004)[1]

IPCC Category	NAEI Sources	Activity: Fuel Consumption	Data Sources / Comments
Civil Aviation	NA	Aviation Gasoline, Jet Gasoline	Regional aircraft movements
Road Transportation	Road Transport	Petrol, Diesel oil, LPG	Road fuel sales, DTI; vehicle km, DETR / DLTR Emission factors: COPERT III (1990-2000), TRL (2001) Composition of fleet: Vehicle Licensing Statistics Report, DfT (GB) Dept of Regional Development (NI). Traffic data: National Traffic Census, DfT (GB: 1990-2005) Dept of Regional Development (NI: 1990-1999), Traffic Census Report (NI: 2000), Vehicle Kilometres of Travel Survey of Northern Ireland Annual Report (NI: 2001-2003), Traffic and Travel Information 2004 (NI: 2004) Fuel consumption: Digest of UK Energy Statistics (1990-2005), 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

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 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*., 2006). Methane emissions factors are unchanged and are same as those used in the last regional inventory compilation. The last inventory used slightly revised methane emission factors for Euro III and IV petrol cars and LGVs to take into consideration the requirement for new vehicles to meet certain hydrocarbon emission durability standards as well as limit values set in the Directive. In addition to this, the current inventory also incorporates slightly revised methane emission factors for motorcycles to take into consideration of introduction of new Euro Standard (EU 2003). Otherwise, the factors are taken from COPERT III (European Environment Agency, 2000).

The factors for N_2O are 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 2004 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 (2005a); 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 regional 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 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, 2005a). 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 1995-2004 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, 2005b). These estimates are based on traffic counts from the rotating census and core census surveys.

Vehicle kilometre data for 1990-2004 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 2004 are taken from the DfT Road Traffic Statistics Bulletin (DfT, 2005c).

Vehicle kilometre data in Northern Ireland for different road classes and vehicle categories were available from the Traffic and Travel Information 2004: Vehicle Kilometres of Travel Annual Report produced for the Department for Regional Development (DoRDNI, 2005b).

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.

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.

[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.

Therefore, in recent years Netcen 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.

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 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 are greater than those estimated using a fuel sales data. In 2004, the estimated CO_2 emissions from the unconstrained vehicle kilometre approach are 10% 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]

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	91601	9061	9026	5525	5511	3244	3221	109719	109360
1995	96151	92640	9469	9123	5759	5549	3648	3517	115027	110829
1998	102132	96774	10053	9529	6123	5801	3940	3740	122248	115845
1999	104478	97674	10027	9374	6227	5825	4158	3883	124890	116756
2000	104737	96765	10235	9452	6205	5734	4328	3987	125505	115938
2001	105729	96666	10288	9405	6248	5714	4437	4049	126703	115835
2002	106651	98326	10495	9676	6378	5878	4655	4294	128178	118174
2003	106982	97864	10614	9712	6425	5878	4813	4411	128833	117865
2004	108207	98464	10746	9780	6558	5968	5301	4829	130811	119042

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

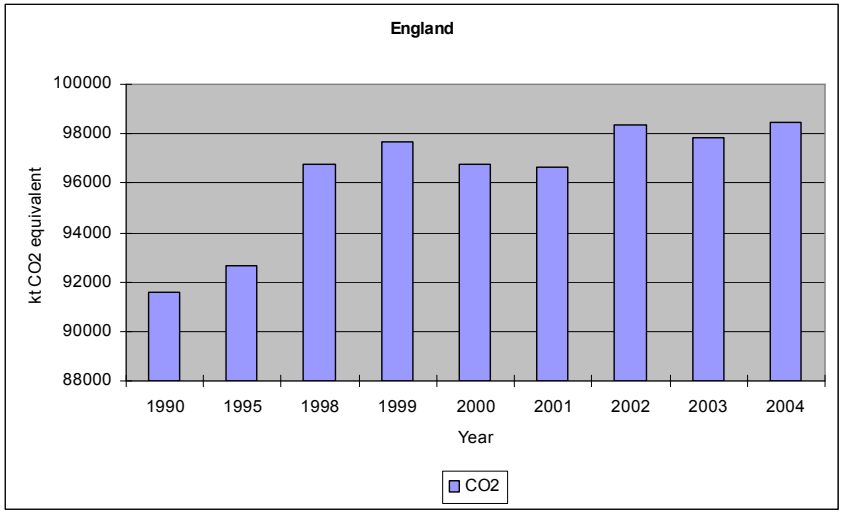
Table 1.4.4b below sets out the CO_2 and GHG emissions from 1990 to the latest inventory year from the two methods of estimating road transport emissions.

