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Greenhouse Gas Inventories, for England, Scotland, Wales and Northern Ireland

AG Salway, TP Murrells, A Cook

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National Environmental Technology Centre
Culham
Abingdon
Oxfordshire
OX14 3ED
Telephone 01235 463168
Facsimile 01235 463005

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	Name	Signature	Date
Author	AG Salway, TP Murrells, A Cook		
Reviewed by	JWL Goodwin		
Approved by	GD Hayman		

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1.1 INTRODUCTION

The UK Greenhouse Gas Inventory compiles estimates of greenhouse gas emissions for submission to UN Framework Convention on Climate Change. The most recent version, reports emissions from 1990 to 1998 (Salway, 2000). This report presents separate inventories of greenhouse gas emissions for England, Scotland, Wales and Northern Ireland for the years 1990, 1995 and 1998 that are consistent with the 1998 UK 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. It was not considered possible to allocate emissions from certain sources to any one region of the UK. These were:

- Domestic Aviation
- Domestic Navigation
- Emissions from the offshore oil and gas industry
- Military Aviation
- Naval

Hence these emissions were calculated but were reported as unallocated. The UK Inventory also reports emissions from marine and aviation bunkers separately for information as required by the Intergovernmental Panel on Climate Change (IPCC). Again these were not allocated to any region but are not included in the unallocated total.

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 necessary to obtain a complete set of equivalent statistics for each region to compile each inventory. In practice, such a set of statistics was not available for all sources and for all regions and it was necessary to disaggregate the UK emission into the four regions 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

$$E = Ae$$

where

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

The activity could be fuel combustion (tonnes), or production of product (tonnes) or numbers of animals. A modified equation was used for the regional inventories:

$$E_i = \frac{d_i Ae}{\sum_{j=1}^{5} d_j}$$

where

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

The driver, d_i can be any one of:

1. The value of the activity data for that region. Examples are actual consumption of specific fuels in the region or industrial production of a product.
2. The fraction of the UK activity in that region.
3. The value of a surrogate activity data in that region. Where the required activity was unavailable on a regional basis, a surrogate value was used. Examples are employment statistics or production of a particular product used instead of fuel consumption data.
4. In cases where the emissions are derived from a complex model, the driver would be the actual emission for the region calculated from the model.

The equation ensures that the sum of the emissions from the regions and unallocated emissions equals the UK fuel emission. 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 data is taken from different sources or may be based on the financial rather than the calendar year. The estimation procedure removes these discrepancies.

Thus the compilation of the regional inventories reduces to the estimation of a set of drivers, each appropriate to a source.

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-A1.8. The IPCC classification is used throughout (IPCC, 1997)

Table A1.1 Energy Industries[1]

IPCC Category	NAEI Sources	Activity: Fuel Consumption	1990	1995/1998
Electricity Production	Power Stations	Coal, oil, , natural gas	Consumption data from Power Generators	Consumption data from Power Generators
		Unrefined natural gas	NO	All plant in S
		Sewage gas	Sewage methane recovered	Sewage methane recovered
		Landfill gas	As landfill methane	As landfill methane
		Orimulsion, MSW, poultry litter and tyres	All plant in E	All plant in E
Petroleum Refining	Refineries	All fuels	UKPIA CO_2 emission estimates for 1997	PI CO_2 emission estimates for 1998
Manufacture of Solid Fuels	Coke Production	Colliery Methane	Assumed E	Assumed E
		Coke Oven gas, natural gas	Coal feed to coke ovens, ISSB, WS, DTI	Coal feed to coke ovens, ISSB, WS, DTI, PI
		Coke	Coke breeze consumption ISSB	Coke breeze consumption ISSB
		Blast Furnace gas	Coke Consumed in blast Furnaces, ISSB, WS	Coke Consumed in blast Furnaces, ISSB, WS
	SSF Production	All fuels	Coal feed to SSF plant, DTI, WS	Coal feed to SSF plant, DTI, WS
Other Energy Industries	Collieries	All other fuels	Deep mined coal prod., CA	Deep mined coal prod., CA
		Coke oven gas	Assumed E	NO
	Gas Production	Colliery methane	Deep mined coal prod., CA	Deep mined coal prod., CA
		Other fuels	Arrivals of natural gas, DTI	Arrivals of natural gas, DTI
	Offshore Own Gas Use	Unrefined natural gas	Extrapolate from 95 on oil and gas arrivals, DTI	UKOOA CO_2 estimates for terminals
	Nuclear Fuel Prod.	natural gas	All plant in E	Data not available

1 See Table A1.9 for abbreviations

1.2 ENERGY INDUSTRIES

The drivers used for the energy industries are summarised in Table A1.1. 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 regional inventory for 1990 and 1995/1998. 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. (Scottish Power (1999), Scottish and Southern Energy (2000), Bell (1999), National Power (1999), PowerGen (1999), Eastern Generation (1999)).

Emissions from solid waste combustion are less certain but all the plant are known to be in England and so the emissions will correspond to the UK emissions. 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).

1.2.2 Petroleum Refining

UKPIA were able to provide a site by site breakdown of UK refining emissions for 1997 (UKPIA, 1998). They advised us that refinery throughput would not have varied since 1990. The CO_2 emissions data were used as a surrogate for all fuel consumption. A correction was applied to take account of the Gulf Oil Refinery, which closed in 1996, based on refinery distillation capacity reported by DTI (1996, 1991). Emissions for 1998 were based on CO_2 emissions reported in the Pollution Inventory (Environment Agency, 1999a). Scottish emissions were based on CO_2 emissions from Grangemouth Refinery (BP, 2000).

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 (1999, 1996, 1991). Recent issues of UK Iron and Steel Statistics are less detailed than earlier ones, though the additional detail is available on request. Two coke ovens in England and Wales are not attached to an integrated iron and steel facility. The consumption of coal by these plant was estimated from WO (1998) and UK data (DTI, 1991,1999). The Welsh statistics are only available to 1993, so this data was used as an estimate of the Welsh non-iron and steel coal consumption in 1995. For 1998, the non-iron and steel coal consumption data was apportioned between England and Wales using CO_2 emissions for the particular sites reported in the Pollution Inventory (Environment Agency, 1999a). Thus the generic driver for coke oven fuel consumption was the consumption of coking coal which is in effect

the regional capacity of coke ovens. This driver was also used for natural gas consumption and coke oven gas consumption. Some coke ovens use blast furnace gas as fuel and the availability will depend on blast furnace gas capacity (see Industrial Processes). Tiny amounts of colliery methane are used and this was judged to occur in England where coking occurs near deep mining. Small amounts of coke breeze are used and this was disaggregated using data on other coke consumption in ISSB (1999, 1996, 1991).

