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Greenhouse Gas Inventories for England, Scotland, Wales and Northern Ireland: 1990 - 2000

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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, 1999 and 2000. 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 2000 UK Greenhouse Gas Inventory (Salway *et al*, 2002). 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 2000 were: England, 73.6%; Scotland, 10.9%; Wales, 8.0%; Northern Ireland, 3.2%; unallocated, 4.2% (see summary table below).

The key trends in emissions that have occurred between 1990 and 2000 for each gas and for each constituent country of the UK are as follows:

- **Carbon dioxide**: Overall UK emissions have fallen by 7.5% between 1990 and 2000, 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 33% between 1990 and 2000, with reductions occurring in waste disposal for all constituent countries.
- **Nitrous oxide**: Overall UK emissions have fallen by 35% between 1990 and 2000, 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 18% between 1990 and 2000, 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 71% between 1990 and 2000, mainly due to control measures in aluminium production in England and Wales.
- **SF_6**: Overall UK emissions have risen by 112% between 1990 and 2000, 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	124.6	17.0	11.1	4.7	7.1	164.5
	1990 Percentage	%	*75.8*	*10.3*	*6.7*	*2.8*	*4.3*	*100.0*
	2000 Emission	Mt C equiv	112.0	16.5	12.3	4.1	7.2	152.1
	2000 Percentage	%	*73.6*	*10.9*	*8.1*	*2.7*	*4.7*	*100.0*
	Change 1990/00	%	*-10.1*	*-2.6*	*10.6*	*-12.4*	*1.7*	*-7.5*
Methane	1990 Emission	Mt C equiv	15.8	2.0	1.6	0.9	0.6	20.9
	1990 Percentage	%	*75.9*	*9.8*	*7.5*	*4.2*	*2.7*	*100.0*
	2000 Emission	Mt C equiv	9.9	1.6	1.2	0.8	0.3	13.9
	2000 Percentage	%	*71.5*	*11.6*	*8.6*	*5.9*	*2.4*	*100.0*
	Change 1990/00	%	*-37.2*	*-21.2*	*-23.4*	*-6.8*	*-39.7*	*-33.4*
N_2O	1990 Emission	Mt C equiv	14.9	1.7	1.0	0.8	0.1	18.5
	1990 Percentage	%	*80.6*	*9.0*	*5.3*	*4.4*	*0.6*	*100.0*
	2000 Emission	Mt C equiv	8.6	1.4	1.0	0.9	0.1	12.0
	2000 Percentage	%	*71.9*	*11.7*	*8.0*	*7.2*	*1.1*	*100.0*
	Change	%	*-42.4*	*-16.1*	*-2.4*	*5.5*	*18.7*	*-35.4*
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*
	2000 Emission	Mt C equiv	2.3	0.11	0.06	0.04	0.0	2.5
	2000 Percentage	%	*91.7*	*4.5*	*2.3*	*1.4*	*0.0*	*100.0*
	Change 1990/00	%	*-24.9*	*NC*	*NC*	*NC*	*0.0*	*-18.1*
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*
	2000 Emission	Mt C equiv	0.08	0.07	0.03	0.00	0.00	0.18
	2000 Percentage	%	*45.6*	*38.7*	*15.6*	*0.2*	*0.0*	*100.0*
	Change 1990/00	%	*-81.1*	*0.3*	*-74.5*	*-84.4*	*0.0*	*-70.7*
SF_6 [a]	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*
	2000 Emission	Mt C equiv	0.36	0.03	0.03	0.01	0.00	0.42
	2000 Percentage	%	*85.3*	*7.3*	*6.0*	*1.3*	*0.0*	*100.0*
	Change 1990/00	%	*129.8*	*59.6*	*27.2*	*141.2*	*0.0*	*112.7*
GWP	1990 Emission	Mt C equiv	159.1	20.8	13.8	6.4	7.8	207.8
	1990 Percentage	%	*76.6*	*10.0*	*6.6*	*3.1*	*3.7*	*100.0*
	2000 Emission	Mt C equiv	133.3	19.8	14.5	5.8	7.7	181.1
	2000 Percentage	%	*73.6*	*10.9*	*8.0*	*3.2*	*4.2*	*100.0*
	Change 1990/00	%	*-16.2*	*-4.9*	*5.6*	*-8.7*	*-1.0*	*-12.8*

NC Not Calculable. Data points in 1990 are zero.

a 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 36% rise in overall UK emissions of SF_6 between 1995 and 2000.

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.

Revisions and updates to the regional inventories

Each year, the regional greenhouse inventories for England, Scotland, Wales and Northern Ireland are extended and updated.

The time series of the inventories are extended by including a new inventory year - for example, the previous report covered the years upto and including 1999; this report gives emission estimates for 1999, and includes estimates for the year 2000 also.

The inventories are updated, and therefore, the emission estimates may be revised, as each year the UK makes a number of amendments to the core energy statistics based on improved data collection or estimation techniques. Much of these core energy data are presented in the Digest of UK Energy Statistics (DUKES), which is produced by the Department for Trade and Industry. These updates to the inventory may mean that estimates of emissions for a given year, stated in this report, may differ from estimates of emissions for that given year, which were quoted in the report for the previous year. Therefore, it is not appropriate to take the figures from previous reports and compare them with the figures in this report without checking first to see whether there have been changes to the methodology used to estimate emissions, or the base data. There is normally a comment in the report to indicate where such changes have occurred.

Contacts

This work forms part of the Global Atmosphere Research Programme of the Department for Environment, Food and Rural Affairs. (Contract EPG/1/1/120). The land use change and forestry estimates were provided by the Centre for Ecology and Hydrology (Edinburgh) (Contract EPG/1/1/106)

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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 and 2001 to include 1999 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, 1999 and 2000. 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*, 2002). This report follows the convention used in Salway *et al* (2002) 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, 1999 and 2000 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 2000 for England, Scotland, Wales and Northern Ireland. Summary tables (IPCC Sectoral Table 7A) are provided for 1995, 1998, 1999 and 2000 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, 1999 and 2000 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	140-11700
PFCs	6500-9200
SF_6	23900

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

Revisions and updates to the regional inventories

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The inventories are updated, and therefore, the emission estimates may be revised, as each year the UK makes a number of amendments to the core energy statistics based on improved data collection or estimation techniques. Much of these core energy data are presented in the Digest of UK Energy Statistics (DUKES), which is produced by the Department for Trade and Industry. These updates to the inventory may mean that estimates of emissions for a given year, stated in this report, may differ from estimates of emissions for that given year, which were quoted in the report for the previous year. Therefore, it is not appropriate to take the figures from previous reports and compare them with the figures in this report without checking first to see whether there have been changes to the methodology used to estimate emissions, or the base data. There is normally a comment in the report to indicate where such changes have occurred.

