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Greenhouse Gas Inventories for England, Scotland, Wales and Northern Ireland: 1990, 1995, 1998 and 1999

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Executive Summary

This report presents estimates of greenhouse gas emission inventories for the devolved administrations of the UK. Separate greenhouse gas emission inventories were estimated for England, Scotland, Wales and Northern Ireland for the years 1990, 1995, 1998 and 1999. The gases reported are:

- Carbon dioxide
- Methane
- Nitrous Oxide
- Hydrofluorocarbons
- Perfluorocarbons
- SF_6

The estimates are consistent with the United Nations Framework Convention on Climate Change (FCCC) reporting guidelines and the 1999 UK Greenhouse Gas Inventory (Salway *et al*, 2001). Some emissions, mainly mobile and offshore sources, could not be allocated to any region, so an unallocated category was used to report these.

The study showed that the distribution of regional greenhouse gas emissions expressed as global warming potentials (GWP) in 1999 were: England, 73.3%; Scotland, 11.2%; Wales, 7.6%; Northern Ireland, 3.5%; unallocated, 4.3% (see summary table below).

The key trends in emissions that have occurred between 1990 and 1999 for each gas and for each constituent country of the UK are as follows:

- **Carbon dioxide**: Overall UK emissions have fallen by 9% between 1990 and 1999, mainly driven by the installation of combined cycle gas turbines (CCGT) in the power generation sector in England.
- **Methane**: Overall UK emissions have fallen by 28% between 1990 and 1999, with reductions occurring in waste disposal and agriculture for all constituent countries.
- **Nitrous oxide**: Overall UK emissions have fallen by 36% between 1990 and 1999, driven by a large fall in England from installation of abatement measures at an adipic acid plant. This overall downward trend is off-set to a small degree by a rise across all constituent countries in nitrous oxide emissions from the transport sector over the period due to increased use of three-way catalytic converters.
- **HFCs**: Overall UK emissions have fallen by 45% between 1990 and 1999, mainly due to a big fall in England from abatement equipment installed at an HCFC plant. However, there is a rising trend in emissions across the other constituent countries due to losses from refrigeration and air conditioning equipment and emissions from industrial aerosols and metered dose inhalers.
- **PFCs**: Overall UK emissions have fallen by 70% between 1990 and 1999, mainly due to control measures in aluminium production in England and Wales.

- **SF_6**: Overall UK emissions have risen by 122% between 1990 and 1999, due to increased magnesium production in England and Wales, greater use of SF_6 in training shoes and electrical switch gear across all constituent countries, and greater use of SF_6 in the electronics industry mainly in Scotland and Wales.

Summary of Greenhouse Gas Emission trends for UK and Constituent Countries (expressed as GWP Weighted Equivalent Mass of Carbon)

Greenhouse Gas			England	Scotland	Wales	Northern Ireland	Un - allocated	United Kingdom
CO_2	1990 Emission	Mt C equiv	124.2	17.2	11.1	4.8	7.1	164.4
	1990 Percentage	%	*75.6*	*10.4*	*6.7*	*2.9*	*4.3*	*100.0*
	1999 Emission	Mt C equiv	109.9	16.6	11.2	4.5	7.2	149.4
	1999 Percentage	%	*73.5*	*11.1*	*7.5*	*3.0*	*4.8*	*100.0*
	Change 1990/99	%	*-11.5*	*-3.3*	*1.3*	*-7.3*	*1.4*	*-9.1*
Methane	1990 Emission	Mt C equiv	16.0	2.1	1.6	0.9	0.6	21.0
	1990 Percentage	%	*75.9*	*9.8*	*7.5*	*4.2*	*2.6*	*100.0*
	1999 Emission	Mt C equiv	10.9	1.7	1.2	0.9	0.4	15.1
	1999 Percentage	%	*72.4*	*11.1*	*8.3*	*5.7*	*2.5*	*100.0*
	Change 1990/99	%	*-31.6*	*-18.4*	*-20.8*	*-3.0*	*-32.8*	*-28.3*
N_2O	1990 Emission	Mt C equiv	14.8	1.6	0.9	0.8	0.1	18.3
	1990 Percentage	%	*80.9*	*8.9*	*5.2*	*4.4*	*0.6*	*100.0*
	1999 Emission	Mt C equiv	8.2	1.5	1.0	0.9	0.1	11.7
	1999 Percentage	%	*69.7*	*12.4*	*8.7*	*8.0*	*1.1*	*100.0*
	Change 1990/99	%	*-44.8*	*-10.4*	*7.6*	*16.5*	*14.6*	*-35.9*
HFC	1990 Emission	Mt C equiv	3.1	0.0	0.0	0.0	0.0	3.1
	1990 Percentage	%	*100.0*	*0.0*	*0.0*	*0.0*	*0.0*	*100.0*
	1999 Emission	Mt C equiv	1.5	0.1	0.05	0.03	0.0	1.7
	1999 Percentage	%	*89.3*	*5.9*	*3.0*	*1.8*	*0.0*	*100.0*
	Change 1990/99	%	*-51.3*	*NC*	*NC*	*NC*	*0.0*	*-45.4*
PFC	1990 Emission	Mt C equiv	0.44	0.07	0.11	0.00	0.00	0.62
	1990 Percentage	%	*70.5*	*11.3*	*17.9*	*0.3*	*0.0*	*100.0*
	1999 Emission	Mt C equiv	0.08	0.07	0.03	0.00	0.00	0.18
	1999 Percentage	%	*45.8*	*38.3*	*15.7*	*0.2*	*0.0*	*100.0*
	Change 1990/99	%	*-80.7*	*0.8*	*-73.9*	*-84.0*	*0.0*	*-70.3*
SF_6	1990 Emission	Mt C equiv	0.16	0.02	0.02	0.00	0.00	0.20
	1990 Percentage	%	*78.9*	*9.8*	*10.1*	*1.2*	*0.0*	*100.0*
a	1999 Emission	Mt C equiv	0.38	0.03	0.03	0.01	0.00	0.45
	1999 Percentage	%	*85.5*	*7.0*	*6.2*	*1.2*	*0.0*	*100.0*
b	Change 1990/99	%	*139.8*	*65.3*	*37.2*	*121.6*	*0.0*	*121.9*
Total	1990 Emission	Mt C equiv	158.6	20.9	13.7	6.5	7.8	207.6
	1990 Percentage	%	*76.4*	*10.1*	*6.6*	*3.1*	*3.7*	*100.0*
	1999 Emission	Mt C equiv	130.9	19.9	13.6	6.3	7.7	178.5
	1999 Percentage	%	*73.3*	*11.2*	*7.6*	*3.5*	*4.3*	*100.0*
	Change 1990/99	%	-17.5	-4.8	-1.0	-3.3	-0.8	-14.0

NC Not Calculable. Data points in 1990 are zero.

a Emissions of SF_6 exceed the official UK total owing to more recent data on electrical insulation emissions.

b 1995 is used as the base year for emissions of HFCs, PFCs and SF6 in the UK's Climate Change Programme, in accordance with Article 3.8 of the Kyoto Protocol. There was a 45% rise in overall UK emissions of SF_6 between 1995 and 1999.

Where possible the same methodology was used to calculate the regional emissions as for the UK Inventory. However, it was found that the data available for regional emission sources were

less detailed than for the UK, and in some cases were not available. In particular, complete sets of fuel consumption data could not be found for England, Wales and Scotland. In order to make emission estimates, it was necessary to supplement the available fuel consumption data with surrogate statistics. These included, plant capacities, boiler capacities, employment statistics and production of industrial products. These were used to estimate regional emissions from the UK emission. There were fewer problems in obtaining data in the other major categories: industrial processes; agriculture; land-use change and forestry; and waste disposal. Here a representative set of regional data was available though with less detail than for the UK. As a result of these data availability issues the regional estimates are more uncertain than the UK estimates.

CO_2 data include estimated emissions from Land Use Change and Forestry. LUCF estimates have been substantially revised and the revisions applied to the whole time series. This revision is due to improved soil carbon density data and has resulted in a significant reduction in carbon emissions in Scotland.

Contacts

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1. Introduction

The United Nations Framework Convention on Climate Change (FCCC) was ratified by the United Kingdom in December 1993 and came into force in March 1994. Parties to the Convention are committed to develop, publish and regularly update national emission inventories of greenhouse gases (GHG).

Following devolution, a national UK inventory will continue to be needed to ensure the UK fulfils its reporting requirements under the FCCC and to monitor the legally binding commitments under the Kyoto Protocol to reduce greenhouse gas emissions. However, some of the measures to deliver GHG emission reductions will be devolved and information on the emissions from the four individual countries is needed to support action in each country. Therefore, DEFRA agreed with the Scottish Executive (SE), the National Assembly for Wales (NAW) and in Northern Ireland, the Department of the Environment, to carry out a joint research project to provide first estimates of GHG emissions inventories for England, Scotland, Wales and Northern Ireland. The results of this study were published in *Greenhouse Gas Inventories for England, Scotland, Wales and Northern Ireland: 1990 and 1995: A Scoping Study, AG Salway et al (1999).* This was updated in 2000 to include 1998 data.

This report updates and revises the earlier studies and presents separate GHG Inventories for England, Scotland, Wales and Northern Ireland for the years 1990, 1995, 1998 and 1999. Emissions of the six direct greenhouse gases are reported, namely:

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

Inventories are reported in the Intergovernmental Panel on Climate Change (IPCC) Sectoral Tables which are a subset of the IPCC Common Reporting Format (CRF) and are consistent with the most recent UK Greenhouse Gas Inventory, (Salway *et al*, 2001). This report follows the convention used in Salway *et al* (2001) of reporting carbon dioxide emissions and removals as separate totals. This differs from the approach used in the CRF tables submitted to UNFCCC where the carbon dioxide data are reported as net emissions (*i.e*. emissions minus removals). Hence the UK National Total Emission quoted is higher than that quoted on the CRF basis. Certain emissions could not be allocated to a country and were reported in a table for unallocated emissions. These emission sources were:

- Shipping
- Aviation
- Military Aviation
- Naval

- Offshore Oil and Gas.

This report is divided into two parts, the main part of the report and the Appendices.

The main part of the report presents the regional greenhouse gas emissions for the years 1990, 1995, 1998 and 1999 and discusses the reasons for the trends, the availability of data and uncertainty estimates. Tables 10.1 to 10.3 give the regional summary data for these years and include global warming potential (GWP) weighted emissions as well as actual emissions. Figures 1 to 6 provide a regional and sectoral distribution for each gas.

Appendix 1 describes in detail the methodology of the estimates and how the regional inventories relate to the UK Greenhouse Gas Inventory.