The estimation of emissions from SSF production is rather uncertain, since there are a number of processes operating and the available fuel data are not detailed. Moreover, many of these are the new briquetting processes rather than coking processes and produce negligible emissions. SSF plant were operating in England and Wales over the period hence it was possible to estimate regional consumption using UK data: (DTI; 1991,1999) and Welsh data (WO, 1998). Again it was necessary to estimate the Welsh data for 1995. By 1998 all SSF coking plant still operating were in England. Thus the driver used was coal consumed by SSF plant. This was applied to all fuel consumption.

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 regional inventory only the emissions from oil and gas terminals were reported based on data provided by UKOOA (1999). Data is only available for 1995 and 1998 and so emissions for 1990 were extrapolated based on the arrivals of crude oil and natural gas in Scotland and England, (DTI, 1991,1996).

A similar approach was adopted for gas production, which is mainly fuel consumption, by gas separation plant. The driver was based on the arrivals of natural gas in England and Scotland (DTI, 1991, 1996, 1999).

Other sources are minor and are covered in Table A1.1

1.3 MANUFACTURING INDUSTRIES AND CONSTRUCTION

The drivers used for manufacturing and construction are summarised in Table A1.2.

1.3.1 Iron and Steel

ISSB (1991, 1996, 1999) reports detailed regional consumption of fuel by the steel industry. Recent issues of UK Iron and Steel Statistics are less detailed than earlier ones, though the additional detail is available on request. The consumption of coke by sinter plant can be estimated as the non-blast furnace coke consumption as this is the main other use of coke. The consumption of coke oven gas was distributed as the coal feed to coke ovens and the consumption of blast furnace gas as the coke

feed to blast furnaces. The production of these gases should be proportional to the fuel used as feedstock. 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, so that the DTI data used in the UK GHGI is higher than the ISSB data. Nevertheless, the regional ISSB data was used as a surrogate, since it is likely that the distribution of the wider steel industry will be similar to the primary industry. Moreover, the emissions from these secondary plant are considerably lower than the primary plant, which are accurately estimated.

1.3.2 Other Industry

DTI (1999, 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 was extrapolated from 1993.

Burning oil is mainly consumed in the residential sector, but there is a significant use by industry. Hence industrial consumption of burning oil was distributed according to remaining consumption after domestic consumption had been deducted. This is a change in methodology, since the previous methodology gave anomalously high estimates for Northern Ireland when applied to 1998 data.

Fuel oil has a significant use in industry. Here, consumption was distributed as the oil remaining after all other uses were deducted from the total. Drivers were calculated for England, Scotland, Wales and Northern Ireland. This driver was used for other industry and commercial sectors.

The driver for gas oil was calculated differently. Here, consumption was distributed according to the Science Policy Research Unit (SPRU) database. This is a database of around 6000 small boilers (<50 MW) based on insurance records collected in the period 1992-94. The database records a grid reference, economic sector, nominal fuel consumption and fuel type. Drivers were calculated for England, Scotland, Wales and Northern Ireland.

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 were based on male employment in the construction industry (ONS, 1996, 2000).

Liquid Petroleum Gas (LPG) has a number of uses, which are more precisely characterised in other sources such as domestic use. Hence the industrial use of LPG was based on a mass balance based on total regional consumption (calculated in a similar manner as fuel oil) less consumption by all other sources.

DTI (1999) estimate that 40% of lubricants sold are eventually used as a fuel. Hence, the driver was based on regional lubricant sales (DTI, 1991, 1996, 1999)

with England and Wales being disaggregated based on regional manufacturing employment statistics (ONS, 2000).

Transco (2000) supplied data on sales of natural gas to consumers categorised by consumer size and region. This, however excluded consumption by large industrials and power generators which were not regionally allocated. The approach adopted was to match the regional Transco totals with the NAEI totals and to apply the appropriate drivers for domestic and commercial. The consumption for other industry and autogenerators was then estimated by deducting all the other known sources from the totals. The same driver was used for autogenerators as for other industry.

Regional coal data is fairly sparse: sectoral data is available for Northern Ireland, NIO, (1999) up to the present and Wales (WO, 1998) to 1993. Published data for Scotland and England are entirely absent. Industrial coal consumption for 1995 and 1998 was estimated from sales data, gathered from major coal producers. A mass balance was performed on production, imports, stock-changes and imports. Coal was allocated to sources where consumption was known or estimated using other drivers (power generation, iron & steel, cement kilns) and imports allocated to the most likely consumers (power generation, coking, domestic anthracite). English and Welsh sales data were fairly complete but Scottish data were incomplete and it was necessary to extrapolate Scottish industrial coal consumption using the SPRU data for other industry. Stock changes are significant and were disaggregated on regional production (Coal Authority, 2000). The estimates obtained are likely to be fairly approximate. Estimates for 1990 are based on WO (1998) and NIO (1996). Corrections were applied for the consumption by other industrial sectors (iron and steel, cement etc). The remaining consumption was allocated to England and Scotland on the basis of the 1995 England/Scotland split. The data collected for 1998 was not sufficiently complete to allow a balance to be made. Hence the 1995 driver was used for 1998 with a correction for Northern Ireland

Drivers for fuel consumption in cement kilns were based on regional capacity data for 1995 and 1998 supplied by British Cement Association (1999). These were applied to all fuels though a correction was applied to Northern Ireland to account for the absence of natural gas. Lime production occurs only in England and was assumed to be coal fired.

Autogeneration refers to electricity generation by industry for its own use. In the case of coal the consumers were identified as Alcan and Brunner Mond, both of which are in England. Gas autogeneration was not a large source and was distributed according to the other industry: natural gas driver discussed above.

Table A1.2 Manufacturing Industry and Construction[1]