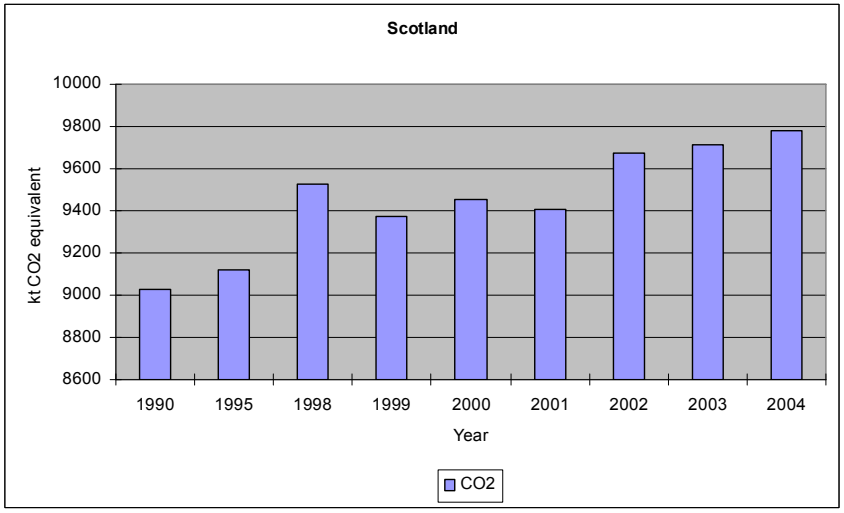
Table 1.4.4b Emissions of GHGs from UK road transport, according to fuel type consumed, and percentage changes from 1990 to the latest inventory year.(kt CO_2 equivalent)

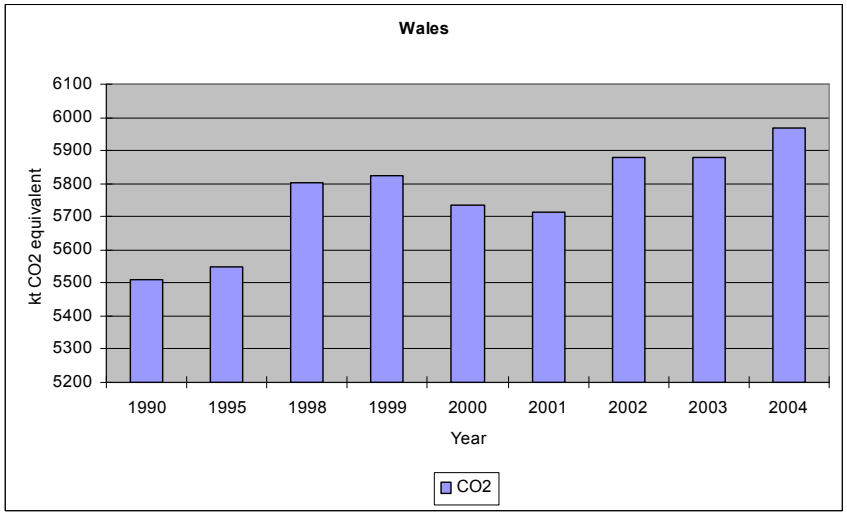
Calculation method	GHG	Fuel used	1990	2004	Percentage change
Constrained to fuel sales data **See text below**	Carbon	LPG	-	330.26	
		Petrol and DERV	109,359.71	119,041.85	
		Lubricants	262.77	218.56	
	CH_4	Petrol and DERV	613.31	185.24	
	N_2O	Petrol and DERV	1,023.60	5,033.11	
		Sum	111,259.39	124,809.03	12.2%
Unconstrained to fuel sales data (by using vkm) **See text below**	Carbon	LPG	-	330.26	
		Petrol and DERV	109,718.70	130,811.47	
		Lubricants	262.77	218.56	
	CH_4	Petrol and DERV	613.31	185.24	
	N_2O	Petrol and DERV	1,023.60	5,033.11	
		Sum	111,618.38	136,578.64	22.4%

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 1990-2004: Current Methodology







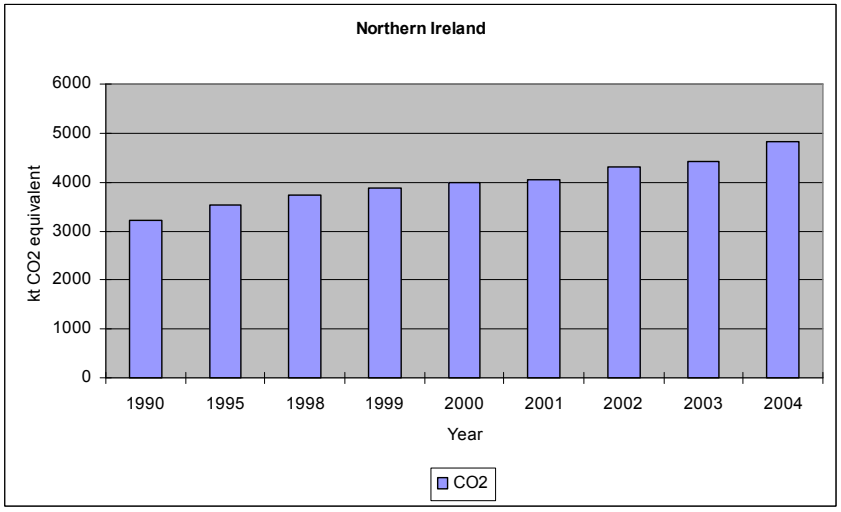


Figure A1.4.4.2 Road Transport CO_2 Emission Trends 1990-2004: Alternative Methodology