Appendix 2 provides IPCC Sectoral Tables for 1990 and 1999 for England, Scotland, Wales and Northern Ireland. Summary tables (IPCC Sectoral Table 7A) are provided for 1995 and 1998 for England, Scotland, Wales and Northern Ireland. UK Summary tables are also reported. Table 3 of the Sectoral Tables has been omitted because this reports Volatile Organic Compounds (VOCs) which are not relevant to this study. In IPCC Tables, emissions are reported in Gigagrammes (Gg).[1] . A full set of IPCC Sectoral Tables for 1990, 1995, 1998 and 1999 is given on a CD ROM attached to this report.

Global Warming Potential

Greenhouse gases all have different degrees of effectiveness in global warming. The Global Warming Potential (GWP) is an attempt to provide a simple measure of the relative radiative effects of the emissions of the various gases. The index is defined as the cumulative radiative forcing between the present and some chosen time horizon caused by a unit mass of gas emitted now, expressed relative to that of CO_2. It is necessary to define a time horizon because the gases have different lifetimes in the atmosphere. Table 1.1 shows GWPs defined on a 100 year horizon, IPCC(1996). A range of GWP values is shown for HFCs and PFCs because these refer to a number of species, each with its own GWP. By weighting the emission of a gas with its GWP it is possible to estimate the total contribution to global warming of UK greenhouse gas emissions. The GWP weighted emissions in Tables 10.1 and 10.2 are expressed in equivalent masses of CO_2 and carbon.

Table 1.1 GWP of Greenhouse Gases on 100 Year Horizon (t CO_2 equiv/ t gas)

Gas	GWP
Carbon Dioxide	1
Methane	21
Nitrous Oxide	310
HFCs	100-3000
PFCs	5000-10000
SF_6	23900

[1] One Gigagramme (Gg) equals one thousand tonnes (kt)

2. Emissions in England

2.1 CARBON DIOXIDE

Figure 1 shows the emissions of carbon dioxide for 1990 to 1999 broken down by major IPCC source category. Total emissions of carbon dioxide in England were around 74% of the UK total in 1999 and have declined by 12% since 1990.

The largest source is Energy Industries which includes power generation, refineries, solid fuel transformation processes and the oil and gas industry. Electricity generation in England contributed around 28% of the total English carbon dioxide emission, which is higher than the UK proportion of 26%. The mix of generation capacity is different in England from *the rest of the* UK: there being a much higher proportion of combined cycle gas turbines (CCGT) stations; a lower proportion of conventional fossil fuel stations; a lower proportion of nuclear generation and no hydroelectricity. Emissions from Energy Industries have decreased by 30% since 1990 in contrast with a fall of 27% in UK emissions. This is explained by the installation of CCGTs in England and increased nuclear capacity and utilisation over the period. The CCGTs have higher efficiency than conventional thermal stations and produce lower emissions per GWh electricity generated. This reduction in emissions is largely responsible for the 12% reduction in the English total emission over the period.

Petroleum Refining constitutes a similar proportion of English national emissions at 3.1% compared with 3.4% for the UK. Emissions have increased by 10% since 1990. The other energy emissions are relatively small and are mostly gas consumption at oil and gas terminals, gas separation plant, coking and solid fuel production. Only emissions arising from on-shore installations in England have been included. Other energy emissions have however increased by18% from 1990 to 1999 as a result of an increase in gas consumption by from the oil and gas industry, though the 1990 estimates for terminals are highly uncertain.

Combustion emissions from Manufacturing Industry and Construction account for around 16% of the English total compared with 16% for the UK. The iron and steel industry in England accounts for 52% of UK Iron and Steel combustion emissions. The other industry category is around 81% of the UK other industry total.

Road Transport is the largest single source after power generation and contributes around 25% to the total English carbon dioxide emission. The contribution of English Road Transport to UK Road Transport emissions is 87%, which is slightly more than that which would be expected from England's population (84% of UK population). The emission has risen by 7.1% from 1990 to 1999 compared with a 4.8 % rise for the UK. Emissions were estimated from road fuel sales data. The estimates for 1995, 1998 and 1999 are rather uncertain since after 1993, the only data available are for England and Wales combined. Hence it was necessary to extrapolate from 1993 data.

Other combustion emissions arise from the domestic (Residential), commercial and public sectors. These are fairly uncertain due to lack of data. English domestic emissions are around

17% of the English total. As a proportion of UK domestic emissions they are 82% which is similar to that which would be expected from the population.

Fugitive emissions from fuels arise mainly from flaring of coke oven gas and flaring at terminals and are not significant.

Industrial processes produce emissions from non-combustion sources such as the use of limestone in cement and glass making. The largest contribution is from Cement Production constituting 1.2% of the English total with smaller emissions from glass, ammonia, aluminium, iron and steel production. Together, these processes emitted around 2.6% of the total in 1999. England emits all of the UK's emissions from lime production and ammonia production, but these emissions are not significant in terms of the English total. It should be noted that these emissions are non-combustion emissions - combustion emissions from industry are covered by category 1A2.

Carbon dioxide emissions from waste incineration are not significant. Since 1997 all waste incinerators were converted to generate electricity and so their emissions are reported under public power.

In spite of England's relatively large area, *emissions* from Land Use Change and Forestry (LUCF) constitute only 0.33% of the total English emission and contribute only around 8% of the UK LUCF emission. In 1999 all of this emission arose from the source 5E Other which refers to land drainage and peat extraction. Overall LUCF emissions have fallen since 1990 because the category 5D CO_2 Emissions and Removals from Soils has decreased from being a significant source of CO_2 in 1990 to being a sink in 1995, 1998 and 1999. The reporting of emissions from 5D CO_2 Emissions and Removals from Soils is slightly anomalous since these change from a source in 1990 to a sink in 1999. In order to obtain totals consistent with the UK total, this sink is reported as a negative quantity in the emissions column in 1995, 1998 and 1999. Milne (see Appendix 1.10) discusses the assumptions underlying these emissions in more detail. In 1999 a carbon sink (removal from the atmosphere) of around 3.3 Mt CO_2 arises from 5A Changes in Forests and Other Woody Biomass; 5D CO_2 Emissions and Removals from Soils; and 5E Crop Biomass. The English removals represent around 28% of UK removals.

2.2 METHANE

Unlike carbon dioxide, fuel combustion is not the predominant source of methane. The major sources are waste disposal, coal mining, leakage from the gas distribution system and agriculture. Emissions of methane are shown in Figure 2. Total emissions from England are declining and have fallen by 32% from 1990 to 1999.

The largest source of methane emissions in England is waste disposal. This contributes around 33% to England's emissions and is overwhelmingly landfill methane with a small contribution from wastewater treatment. The landfill emission is around 83% of UK landfill emissions which is consistent with the respective populations (83%). Estimates were based on data on disposals of municipal solid waste and sewage sludge in England but using UK data for their composition. Landfill emissions have fallen by 36%, from 1990 to 1999 because of increasing use of methane recovery systems, though this reduction assumes the UK trend. Emissions from wastewater treatment are around 1.6% of the English total methane emissions and comprise 86% of UK

wastewater emissions. Emissions reflect the treatment methods used which vary regionally as well as disposals of sewage and are rather uncertain.

The next largest source of methane is agriculture. Emissions arise from enteric fermentation in livestock and the treatment of their wastes. Around 30% of English emissions arise from agriculture with cattle responsible for 23%. Emissions from agriculture are dependent on the numbers of livestock and have fallen by 7% from 1990 to 1999 resulting from a decline in cattle and sheep numbers. England accounts for around 57% of UK agricultural emissions.

The category Fugitive Emissions from fuels reports emissions of methane from coal mining, coking, the oil and gas industry and natural gas distribution. The combined emission is around 33% of the English total methane emission. This is a higher proportion compared with the total of England, Scotland, Wales and Northern Ireland where fugitives are around 28% of the total. The higher English emission is due to the greater contribution of coal mining and leakage from the gas transmission system in England than elsewhere in the UK. Of these fugitive methane emissions, coal mining contributes 15%, natural gas distribution 18% and oil and gas terminals 0.2% of the English total. Coal mining emissions have declined by 62% from 1990 to 1999 due to the decline in the coal industry. Gas leakage from the gas transmission system is reducing as the mains and services are renewed. The reduction in leakage between 1990 and 1999 is around 8%.

Fuel combustion emissions of methane are not important and only account for 4% of the UK emissions. Most of these emissions are from domestic coal combustion and road transport.

2.3 NITROUS OXIDE

Emissions of nitrous oxide arise from a range of diverse sources including, combustion, agriculture and chemical processes. Emissions are uncertain, particularly those from agriculture.

Figure 3 shows emissions of nitrous oxide for 1990 and 1999 broken down by major IPCC source category. Total emissions from England were around 70% of the UK total in 1999 and have declined by 45% since 1990.

Of the total English emission of 96 kt in 1999, around 63 kt of this was from agriculture representing around 66% of the total. Most of these were emissions arising from the category agricultural soils as a result of processes in the soil arising from (in order of magnitude):

- synthetic fertiliser application
- leaching of fertiliser N to ground and surface water
- wastes from grazing animals
- manure used as fertiliser
- ploughing in crop residues
- atmospheric deposition of NH_3 and NO_x
- cultivation of legumes
- improved grass
- histosols (i.e. high organic content soils)
- field burning (discontinued in 1993)

A relatively small proportion (3 kt) is emitted from the treatment of agricultural wastes (animal manure management). English agricultural emissions are around 66% of UK agricultural emissions and by 1999, had fallen by around 6% below the English 1990 levels.

In 1998, unlike other parts of the UK, a substantial proportion of England's nitrous oxide emissions was produced by chemical processes, namely adipic acid production and to a lesser extent nitric acid production. In 1998, these processes constituted around 41% of England's N_2O emissions and 98% of UK industrial process N_2O emissions. By 1999, these proportions had changed significantly, as a nitrous oxide abatement system had been fitted to the adipic acid plant. Now, the sum of the English emissions from the nitric acid and adipic acid production is around 10 kt, equivalent to 10% of the UK N_2O emission.

The remaining 21 kt (21% of the total English N_2O emission in 1999) of nitrous oxide emissions result from fuel combustion. Just over half of this (12%) is from road transport with the remainder arising from stationary combustion - mainly combustion in power generation and industry. Whilst small, road transport emissions have risen by a factor of 4.5 over the period. This is a result of the increasing use of catalytic converters on cars.

2.4 HYDROFLUOROCARBONS

In 1998, the largest source of HFCs was fugitive emissions from the manufacture of HCFCs and HFCs. All production is located in England and in 1998 contributed 84% of HFC emissions (as CO_2 equivalent) in England and 82% of total HFC emissions (as CO_2 equivalent) in the UK.