IPCC Category	NAEI Sources	Activity: Fuel Consumption	1990	1995/98
Iron and Steel	Sinter Plant	Coke-breeze	Other coke consumption, ISSB	Other coke consumption, ISSB
	Iron & Steel	Blast furnace gas	Coke Consumed in blast furnaces, ISSB, WO	Coke Consumed in blast furnaces, ISSB, WO
		Coke oven gas	Coal feed to coke ovens, ISSB, WS	Coal feed to coke ovens, ISSB, WS
		Coke	Coke consumed in blast Furnaces, ISSB, WO[1]	Coke consumed in blast Furnaces, ISSB, WO
		Fuel oil, gas oil, LPG, natural gas, coal	Consumption of specified fuel, ISSB	Consumption of specified fuel, ISSB
Other Industry	Other Industry	Burning oil, fuel oil	Regional oil consumption, DTI, WO Remainder after other uses	Regional oil consumption, DTI, WO Remainder after other uses
		Gas oil	SPRU database: Other Industry; oil	SPRU database: Other Industry; oil
		OPG	All Scotland, DTI	All Scotland, DTI
		LPG	Mass balance, DTI	Mass balance, DTI
		Lubricants	Regional sales, DTI	Regional sales, DTI
		Natural gas	Natural gas consumed, Transco	Natural gas consumed, Transco
		Colliery Methane	Deep mined coal prod., CA	Deep mined coal prod., CA
		Coal, coke	Coal consumption, WO, NIO	Coal sales estimates, NIO
		Coke oven gas	Coal feed to coke ovens, ISSB, WO	Coal feed to coke ovens, ISSB, WS
		SSF	NAEI spatial inventory	NAEI spatial inventory
		Wood	SPRU database: non-traded fuel	SPRU database: non-traded fuel
	Cement & Lime	Coal, oil, gas, petrocoke, tyres, waste oil	Regional Cement & Lime capacity	Regional Cement & Lime capacity
	Ammonia (combustion)	Natural Gas	All plant in England	All plant in England
	Autogenerators	Coal	All plant in England	All plant in England
		Natural gas	As Other Industry	As Other Industry
	Other-Industry: Off-road	Gas oil, petrol	Male employment in construction, ONS	Male employment in construction, ONS

1 See Table A1.9 for abbreviations

1.4 TRANSPORT

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

1.4.1 Aviation and Navigation

All domestic aviation and navigation emissions are reported as unallocated. The UK fuel statistics for coastal shipping contain oil consumption by the offshore industry which includes on-shore terminals. However, in the regional inventories, terminal emissions are reported under 1B2 Oil and Gas Fugitives. Terminal emissions data were supplied by UKOOA (1999), for 1998 and 1995, and estimates for 1990 were extrapolated from 1995 based on landings of natural gas and crude oil in England and Scotland. Emissions from aircraft support equipment were distributed according to aircraft movement data at the major UK airports (DETR, 1999).

1.4.2 Road Transportation

Carbon dioxide, methane and nitrous oxide are emitted from the exhaust of all road vehicles with internal combustion engines running on petrol and diesel fuels. 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 in 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 limit values, in contrast to 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.

Total emissions from road transport in a country or region are normally 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 the different exhaust emission regulations which have been in effect and successively tightened up over the past 25 years. One of the defining factors for the 1995/98 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.

- National or regional fuel consumption statistics. This provides a particularly good indicator of carbon dioxide emissions.

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 II (1997) program and database, recommended for CORINAIR and form the basis of the IPCC Guidelines.

Emission factors

The emission and fuel consumption factors used for the regional inventories are reported in Salway (2000). These are broken down by the vehicle type and emission standard with which the vehicle was compliant when manufactured and first registered. The approximate dates of introduction of the emission standards in the UK are shown. The data are based on various European programmes of measurements of exhaust emissions from in-service vehicles made over defined drive cycles, usually on rolling roads or engine test beds. In the case of fuel consumption factors, speed-emission functions were used to calculate emission factors at average speeds on urban, rural single carriageway, rural dual carriageway and motorway roads in the regions. The speed-dependency of emission factors of methane and nitrous oxide are not known, so the same values were used for all the road types.

Age and composition of the fleet

Information on the age and composition of the vehicle fleet in the regions in 1990, 1995 and 1998 was 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 DETR (1999b); this is based on the DVLA files of vehicles licensed in Great Britain at the end of each year.

Additional information was obtained directly from DETR which showed the post-town where the vehicles were registered and the year of first registration of vehicles currently licensed in 1998 (DETR, 1999a). 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 Bureau of the Department of Environment for Northern Ireland which showed a newer fleet than in Great Britain (Department of the Environment, Northern Ireland, 1999a). It is felt that most of the vehicles on the road in Northern Ireland will be those licensed in Northern Ireland and *vice versa*, meaning that a newer fleet should reflect a higher proportion of cars fitted with three-way catalysts on the road in 1995 and 1998 than in England, Scotland and Wales. This trend may be further reflected by the fact that fuel delivery statistics for 1995 suggest a slightly higher proportion of petrol was sold as unleaded in Northern Ireland (65.2%, [Department of the Environment, Northern Ireland, (1999b)]) compared with in Great Britain (63.0%, [DTI (1999)]). This would be expected if a higher proportion of cars were fitted with catalysts which require them to be run on unleaded petrol.

Neither the vehicle licensing statistics nor traffic flow data for Northern Ireland were able to separate private cars from light goods vehicles or vans (LGVs) (Department of the Environment for Northern Ireland, 1997). However, the proportion of diesel vehicles in the PLG class in Northern Ireland was 23.3% in 1995 (Department of the Environment, Northern Ireland, 1999b) compared with 13.6% in Great Britain (DETR, 1999). This was interpreted as indicating that a higher proportion of PLG vehicles in Northern Ireland were LGVs than in Great Britain. In the absence of any additional information, it was assumed that the proportions of diesels in the private car fleet and in the LGV fleet were the same in Northern Ireland as in Great Britain (8.9% and 57.1%, respectively, for 1995 (DETR, 1999)). This leads to the conclusion that 29.9% of the PLG fleet and, it is assumed, the PLG vehicle kilometres in Northern Ireland were as LGVs.

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 DETR 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 (DETR, 1999a). These estimates are based on traffic counts from the rotating census and core census surveys (DETR, 1999).

Whilst vehicle kilometre data for 1990, 1995 and 1998 were available from DETR separated into the road networks in England, Scotland and Wales, combining this information with the fleet data and vehicle fuel consumption factors leads to an anomalously high growth in petrol and diesel consumption in Scotland between 1990 and 1995 when compared with the trends calculated for England and Wales. It is also a trend which is not borne out by actual fuel delivery statistics for Scotland. For example, calculations based on traffic flow suggest a 12% growth in petrol consumption in Scotland between 1990 and 1995 (52% growth in diesel consumption) compared with an 11% *decrease* in petrol consumption in England and Wales (23% growth in diesel consumption) over the same period. Actual fuel delivery statistics from DTI (1999) suggest a similar trend over this period for England, Scotland and Wales: a 9% decrease in petrol consumption and a 24-27% increase in diesel consumption.

Closer inspection of this inconsistency between fuel delivery and vehicle kilometre data for the regions suggested that the problem lay in the vehicle kilometre figures for minor roads in the regions. These make a significant contribution to the total traffic flow on the road networks. It is believed by DETR that anomalous trends in the minor road traffic data for Scotland is probably due to a sampling artefact of the traffic census and this leads to high levels of uncertainty in the minor road data for the smaller regions.

Fuel consumption in the regions

Because of the high level of uncertainty in the minor traffic flow data for the regions, it was felt that inland fuel deliveries of petrol and diesel in the regions were better indicators of traffic activity.