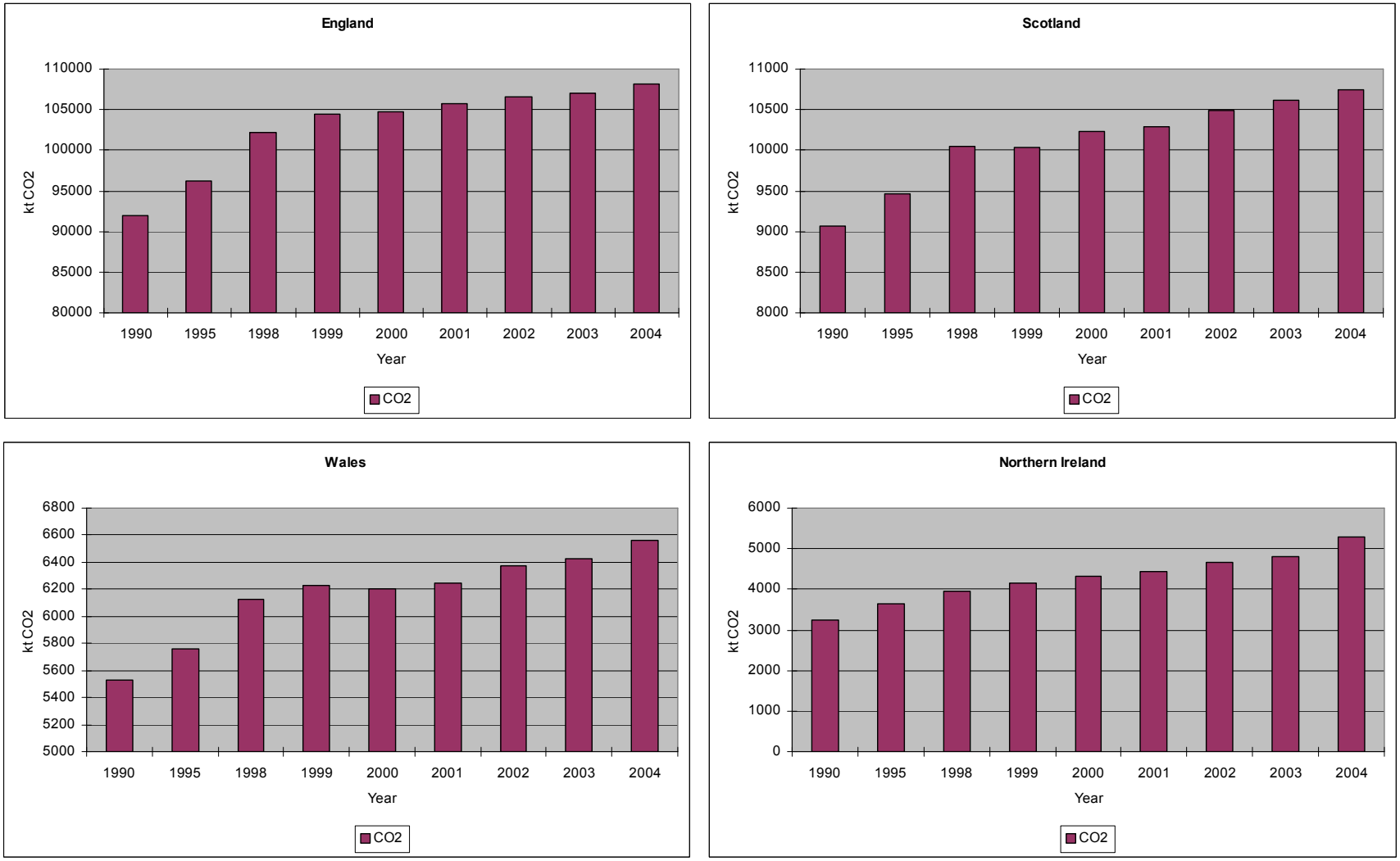
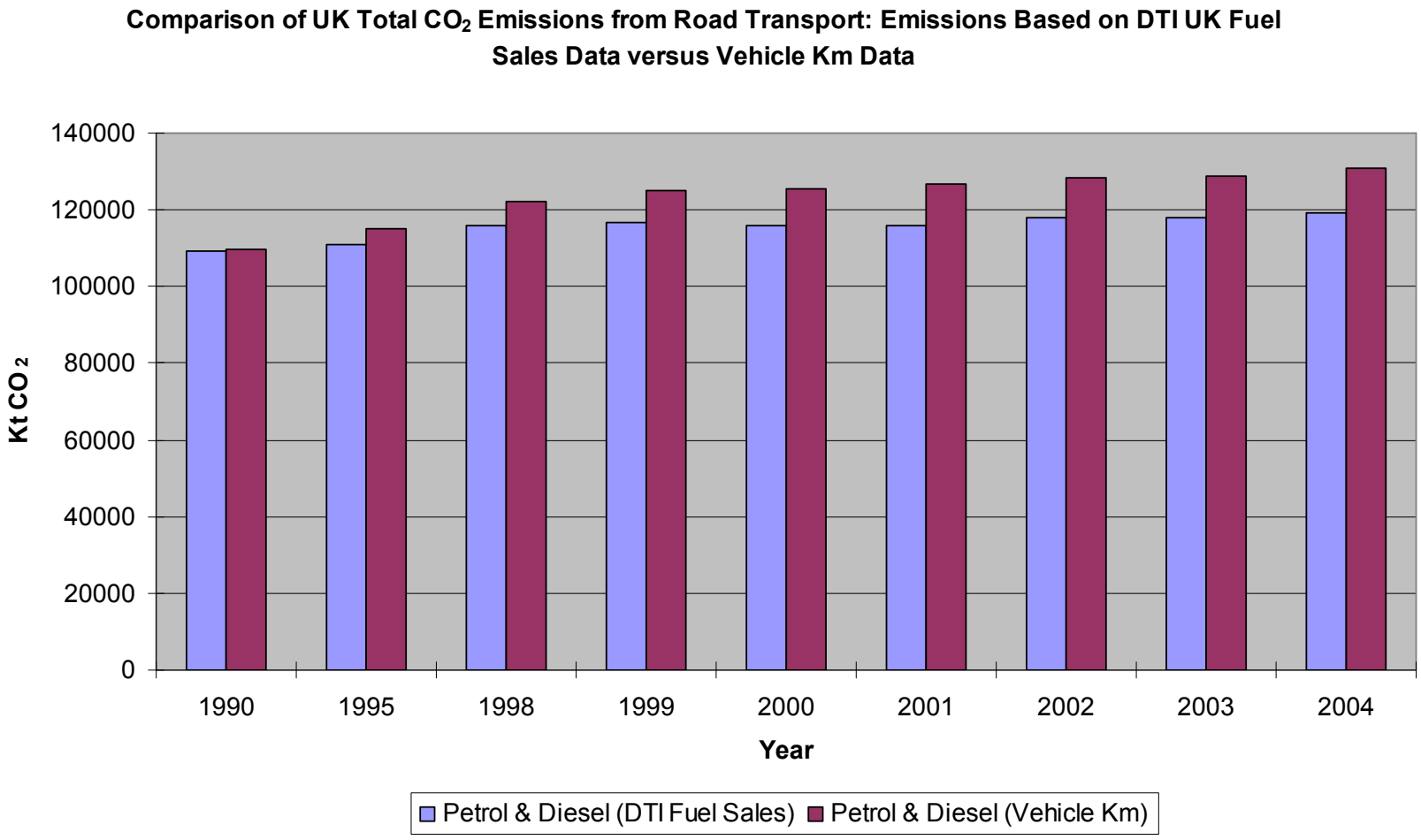