In 1999, HFC emissions from the manufacture of HCFCs and HFCs had fallen. In 1999, HCFC and HFC production in England contributed 35% of total English HFC emissions (as CO_2 equivalent) and 31% of total UK HFC emissions (as CO_2 equivalent). The reduction arises from an abatement system installed on the HCFC plant

As a result of the reduction in emissions from halocarbon manufacture, refrigeration is now the largest source and contributes 43% of total English HFC emissions (as CO_2 equivalent). Here emissions arise from losses from refrigeration and air conditioning equipment during its manufacture and lifetime.

In 1999, aerosols contributed 21% to the total English HFC GWP emission. The category includes mainly industrial aerosols and also medical use in metered dose inhalers. The remaining emission sources, namely, foams and fire fighting are negligible.

In 1998, the total GWP emission of HFCs in England had increased by a factor of 2.4 since 1990 due to the increasing use of HFCs in aerosols and refrigeration and the increased production of HCFCs and HFCs. This situation changed markedly in 1999 owing to the commissioning of an abatement system on the HCFC production plant. Emissions in 1999 are now approximately half of their 1990 levels.

2.5 PERFLUOROCARBONS

The largest source of perfluorocarbons in England is aluminium production, which contributed around 34% of total English PFC emissions (as CO_2 equivalent) in 1999. Aluminium production plant are also located in Scotland and Wales, with the result that England's contribution to UK aluminium production emissions is 51%. The next largest source is IPCC Category 2F6 Other which consists mostly of emissions from the electronics industry with a small contribution from leakage from the soles of certain brands of training shoes. This accounts for around 57% of the English PFC total (as CO_2 equivalent). There are concentrations of the electronics industry in Scotland and Wales so that the English emission from electronics accounts for 39% of the UK electronics emission. All PFC production is located in England but emissions from PFC production are negligible. The remaining sources are refrigeration and fire extinguishers, which are negligible. Overall English emissions are 46% of the UK PFC total (as CO_2 equivalent). Emissions of PFC in England have declined by 81% mainly as a result of better control measures in aluminium production.

2.6 SULPHUR HEXAFLUORIDE

The main source of sulphur hexafluoride emissions is from use as a cover gas in magnesium production. This accounted for around 47% of total emissions in 1999. Magnesium production is largely concentrated in England and accounts for 92% of the UK magnesium production emission. Sulphur hexafluoride is also emitted from other sources: electrical switchgear used in power transmission, electronics applications, and leakage from the soles of certain brands of training shoes. The total of these emissions accounts for around 53% of total English emission. Overall emissions from England are 86% of the UK total. Emissions of SF_6 in England have increased by 144 % as a result of increasing use in trainers, magnesium production and switchgear.

3. Emissions in Scotland

3.1 CARBON DIOXIDE

Figure 1 shows emissions of carbon dioxide for 1990 to 1999 broken down by major IPCC source category. Total emissions were around 11% of the UK total in 1999. Scottish emissions of carbon dioxide have declined by 3% since 1990.

Data are calculated and presented in this report for emissions and removals of carbon dioxide from Land Use Change and Forestry (LUCF). In previous inventories this has been largest emission source in Scotland (Salway *et al*, 2000). However, in this work these emissions have been substantially reduced due to revisions in the soil carbon density data used for Scotland -see Appendix 1.10. LUCF is now the second largest source of CO_2 in Scotland and constitutes around 20% of the total Scottish emission and contributes around 76% of the UK LUCF Emission. Most of this emission arises from the IPCC source category 5D CO_2 Emissions and Removals from Soils. This estimate is particularly uncertain since it depends critically on assumptions made on the rate of loss or gain of carbon in the organic matter rich soils which predominate in Scotland. A carbon sink of -6.6 Mt CO_2 arises mostly from 5A Changes in Forests and Other Woody Biomass. The magnitude of this sink has increased by 16% over the period. Milne discusses the assumptions underlying these emissions in more detail in Appendix 1.10. LUCF emissions are much less significant in other parts of the UK and overall, UK LUCF emissions constitute around 3% of the UK Total.

In the following discussions on emissions from energy consumption, the non-LUCF total is referred to, since this gives a better basis for comparison with regions where LUCF emissions are less important.

The largest source is Energy Industries, which includes power generation, refineries, solid fuel transformation processes and the oil and gas industry. Electricity Generation contributed around 26% of the total emission (33% of the non-LUCF emission) which is similar to the UK proportion of 26%. The mix of generation capacity is different from the rest of the UK, there being a higher proportion of nuclear and hydro-electricity. Fossil fuel generation is from conventional coal and gas fired stations. Emissions have increased by 10% since 1990 in contrast with a fall of 29% in UK emissions. This is explained by the installation of combined cycle gas turbines (CCGT) in England and Wales and increased nuclear capacity and utilisation over the period. The CCGTs have higher efficiency than conventional thermal stations.

Petroleum refining constitutes a larger proportion of national emissions at 7% (of non-LUCF) compared with 3.4% for the UK. The other energy emissions are mostly gas consumption at oil and gas terminals and gas separation plant and account for around 4% of non-LUCF emissions. Only those emissions arising from on-shore installations in Scotland have been included. These emissions have however increased by 30% over the period, though the 1990 estimates for terminals are highly uncertain.

Emissions from manufacturing industry account for around 14% of the non-LUCF total compared with 16% for the UK. Emissions have declined over the period by 29% largely as a result of the Ravenscraig Steel Plant closing.

Road transport is the largest single source after power generation and comprises around 17% of the non-LUCF total. Its contribution to UK emissions is 7% which is slightly lower than would be expected from Scotland's population (9%). The emission has fallen by 3% over the period compared with a 5% rise for the UK. Emissions were estimated from road fuel sales data.

Other combustion emissions arise from the domestic, commercial and public sectors. These are fairly uncertain due to lack of data. Domestic emissions are around 15% of the non-LUCF total. As a proportion of UK domestic emissions they are 9%, which is consistent with the population.

Around 1.5% of non-LUCF emissions arise from oil and gas fugitives, mainly from flaring at terminals. Flaring has fallen by 65% over the period.

Industrial processes produce emissions from non-combustion sources such as the use of limestone in cement and glass making. The largest contribution is from cement with smaller emissions from glass and aluminium production. Together these processes emitted around 1% of the non-LUCF total in 1999. Since 1990 emissions from iron and steel processes have become negligible resulting in a 52% reduction in these sources.

Carbon dioxide emissions from waste incineration are not significant

Over the period the total non-LUCF emission has fallen by 5%.

3.2 METHANE

Unlike carbon dioxide, fuel combustion is not the predominant source of methane. The major sources are waste disposal, coal mining, leakage from the gas distribution system and agriculture. Emissions of methane are shown in Figure 2. Total emissions are declining and have fallen by 18% from 1990 to 1999.

The largest source of methane emissions in Scotland is agriculture. Emissions arise from enteric fermentation in livestock and the treatment of their wastes. Around 56% of Scottish emissions arise from agriculture with cattle responsible for 39%. Emissions are dependent on the numbers of livestock and have fallen by 2% over the period resulting from a small decline in cattle and sheep numbers. Scotland accounts for around 16% of UK agricultural emissions.

The next largest source of methane is waste disposal. This contributes around 24% to Scotland's emissions and is overwhelmingly landfill methane with a small contribution from wastewater treatment. The landfill emission is around 9% of UK landfill emissions which is consistent with the respective populations. Estimates were based on data on disposals of municipal solid waste and sewage sludge in Scotland but using UK data for their composition. Also it was assumed that the degree of methane recovery from Scottish landfills reflected that of the UK. Landfill emissions have fallen by 35% because of increasing use of methane recovery systems, though this reduction assumes the UK trend. Emissions from wastewater treatment are estimated to be

around 8% of UK wastewater treatment emissions. They have increased significantly since 1998 when sea dumping ended and other disposal routes were adopted

The category fugitive emissions from fuels reports emissions of methane from coal mining, the oil and gas industry and natural gas distribution. The combined emission is around 16% of the Scottish total. This is a lower proportion compared with the total of England, Scotland, Wales and Northern Ireland where fugitives are around 28% of the total. This is a result of the greater contribution of coal mining and leakage from the gas transmission system elsewhere in the UK. Of these emissions, those from coal mining contributed 6%, oil and gas terminals 0.8% and natural gas distribution 10% of the Scottish total. Coal mining emissions have declined by 35% over the period due to the decline in the coal industry. Terminal emissions have decreased by 82% over the period though the estimates for 1990 are very uncertain. Gas leakage from the gas transmission system is reducing as the mains and services are renewed. The estimate of gas leakage from the gas transmission system is based on Transco data. This estimate is uncertain since leakage is not directly related to gas throughput, and it assumes that changes in the Scottish system reflect those of the UK. The reduction in gas leakage between 1990 and 1999 was around 8%.

Fuel combustion emissions of methane are not important and only account for 4.4%. Most of these emissions are from domestic coal combustion.

3.3 NITROUS OXIDE

Emissions of nitrous oxide arise from a range of diverse sources including, combustion, agriculture and chemical processes. Emissions are uncertain, particularly those from agriculture.

Figure 3 shows emissions of nitrous oxide for 1990 and 1999 broken down by major IPCC source category. Total emissions were around 12% of the UK in 1999 and have declined by 10% since 1990.

Of the total emission of 17 kt in 1999, around 14 kt of this was from agriculture. Most of these were emissions arising from the category agricultural soils as a result of processes in the soil arising from (in order of magnitude):

- synthetic fertiliser application
- leaching of fertiliser N to ground and surface water
- wastes from grazing animals
- manure used as fertiliser
- ploughing in crop residues
- atmospheric deposition of NH_3 and NO_x
- improved grass
- cultivation of legumes
- histosols (i.e. high organic content soils)
- field burning (discontinued in 1993)

A relatively small proportion (0.8 kt) is emitted from the treatment of agricultural wastes. Scottish agricultural emissions are around 15% of UK agricultural emissions and have fallen by around 10% since 1990.

The remaining 2.5 kt (15%) of nitrous oxide emissions result from fuel combustion. Just under half of this is from road transport with the remainder arising from stationary combustion - mainly combustion in power generation and industry. Whilst small, road transport emissions have risen by a factor of 4 over the period. This is a result of the increasing use of catalytic converters on cars.

In 1990 around 1.3 kt of nitrous oxide were emitted from a nitric acid plant in Leith, however by 1995 this had been dismantled and moved to Dublin. This is the major component of the reduction in emissions.