Fuel delivery data for 1990, 1995 and 1998 are available for England & Wales, Scotland and Northern Ireland from DTI (1993, 1998, 1999). Separate fuel delivery data for Wales was available from the Welsh Office for 1990, but not for 1995 (WO, 1998). Therefore, the split in petrol and diesel consumed between England and Wales in 1990 was assumed to apply to the DUKES England & Wales total for 1995 and 1998. This was felt a reasonable assumption to make on the basis that the model predictions of the relative proportions of fuel consumed in England and Wales based on traffic data in 1990 were very similar to the actual figures based on fuel deliveries in these regions and the model predictions were that the England/Wales split for 1995 would be very similar to 1990.

The fuel data showed reductions in diesel consumption (-11%) and a larger reduction in petrol consumption (-36%) from 1990 to 1998 in Northern Ireland compared to increases in diesel consumption (+44%) and reductions in petrol use (-9.5 %) in England, Scotland and Wales.

Method for calculating emissions of CO_2, CH_4 and N_2O from road transport in the regions

The sum of the petrol and diesel fuel deliveries in England, Scotland, Wales and Northern Ireland each year were normalised against the total amounts of these fuels consumed by road transport in the UK, as estimated by the NAEI, to derive the amounts consumed by road transport in each of the regions. This then takes account of the very small amount of these fuels consumed by off-road vehicles and machinery.

The normalised fuel consumption data for England, Scotland, Wales and Northern Ireland leads directly to the CO_2 emissions for road transport in the regions. Although there will be movement of traffic across borders between regions, so that some emissions at source will be in a region adjacent to that where the fuel was actually purchased, this procedure adopted is consistent with IPCC guidelines on reporting Greenhouse emissions which states that emissions are to be attributed to the country in which the fuel is loaded into the vehicle.

To calculate CH_4 and N_2O emissions from road transport using fuel consumption in the regions as an activity factor for traffic, it was necessary to:

a) Partition the fuel consumed in each region by each main vehicle type (petrol car, diesel car, petrol LGV, diesel LGV, rigid and articulated HGV, buses and motorcycles), and
b) Derive fleet-averaged, fuel based emission factors for each main vehicle type and pollutant

The amount of petrol and diesel fuel consumed in each of the regions was partitioned between each of the main vehicle types according to the fuel efficiency factors of all the vehicle sub-categories shown in Table A1.3 (in g fuel/km) and the relative distances they travelled each year on each road type in the region.

Fuel-based emission factors in units of g pollutant/kg fuel consumed were calculated from the vehicle kilometre-based emission factors (Salway, 2000) and fuel consumption factors of Table A1.3 and an average value derived for each main vehicle type, weighted according the proportion of mileage travelled by each emission standard on each type of road.

Emissions from each main vehicle type in the region were then calculated by multiplying the fuel-based emission factors with the amount of fuel consumed by the vehicle type in the region.

Following this procedure ensured that the emissions for each region were consistent with the amount of fuel consumed there and also took account of the regional differences in the fleet composition and traffic mix in terms of the age of the fleet (i.e. the newer fleet in Northern Ireland compared with Great Britain) and the relative distances travelled on each road type.

1.4.3 Railways

Emissions from railway locomotives were disaggregated based on diesel oil consumption data for 1997 supplied by Railtrack (1999) and NIR (2000). Data for earlier years was not available. The data is reported on the basis of railway companies whose area of operation could in most cases be allocated to one of the four regions. Some companies operations were spread across regions and it was necessary to allocate fuel consumption based on their advice.

Table A1.3 Fuel Consumption Factors for Road Transport (in g fuel/km)

	Emission standard	Urban	Rural single c/way	Rural dual c/way	Motorway
Petrol cars	Pre- ECE	79.5	61.7	62.2	77.1
	ECE 15.00	68.3	50.8	49.4	62.8
	ECE 15.01	68.3	50.8	49.4	62.8
	ECE 15.02	63.0	49.7	50.0	64.9
	ECE 15.03	63.0	49.7	50.0	64.9
	ECE 15.04	55.9	44.4	47.0	58.2
	Stage I (91/441/EEC)	62.9	48.9	47.4	74.9
	Stage II	62.9	48.9	47.4	74.9
Diesel cars	Pre-Stage I	61.6	45.7	41.4	64.0
	Stage I	46.7	35.0	29.2	37.2
	Stage II	46.7	35.0	29.2	37.2
Petrol LGV	Pre-Stage 1	83.9	64.4	60.7	93.9
	Stage I	83.9	64.4	60.7	93.9
	Stage II	83.9	64.4	60.7	93.9
Diesel LGV	Pre-Stage 1	74.1	65.7	80.2	149
	Stage I	94.1	78.6	76.2	104
	Stage II	94.1	78.6	76.2	104
HGV rigid	Old	251	171	157	164
	Pre-Stage I	251	171	157	164
	Stage I	251	171	157	164
	Stage II	251	171	157	164
HGV artic	Old	502	371	345	297
	Pre-Stage I	502	371	345	297
	Stage I	502	371	345	297
	Stage II	502	371	345	297
Buses	Old	376	262	240	198
	Pre-Stage I	376	262	240	198
	Stage I	376	262	240	198
	Stage II	376	262	240	198
Motorcycles	< 50 cc	18	18	18	18
	> 50 cc, 2st	30	30	30	30
	> 50 cc, 4st	38	38	38	38

Table A1.4 Transport[1]

IPCC Category	NAEI Sources	Activity: Fuel Consumption	1990	1995/1998
Civil Aviation	NA	Aviation Gasoline, Jet Gasoline	Unallocated	Unallocated
Road Transportation	Road Transport	Petrol, diesel oil	Road fuel sales, DTI, vehicle km, DETR	Road fuel sales, DTI, vehicle km, DETR
Railways	Railways	Gas oil,	Regional gas oil consumption, 1997, Railtrack, NIR	Regional gas oil consumption, 1997, Railtrack, NIR
Navigation	Coastal	gas oil, fuel oil	Unallocated except for terminals	Unallocated except for terminals
Other	Aircraft Support	gas oil	Regional aircraft movements	Regional aircraft movements

1 See Table A1.9 for abbreviations

Table A1.5 Other Sectors[1]