Figure A1.4.4.3 Road Transport CO_2 Emission Trends 1990-2004: UK Comparison between methods



1.4.4 Railways

Emissions from railway locomotives in Great Britain are disaggregated based on diesel oil consumption data supplied by ATOC (2005) for passenger services and NAEI estimates for freight services. The data used in the 2003 inventory was reported for each railway company, whose area of operation can in most cases be allocated to one of the four regions. This same split has been assumed in the 2004 inventory. Emissions from railways in Northern Ireland are based on fuel consumption data supplied by Translink (2005).

1.5 OTHER SECTORS

1.5.1 Commercial & Institutional

The NAEI categories "public administration" and "miscellaneous" are considered together for the DA inventories, as regional statistics are not available to this level of sectoral detail.

Miscellaneous coal use has been allocated based on regional GVA data (ONS, 2006). The regional split was previously reported based on the SPRU database, but this is now becoming outdated and has therefore been replaced by GVA, which is a better indication of economic activity in the regions.

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 consumption 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 (2001-2005). This data is used as a driver to distribute the NAEI miscellaneous and public service gas consumption in GB. Natural gas consumption 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.

Fuel oil and **gas oil** use in these sectors is distributed using regional employment statistics in non-industrial sectors from the ONS employment database (ONS: 2005).

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 (2005) 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	Regional GVA, ONS
		SSF	NAEI spatial inventory
		Natural gas	Commercial Sales, DTI.
		Landfill gas	Landfill methane emissions
		Sewage gas	Sewage methane recovered
		fuel oil, gas oil	Non-Industrial Employment, ONS
		MSW	As MSW incinerators
		Burning oil	As other industry
	Railways (Stationary)	fuel oil, burning oil, coal	Regional gas oil consumption
		Natural gas	Assumed as all England
Residential	Domestic	Coal, anthracite, wood	Coal consumption / sales data, NIO & WO
		SSF, coke	See text
		Natural gas	Domestic Gas, DTI
		Burning oil	Regional burning oil, DTI, WO. LRC data for NI.
		Gas oil, LPG	Regional population, ONS, LRC data for NI
		Fuel oil	Regional population, ONS
	House & Garden	DERV, petrol	Regional population, ONS
Agriculture, Forestry & Fishing	Agriculture	coal, coke, fuel oil, gas oil, natural gas	Agricultural employment, MAFF
		burning oil	Regional burning oil, DTI, WO
		straw	Wheat production, MAFF
	Agriculture Power Units	Gas oil, petrol	Agricultural employment, MAFF