2. Emissions in England

2.1 CARBON DIOXIDE

Figure 1 shows the emissions of carbon dioxide for 1990 to 2000 broken down by major IPCC source category. Total emissions of carbon dioxide in England were around 74% of the UK total in 2000 and have declined by 10% 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 29% of the total English carbon dioxide emission, which is higher than the UK proportion of 28%. 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 27% since 1990 in contrast with a fall of 16% 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 10% reduction in the English total emission over the period.

Petroleum Refining constitutes a similar proportion of English national emissions at 2.8% compared with 3.0% for the UK. Emissions in England are similar to those in 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 by 42% from 1990 to 2000 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 15% of the English total, which is similar to the UK ratio of 16%. The iron and steel industry in England accounts for 51% 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 88%, which is higher than that which would be expected from England's population. The emission has risen by 9.5% from 1990 to 2000 compared with a 6% rise for the UK. Emissions were estimated from road fuel sales data. The estimates are rather uncertain after 1993, since the only data available are for England and Wales combined. Hence it was necessary to extrapolate the English emission 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 1.7% of the total in 2000. 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 0.08% of the total English emission and contribute only around 2.3% of the UK LUCF emission. In 2000 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, 1999 and 2000. 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 2000. In order to obtain totals consistent with the UK total, this sink is reported as a negative quantity in the emissions column in 1995 and from1998 to 2000 columns. Milne (see Appendix 1.10) discusses the assumptions underlying these emissions in more detail. In 2000 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 37% from 1990 to 2000.

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 the UK landfill emission which is consistent with the respective populations (84%). 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 59%, from1990 to 2000 because of increasing use of methane recovery systems, though this reduction assumes the UK trend. Emissions from wastewater treatment are around 1.8% 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 32% of English emissions arise from agriculture with cattle responsible for 24%. Emissions from agriculture are dependent on the numbers of livestock and have fallen by 10% from 1990 to 2000 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 31% 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 26% 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 14%, natural gas distribution 17% and oil and gas terminals 0.2% of the English total. Coal mining emissions have declined by 68% from 1990 to 2000 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 2000 is around 17%.

Fuel combustion emissions of methane are not important and only account for 2% 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 72% of the UK total in 2000 and have declined by 42% since 1990.

Of the total English emission of 102 kt in 2000, around 60 kt of this was from agriculture representing around 59% 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 (2.9 kt) is emitted from the treatment of agricultural wastes (animal manure management). English agricultural emissions are around 66% of UK agricultural emissions.

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 40% 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. In 2000, the sum of the English emissions from the nitric acid and adipic acid production is around 18.4 kt, equivalent to 13% of the UK N_2O emission.

The remaining 23 kt of nitrous oxide emissions result from road transport (10.6 kt) and other combustion (12.4 kt) - mainly combustion in power generation and industry. Whilst small, road transport emissions have risen by a factor of 3.9 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 2000, HFC emissions from the manufacture of HCFCs and HFCs had fallen. In 2000, HCFC and HFC production in England contributed 51% of total English HFC emissions (as CO_2 equivalent) and 46% of total UK HFC emissions (as CO_2 equivalent). The reduction arises from an abatement system installed on the HCFC plant

Refrigeration is the second largest source and contributes 33% 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 2000, aerosols contributed 15% 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 contribute 1% of total English HFC emissions and 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. However, emissions increased by 8% between 1999 and 2000. This increase offsets the important decrease during the 1990-1999 period. Emissions are now approximately 75% 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 2000. Aluminium 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 56% 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% since 1990 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 42% of total emissions in 2000. 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 58% of total English emission. Overall emissions from England are 85 % of the UK total. Emissions of SF_6 in England have increased by 130% 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 2000 broken down by major IPCC source category. Total emissions were around 11% of the UK total in 2000. 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). LUCF is the second largest source of CO_2 in Scotland and constitutes around 20% of the total Scottish emission and contributes around 81% 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 -6.7 Mt CO_2 arises mostly from 5A Changes in Forests and Other Woody Biomass. The magnitude of this sink has increased by 21% 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 30% of the total emission (38% of the non-LUCF emission) which is similar to the UK proportion of 28%. 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 27% since 1990 in contrast with a fall of 22% 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 5.3% (of non-LUCF) compared with 3% for the UK. The other energy emissions are mostly gas consumption at oil and gas terminals and gas separation plant and account for around 4.3% of non-LUCF emissions. Only those emissions arising from on-shore installations in Scotland have been included. These emissions have however increased by 34% 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 34% largely as a result of the Ravenscraig Steel Plant closing.

Road transport is the largest single source after power generation and comprises around 15% of the non-LUCF total. Its contribution to UK emissions is 6% which is lower than would be expected from Scotland's population (9%). The emission has fallen by 14% over the period compared with a 6% 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 8.2% which is slightly lower than would be expected from Scotland's population (9%).

Around 1.9 % of non-LUCF emissions arise from oil and gas fugitives, mainly from flaring at terminals. Flaring has fallen by 60% 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 2000. Since 1990 emissions from iron and steel processes have become negligible.

Carbon dioxide emissions from waste incineration are not significant

Over the period the total non-LUCF emission has fallen by 4%.

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 21% from 1990 to 2000.

The largest source of methane emissions in Scotland is agriculture. Emissions arise from enteric fermentation in livestock and the treatment of their wastes. Around 57% of Scottish emissions arise from agriculture with cattle responsible for 40%. Emissions are dependent on the numbers of livestock and have fallen by 3% over the period resulting from a small decline in cattle and sheep numbers. Scotland accounts for around 17% of UK agricultural emissions.

The next largest source of methane is waste disposal. This contributes around 23% to Scotland's emissions and is overwhelmingly landfill methane with a small contribution from wastewater treatment. The landfill emission is around 9% of the UK landfill emission 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 40% 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 15% of the

Scottish total. This is a lower proportion compared with the total of England, Scotland, Wales and Northern Ireland where fugitives are around 26% 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 5%, oil and gas terminals 1.2% and natural gas distribution 9.4% of the Scottish total. Coal mining emissions have declined by 47% 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. The estimate of gas leakage from the gas transmission system is based on Transco data. The reduction in gas leakage between 1990 and 1999 was around 8%.