3.4 HYDROFLUOROCARBONS

Total emissions of HFCs were 6% of the UK total (as CO_2 equivalent) in 1999. The main sources are aerosols and refrigeration. Emissions arise due to losses from refrigeration and air conditioning equipment during its manufacture and lifetime and these account for around 67% of HFC emissions (as CO_2 equivalent). The category aerosols includes mainly industrial aerosols and also medical use in metered dose inhalers. These account for 32% of HFC emissions (as CO_2 equivalent). The remaining emission source, fire fighting was negligible. The total emission has increased from virtually zero in 1990.

3.5 PERFLUOROCARBONS

The largest source of perfluorocarbons in Scotland is consumption by the electronics industry, which contributed around 84% of the total Scottish PFC emission (as CO_2 equivalent) in 1999. Electronics production is concentrated in Scotland and contributes around 52% of UK electronics emissions and 32% of the UK PFC total (as CO_2 equivalent). Aluminium production also makes an important contribution accounting for 14% of Scotland's PFC emissions (as CO_2 equivalent) and 18% of UK aluminium production PFC emissions. The remaining sources are fire extinguishing systems, refrigeration and leakage from the soles of certain brands of training shoes. Overall emissions are 38% of the UK total (as CO_2 equivalent).

3.6 SULPHUR HEXAFLUORIDE

The main source of sulphur hexafluoride is emissions from the electronics industry which accounted for 24% of the total emission for Scotland in 1999. Other emission sources are leakage from the soles of certain brands of training shoes and leakage from electrical switchgear used in power transmission. Overall emissions are 7% of the UK total.

4. Emissions in Wales

4.1 CARBON DIOXIDE

Figure 1 shows emissions of carbon dioxide for 1990 to 1999 broken down by major IPCC source category. Total Welsh emissions were around 8% of the UK total in 1999. Welsh emissions increased by 1.3% from 1990 to 1999.

The largest source is Energy Industries, which includes power generation, refineries and solid fuel transformation processes. Electricity generation contributed around 19% of the total Welsh carbon dioxide emission in 1999, which is lower than the UK proportion of 26%. The mix of generation capacity is different from the rest of the UK, and there is a higher proportion of nuclear stations and gas fired CCGTs. The remaining fossil fuel generation is from a conventional coal station. Emissions in Electricity Generation have decreased by 27% since 1990 compared with a fall of 29% in UK emissions over the same period (1990 to 1999). This is explained by reductions in fuel consumption and hence electricity production at the coal fired station at Aberthaw and the closure of the oil fired station at Pembroke. This is partly offset by the opening of a 528 MW combined cycle gas turbine (CCGT) at Deeside in 1994 and a 1420 MW CCGT at Connahs Quay in 1996. Power generation emissions in Wales are around 6% of UK power generation emissions.

Petroleum refining constitutes a larger proportion of Welsh emissions at 6% compared with 3.4% for the UK. The other energy emissions are mostly combustion emissions from coke ovens and solid fuel plant and account for 2% of the Welsh carbon dioxide total emission. There are no significant emissions from oil and gas production.

Combustion emissions from Manufacturing Industries and Construction account for around 35% of the Welsh total compared with 16% for the UK. The high contribution from industry can be explained by the high concentration of iron and steel plant in Wales. This accounts for 47% of UK Iron and Steel combustion emissions. The other industry category is around 5% of the UK 'other industry' total. Iron and Steel combustion emissions have increased by 42% over the period. This estimate is based on estimates of both fuel consumption and iron and steel production.

Road transport is the largest single source after power generation and iron and steel, and comprises around 13% of the total Welsh carbon dioxide emission. Its contribution to UK road transport emissions is 4.6%, which is consistent with Wales' population (5% of UK population). The estimates for 1995, 1998 and 1999 are rather uncertain since Welsh road fuel sales data are unavailable after 1993. Hence it was necessary to extrapolate from England/Wales data. The estimate was found to be consistent with estimates produced from Welsh vehicle km data. The emission has risen by 8% over the period which is similar to the UK.

Other combustion emissions arise from the domestic (Residential), commercial and public sectors. These are fairly uncertain due to lack of data. Domestic emissions are around 11% of

the Welsh total. As a proportion of UK domestic emissions they are 5% which is consistent with the relative population sizes.

Oil and gas fugitive emissions are largely absent however there are some fugitive emissions from coking and solid fuel production. These result mainly from the flaring of coke oven gas (Solid Fuel Transformation) and account for around 2% of the total Welsh emission.

Data are calculated and presented in this report for emissions and removals of carbon dioxide from Land Use Change and Forestry. Emissions of carbon dioxide (*excluding removals*) from Land Use Change and Forestry (LUCF) constitute around 2% of the total Welsh emission and contribute around 6% of the UK LUCF Emission. Most of this emission arises from the source 5D CO_2 Emissions and Removals from Soils. A carbon sink of -1.0 Mt CO_2 arises from 5A Changes in Forests and Other Woody Biomass which is of similar order to the LUCF emission. These emissions show little change over the period (1990 carbon dioxide removal -1.155 Mt CO_2; 1999 removal -1.001 Mt CO_2).

Industrial processes also produce emissions from non-combustion sources such as the use of limestone in cement and glass making. In Wales the largest contribution is from the Iron and Steel Industry from a range of sources including limestone use in blast furnaces, flaring of blast furnace gas and electric arc furnaces. Other industrial processes include cement, aluminium and glass production. Together these processes emitted around 5% of the Welsh total in 1999. The Welsh industrial process emission is around 17% of the UK on account of the high proportion of iron and steel and aluminium production in Wales.

There are no municipal waste incinerators in Wales.

4.2 METHANE

Unlike carbon dioxide, fuel combustion is not the predominant source of methane. The major sources are agriculture, waste disposal, coal mining and leakage from the gas distribution system. Emissions of methane are shown in Figure 2. Total emissions are declining and have fallen by 21% from 1990 to 1999.

The largest source of methane emissions in Wales is agriculture. Emissions arise from enteric fermentation in livestock and the treatment of their wastes. Around 67% of Wales' emissions arise from agriculture with cattle and sheep contributing respectively 36% and 27% to the Welsh total. Emissions are dependent on the numbers of livestock and were fairly constant over the period with slight decreases in cattle numbers but increases in sheep. Wales accounts for around 15% of UK agricultural emissions.

The next largest source of methane is waste disposal. This contributes around 16% to Wales' emissions and is overwhelmingly landfill methane with a small contribution from wastewater treatment. The landfill emission is around 5% of UK landfill emissions which is consistent with the respective populations. Estimates were based on data on disposals of municipal solid waste and sewage sludge in Wales but using UK data for their composition. Also it was assumed that the degree of methane recovery on Welsh landfills reflected that of the rest of the UK. On this basis, landfill emissions have fallen by 37% because of increasing use of methane recovery

systems reflecting the UK trend. Emissions from Welsh wastewater treatment are around 3% of UK emissions and are dependent on the data on sewage disposals and disposal routes used.

The category fugitive emissions from fuels reports emissions of methane from coal mining, coke production and natural gas distribution. The combined emission is around 12% of the Welsh total. This is a lower proportion compared with the total of England, Scotland, Wales and Northern Ireland where fugitive emissions are around 28% of the total. This is a result of the greater contribution of coal mining, oil and gas production and leakage from the gas transmissions system elsewhere in the UK. Of these fugitive emissions, coal mining contributes 4%, coking (solid fuel transformation) 0.1% and natural gas distribution 8% to the Welsh total methane emission. Coal mining emissions have declined by 82% over the period due to the decline in the coal industry. Gas leakage from the gas transmission system is reducing as the mains and services are renewed.

Fuel combustion activitiess are not an important source of methane. Altogether they account for around 4% of the total. Most of this comes from sintering in the iron and steel industry and domestic combustion of coal and anthracite.

4.3 NITROUS OXIDE

Emissions of nitrous oxide arise mainly from agriculture and combustion. Emissions are uncertain, particularly those from agriculture.

Figure 3 shows emissions of nitrous oxide for 1990 to 1999 broken down by major IPCC source category. Total Welsh emissions were around 9% of the UK in 1999 and have increased by 8% since 1990.

Of the total Welsh emission of 12.1 kt in 1999, around 10.2 kt of this was from agriculture. Most of these were emissions arising from the category agricultural soils as a result of processes in the soil arising from (in order of magnitude):

- wastes from grazing animals
- leaching of fertiliser N to ground and surface water
- synthetic fertiliser application
- manure used as fertiliser
- atmospheric deposition of NH_3 and NO_x
- ploughing in crop residues
- improved grass
- cultivation of legumes
- histosols (i.e. high organic content soils)
- field burning (discontinued in 1993)

A relatively small proportion (0.5 kt) is emitted from the treatment of agricultural wastes (Manure Management). Welsh agricultural emissions are around 11% of UK agricultural emissions and Welsh emissions have increased by 2.2% since 1990.

The remaining 1.7 kt (14% of Welsh total) of nitrous oxide emissions result from fuel combustion activities. The main sources are power generation, road transport and manufacturing

industry. Whilst small (0.76 kt), road transport emissions have risen by a factor of nearly 5 over the period. This is a result of the increasing use of catalytic converters on cars.

4.4 HYDROFLUOROCARBONS

In 1999 the total HFC emission in Wales was 3% of the UK HFC total (as CO_2 equivalent). Refrigeration is the largest source and contributes 75% to the total Welsh emission (as CO_2 equivalent). Here emissions arise due to losses from refrigeration and air conditioning equipment during its manufacture and lifetime. Aerosols contribute 23% to the total emission (as CO_2 equivalent). The category aerosols includes mainly industrial aerosols but also medical use in metered dose inhalers. The remaining emission source; fire fighting was negligible. The total emission has increased from virtually zero in 1990.

4.5 PERFLUOROCARBONS

The largest emission source of perfluorocarbons in Wales is the aluminium industry, which contributed around 62% of the total Welsh PFC emission (as CO_2 equivalent) in 1999. This is around 31% of UK aluminium emissions. The electronics industry also makes an important contribution accounting for 10% of Wales' PFC emission (as CO_2 equivalent) and 9% of UK electronics emissions. The remaining sources are fire extinguishers, refrigeration and leakage from the soles of certain brands of training shoes. Overall, Welsh PFC emissions are 16% of the UK PFC total (as CO_2 equivalent). Emissions of PFC have decreased by 74% from 1990 to 1999 mainly as a result of improved control measures in the aluminium industry.