1 See Section 1.1.3 for abbreviations

Table A1.5b Other Sectors (1995; 1998 to 2004)

IPCC Category	NAEI Sources	Activity: Fuel Consumption	Data Sources / Comments
Commercial & Institutional	Miscellaneous, Public service	Coal	Regional GVA, ONS
		SSF	NAEI spatial inventory
		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	Non-Industrial Employment, ONS
		MSW	As MSW incinerators
		Burning oil	As other industry
	Railways (Stationary)	fuel oil, burning oil, coal	Regional gas oil consumption, data from Network Rail (GB) and Translink (NI)
		Natural gas	Assumed as all England
Residential	Domestic	Coal, anthracite, wood	Coal consumption / sales data, NIO & WO
		SSF, coke	See text
		Natural gas	Customers < 73200 kWh, DTI & Transco (now UK National Grid) for GB, Phoenix for NI
		Burning oil	Regional burning oil, DTI, WO. LRC data for NI.
		Gas oil, LPG	Regional population, ONS, LRC data for NI
		Fuel oil	Regional population, ONS
	House & Garden	DERV, petrol	Regional population, ONS
Agriculture, Forestry & Fishing	Agriculture	coal, coke, fuel oil, gas oil, natural gas	Agricultural employment, MAFF / DEFRA
		burning oil	Regional burning oil, DTI, WO
		straw	Wheat production, MAFF / DEFRA
	Agriculture Power Units	Gas oil, petrol	Agricultural employment, MAFF / DEFRA

1.5.2 Residential

Domestic **coal** consumption is reported in NIO (2005) up to the present and in WO (1998) to 1993. These data also include anthracite and (for NI) other solid smokeless fuels. Published data for Scotland and England have not been identified, and hence estimates are uncertain. The methodology for estimating regional coal consumption has been extensively revised in order to simplify it and to obtain a more consistent time series.

Domestic coal consumption for 1995 and 1998 to 2004 is estimated from sales data, requested from all major coal producers. A mass balance (considering production, imports, stock-changes and imports) enables estimation of the amount of British coal that is not included in the sales data. The allocation of this "unknown" coal and anthracite between the regions is conducted such that England, Scotland and Wales are each allocated a percentage of the total "unknown" which is proportional to the "known" sales data in these regions.

Industry figures suggest that only small amounts of British Coal are shipped to NI. Any consumption in NI over and above the known amount of British coal shipments, are accounted as foreign imports of anthracite and steam coal. The remaining UK foreign anthracite imports are then allocated to England, Scotland and Wales in proportion to the "known" consumption. Any remaining UK foreign coal imports are assumed to be imported steam coal and allocated to England. Estimates for 1990 are based on WO (1998) and NIO (1996), together with DTI data. The England-Scotland split in 1990 is derived from the 1995 England-Scotland ratio.

The regional data available is not sufficiently detailed to report consumption of **manufactured solid smokeless fuels (SSF).** Hence a driver has been estimated based the NAEI disaggregated inventory database. This uses the distribution of smoke control areas and assumes a distribution for areas where there is no gas consumption (i.e. population density < cut off value) and allocates the UK SSF consumption to these areas. The NI data includes SSF imports under coal and anthracite and so a correction is applied to avoid double counting. The same driver is used for commercial and other industry use of SSF.

Domestic **natural gas** consumption data is available for 1990, 1995 and 1998-2004 (DTI: 1991, 1996, 1999-2006), with additional information from UK National Grid (2006) and Phoenix Gas for NI (2006).

Regional consumption of **liquid fuels** are reported by DTI (1991, 1999-2006) as totals for: England and Wales combined; Scotland and Northern Ireland. WO (1998) reported similar data on liquid fuel consumption up to 1993.

A large proportion of **burning oil** is consumed in the domestic sector and in the original inventory the regional totals were used as the domestic driver. However, this resulted in a very high estimate for domestic consumption in Northern Ireland in 1998. This could not be reconciled to the house conditions survey of the same year. An improved procedure has been adopted whereby Northern Ireland's domestic consumption is estimated from the house conditions survey, with the remaining burning oil consumption allocated to England, Wales and Scotland according to the DTI totals. Welsh consumption is extrapolated from 1993 data.

The consumption of **fuel oil** by the domestic sector is a very small amount, and is distributed simply according to population (ONS: 2005).

For domestic consumption of **gas oil**, once again the consumption pattern across Northern Ireland must be accounted for. Data from the House Conditions Survey used in the Greater Belfast Local Inventory (LRC: 1999) suggests that most domestic oil consumption is burning oil and hence domestic gas-oil consumption in the region is taken as zero. Domestic gas oil consumption for England, Scotland and Wales is then allocated by population (ONS: 2005).

The domestic consumption of **liquid petroleum gas (LPG)** in Northern Ireland is proportionately higher than in Great Britain due to the historical absence of mains gas supplies. The consumption for Northern Ireland is estimated using data on the consumption per household from the House Conditions Survey used in the Greater Belfast Local Inventory (LRC: 1999). Consumption for England, Scotland and Wales is once again allocated on the basis of population (ONS: 2005).

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 (2005).

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 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.