Fuel combustion emissions of methane are not important and only account for 3.6. 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 2000 broken down by major IPCC source category. Total emissions were around 12% of the UK in 2000 and have declined by 16% since 1990.

Of the total emission of 17 kt in 2000, 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 (0.7 kt) is emitted from the treatment of agricultural wastes. Scottish agricultural emissions are around 15% of UK agricultural emissions.

The remaining 2.8 kt (17%) 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 3 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 4.5% of the UK total (as CO_2 equivalent) in 2000. 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 68% 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 29% 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 85% of the total Scottish PFC emission (as CO_2 equivalent) in 2000. Electronics production is concentrated in Scotland and contributes around 51% of UK electronics emissions and 33% 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 39% 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 20% of the total emission for Scotland in 2000. 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 2000 broken down by major IPCC source category. Total Welsh emissions were 8% of the UK total in 2000. Welsh emissions increased by 10.6% from 1990 to 2000.

The largest source is Energy Industries, which includes power generation, refineries and solid fuel transformation processes. Electricity generation contributed around 25% of the total Welsh carbon dioxide emission in 2000, which is lower than the UK proportion of 28%. 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 two conventional coal stations. Emissions in Electricity Generation have increased by 4.1% since 1990 compared with a fall of 22% in UK emissions over the same period (1990 to 2000). This is explained by reductions in fuel consumption and hence electricity production at the coal fired station at Aberthaw, the closure of the oil fired station at Pembroke and the closure of the coal fired station at Uskmouth[2]. This is 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 a 250 MW CCGT at Barry in 1998 and a 393 MW coal station at Fifoots. Power generation emissions in Wales are around 7% of UK power generation emissions. There was an omission in the 1999 regional inventory, and the increase in emissions from Energy Industries from 1999 to 2000 is mostly due to the inclusion of Barry (gas fired plant operated by BP) which had been previously accidentally omitted.

Petroleum refining constitutes a larger proportion of Welsh emissions at 6% compared with 3% 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 32% 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 49% of UK Iron and Steel combustion emissions. The other industry category is around 6% of the UK 'other industry' total. Iron and Steel combustion emissions have increased by 38% 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 12% of the total Welsh carbon dioxide emission. Its contribution to UK road transport emissions is 4.7%, which is consistent with Wales' population (5% of UK population). The estimates for 1995, 1998, 1999 and 2000 are rather uncertain since Welsh road fuel sales

[2] The power station at Uskmouth is the same as Fifoots. It was closed and mothballed as Uskmouth, and subsequently re-opened with the new name after upgrading and fitting of Flue Gas Desulphurisation. (per. comm., Harvard Prosser, Environmental Science Advisor, Welsh Assembly)

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 10% over the period.

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 10% 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 1.5% 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.

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 2000. 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 but a small emission from clinical incineration is reported.

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 23% from 1990 to 2000.

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 39% 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 14% 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 39% 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 26% 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 5%, coking (solid fuel transformation) 0.1% and natural gas distribution 7% to the Welsh total methane emission. Coal mining emissions have declined by 80% over the period due to the decline in the coal industry[3]. Gas leakage from the gas transmission system is reducing as the mains and services are renewed.

Fuel combustion activities are not an important source of methane. Altogether they account for 4.5% 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 2000 broken down by major IPCC source category. Total Welsh emissions were around 8% of the UK in 2000. After fluctuating during the 1990-1999 period, the total Welsh emission in 2000 is similar to the 1990 level.

Of the total Welsh emission of 11.3 kt in 2000, 9.4 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)

[3] Emissions from closed mines are not reported separately. A limited data reviewed by Sage (2001) "Methane from abandoned coal mines in the UK", AEAT/ENV/R/0500, suggests emissions are in the range 20-300kt/year. See Appendix 1 for further details.

A relatively small proportion (0.4 kt) is emitted from the treatment of agricultural wastes (Manure Management). Welsh agricultural emissions are around 10% of UK agricultural emissions.

The remaining 1.9 kt (17% 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 (0.65 kt), road transport emissions have risen by a factor of nearly 3.8 over the period. This is a result of the increasing use of catalytic converters on cars.

Estimated emissions of N_2O have been revised slightly for the baseline year (1990) between this inventory and the previous inventory (Salway *et al*., 1999). The 1990 estimate of total N_2O emissions from Wales in the 1999 inventory was 11.2 Gg, and the 1990 estimate in this inventory (the 2000 inventory) has been increased to 11.6 Gg. Changes in the estimates of emissions from agriculture were responsible for 85% of this difference. Specifically, emissions from agricultural soils increased from 9.51 Gg (1999 estimate of emissions in 1990) to 9.81 Gg (2000 estimate of emissions in 1990).

4.4 HYDROFLUOROCARBONS

In 2000 the total HFC emission in Wales was 2.3% of the UK HFC total (as CO_2 equivalent). Refrigeration is the largest source and contributes 76% 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 21% 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 2000. This is around 31% of UK aluminium emissions. The electronics industry also makes an important contribution accounting for 36% 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 2000 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 2000. The main source of emissions is from use as a cover gas in magnesium production. These account for around 51% 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 49% of the total Welsh emission.

5. Emissions in Northern Ireland

5.1 CARBON DIOXIDE

Figure 1 shows emissions of carbon dioxide for 1990 and 2000 broken down by major IPCC source category. Total emissions in Northern Ireland were around 3% of the UK total in 2000 and have decreased by 12% 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 42% of the total emission, which is higher than the UK proportion of 28%. 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 18% over the period but have declined by 5% since 1995. The recent decline is largely due to the conversion to natural gas.

Combustion emissions from Manufacturing Industries and Construction account for around 10% 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 2.4% of the UK Other Industry total, and has declined by about 16% from 1990 to 2000.

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 1.2% which is less that which would be expected from Northern Ireland's population (2.5% of the UK). In 2000 the emission had fallen by 51% from 1990 levels, contrary to the UK trend of an increase of 6% 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 23% 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 a glass factory, which contribute around 1.4% 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 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. A carbon sink of -0.62 Mt CO_2 arises mainly from 5A Changes in Forests and Other Woody Biomass. These LUCF emissions have fallen by around 20% over the period 1990 to 2000.

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 have decreased by around 7% over the period 1990 to 2000.