IPCC Category	NAEI Sources	Activity: Fuel Consumption	1990	1995/1998
Commercial/Institutional	Miscellaneous, Public service, Other non-industrial	Coal	SPRU database: Miscellaneous; coal	SPRU database: Miscellaneous; coal
		SSF	NAEI spatial inventory	NAEI spatial inventory
		Natural gas	Commercial Sales, DTI	Natural gas consumed, Transco
		Landfill gas	Landfill methane Emissions	Landfill Methane Emissions
		Sewage gas	Sewage methane recovered	Sewage methane recovered
		fuel oil	SPRU database: miscellaneous; natural gas	SPRU database: miscellaneous; natural gas
		gas oil	Regional Oil Consumption, DTI, WO. Remainder after other uses.	Regional Oil Consumption, DTI, WO. Remainder after other uses.
		Burning oil	As other industry	As other industry
	Railways(Stationary)	fuel oil, burning oil, coal	Regional gas oil consumption, 1997,Railtrack, NIR	Regional gas oil consumption, 1997,Railtrack, NIR
		Natural gas	England	England
Residential	Domestic	Coal, anthracite	Coal consumption, NIO, WO	Based on 1995 coal sales data, NIO
		SSF, coke	See text	See text
		Natural gas	Domestic gas, DTI	Customers < 73200 kWh, DTI
		Burning oil	Regional burning oil, DTI, WO. LRC data for NI.	Regional burning oil, DTI, WO. LRC data for NI.
		Gas oil, LPG	Regional population, ONS, LRC data for NI	Regional population, ONS, LRC data for NI
		Fuel oil, wood	Regional population, ONS	Regional population, ONS
	House & Garden	DERV, petrol	Regional dwellings, ONS	Regional dwellings, ONS
Agriculture/Forestry/ Fishing	Agriculture	coal, coke, fuel oil, gas oil, natural gas	Agricultural employment, MAFF	Agricultural employment, MAFF
		burning oil	Regional burning oil, DTI, WO	Regional burning oil, DTI, WO
		straw	Wheat production, MAFF	Wheat production, MAFF
	Agriculture Power Units	Gas oil, petrol	Agricultural employment, MAFF	Agricultural employment, MAFF
	Fishing	gas oil, fuel oil	Unallocated	Unallocated

1 See Table A1.9 for abbreviations

1.5 OTHER SECTORS

1.5.1 Commercial/Institutional

The NAEI categories, public administration, miscellaneous and other non-industrial were combined because regional statistics are not available to this level of sectoral disaggregation. Only WO (1998) reports miscellaneous coal consumption, whereas NIO (1999) reports only an industrial category. Estimates for 1990,1995 and 1998 were based on the SPRU database for miscellaneous coal consumption.

DTI (1992) reports regional gas sales to the commercial sector for 1990. For 1995 and 1998 Transco data was used for regional gas consumption in the 73-732 MWh range. This is the closest data available for commercial/institutional consumers in these years but is rather smaller than the UK data reported by DTI (1999).

For fuel oil, the SPRU drivers for oil were used.

Stationary combustion by the railway sector is classified as commercial. Consumption of burning oil, fuel oil, and coke is tiny and was allocated according to the diesel oil driver used for locomotives. Natural gas consumption for electricity generation refers to the London Underground.

1.5.2 Residential

Domestic coal consumption is reported in NIO (1999) up to the present and in WO (1998) to 1993. These data also include anthracite and for NI other solid smokeless fuels. Domestic coal consumption for 1995 was estimated from sales data, gathered from major coal producers. A mass balance was performed on production, imports, stock-changes and imports. Coal was allocated to sources where consumption was known or estimated using other drivers (power generation, iron & steel, cement kilns) and imports allocated to the most likely consumers (steam coal to power generation; coking coal to coke production; anthracite to domestic anthracite). It was assumed that the degree of penetration of imported anthracite was the same for England, Scotland and Wales. All coal in Northern Ireland is imported, mostly from abroad. English and Welsh sales data was fairly complete but Scottish data was incomplete and only accounted for around 71% of Scottish production. Hence it was necessary to estimate Scottish consumption as the difference between the UK and the other regions. Stock changes are significant and were disaggregated on regional production (Coal Authority, 2000). The estimates obtained are likely to be fairly approximate. For 1990, data for Wales, Northern Ireland and UK are available; hence consumption in England and Scotland was estimated by interpolation based on the 1995 split between England and Scotland. The 1998 coal sales data was too incomplete to apply the mass balance method satisfactorily. The procedure adopted was to assume all imported domestic anthracite was used in Northern Ireland and to apply the 1995 driver to England, Scotland and Wales.

The regional data available is not sufficiently detailed to report consumption of manufactured solid smokeless fuels (SSF). Hence a driver was 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 Northern Ireland data includes SSF imports under coal and anthracite and so a correction was applied to avoid double counting. The same driver was used for commercial and other industry.

Domestic natural gas data is available for 1990 (DTI, 1991), and a very similar category; customers consuming less than 73200 kWh is reported in later editions.

DTI (1999, 1991) reports regional consumption of liquid fuels but only as totals for: England and Wales combined; Scotland and Northern Ireland. WO (1998) reports similar data on liquid fuel consumption up to 1993. A large proportion of burning oil (76%) is consumed in the domestic sector and in the previous 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. The procedure adopted was to estimate Northern Ireland's domestic consumption from the house conditions survey and then to allocate consumption England, Wales and Scotland according to the totals. The Welsh consumption was extrapolated from 1993.

The consumption of fuel oil by the domestic sector is tiny and was distributed according to population ONS (2000). For gas oil, it was necessary to account for the pattern of consumption in Northern Ireland. Here data from the House Conditions Survey used in the Greater Belfast Local Inventory (LRC, 1999) suggested that most domestic oil consumption is burning oil. Hence as a simplifying assumption domestic gas-oil consumption was taken as zero. Domestic gas oil consumption for England, Scotland and Wales was allocated on population.

The domestic consumption of liquid petroleum gas in Northern Ireland is proportionately higher than in Great Britain because of the lack of mains gas. The consumption for Northern Ireland was 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 Wales was allocated on the basis of population.

1.5.3 Agriculture/Forestry/Fisheries

Regional fuel consumption by agriculture is not available. Emissions were allocated on the basis of employment, MAFF (2000). Fishing emissions are unallocated.

1.6 MILITARY

Emissions from military aircraft and naval vessels were unallocated. Army emissions are included in the road transportation and public service categories and cannot be identified.

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. Hence regional estimates were obtained on regional coal production derived from a number of sources: Coal Authority (2000), BGS (1991,1996), 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 was made to allow for this. The UK estimate of coal bed methane emissions neglects emissions from abandoned mines, as these are believed to be negligible.

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 were disaggregated based on the regional consumption of coking coal discussed in 1.1.3.3.

For solid smokeless fuel (SSF) plant, the only fugitive emissions estimated, were the 'residual' CO_2 emission and the process methane. The driver used was the regional consumption of coal by SSF plant (see 1.1.1.3). It is known that some petroleum coke is used in SSF production but the amount is uncertain. The same driver was 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 and Scotland and from the on-shore oil and gas fields.