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 (2005) data for 1995, 1998-2004. 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 2000-2004 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: 2005b). 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 (2005) provides data for **fugitive** emissions of CO_2 and methane from terminals for 1998-2004. 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 specific leakage rates from the mains & services, and data on the stock of mains & services. The baseline estimate is for 1991, with figures for subsequent years based on the upgrading of the system.

Transco have developed a model, which produces regional leakage estimates from the low-pressure transmission system for 1998 to 2004. The 1998 regional split was applied to the estimates of the 'old' model to obtain estimates for 1990 and 1995. Whilst leakage from low-pressure mains and services accounts for most of the emission, there is also a contribution from high-pressure mains, storage and other losses. These additional emissions are allocated using the same regional split as the low-pressure leakage.

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
	Open cast coal	Open cast mine coal production.	Regional open cast mine production, British Coal Authority
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	Have used 1998 driver
	Onshore Loading	Oil loaded	Have used 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	Transco estimate for LP mains

1 See Section 1.1.3 for abbreviations

Table A1.7b Fugitive Emissions from Fuels (1995; 1998 to 2004)

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
	Open cast coal	Open cast mine coal production.	Regional open cast mine production, British Coal Authority
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	Transco (now UK National Grid) estimate for LP mains

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, 2005).

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: 2005) 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.

The 2006 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

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

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 Inventory (Environment Agency, 2005) 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 (decarbonizing)	Clinker production	Regional cement capacity, BCA
Lime Production	Lime (decarbonizing)	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
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 2004)

IPCC Category	NAEI Sources	Activity Data	Data Sources / Comments
Cement Production	Cement (decarbonizing)	Clinker production	Point source data from PI
Lime Production	Lime (decarbonizing)	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	Regional aluminium plant capacity, ALCAN
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 2004) (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, 2005).

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, 2005).

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 (2005). 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 and 2004 are based on PI and SPRI data.

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 (2004).

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 - 2004 (MAFF: 1991,1996, 1999, 2000; DEFRA: 2001 - 2004), SEERAD (Scottish Office: 1991, 1996, 1999, 2000; SEERAD 2000-2003) and DARDNI (DANI: 1991, 1996, 1998; DARDNI 1999, 2000-2003). 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 - 2004 (BSFP, 1991; 1996; 1999; 2000; 2001; 2002; 2004), 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 – 2004. 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 AND FORESTRY

Annex 3 of the UK National GHG Inventory for 1990 to 2004 describes the methods for estimating removals and emissions of carbon dioxide due to Land Use, Land Use Change and Forestry (LULUCF) (Baggott *et al.* 2006).

The estimates for Land Use Change and Forestry are from work carried out by the Centre for Ecology & Hydrology described in the scientific literature (Milne and Brown 1997, Milne et al. 1998, Cannell et al. 1999) and in Contract Reports to Defra (see Milne et al. 2006). The data are now reported under the IPCC 2003 Good Practice Guidelines categories: 5A (Forest Land), 5B (Cropland), 5C (Grassland), 5D (Wetland), 5E (Settlements), 5F (Other Land) and 5G (Other). This format for reporting can be seen as "land based": all land in the country is identified as having remained in one of the five land classes (not including 5G) since a previous survey, or as having changed to a different (identified) class in the period since the last survey. Net fluxes within Categories are used without identification of the constituent emissions and removals. The overall Sector 5 (LULUCF) emissions and removals are the same in both the older IPCC 1996 Guidelines' and the current IPCC 2003 Good Practice Guidance reporting structures. The relationship between the two formats for reporting is shown in the table below.

IPCC 1996 Guidelines Categories	IPCC 2003 GPG Categories
5A2 Temperate Forests	5A2 Land converted to Forest Land (Living biomass)
5A5 Other (Harvested Wood)	5G Harvested Wood Products
5B2 Temperate Forests	5C2 Land converted to Grassland (Deforestation)

IPCC 1996 Guidelines Categories	IPCC 2003 GPG Categories
5B2 Temperate Forests	5E2 Land converted to Settlements (Deforestation)
5D Cultivation of Mineral Soils (includes 5D organic soils)	5B2 Land converted to Cropland (Change in soils due to LUC)
5D Cultivation of Mineral Soils (includes 5D organic soils)	5C2 Land converted to Grassland (Change in soils due to LUC)
5D Cultivation of Mineral Soils (includes 5D organic soils)	5E2 Land converted to Settlements (Change in soils due to LUC)
5D Forest Soils	5A2 Land converted to Forest Land (Soils)
5D Liming of Agricultural Soils	5B1 Cropland remaining Cropland (Liming)
5D Liming of Agricultural Soils	5C1 Grassland remaining Grassland (Liming)
5D Lowland Drainage	5B1 Cropland remaining Cropland (Lowland drainage)
5E Other (Changes in Non-forest Biomass)	5B1 Cropland remaining Cropland (Yield improvements)
5E Other (Changes in Non-forest Biomass)	5B2 Land converted to Cropland
5E Other (Changes in Non-forest Biomass)	5C2 Land converted to Grassland
5E Other (Changes in Non-forest Biomass)	5E2 Land converted to Settlements
5E Other (Peat Extraction)	5C1 Grassland remaining Grassland (Peat extraction)