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 83% of Northern Ireland's emissions arise from agriculture with cattle responsible for 72%. Emissions are dependent on the numbers of livestock and have increased by 5% over the period (1990 to 2000) 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 2.7% 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 42% 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 3.2% 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 2000 broken down by major IPCC source category. Total emissions from Northern Ireland were around 7% of the UK emission in 2000. Total emissions from Northern Ireland have increased by 16% from 1990 to 2000. Of the total emission of 10 kt in 2000, around 7.6 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 (0.6 kt) comes from the treatment of animal wastes (Manure Management). Agricultural emissions in Northern Ireland are around 8% of UK agricultural emissions.

Around 1.5 kt of nitrous oxide were emitted from a nitric acid plant contributing 15% to the total Northern Irish emission.

The remaining 1.1 kt (11%) of nitrous oxide emissions result from fuel combustion. Around 0.4 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 3.5 over the period. This is a result of the increasing use of catalytic converters on cars.

5.4 HYDROFLUOROCARBONS

Total emissions of HFCs in 2000 were 1.4% of the UK Total (as CO_2 equivalent). The largest source was refrigeration (including air conditioning) contributing around 69% 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 28% of the Northern Ireland total. The remaining emission source, fire fighting was negligible. The total emission has increased from virtually zero in 1990 to 133 kt CO_2 equivalent in 2000.

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 1.3% of the UK total in 2000. 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 2000 UK total they account for carbon dioxide 4.7%; methane 2.4% and nitrous oxide 1.1%. 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, trade associations and the Environment Agency's Pollution Inventory.

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, 2001) 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 disaggregated by type of consumer. The steel industry is well covered by Iron and Steel Industry Statistics (ISSB, 2001) though in the latest editions some of the most detailed regional 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, 1999 and 2000. 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 and oil consumption in the commercial and public service sectors were based on employment statistics. Some coal consumption data were collected for England and Wales in 1995, 1998, 1999 and 2000 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 15% of the 2000 CO_2 emissions occur in sources where data had to be estimated from surrogates. For Wales and Northern Ireland the proportions are 11% and 37% respectively. The high proportion for Northern Ireland is explained by the absence of iron and steel sources, refineries and the relatively low consumption of natural gas 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 relatively large contributions from the steel industry, power generation and refineries.

A number of changes have been made to the estimates since the last study (Salway *et al*, 2002). Many of these arise from revisions made to the UK Inventory. The most significant are:

- Emissions from power generation in 1998 and 1999 have been revised due to improved data on gas fired and coal generation and revisions in the UK fuel consumption statistics. The revisions are less than 3%.
- There has been a modest increase in CO_2 emissions from soils in Northern Ireland (1571 kt to 1667 kt CO_2 in 1999). This arises from new data on minor holdings in Northern Ireland, which have just become available. See Appendix 1.
- The methodology for estimating N_2O and CH_4 emissions from road transport has been revised to incorporate the more recent COPERT III emission factors.
- The methodology for allocating oil consumption by the commercial and public service sectors has been revised. Employment statistics are now used as a surrogate for these sources.
- The methodology for allocating coal and anthracite to the domestic and industrial sectors has been revised. The new methodology is simpler and should give a more consistent time series. Welsh iron and steel process emissions have reduced from 1109 kt CO_2 to 983 kt CO_2 in 1999
- The methodology for carbon emissions from iron and steel making was revised in the UK inventory to comply with IPCC Good Practice. Consequently there are revisions in the regional allocation of emissions resulting in a significant transfer of emissions from Wales to England (see explanation below).
- Included in the Inventory are some new sources, namely, clinical waste incinerators, methanol production and ethylene production. Clinical waste incineration occurs in all countries. Emissions of methane are reported from methanol production, occurring only in England and ethylene production occurring in England, Scotland and Wales.

The methodology for carbon emissions from iron and steel making was revised in the UK inventory to comply with IPCC Good Practice. The reason for this transfer of emissions from Wales to England is because the methodology for calculating emissions from the iron and steel has been significantly altered. The methodology has been upgraded to an IPCC 'Tier 2' methodology. More data is needed for the methodology, and the way carbon sources and sinks are treated within the iron and steel industry is much more advanced. The methodology assigns carbon to sinks in ways that were not considered before, for example, the carbon content in pig

iron and mild steel etc. is now considered in a carbon mass balance, and these need to be allocated to Wales and the rest of the UK. So, the carbon emissions depend on the type of iron and steel making activity and where this occurs, and this was not considered before.

During the preparation of this report it became apparent that the 2000 fertiliser application estimates used at the time of the UK inventory compilation were incomplete. Hence the nitrous oxide emission arising from 4D Agricultural Soils was previously reported as 86.4 kt but could be as high as 89.8 kt. In this report the previous UK estimate is retained and allocated across the regions based on the available regional fertiliser data.

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 2000 inventory (Salway *et al*, 2002) 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 2000.

		England	Scotland	Wales	N Ireland	UK
CO_2	±%	2	11	8	5	2
Methane	±%	24	19	17	18	21
N_2O	Lower kt	22	3	2	1	35
	Upper kt	340	71	48	40	515
HFC	±%	25[1]				25
PFC	±%	19[1]				19
SF6	±%	13[1]				13
GWP	±%	14	21	20	36	15

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. 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[4] 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.

[4] The uncertainties in the estimates of emissions of CO_2 from Wales (8%) "are high", but only relative to the uncertainty of the emissions from the UK (2%). For an inventory, 8% is not a particularly high uncertainty. An important component of this uncertainty are the assumptions about the fuel oil used in Wales, as data are only available for England and Wales combined. Therefore, a range of assumptions has to be made to estimate the fuel oil use for both regions.