The estimates of terminal flaring emissions are based on UKOOA (1999) data for 1995 and 1998. Data is unavailable for 1990, so these were extrapolated based on flaring volumes for Scottish Terminals and natural gas arrivals to gas terminals in England (DTI, 1991, 1996). Also included were estimates based on flaring volumes from on-shore fields in England (DTI, 1991, 1996). Wytch Farm which lies a few miles off the south coast of England was classified as on-shore for this purpose.

UKOOA was able to supply fugitive emissions of CO_2 and methane from terminals for 1995 and 1998. Estimates for 1990 were extrapolated using data on arrivals of oil and gas in England and Scotland (DTI, 1991, 1996). Emissions of methane also occur at oil terminals when loading tankers. These were allocated to Scotland. Fuel use in terminals is discussed in 1.1.3.4 and 1.1.5.1.

The UK Inventory estimates emissions of methane from leakage from the natural gas transmission system. The estimates are based on Transco estimates of specific leakage rates from the mains and services and data on the stock of mains and services. The baseline estimate is for 1991; subsequent years are based on the upgrading of the system. Recently Transco have developed a new model which produces regional leakage estimates from the low-pressure transmission system for 1998. The emission for 1998 from the new model is about 10kt CH_4 higher than the old which was used for the 'official' 1998 estimate in Salway (2000). The new estimate is used in the current work with the result that the sum of the methane emissions from England, Scotland and Wales is slightly higher than the 'official' UK estimate. 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 were allocated using the same regional split as the low-pressure leakage.

Table A1.6 Fugitive Emissions from Fuels[1]

IPCC Category	NAEI Sources	Activity: Fuel Consumption	1990	1995/1998
Coal Mining	Deep mined coal Coal storage & transport	Deep mine coal production	Regional deep mine production, CA	Regional deep mine production, CA
	Open cast coal	Open cast mine coal production.	Regional open cast mine production, CA	Regional open cast mine production, CA
Solid fuel transformation	Coke production	Coke production	Coal feed to coke ovens, ISSB, WS, DTI	Coal feed to coke ovens, ISSB, WS, DTI, PI
	Flaring	Coke oven gas	Coal feed to coke ovens, ISSB, WS, DTI	Coal feed to coke ovens, ISSB, WS, DTI, PI
	SSF production	Coal Petrocoke	Coal feed to SSF plant, DTI, WS	Coal feed to SSF plant, DTI, WS
Oil	Offshore Oil & Gas	NA	Fugitive emissions from Terminals (extrapolated)	Fugitive emissions from Terminals, UKOOA
	Onshore Loading	Oil loaded	All Scotland	All Scotland
Venting and Flaring	Offshore Flaring	Volume gas flared	Flaring at terminals and onshore fields, UKOOA, DTI	Flaring at terminals and onshore fields, UKOOA, DTI
Natural Gas	Gas Leakage	Natural gas leakage	Transco estimate for LP mains	Transco estimate for LP mains

1 See Table A1.9 for abbreviations

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 these processes are summarised in Table A1.7

1.8.1 Minerals Industries

Large emissions of CO_2 arise from the degradation of limestone used in cement and limekilns. Cement emissions are estimated from the production of cement clinker, hence regional emissions were estimated based on percentage capacity data for the regions supplied by British Cement Association (2000). Discussions with regulatory authorities (Environment Agency, Scottish Environmental Protection Agency, and in Northern Ireland, the Department of the Environment) suggested that, lime calcination only occurs in England.

Limestone and dolomite are also used in iron and steel production. Discussions with British Steel suggested 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 were disaggregated on regional iron production (ISSB, 1991, 1996, 1999).

Limestone, dolomite and soda ash are also used in glass production. Emissions were disaggregated using plant capacity data for 1995/96 supplied by British Glass (1999).

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. The ammonia and adipic acid plants are in England. Nitric acid is produced in England and Northern Ireland and estimates were based on the plant capacities and estimated emission factors.

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 was used as the driver (ISSB, 1991, 1996, 1999). The flaring of waste blast furnace gas was distributed according to the distribution of blast furnaces. The driver used was coal consumption by blast furnaces. (ISSB, 1991, 1996, 1999).

The electrolytic process used to produce aluminium results in a CO_2 emission as the petroleum coke anode is consumed. Emissions were based on plant capacity data for 1990,1995 and 1999 provided by Alcan (1998, 2000). The Kinlocheven plant

uses the older Soderberg process which results in a higher specific emission factor. Aluminium production also results in emissions of PFCs. Regional estimates were obtained by Enviros March (2000) from discussions with Alcan.

1.8.4 Use of Halocarbons and SF_6

The UK emissions of halocarbons and sulphur hexafluoride are based on estimates prepared by Enviros March, MCG (1999). For some sources, the emission is equal to the consumption of fluid (e.g. aerosols) whilst for other sources, emissions occur during manufacture of a product, followed by leakage during the product lifetime, followed by a disposal emission. (e.g. refrigerators). In these cases emissions are estimated from a time dependent model of the bank of fluid held in products, accounting for product production and disposal, MCG (1999). Enviros March performed a short study on regional emissions, and this section summarises their report.
It was felt that supermarket refrigeration was sufficiently different from other refrigeration to warrant a separate study. Emissions were based on a market review of the number and size of supermarkets in the regions plus discussions with gas manufacturers on the sales into this sector. Discussions with supermarket owners also suggested that regional usage could be approximately equated to sales volume, which in turn could be approximated by regional population split.

Air conditioning systems in cars began to use HFC134a from around 1993. Data was 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 were gathered from discussions with Nike. Sales figures for the devolved regions of the UK were not available, so the regional split has been made according to population.

Sulphur hexafluoride is used in electrical switchgear used in the electricity transmission system. Estimates were based on discussions with gas manufacturers, equipment manufacturers and the Electricity Association. The regional split was based on the total electrical capacity of a particular region.

For aerosols the split by region has been done on the basis of population. The aerosols containing these gases often have industrial applications, but it can be assumed that usage can be at least approximately equated with population. Making the split using this method also has the advantage of making the data directly comparable with the figures for the baseline years of 1990 and 1995.

Data for HFC emissions from metered dose inhalers in the UK have been taken from the March predictive model (MCG, 1999). 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.

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

Discussions with end-users in the magnesium industry confirmed the assumptions made in the emissions model; i.e. that there has been growth in production of about 20-25% between 1995 and 1998, that no reclamation of SF6 was yet taking place, and that although SO_2/SF_6 mixtures were being looked at as an alternative for SF_6, reduced legal limits of SO_2 were holding back progress in this area.