There has been some revision of the data and methods used for the 2004 Inventory, but the picture of net emissions/removals has not changed significantly from the previous Inventory. England is a slightly larger net source of CO_2 in 1990 (5,736 Gg rather than 5,659 Gg) and is still a net emitter between 1990 and 2004 (although on a downward trend). Scotland and Wales are slightly smaller net sinks in 1990 (-2,535 Gg rather than -3,049 Gg, and -241 Gg rather than -344 Gg, respectively). Scotland is still a net remover of CO_2 between 1990 and 2004, with removals increasing over time. Wales is also a net remover but does not have a strong trend over time. Northern Ireland has moved from being a small net source of CO_2 in 1990 (379 Gg) to a small net sink (-45Gg), and is a net remover between 1990 and 2004 (with removals increasing over time). This change is largely due to emissions from peat extraction for fuel use being moved from the LUCF sector to the Energy sector.

1.10.1 Summary of LUCF revisions

- Minor modification of planting and forest management (5A)
- Increases in non-forest biomass stocks due to yield improvements are now calculated separately from those due to land use change (5B)
- Changes in stocks of non-forest biomass due to land use change now uses same approach as changes in stocks of carbon in non-forest soils (5B, 5C, 5E)

- Peat extraction for fuel use has been removed from the Land Use Change and Forestry Sector and is now reported in the Energy Sector (5C)
- Emissions due to biomass burning after deforestation are now split between categories 5E and 5C.
- Scottish soil carbon bulk densities have been updated.

1.10.2 5A Forest Land

The estimates of emissions and removals due to afforestation were updated with planting statistics for 2004. The main revision was an adjustment in the forest planting calculations to take account of the impact of non-standard management practices in conifer forests, which were due to either deliberately shortened harvesting rotations or a response to forest disturbance. This revision affected small areas of forest in England and Wales (8.8 kha in England, 20.0 kha in Wales). In England this change results in reporting of -2,733 Gg CO_2 for 1990, compared to -2,632 Gg CO_2 in the previous inventory, and -3,333 Gg CO_2 in 2003 (-3,540 Gg CO_2 in 2004), compared to -3,241 Gg CO_2 reported for 2003 in the previous inventory. In Wales this change results in reporting of -1,179 Gg CO_2 for 1990, compared to -1,337 Gg CO_2 in the previous inventory, and -1,559 Gg CO_2 in 2003 (-1,584 Gg CO_2 in 2004), compared to -1,393 Gg CO_2 reported for 2003 in the previous inventory.

There was a minor revision of the modelling of the emissions due to soil disturbance. This is now estimated within the C-Flow model using a time-step of 0.1 years, rather than as a separate calculation with an annual time-step as used previously.

1.10.3 5B Cropland

There is an annual increase in the biomass of cropland vegetation in the UK that is due to yield improvements (from improved species strains or management, rather than fertilization or nitrogen deposition). There has been a complete revision of the activity data and methodology in this category. The increases in crop yield are now calculated separately from those resulting from land use change. Under category 5.B.1 an annual value is reported for changes in carbon stock, on the assumption that the annual average standing biomass of cereals has increased linearly with increase in yield between 1980 and 2000 (Sylvester-Bradley et al. 2002).

Changes in carbon stocks in non-forest biomass due to land use change are now based on the same area matrices used for estimating changes in carbon stocks in soils. Estimates are made using the Countryside Survey Land Use Change matrix approach, with biomass densities weighted by expert judgment based on the work of Milne and Brown (1997). Five basic land uses were assigned initial biomass carbon densities, then the relative occurrence of these land uses in the four countries of the UK were used to calculate mean biomass carbon

densities for each of the IPCC types, Cropland, Grassland and Settlements. Biomass carbon stock changes due to conversions to and from Forest Land are dealt with elsewhere. 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.

In calculating the changes in soil stocks due to land use change the Scottish soil carbon bulk densities have been updated, giving improved information on carbon content and the bulk density of organic rich soils.

1.10.4 5C Grassland

Peat is extracted in the UK for use as either a fuel or in horticulture. Only peat used in horticulture is now reported in this category. Peat used as a fuel is reported in the Energy Sector of the UK Inventory. In England this results in no change as >99% of peat extraction is for horticultural use. In Scotland this change results in reporting of 60 Gg CO_2 for 1990, compared to 78.8 Gg CO_2 in the previous inventory, and 151 Gg CO_2 in 2003 (69 Gg CO_2 in 2004), compared to 159 Gg CO_2 reported for 2003 in the previous inventory. In Northern Ireland no new data on use of peat for horticultural use is available, but a recent survey of extraction for fuel use suggested that there is no significant trend for this purpose. Emissions due to peat extraction in Northern Ireland are therefore assumed to be constant at 102 Gg CO_2 from 1990 to 2004, compared to a constant of 484 Gg CO_2 when peat extraction for fuel use is included. Peat extraction is negligible in Wales.