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10. Summary Tables

Detailed summaries of the greenhouse gas emissions for the years 1990, 1995, 1998, 1999 and 2000 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	124.6	17.0	11.1	4.7	7.1	164.5
	1995 Emission	113.8	16.9	10.7	4.8	7.4	153.7
	1998 Emission	112.8	17.1	11.3	4.3	7.7	153.2
	1999 Emission	111.1	16.7	11.3	4.4	7.2	150.8
	2000 Emission	112.0	16.5	12.3	4.1	7.2	152.1
Methane	1990 Emission	15.8	2.0	1.6	0.9	0.6	20.9
	1995 Emission	12.8	1.9	1.3	0.9	0.5	17.3
	1998 Emission	11.3	1.8	1.3	0.9	0.4	15.6
	1999 Emission	10.7	1.7	1.2	0.9	0.4	14.8
	2000 Emission	9.9	1.6	1.2	0.8	0.3	13.9
N_2O	1990 Emission	14.9	1.7	1.0	0.8	0.1	18.5
	1995 Emission	12.1	1.5	1.0	0.9	0.1	15.6
	1998 Emission	12.2	1.5	1.1	0.9	0.1	15.8
	1999 Emission	8.6	1.5	1.1	0.9	0.1	12.2
	2000 Emission	8.6	1.4	1.0	0.9	0.1	12.0
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	2.2	0.10	0.05	0.03	0.0	2.3
	2000 Emission	2.3	0.11	0.06	0.04	0.0	2.5
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
	2000 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
	1998 Emission	0.34	0.03	0.02	0.01	0.00	0.40
	1999 Emission	0.35	0.03	0.03	0.01	0.00	0.41
	2000 Emission	0.36	0.03	0.03	0.01	0.00	0.42
GWP	1990 Emission	159.1	20.8	13.8	6.4	7.8	207.8
	1995 Emission	143.2	20.5	13.1	6.6	8.0	191.4
	1998 Emission	142.0	20.6	13.7	6.1	8.2	190.7
	1999 Emission	133.0	20.1	13.8	6.2	7.7	180.8
	2000 Emission	133.3	19.8	14.5	5.8	7.7	181.1

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

Greenhouse Gas		England	Scotland	Wales	Northern Ireland	Un-Allocated	United Kingdom
CO_2	1990 Emission	456.9	62.3	40.7	17.2	26.1	603.1
	1995 Emission	417.4	62.0	39.2	17.7	27.2	563.6
	1998 Emission	413.6	62.8	41.3	15.7	28.2	561.6
	1999 Emission	407.4	61.4	41.6	16.0	26.4	552.9
	2000 Emission	410.6	60.7	45.0	15.0	26.5	557.7
Methane	1990 Emission	58.1	7.5	5.7	3.2	2.0	76.5
	1995 Emission	47.0	7.0	4.8	3.1	1.7	63.6
	1998 Emission	41.3	6.5	4.6	3.2	1.5	57.2
	1999 Emission	39.2	6.1	4.5	3.1	1.4	54.4
	2000 Emission	36.4	5.9	4.4	3.0	1.2	51.0
N_2O	1990 Emission	54.7	6.1	3.6	3.0	0.4	67.9
	1995 Emission	44.3	5.6	3.6	3.2	0.5	57.1
	1998 Emission	44.7	5.5	3.9	3.4	0.5	58.0
	1999 Emission	31.6	5.3	4.1	3.4	0.5	44.9
	2000 Emission	31.5	5.1	3.5	3.2	0.5	43.8
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	7.9	0.4	0.2	0.1	0	8.6
	2000 Emission	8.5	0.4	0.2	0.1	0	9.3
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
	2000 Emission	0.30	0.26	0.10	0.0012	0	0.67
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
	1998 Emission	1.26	0.12	0.09	0.02	0	1.48
	1999 Emission	1.28	0.11	0.09	0.02	0	1.51
	2000 Emission	1.31	0.11	0.09	0.02	0	1.54
GWP	1990 Emission	583.2	76.2	50.5	23.4	28.5	761.8
	1995 Emission	525.1	75.3	47.9	24.1	29.4	701.7
	1998 Emission	520.8	75.5	50.1	22.4	30.2	699.1
	1999 Emission	487.8	73.5	50.6	22.7	28.3	662.9
	2000 Emission	488.7	72.5	53.3	21.4	28.2	664.1

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

Greenhouse Gas		England	Scotland	Wales	Northern Ireland	Un-Allocated	United Kingdom
CO_2	1990 Emission	456.9	62.3	40.7	17.2	26.1	603.1
	1995 Emission	417.4	62.0	39.2	17.7	27.2	563.6
	1998 Emission	413.6	62.8	41.3	15.7	28.2	561.6
	1999 Emission	407.4	61.4	41.6	16.0	26.4	552.9
	2000 Emission	410.6	60.7	45.0	15.0	26.5	557.7
Methane	1990 Emission	2.765	0.357	0.274	0.153	0.097	3.645
	1995 Emission	2.238	0.332	0.228	0.149	0.082	3.028
	1998 Emission	1.969	0.311	0.219	0.153	0.072	2.724
	1999 Emission	1.868	0.291	0.215	0.149	0.065	2.589
	2000 Emission	1.735	0.281	0.209	0.143	0.058	2.427
N_2O	1990 Emission	0.177	0.020	0.012	0.010	0.001	0.219
	1995 Emission	0.143	0.018	0.012	0.010	0.001	0.184
	1998 Emission	0.144	0.018	0.013	0.011	0.002	0.187
	1999 Emission	0.102	0.017	0.013	0.011	0.002	0.145
	2000 Emission	0.102	0.017	0.011	0.01	0.002	0.141
HFC	1990 Emission	0.973	0.000	0.000	0.000	0.0	0.973
	1995 Emission	1.836	0.065	0.036	0.019	0.0	1.956
	1998 Emission	3.302	0.190	0.108	0.061	0.0	3.660
	1999 Emission	2.560	0.219	0.105	0.069	0.0	2.954
	2000 Emission	2.914	0.251	0.123	0.080	0.0	3.368
PFC	1990 Emission	0.233	0.037	0.111	0.001	0.0	0.331
	1995 Emission	0.069	0.073	0.015	0.0001	0.0	0.157
	1998 Emission	0.043	0.035	0.016	0.0002	0.0	0.094
	1999 Emission	0.045	0.037	0.015	0.0002	0.0	0.098
	2000 Emission	0.044	0.037	0.015	0.0002	0.0	0.097
SF_6	1990 Emission	0.024	0.003	0.003	0.0004	0.0	0.030
	1995 Emission	0.040	0.004	0.003	0.0004	0.0	0.047
	1998 Emission	0.053	0.005	0.004	0.001	0.0	0.062
	1999 Emission	0.054	0.005	0.004	0.001	0.0	0.063
	2000 Emission	0.055	0.005	0.004	0.001	0.0	0.064