4.6 SULPHUR HEXAFLUORIDE

Welsh emissions of sulphur hexafluoride were 6% of the UK total in 1999. The main source of emissions is from use as a cover gas in magnesium production. These account for around 56% of total Welsh emissions and comprise 8% of the UK magnesium production emission. The next largest sources of sulphur hexafluoride are leakage from the soles of certain brands of training shoes, emissions from the electrical switchgear used in electricity transmission and emissions from the electronics industry. Together these account for 44% of the total Welsh emission.

5. Emissions in Northern Ireland

5.1 CARBON DIOXIDE

Figure 1 shows emissions of carbon dioxide for 1990 and 1999 broken down by major IPCC source category. Total emissions in Northern Ireland were around 3% of the UK total in 1999 and have decreased by 7% since 1990.

The largest source is Energy Industries which is entirely power generation as there are no refineries, collieries, solid fuel transformation plant or oil and gas processing. Electricity generation contributed around 38% of the total emission, which is higher than the UK proportion of 26%. The mix of generation capacity is quite different from the rest of the UK and from 1990 to 1995 consisted entirely of coal and oil fired stations. Since 1996, the largest power station in Northern Ireland has been converted from oil firing to operate on natural gas. The lack of nuclear and renewable generation up to 1996, together with the lack of natural gas contributed to the proportionately high emission from electricity generation. Moreover, the non-availability of natural gas led to a proportionately higher consumption of electricity than in the rest of the UK, also increasing emissions. The emission of CO_2 per unit energy produced is lower for natural gas than other fossil fuels. Natural gas has been supplied to some industrial, commercial and domestic users since 1999. Emissions from electricity generation increased by 16% over the period but have declined by 7% since 1995. The recent decline is largely due to the conversion to natural gas.

Combustion emissions from Manufacturing Industries and Construction account for around 12% of the total Northern Ireland carbon dioxide emission compared with 16% for the UK. There is no iron and steel production so the category is entirely other industry. The Other industry Category is around 3% of the UK Other Industry total, and has declined by about 6% from 1990 to 1999.

Road transport is the largest single source after power generation and residential, and comprises around 10% of the Northern Ireland total carbon dioxide emission. Northern Ireland's road transport contribution to UK road transport emissions is 1.5% which is less that which would be expected from Northern Ireland's population (2.5% of the UK). In 1999 the emission had fallen by 42% from 1990 levels, contrary to the UK trend of an increase of 5% over the same period. Emissions are based on data on road fuel sales in Northern Ireland only and it is very likely that the figures quoted have been significantly affected by the amount of fuel used in Northern Ireland which has been purchased in the Republic of Ireland. IPCC (1997) guidelines require that carbon dioxide emissions in a country be based on fuel sales in that country, rather than fuel usage.

Other combustion emissions arise from the domestic, commercial and public sectors. Commercial and farming emissions are uncertain due to lack of data for this sector. Domestic (Residential) emissions are around 22% of the Northern Irish total and are the largest source after power generation. As a proportion of UK domestic emissions, the Northern Irish emissions are 4%, which is higher than would be consistent with the population. The reason for this is the

very limited availability of natural gas resulting in the high consumption of coal, burning oil and gas oil in the domestic sector. Northern Ireland has a proportionately higher consumption of LPG (bottled gas) than the rest of the UK, but in absolute terms this is not a significant source of carbon dioxide emissions. The high consumption of coal and oil result in a higher emission per unit energy consumed than in the rest of the UK.

The only industrial process sources of carbon dioxide are two cement plants and two glass factories, which contribute around 2.3% to the total Northern Irish emission. Waste incineration is not a significant source of CO_2.

Data are calculated and presented in this report for emissions and removals of carbon dioxide from Land Use Change and Forestry. Emissions from Land Use Change and Forestry (LUCF) (*excluding removals*) constitute around 10% of the total Northern Irish emission of carbon dioxide and contribute around 10% of the UK LUCF Emission. Around 1.01 Mt CO_2 of this emission arises from the source 5D CO_2 Emissions and Removals from Soils whilst 0.56 Mt CO_2 result from other LUCF sources. These other sources are upland drainage and peat extraction. Peat extraction results in an emission of around 0.48 Mt CO_2. A carbon sink of -0.63 Mt CO_2 arises from 5A Changes in Forests and Other Woody Biomass. These LUCF emissions have fallen by around 19% over the period 1990 to 1999.

5.2 METHANE

Unlike carbon dioxide, fuel combustion is not the predominant source of methane. The major sources are waste disposal and agriculture. Emissions of methane are shown in Figure 2. Total emissions show no particular trend over the period 1990 to 1999.

The largest source of methane emissions in Northern Ireland is agriculture. Emissions arise from enteric fermentation in livestock and the treatment of their wastes. Around 82% of Northern Ireland's emissions arise from agriculture with cattle responsible for 70%. Emissions are dependent on the numbers of livestock and have increased by 8% over the period (1990 to 1999) resulting from an increase in cattle and sheep numbers. Northern Ireland accounts for around 12% of UK agricultural emissions.

The next largest source of methane is waste disposal (Solid Waste Disposal on Land). This contributes around 13% to Northern Ireland's emissions and is overwhelmingly landfill methane with a small contribution from wastewater treatment. The landfill emission is around 2.8% of UK landfill emissions which is consistent with the respective populations. Estimates were based on data on disposals of municipal solid waste and sewage sludge in Northern Ireland but using UK data for their composition. Also it was assumed that the degree of methane recovery on Irish landfills reflected that of the rest of the UK. On this basis landfill emissions have fallen by 35% because of increasing use of methane recovery systems reflecting the UK trend. Emissions from wastewater treatment are around 3% of UK emissions and are dependent on the data on sewage disposals used.

Combustion emissions are not a large source of methane. Altogether they account for around 4% of the total Northern Irish Emission. Most of this comes from the domestic combustion of coal and anthracite.

5.3 NITROUS OXIDE

Emissions of nitrous oxide arise from a range of diverse sources including, combustion, agriculture and chemical processes. Emissions are highly uncertain, particularly those from agriculture.

Figure 3 shows emissions of nitrous oxide for 1990 to 1999 broken down by major IPCC source category. Total emissions from Northern Ireland were around 8% of the UK emission in 1999 and have increased by 17% from 1990 to 1999.

Of the total emission of 11.1 kt in 1999, around 8.1 kt of this was from agriculture. Most of these were emissions from the source category agricultural soils as a result of processes in the soil arising from (in order of magnitude):

- leaching of fertiliser N to ground and surface water
- synthetic fertiliser application
- wastes from grazing animals
- manure used as fertiliser
- atmospheric deposition of NH_3 and NO_x
- ploughing in crop residues
- improved grass
- cultivation of legumes
- histosols (i.e. high organic content soils)
- field burning (discontinued in 1993)

A relatively small emission (0.7 kt) comes from the treatment of animal wastes (Manure Management). Agricultural emissions in Northern Ireland are around 9% of UK agricultural emissions and have increased by 6% since 1990.

Around 1.8 kt of nitrous oxide were emitted from a nitric acid plant contributing 16% to the total Northern Irish emission.

The remaining 1.0 kt (10%) of nitrous oxide emissions result from fuel combustion. Around 0.5 kt of this arises from road transport with the remainder arising from stationary combustion spread across all sectors. Whilst small, road transport emissions have risen by a factor of 4 over the period. This is a result of the increasing use of catalytic converters on cars.

5.4 HYDROFLUOROCARBONS

Total emissions of HFCs in 1999 were 2% of the UK Total (as CO_2 equivalent). The largest source sources was refrigeration (including air conditioning) contributing around 68% of the Northern Ireland HFC total. Emissions arise from losses from refrigeration and air conditioning equipment during its manufacture and lifetime. The category aerosols, includes mainly industrial aerosols but also medical use in metered dose inhalers and accounts for around 31% of the Northern Ireland total. The remaining emission source, fire fighting was negligible. The total emission has increased from virtually zero in 1990 to 115 kt CO_2 equivalent in 1999.

5.5 PERFLUOROCARBONS

Emissions of PFCs in Northern Ireland are very small. Overall emissions are 0.2% of the UK total (as CO_2 equivalent). The main sources are refrigeration and the gas filled soles of training shoes. The remaining emission from fire extinguishing systems is negligible. The use of PFCs in the electronics industry in Northern Ireland is not significant.

5.6 SULPHUR HEXAFLUORIDE

Overall emissions were 1.2% of the UK total in 1999. The main sources of sulphur hexafluoride emissions are leakage from the electrical switching gear used in electricity transmission and the soles of certain brands of training shoes. The use of SF_6 in the electronics industry in Northern Ireland is negligible.

6. Unallocated Emissions

These emissions arise from

- offshore oil and gas installations,
- fishing,
- coastal shipping,
- domestic aviation
- naval vessels
- military aircraft.

It was felt that they could not be allocated to the regions since they pertain to the UK as a whole. As a proportion of the 1999 UK total they account for carbon dioxide 5%; methane 2.5% and nitrous oxide 1%. There were no unallocated emissions of halocarbons and sulphur hexafluoride. Details of unallocated emissions are given on the CD ROM attached to this report.

7. Availability of Data

In order to estimate a complete greenhouse gas inventory for each region, it would be necessary to have a complete set of activity data for each region to the same level of detail as that used for the UK Inventory. However, a complete set of regional data was not available. The precise availability of data is discussed in Appendix 1. Generally, sufficient data were available for the following sectors:

- Agriculture (DEFRA, previously MAFF)
- Land Use Change and Forestry (Centre for Ecology and Hydrology)
- Waste: although of poor quality, sufficient regional data were available
- Industrial Processes: For most of these some sort of regional data was available from producers and trade associations.

In the case of fuel combustion the availability of data was variable. Only Northern Ireland produces a complete annual set of fuel statistics, though this only gives sectional consumption for coal and total consumption for oil products. Up until 1994, the Welsh Office produced a fairly detailed set of fuel statistics based on DTI estimates. However this has been discontinued since the privatisation of the energy industries, owing to the problems of reporting potentially commercial data. Scotland does not publish fuel statistics though some data on coal production and gas consumption in 1990 was provided for this work. The Digest of UK Energy Statistics (DTI, 2000) reports some regional data such as coal production, domestic gas consumption in and consumption of liquid fuels. The liquid fuel data consist of totals of different types of liquid fuel for Northern Ireland, Scotland and England & Wales combined. Earlier editions of the Digest of UK Energy Statistics report regional gas consumption. Transco was able to provide a set of gas sales statistics disaggregated by region and consumer size. Phoenix Natural Gas provided natural gas consumption in Northern Ireland diaggregated by type of consumer. The steel industry is well covered by Iron and Steel Industry Statistics (ISSB, 2000) though in the latest editions some of this data are not reported. Equivalent data are however available on request. The ISSB data deal with primary iron and steel production but excludes most secondary processes. Data on power generation were obtained from the major power generators and regional cement production capacity data from the British Cement Association. Carbon emissions data were available for refineries from UKPIA and the Environment Agency's Pollution Inventory and detailed data were available on the offshore industry from UKOOA for 1995, 1998 and 1999. Hence the main areas where data had to be estimated were:

- Domestic: coal; oil
- Miscellaneous/Commercial: coal/oil
- Agriculture: coal/oil
- Other Manufacturing Industry excluding cement and autogeneration (i.e. electricity generation by industry for its own consumption)

Various surrogates were used to estimate these sources. Emissions from commercial and other manufacturing industry were estimated from the Science Policy Research Unit (SPRU)

database of boiler capacities, which reports boiler size, fuel type and location for the period 1992-94. Agricultural fuel combustion emissions were based on employment statistics. Some coal consumption data were collected for England and Wales in 1995, 1998 and 1999 from coal producers. Some of the domestic oil use was estimated based on population, though for Northern Ireland, Housing Survey data were used.