Regional data for emissions of PFCs and SF_6 from semiconductor wafer manufacture for the years 1995 and 1998 were kindly provided by Future Horizons, a semiconductor industry consultancy. The predicted total UK emissions closely match the actual emissions calculated in the current study (MCG, 1999). However, it should be noted that in light of information provided, the regional split has been altered for emissions in 1995. The previous figures underestimated emissions from England and overestimated those from Wales. Although UK semiconductor manufacture increased by approximately 50% between 1995 and 1998, emissions from this sector have actually declined by about 50%. This is due to a vast improvement in the emissions rate of the gases, as the semiconductor manufacturers have become aware of the environmental impact of the fluids used. Initiatives have been undertaken to prevent evaporation to the atmosphere and for disposal in an environmentally responsible manner.

Table A1.7 Industrial Processes[1]

IPCC Category	NAEI Sources	Activity Data	1990	1995/98
Cement Production	Cement (decarbonizing)	Clinker production	Regional cement capacity, BCA[1]	Regional cement capacity, BCA[1]
Lime Production	Lime (decarbonizing)	Limestone consumption	Plant in England	Plant in England
Limestone and Dolomite Use	Glass production	Limestone and dolomite consumption	Regional glass production 96/97, BGlass	Regional glass production 96/97, BGlass
	Blast Furnaces	Limestone and dolomite consumption	Iron production, ISSB	Iron production, ISSB
Soda Ash Production and Use	Glass production	Soda Ash Consumption	Regional glass production 96/97, BGlass	Regional glass production 96/97, BGlass
Ammonia Production	Ammonia feedstock	Natural gas feedstock	Plant in England	Plant in England
Nitric Acid Production	Nitric Acid Production	Plant capacity	Regional plant capacity	Regional plant capacity
Adipic Acid Production	Adipic Acid Production	Adipic acid made	Plant in England	Plant in England
Iron and Steel	Electric Arc Furnace	EAF steel production	Regional EAF production, ISSB	Regional EAF production, ISSB
	Flaring	Blast furnace gas	Coke Consumed in blast furnaces, ISSB, WO[1]	Coke Consumed in blast furnaces, ISSB, WO[1]
Aluminium Production	Aluminium production	Primary aluminium produced	Regional aluminium plant capacity, ALCAN	Regional aluminium plant capacity, ALCAN
SF_6 Used in Aluminium and Magnesium Foundries	SF_6 Cover gas	NA	Regional consumption, EM[1]	Regional consumption, EM[1]

1 See Table A1.9 for abbreviations

Table A1.8 Halocarbons and Sulphur Hexafluoride[1]

IPCC Category	NAEI Sources	Activity Data	1990	1995/98
Halocarbon & SF6 By-Product Emissions	Halocarbon Production	NA	All plant in England	All plant in England
Refrigeration and Air Conditioning	Refrigeration	NA	Regional population, ONS	Regional population, ONS
	Supermarket Refrigeration	NA	Regional population, EM	Regional population, EM[1]
	Mobile Air conditioning	NA	Regional population, EM	Regional population, EM
Foam Blowing	Foams	NA	Regional population, ONS	Regional population, ONS
Fire Extinguishers	Fire fighting	NA	Regional population, ONS	Regional population, ONS
Aerosols	Metered Dose Inhalers	NA	Regional population, ONS	Regional population, ONS
	Aerosols (halocarbons)	NA	Regional population, ONS	Regional population, ONS
Other	Electronics	NA	Regional electronics plant Consumptn, EM	Regional electronics plant Consumptn, EM
	Training shoes	NA	Regional population, EM	Regional population, EM
	Electrical Insulation	NA	Regional electrical capacity, EM	Regional electrical capacity, EM

1 See Table A1.9 for abbreviations

Table A1.9 Summary of Abbreviations used in Tables A1.1to A1.8

BCA	British Cement Association
BGlass	British Glass
CA	Coal Authority
DTI	Department of Trade and Industry
E	England
EAF	Electric Arc Furnace
EM	Enviros March previously MCG
IPCC	Intergovernmental Panel on Climate Change
ISSB	Iron and Steel Statistics Bureau
LPG	Liquefied petroleum gas
LRC	London Research Centre
MAFF	Ministry of Agriculture, Fisheries and Food
MCG	March Consulting Group now EM
MSW	Municipal Solid Waste
NA	Not Available
NAEI	National Atmospheric Emissions Inventory
NIO	Northern Ireland Office
NIR	Northern Ireland Railways
NO	Not occurring
ONS	Office for National Statistics
OPG	Other petroleum gas
PI	Pollution Inventory
S	Scotland
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

1.9 AGRICULTURE

The UK inventory was disaggregated to 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 MAFF June Agricultural Census for 1990, 1995 and 1998. (MAFF, 1991,1996,1999). Most of the data previously submitted for 1990 and 1995 is unchanged, but in 1995 the following figures have been updated using the latest production statistics in Agriculture in the

UK and Basic Horticultural Statistics for the UK (from which all crop production numbers are obtained):

- Total cereal
- Oilseed rape
- Linseed
- Sugar beet
- Phaseolus beans

Fertiliser applications were derived using regional crop areas and average application rates published in the British Survey of Fertiliser Practice for 1990, 1995 and 1998, (BSFP, 1991, 1996, 1999). Application rates in Wales were assumed to be equivalent to those in England, and rates in Northern Ireland were assumed to be the same as Scottish applications. 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.

There remains a difference between the 1998 national fertiliser N figure and the UK total derived through disaggregation. The method used for disaggregating the fertiliser N application data in 1990/95 is not applicable to 1998 since there is a paucity of data for some categories. Instead, another method was used. This derives the fertiliser N application from MAFF census crop areas and British Survey of Fertiliser Practice application rates, and results in a total that is only 0.04% different to the value previously submitted in the national inventory for 1998, as opposed to a 1.4% difference using the 1990/95 method and the available data.

Livestock numbers were obtained from the MAFF June Agricultural Census for 1990, 1995, 1998 with the exception of deer, which were derived from the distribution reported in *Economic Report on Scottish Agriculture*, (SO, 1996)
The following categories have been updated in the disaggregated inventory for 1998:

- Dairy in milk
- Dairy not in milk
- Beef (including heifers in first calf)
- Other cattle > 2
- Other cattle < 2
- Beef and all others < 2
- Other cattle 1-2

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 in effect normalising the regional inventories so the sum of England, Scotland, Wales and Northern Ireland equals the UK Emission. The details of the normalisation procedure are explained in Section 1.1.2.

1.10 LAND USE CHANGE AND FORESTRY

The estimates for Land Use Change and Forestry are from work done at the Centre for Ecology and Hydrology (Edinburgh)[†] (Cannell *et al*. 1999, Milne and Brown 1999).
Emissions and Removals are estimated based on a model based on England, Scotland, Wales and Northern Ireland. The methodology is discussed by Milne in Salway (2000).