Figure 1 Emissions of Carbon Dioxide

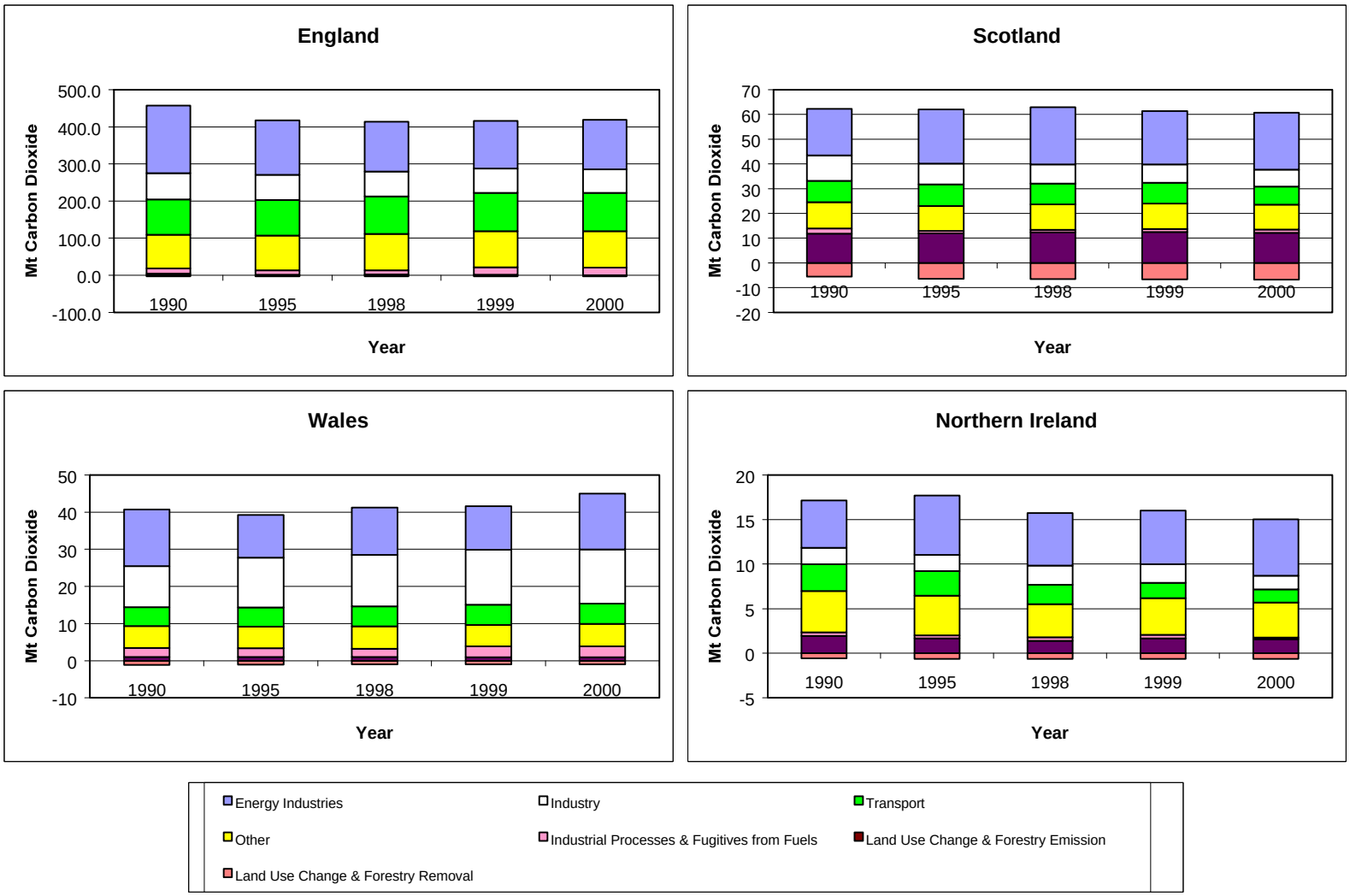


Figure 2 Emissions of Methane

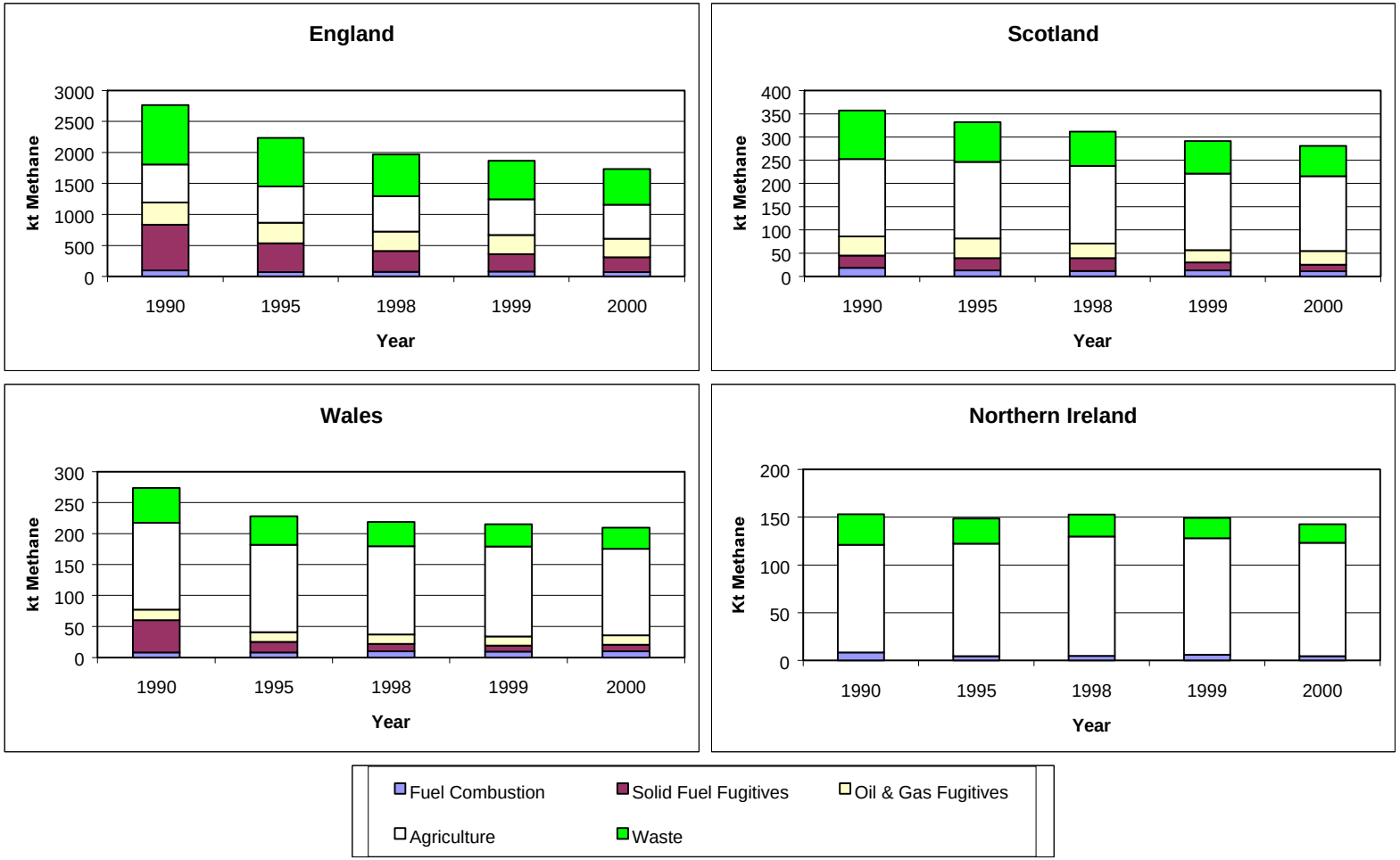