For England and Scotland around 16% of the 1999 CO_2 emissions occur in sources where data had to be estimated from surrogates. For Wales and Northern Ireland the proportions are 11% and 42% respectively. The high proportion for Northern Ireland is explained by the absence of natural gas and iron and steel sources for which good quality data are available. Northern Ireland does however have good data for total fuel consumption, hence whilst the categorisation of emissions may be poor, the total estimate is of good quality. The low figure for Wales is explained by the large contribution from the steel industry.

A number of changes have been made to the estimates since the earlier study (Salway *et al*, 2000). Many of these arise from revisions made to the UK Inventory. The most significant are:

- Emissions from power generation in England and Wales in 1990 and 1998 have been revised due to improved data on gas fired and coal generation. Emissions in Wales have increased as a result.
- The emissions from glass production in Wales and Northern Ireland have been revised based on more recent data on glass plant capacity.
- There has been a large reduction in CO_2 emissions from soils in Scotland (21774 to 11190 kt CO_2 in 1998). This arises from revisions in the soil carbon density data used for Scotland - see Appendix 1.10.
- The methodology for estimating N_2O and CH_4 emissions from road transport has been revised to remove anomalies arising from Northern Ireland road fuel consumption.
- The consumption of coal by cement and lime kilns has been revised in the UK Inventory. This has affected the distribution of coal consumption by manufacturing industry.
- Emissions from SF_6 from electrical insulation have been revised upwards in 1998 and 1999. The emission reported is around 13 tonnes SF_6 higher than the UK estimate. This arises from more recent estimates from Enviros March. The effect on UK GWP is negligible.

8. Uncertainty in the Inventories

A recent study (Eggleston *et al*, 1998) estimated the uncertainty in the UK Inventory. These estimates have been revised to account for changes in the 1999 inventory (Salway *et al*, 2001) and are given in Table 8.1

As a result of the activity data gaps in the devolved regional inventories, the regional estimates will be more uncertain. A very approximate estimate of the uncertainties in the totals was estimated using a Monte Carlo simulation. It is difficult to estimate the uncertainties in some of the activity data used in the regional inventories due to the data gaps since it is unknown how closely the surrogate data reflect actual fuel consumption. Hence, in the simulation it was necessary to make fairly speculative assumptions on the uncertainties in the regional activity data. The approach adopted is discussed in Appendix 1. The uncertainty estimates are reported in Table 8.1. The N_2O distribution is heavily skewed, so that 2.5% and 97.5% confidence limits are quoted.

Table 8.1. Estimated Uncertainties[2] in the Regional Inventories in 1999.

		England	Scotland	Wales	N Ireland	UK
CO_2	±%	2	11	5	4	2
Methane	±%	23	19	17	18	20
N_2O	Lower kt	21	3	2	1	33
	Upper kt	341	73	53	45	532
HFC	±%	25[1]				25
PFC	±%	19[1]				19
SF6	±%	13[1]				13
GWP	±%	16	23	24	38	17

1 Uncertainty is assumed to be equal to that of the UK estimate
2 Uncertainty is defined as ± 2×(standard deviation)/mean %

The high uncertainty in the Scottish CO_2 inventory reflects the large contribution made by land use change and forestry. This uncertainty has reduced somewhat owing to the downward revision in the Scottish land use change and forestry estimates. The high uncertainty in Northern Ireland is a consequence of the large contribution of methane and agricultural N_2O. The high uncertainty in Wales is a consequence of the relatively high uncertainty in CO_2 emissions and significant contributions from methane and agricultural N_2O. The low uncertainty for England is a consequence of the relatively low contributions from high uncertainty sources: namely land use change and forestry and agricultural N_2O.

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10. Summary Tables

Detailed summaries of the greenhouse gas emissions for the years 1990, 1995, 1998 and 1999 for the UK and all constituent countries are shown in Tables 10.1 to 10.3. They are reported as GWP weighted equivalent mass of carbon (Table 10.1); GWP weighted equivalent mass of CO_2 (Table 10.2) and the mass of each gas emitted (Table 10.3).

Table 10.1 Summary of Greenhouse Gas Emissions as GWP Weighted Equivalent Mass of Carbon (MtC)

Greenhouse Gas		England	Scotland	Wales	Northern Ireland	Un - allocated	United Kingdom
CO_2	1990 Emission	124.2	17.2	11.1	4.8	7.1	164.4
	1995 Emission	113.7	16.9	10.7	5.0	7.4	153.7
	1998 Emission	112.5	17.0	11.2	4.5	7.7	152.8
	1999 Emission	109.9	16.6	11.2	4.5	7.2	149.4
Methane	1990 Emission	16.0	2.1	1.6	0.9	0.6	21.0
	1995 Emission	13.0	1.9	1.3	0.9	0.5	17.5
	1998 Emission	11.5	1.8	1.3	0.9	0.4	15.8
	1999 Emission	10.9	1.7	1.2	0.9	0.4	15.1
N_2O	1990 Emission	14.8	1.6	0.9	0.8	0.1	18.3
	1995 Emission	11.9	1.5	1.0	0.9	0.1	15.4
	1998 Emission	12.3	1.5	1.1	0.9	0.1	15.9
	1999 Emission	8.2	1.5	1.0	0.9	0.1	11.7
HFC	1990 Emission	3.1	0.0	0.0	0.0	0.0	3.1
	1995 Emission	4.1	0.03	0.02	0.008	0.0	4.1
	1998 Emission	5.3	0.09	0.05	0.03	0.0	5.5
	1999 Emission	1.5	0.1	0.05	0.03	0.0	1.7
PFC	1990 Emission	0.44	0.07	0.11	0.00	0.00	0.62
	1995 Emission	0.13	0.14	0.03	0.00	0.0	0.3
	1998 Emission	0.08	0.07	0.03	0.00	0.0	0.2
	1999 Emission	0.08	0.07	0.03	0.00	0.00	0.18
SF_6	1990 Emission	0.16	0.02	0.02	0.00	0.00	0.20
	1995 Emission	0.26	0.03	0.02	0.00	0.00	0.31
a	1998 Emission	0.37	0.03	0.03	0.01	0.00	0.44
a	1999 Emission	0.38	0.03	0.03	0.01	0.00	0.45
Total	1990 Emission	158.6	20.9	13.7	6.5	7.8	207.6
	1995 Emission	143.0	20.4	13.0	6.7	8.0	191.3
	1998 Emission	142.0	20.4	13.6	6.3	8.2	190.6
	1999 Emission	130.9	19.9	13.6	6.3	7.7	178.5

Table 10.2 Summary of Greenhouse Gas Emissions as GWP weighted Equivalent Mass of CO_2 (Mt)

Greenhouse Gas		England	Scotland	Wales	Northern Ireland	Unallocated	United Kingdom
CO_2	1990 Emission	455.4	62.9	40.7	17.7	26.1	602.8
	1995 Emission	416.8	61.9	39.3	18.3	27.2	563.4
	1998 Emission	412.3	62.2	41.0	16.5	28.2	560.3
	1999 Emission	402.9	60.9	41.2	16.4	26.4	547.8
Methane	1990 Emission	58.5	7.5	5.8	3.2	2.0	77.1
	1995 Emission	47.5	7.0	4.8	3.1	1.7	64.1
	1998 Emission	42.0	6.6	4.6	3.3	1.5	58.0
	1999 Emission	40.0	6.2	4.6	3.1	1.4	55.3
N_2O	1990 Emission	54.1	6.0	3.5	3.0	0.4	66.9
	1995 Emission	43.8	5.4	3.5	3.1	0.5	56.3
	1998 Emission	45.0	5.4	3.9	3.4	0.5	58.2
	1999 Emission	29.9	5.3	3.7	3.4	0.5	42.9
HFC	1990 Emission	11.4	0.0	0.0	0.0	0	11.4
	1995 Emission	15.0	0.1	0.06	0.03	0	15.2
	1998 Emission	19.6	0.3	0.2	0.1	0	20.2
	1999 Emission	5.5	0.4	0.2	0.1	0	6.2
PFC	1990 Emission	1.61	0.26	0.41	0.007	0	2.28
	1995 Emission	0.48	0.51	0.10	0.0010	0	1.09
	1998 Emission	0.30	0.24	0.11	0.0012	0	0.65
	1999 Emission	0.31	0.26	0.11	0.0012	0	0.68
SF_6	1990 Emission	0.57	0.07	0.07	0.01	0	0.72
	1995 Emission	0.95	0.10	0.07	0.01	0	1.13
a	1998 Emission	1.37	0.12	0.10	0.02	0	1.61
a	1999 Emission	1.40	0.11	0.10	0.02	0	1.63
Total	1990 Emission	581.6	76.8	50.4	23.9	28.5	761.2
	1995 Emission	524.5	75.0	47.8	24.6	29.4	701.3
	1998 Emission	520.6	74.9	49.9	23.3	30.2	698.9
	1999 Emission	480.0	73.1	49.9	23.1	28.3	654.5

Table 10.3 Summary of Greenhouse Gas Emissions (Mass gas emitted)