These are emissions of CO_2, CH_4 and N_2O resulting from the burning of forest biomass when Forest Land is converted to Grassland. In the 2003 Inventory deforestation was assumed only to be a conversion to Settlements. A revised interpretation of the available data allows the emissions to be disaggregated into deforestation to Grassland and Settlements. Deforestation to Cropland in the UK is negligible.

Methods for estimating changes in non-forest biomass and soils due to land use change have been updated in the manner described under 5B Croplands.

1.10.5 Wetlands (5D)

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 used in the Countryside Survey.

1.10.6 Settlements (5E)

Methods for estimating changes in non-forest biomass and soils due to land use change have been updated in the manner described under 5B Croplands. Emissions from biomass burning after the conversion of Forest Land to Settlement are now disaggregated into deforestation to Grassland and Settlements.

1.10.7 Other Land (5F)

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.

1.10.8 Other Activities (5G)

Changes in stocks of carbon in harvested wood products (HWP) are reported here. There has been no change to the methodology for calculating this category in the 2004 Inventory.

1.11 WASTE

1.11.1 Solid Waste Disposal on Land

***Note**: Since the compilation of the 1990-2004 DA inventories, the method for calculation of methane from landfill has been revised. Please see the second edition of the UK NIR (2006), provided on the CD accompanying this report. A comparison of emissions estimates for each of the DAs, calculated using the old and new methodologies is presented below.*

Table 1.11.1 Comparison of landfill methane emissions using the original, and revised, methodologies (kt CO_2 Equivalent)

Methodology	Revised	Original	Revised	Original	Revised	Original	Revised	Original	Revised	Original
Region	England	England	Scotland	Scotland	Wales	Wales	Northern Ireland	Northern Ireland	Total	Total
1990	43,743	33,595	2,764	2,122	2,589	1,987	614	472	49,710	38,175
1995	38,662	29,718	2,582	1,983	2,295	1,763	610	469	44,149	33,933
1998	31,854	24,685	2,215	1,715	1,880	1,456	546	423	36,494	28,278
1999	28,895	20,410	2,049	1,446	1,702	1,201	515	363	33,161	23,421
2000	26,898	19,499	1,956	1,417	1,598	1,158	503	364	30,955	22,438
2001	23,337	16,169	1,704	1,180	1,385	959	440	304	26,866	18,613
2002	21,253	14,800	1,510	1,051	1,266	881	407	283	24,437	17,015
2003	18,586	13,118	1,333	940	1,111	783	333	235	21,363	15,077
2004	17,222	12,165	1,217	860	1,051	742	332	234	19,823	14,001

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 has been modified again by Golder Associates (Golder, 2005) and incorporated into the 2004 inventory.

The main changes made by LQM are summarised as follows:

- New waste inventory data for 1995 (MSW) and 1999 (commercial and industrial waste) have been used to revise the estimates of UK waste arisings. Degradable organic carbon (DOC) parameters were revised, resulting in much higher values than those used previously, especially for paper.
- Instead of using the IPCC default of 10% for the oxidation of methane in the landfill cover, LQM have developed a model to estimate the residual methane oxidation factor based on field and laboratory observations of soil oxidation capacity and expert judgement. Oxidation factors are estimated to be much higher than the IPCC default – up to 90%.
- The estimates of capture of landfill gas for flaring or utilisation have been increased, based on a survey of installed flare capacity.

The main changes by Golder are summarised as follows:

- Revised MSW arisings from 2001 based on the Local Authority Waste Recycling and Disposal (LAWRRD) model (AEA Technology, 2005).
- C&I arisings have been modified for 2002 (assumed constant thereafter) based on Environment Agency data; years 1999, 2000 and 2001 are scaled values between 1998 and 2002,
- The oxidation factor discussed above has been reassessed, decreasing the amount of methane oxidised. The combination of the fissure fracture and oxidation efficiency parameters give a higher overall methane oxidation factor (25%) compared to the IPCC default of 10%.
- Methane emission predictions are extended to 2050.

The overall effect of the LQM (2003) changes is to predict more methane generation, but also more capture and much more oxidation of methane. The Golder (2005) model has altered methane generation slightly post 1996; the decreased oxidation and increased loss via fractures has increased methane emissions post 1980. The Golder model has increased emissions between 1990 and 1998 by in excess of

600 kt per year. The increase in emissions declines until 2004 onwards where it is in the region of 300 kt per year.

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 (2004a) 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: 2004, 1996, 1991).

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: 2004), 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 regional 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 regional 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 regional 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 Regional Uncertainty Estimation

The uncertainties in the regional 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 regional 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 far easier to form a view of 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.

Example: Sales data from the DTI is used to estimate burning oil consumption in Scotland and Northern Ireland. It is reasonable to assume that the uncertainty of this data is similar to that of the UK burning oil consumption figures.

For England & Wales, sales data is available only as a combined figure, and therefore the estimates for burning oil use in each of England and Wales are calculated using population as a surrogate factor to divide the available data.

This extra calculation step introduces greater uncertainty, and hence it has been estimated that the uncertainty for the Wales and England data are double that for Scotland and Northern Ireland.

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]

Thus, in the example above, it is necessary to check that the calculated uncertainty for England and Wales appeared reasonable and could be reconciled to the uncertainties for the other regions.

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.