Figure 3 Emissions of Nitrous Oxide

Figure 4 Emissions of HFCs

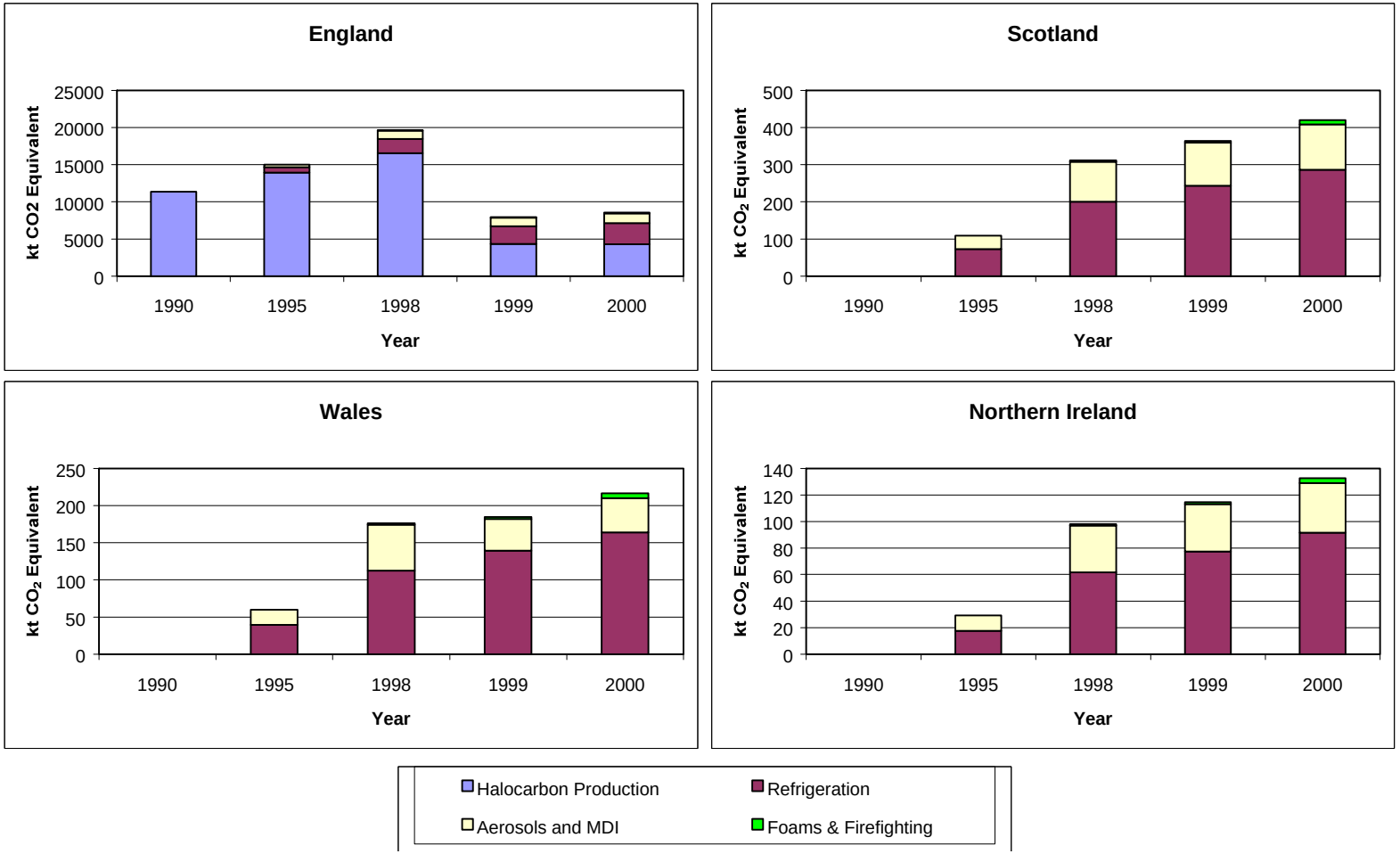


Figure 5 Emissions of PFCs

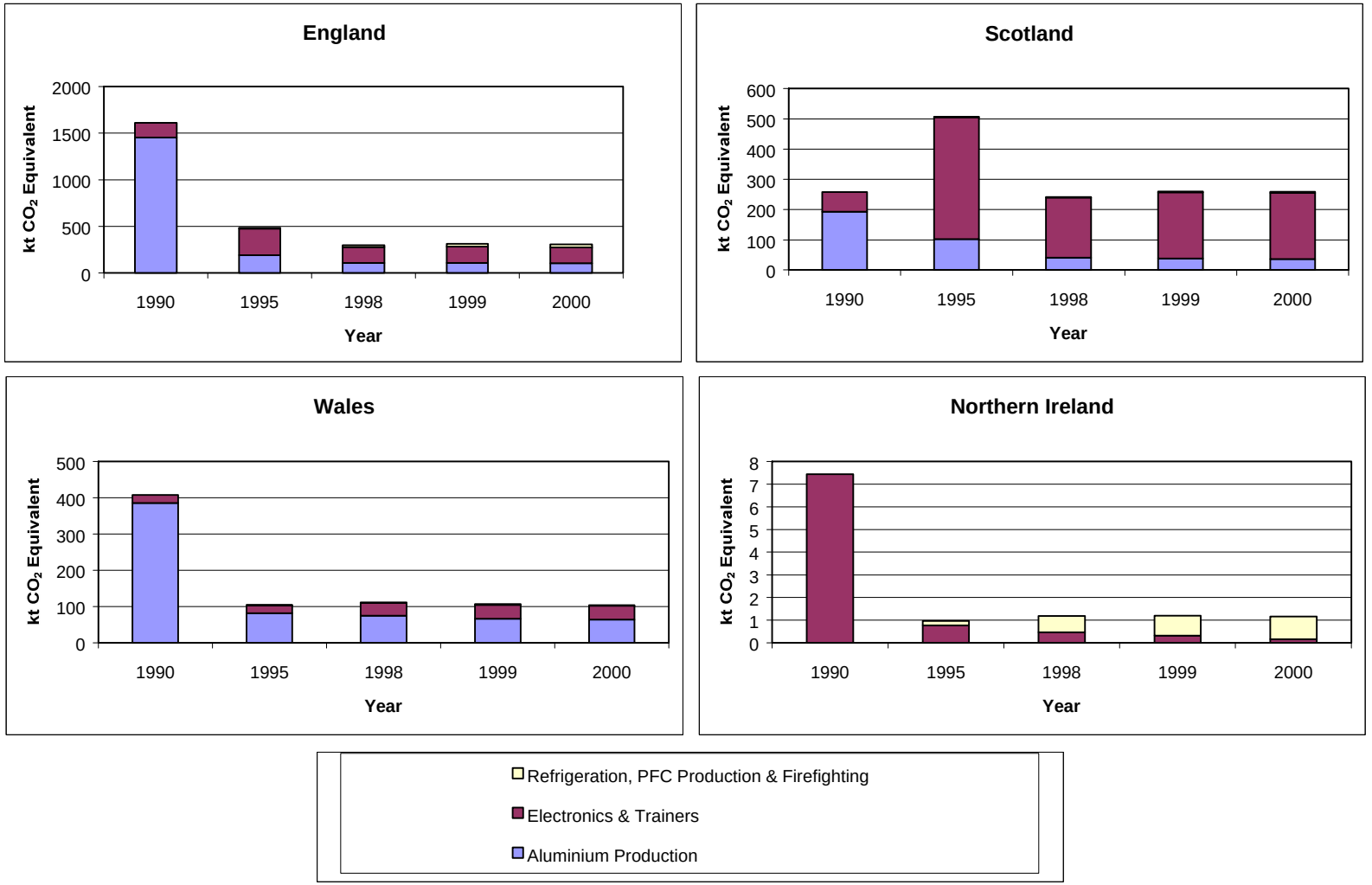