Greenhouse Gas			England	Scotland	Wales	Northern Ireland	Unallocated	United Kingdom
CO_2	1990 Emission	Mt	455.4	62.9	40.7	17.7	26.1	602.8
	1995 Emission	Mt	416.8	61.9	39.3	18.3	27.2	563.4
	1998 Emission	Mt	412.3	62.2	41.0	16.5	28.2	560.3
	1999 Emission	Mt	402.9	60.9	41.2	16.4	26.4	547.8
Methane	1990 Emission	Mt	2.786	0.359	0.274	0.154	0.097	3.670
	1995 Emission	Mt	2.261	0.333	0.228	0.149	0.082	3.053
	1998 Emission	Mt	2.002	0.315	0.219	0.155	0.072	2.763
	1999 Emission	Mt	1.907	0.293	0.217	0.150	0.065	2.632
N_2O	1990 Emission	Mt	0.175	0.019	0.011	0.010	0.001	0.216
	1995 Emission	Mt	0.141	0.017	0.011	0.010	0.001	0.182
	1998 Emission	Mt	0.145	0.018	0.013	0.011	0.002	0.188
	1999 Emission	Mt	0.096	0.017	0.012	0.011	0.002	0.138
HFC	1990 Emission	kt	0.973	0.000	0.000	0.000	0.0	0.973
	1995 Emission	kt	1.836	0.065	0.036	0.019	0.0	1.956
	1998 Emission	kt	3.302	0.190	0.108	0.061	0.0	3.660
	1999 Emission	kt	2.355	0.219	0.105	0.069	0.0	2.749
PFC	1990 Emission	kt	0.233	0.037	0.111	0.001	0.0	0.331
	1995 Emission	kt	0.069	0.073	0.015	0.000	0.0	0.157
	1998 Emission	kt	0.043	0.035	0.016	0.000	0.0	0.094
	1999 Emission	kt	0.045	0.037	0.015	0.000	0.0	0.098
SF_6	1990 Emission	kt	0.024	0.003	0.003	0.0004	0.0	0.030
	1995 Emission	kt	0.040	0.004	0.003	0.0004	0.0	0.047
a	1998 Emission	kt	0.057	0.005	0.004	0.001	0.0	0.067
a	1999 Emission	kt	0.058	0.005	0.004	0.001	0.0	0.068

a Emissions of SF_6 exceed the official UK total owing to more recent data on electrical insulation emissions.