1.11 WASTE

1.11.1 Solid Waste Disposal on Land

In the UK Inventory, emissions are estimated based on a model of methane production in landfill sites. (Brown *et al*, 1999). The model classifies landfill sites into four different types depending on their age and the extent of methane recovery system installed. 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 only available data is based on studies from 1995 onwards and previous year's data are extrapolated based on production indices.

The regional estimates were calculated using the Brown *et al* (1999) model. This involved estimating the input data for Wales, Scotland and Northern Ireland. The data estimated were:

- Annual arisings of MSW. Data for Scotland, Wales, Northern Ireland and England for 1995 are given in Brown *et al* (1999) and DETR (1997) and are consistent. Previous years' data were extrapolated using the model's estimates for UK arisings. The 3 components (household, civic amenity, co-collection) were allocated according to their proportions in 1995 or allocated as zero when they were known not to occur.

[†] The land use change and forestry estimates were provided by the Institute of Terrestrial Ecology (Contract EPG/1/1/39). Technical enquiries on land use change and forestry should be addressed to Dr R Milne, Centre for Ecology and Hydrology (Edinburgh), Bush Estate, Penicuik, EH26 OQB, UK (tel +44 (0) 131 445 8575. fax +44 (0) 131 445 3943, E-mail, rmilne@ceh.ac.uk

- The model uses data on the percentage composition of MSW and the proportion of each component landfilled. The UK data were taken as defaults for the regions but were scaled so that total MSW disposals matched the known 1995 data. For Scotland and Northern Ireland, this meant higher percentage disposals than for England and Wales. The model assumes higher disposals in the past and these data were scaled using a single factor to produce a time series. For Northern Ireland, the average percentage of waste disposed of in 1995 was found to be 95%. Scaling this using the UK historic time series gave disposals in excess of 100%. Hence a fixed disposal rate of 95% was used for all years.
- Industrial and Commercial Waste. This includes some sewage sludge. Data for Scotland, Northern Ireland and England/Wales were taken from DETR (1997) and entered directly back to 1991. The 1991 entry was used for all previous years. Welsh sewage disposals to landfill in 1996/97 were zero (Environment Agency, 1999) and this value was used for all years. The remaining waste categories were interpolated based on population and a time series produced by scaling on the UK time series.
- All other data on Degradable Organic Carbon contents distribution of landfill types etc was taken from the UK Model.

Emissions for England were estimated as the difference between the UK and the remaining regions. Landfill gas is recovered and used as a fuel for electricity generation. The methodology assumes that the degree of recovery was the same in all regions, so the methane emission driver could be used to distribute landfill gas consumption.

1.11.2 Waste Water Handling

The UK emission of methane from sewage treatment is based on a model reported by Hobson et al (1996). This breaks down the UK arisings of sewage into the amounts treated by up to 14 different disposal routes. Empirical emission factors are applied to each route to estimate methane emissions. Methane recovery is assumed for the anaerobic digestion route. The model requires estimates of the annual arisings of sewage and the proportion treated by the disposal routes. These data are taken from the UK Sewage Sludge Survey for 1990/91 (DOE, 1993). A more recent survey for 1995/96 has just been released (Environment Agency, 1999), however the Inventory estimates are based on the earlier work and so the regional disaggregation was also. The survey reports disposals of sewage for Scotland, Northern Ireland and England/Wales and gives data on disposal routes. However the data is incomplete and it was necessary to make assumptions to account for all disposals. Where assumptions had to be made, the UK defaults were adopted. Data for Wales were taken from the later survey since the earlier work did not specifically identify Wales. The Welsh estimates were based on data reported by Welsh Water whose area of activity does not exactly match the Welsh National Territory but should give a reasonable estimate. Using the regional data, estimates were made for 1990 and 1995 for Scotland, Northern Ireland and Wales. It was assumed that the percentage mix of disposal routes did not change between 1990 and 1998 but that sewage disposals increased in line with the UK.

The model also predicts the amount of sewage gas recovered for use or disposal. This data was used as the driver for sewage gas combustion.

1.11.3 Waste Incineration

The UK Inventory reports emissions from the incineration of sewage sludge and municipal solid waste. Regional estimates are based on DETR (1997) which reports data for the amount sewage incinerated for Scotland, Northern Ireland and England/Wales. Wales is known to be zero (RCEP, 93). Emissions from MSW Incinerators are based on capacity data for individual incinerators taken from RCEP (1993). It is assumed there were no significant changes between 1990 and 1995. Comparison with lists prepared for 1996 (Smyllie, 1996) suggest this is reasonable. Some of these incinerators generate electricity and are reported as power stations. The consumption of these incinerators is reported in DTI (1996, 1991) and is known to be located in England. By 1998 all UK Incinerators generated electricity and are reported as power stations.

1.12 UNCERTAINTIES

1.12.1 Introduction

The uncertainties in the UK Inventory were estimated using a Monte Carlo simulation. Eggleston et al (1999) and Salway (2000) 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 would 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 were 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 was 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 were estimated by a Monte Carlo simulation. In order, to simplify the calculations the source categories were far broader than those used in the UK Inventory simulation. In the regional

simulation, the combustion categories were effectively the total consumption of a particular fuel. This contrasts with the UK simulation where there was a further disaggregation into sectoral categories (e.g. power stations, refineries). The rationale for this was that it was 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 were being used.

For each of the broad source categories an estimate of the activity uncertainty was made for Scotland, Wales, Northern Ireland and Unallocated. The approach adopted was to estimate a factor to scale the UK. For example, sales data is available for burning oil consumption in Scotland and Northern Ireland. Hence, it seems reasonable to assume that its uncertainty is similar to that of the UK burning oil data. Sales data is only available for England and Wales combined so that estimates for England and Wales were made by splitting the available data using population as a surrogate. Thus it was assumed that the uncertainty for Wales was twice that for Scotland and Northern Ireland which were the same as the UK.

It is important to note that the uncertainties in the inventories for the UK, England, Scotland, Wales, Northern Ireland, Unallocated are not independent. This is because:

Emissions from UK = Emissions from England, Scotland, Wales, Northern Ireland and Unallocated

Thus, in the simulation, the uncertainties for UK, Scotland, Wales, Northern Ireland and Unallocated were estimated and the total uncertainties for UK, Scotland, Wales, Northern Ireland, Unallocated and *England* were calculated. It was necessary to check that the calculated uncertainty for England 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 was unlikely there would be any variation in uncertainties between regions. The practice in these cases was to assume a low uncertainty for the activity data, say 1% for each region and to use the UK uncertainty for the emission factor.

In the case of halocarbon and SF_6 emissions it was not considered feasible to attempt to assume varying uncertainties across the regions. Hence it was assumed that the uncertainty of each regional emission was 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 seemed a reasonable working approximation.

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