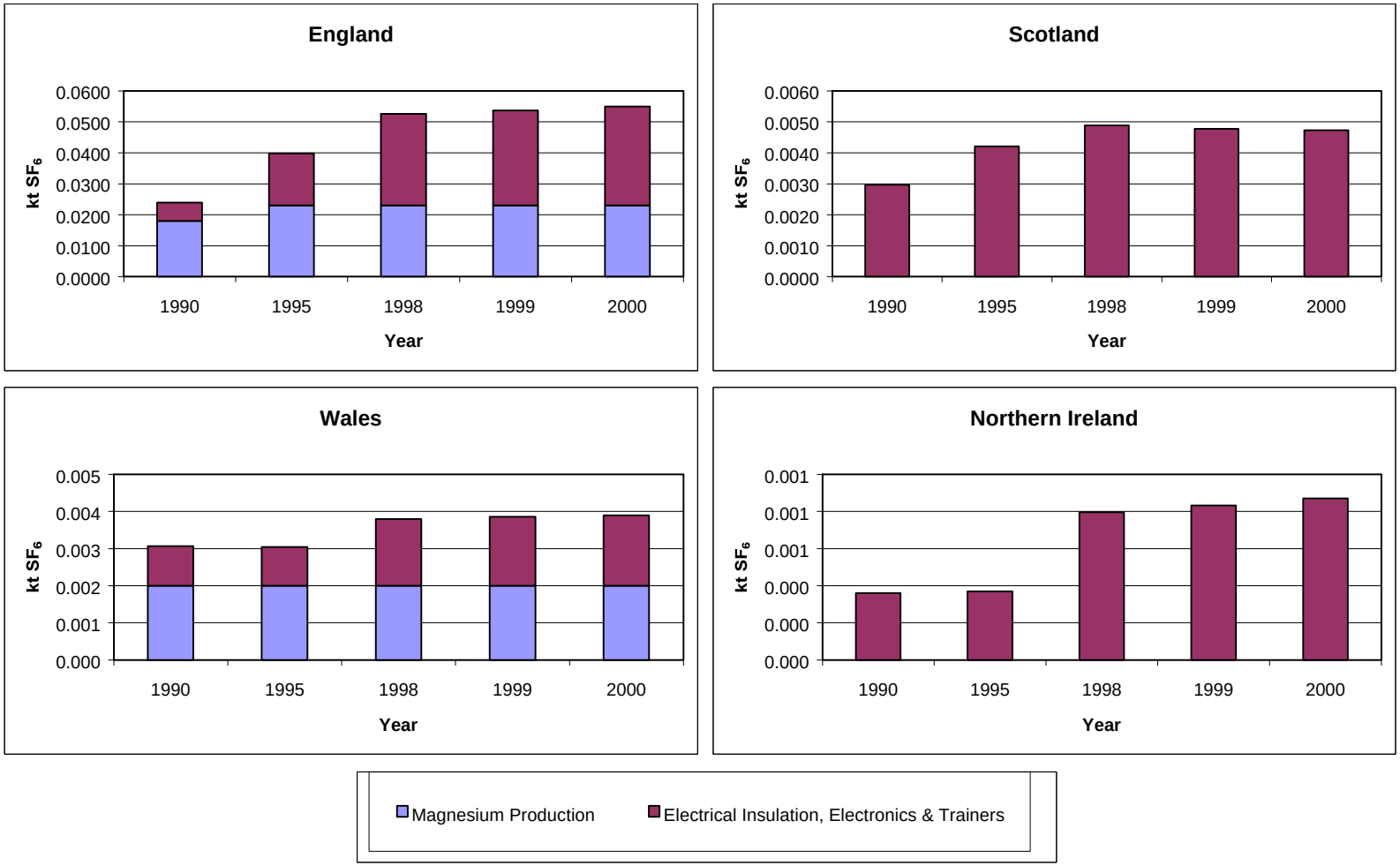


Figure 6 Emissions of SF6



Appendices

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