Figure 1 Emissions of Carbon Dioxide

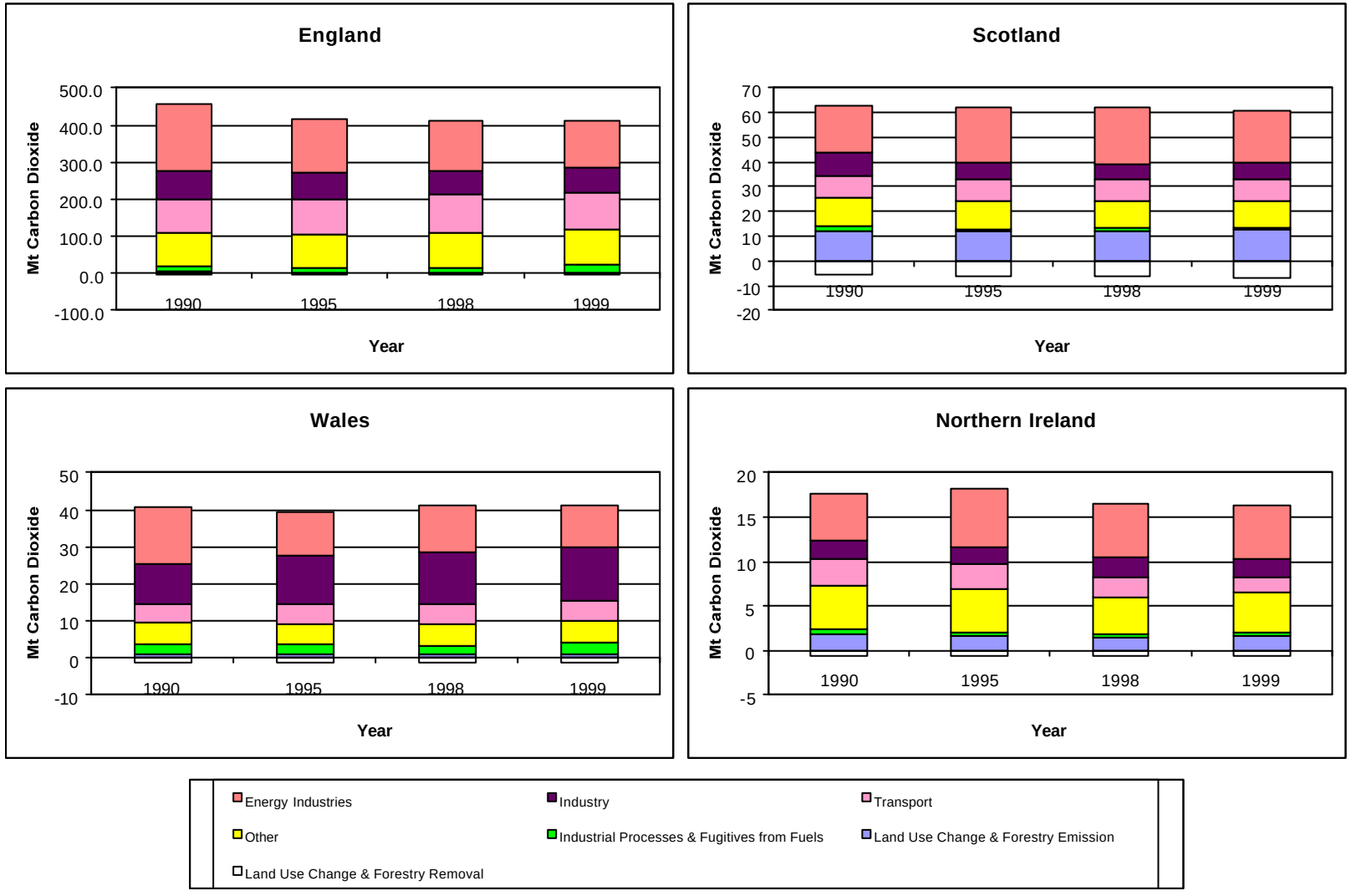

Figure 2 Emissions of Methane

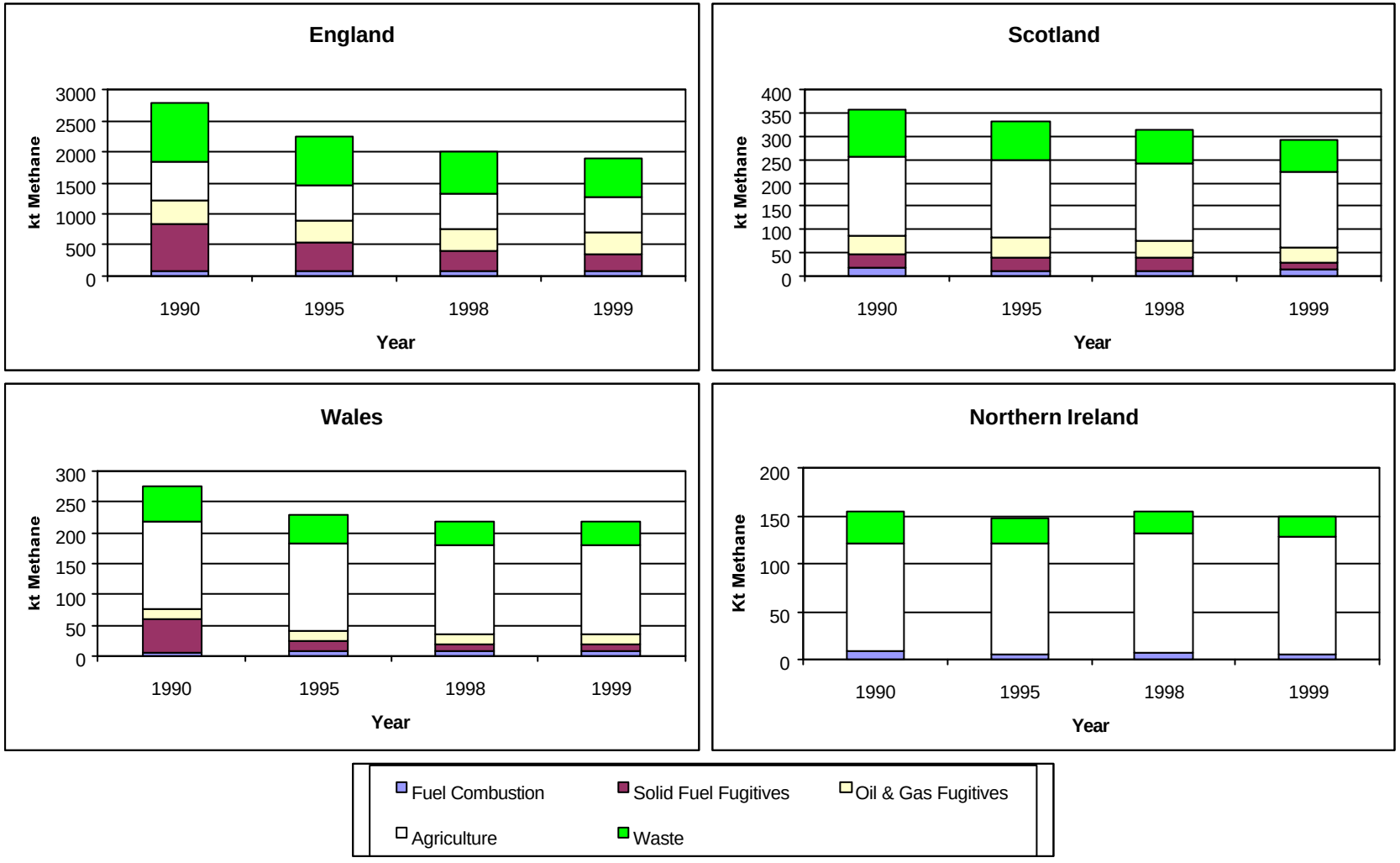

Figure 3 Emissions of Nitrous Oxide

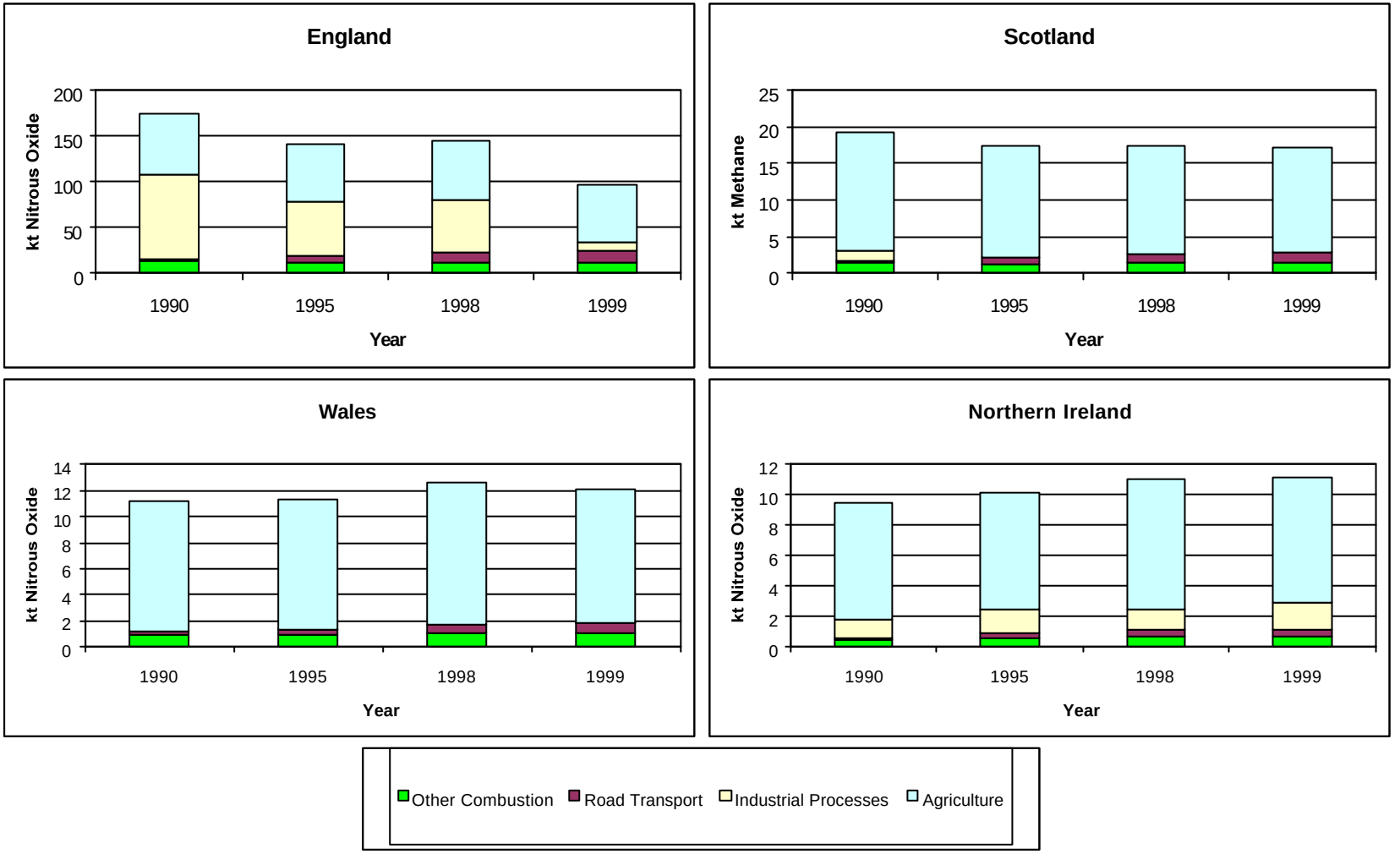

Figure 4 Emissions of HFCs

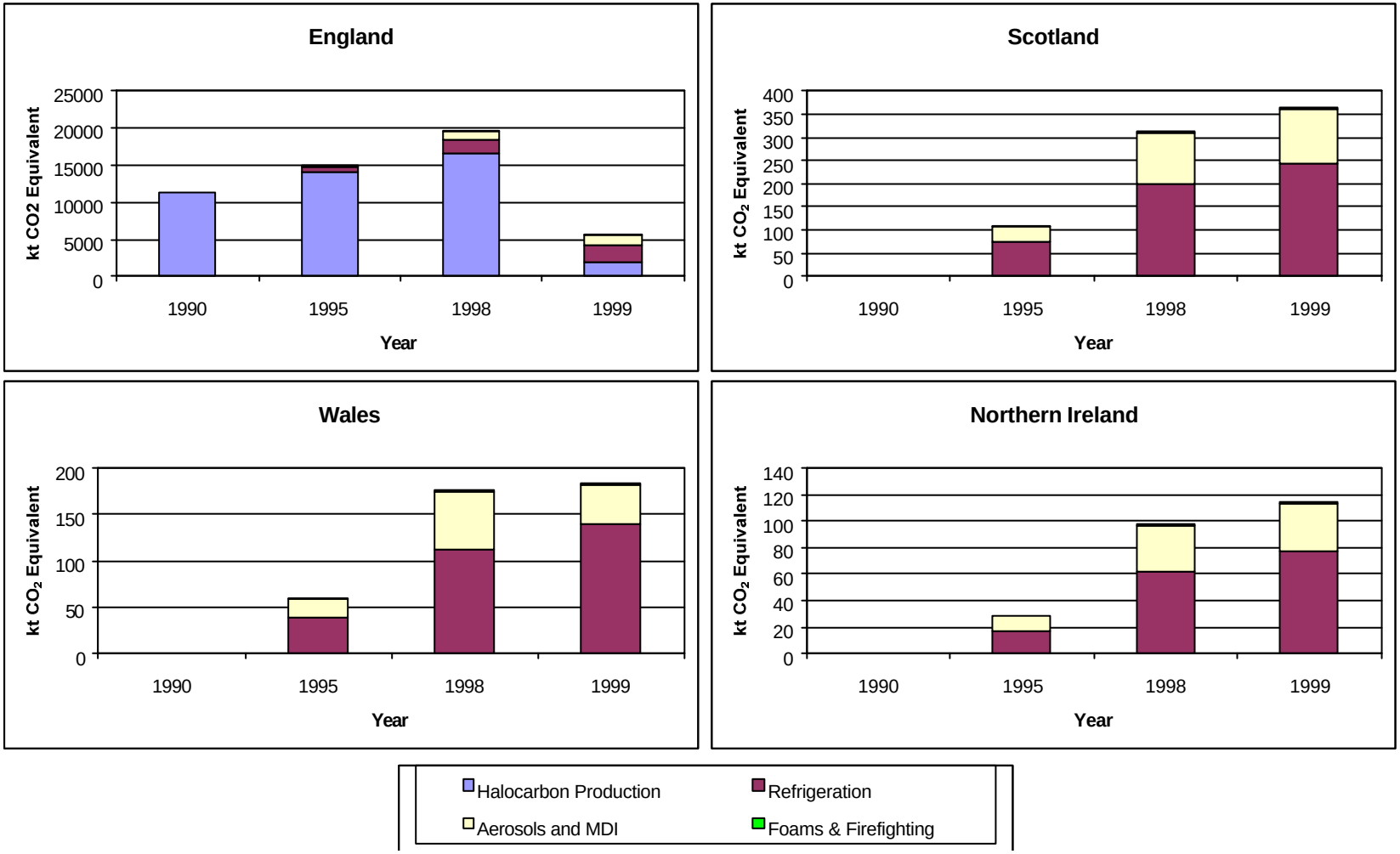

Figure 5 Emissions of PFCs

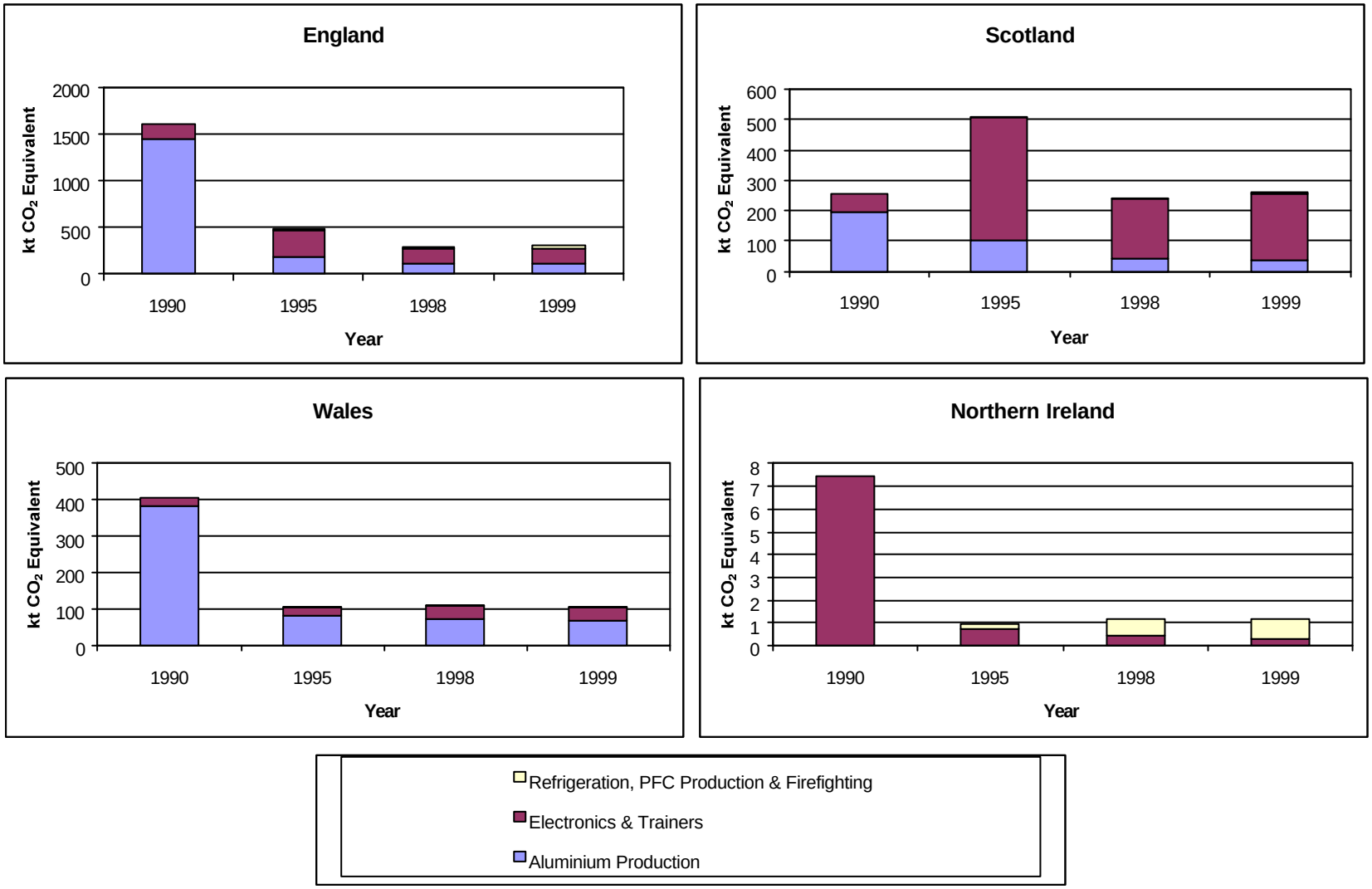

Figure 6 Emissions of SF6

Appendices

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