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

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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 and 1998[†]. The gases reported are:

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

The estimates are consistent with the 1998 UK Greenhouse Gas Inventory (Salway, 2000) and hence the UNFCCC reporting guidelines. Some emissions mainly mobile and offshore sources could not be allocated to any region, so an extra unallocated category was used to report these.

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 problems the regional estimates are more uncertain than the UK estimates.

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The study showed that the distribution of regional greenhouse gas emissions expressed as global warming potentials in 1998 were: England, 74.0%; Scotland, 12.0%; Wales, 6.4%; Northern Ireland, 3.3%; unallocated, 4.3%. Detailed summaries of the emissions are shown in Table 1 to 3. They are reported as GWP weighted equivalent mass of carbon (Table 1); GWP weighted equivalent mass of CO_2 (Table 2) and the mass of each gas emitted (Table 3)

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Table 1 Summary of Greenhouse Gas Emissions as GWP Weighted Equivalent Mass of Carbon

Gas			England	Scotland	Wales	Northern Ireland	Un-allocated	United Kingdom
CO_2	1990 Emission	Mt C equiv	125.3	20.0	10.8	4.9	7.0	168.0
	1990 Percentage	%	*74.6*	*11.9*	*6.4*	*2.9*	*4.2*	*100.0*
	1995 Emission	Mt C equiv	113.6	19.7	10.9	5.1	7.4	156.7
	1995 Percentage	%	*72.5*	*12.6*	*7.0*	*3.2*	*4.7*	*100.0*
	1998 Emission	Mt C equiv	113.6	19.7	10.0	4.5	7.7	155.5
	1998 Percentage	%	*73.0*	*12.7*	*6.4*	*2.9*	*4.9*	*100.0*
	Change C equiv 90/98	%	*-9.4*	*-1.2*	*-6.9*	*-8.8*	*9.6*	*-7.4*
Methane[1]	1990 Emission	Mt C equiv	16.0	2.1	1.6	0.9	0.6	21.1
	1990 Percentage	%	*75.9*	*9.8*	*7.5*	*4.2*	*2.6*	*100.0*
	1995 Emission	Mt C equiv	12.2	1.9	1.3	0.8	0.5	16.7
	1995 Percentage	%	*73.2*	*11.1*	*7.8*	*5.1*	*2.8*	*100.0*
	1998 Emission	Mt C equiv	10.9	1.7	1.2	0.9	0.4	15.2
	1998 Percentage	%	*71.9*	*11.5*	*8.2*	*5.7*	*2.7*	*100.0*
	Change C equiv 90/98	%	*-31.8*	*-15.5*	*-21.9*	*-0.9*	*-26.0*	*-28.0*
N_2O	1990 Emission	Mt C equiv	14.5	1.6	0.9	0.8	0.1	17.9
	1990 Percentage	%	*80.9*	*9.1*	*5.2*	*4.5*	*0.3*	*100.0*
	1995 Emission	Mt C equiv	11.8	1.4	0.9	0.8	0.1	15.0
	1995 Percentage	%	*78.3*	*9.6*	*6.3*	*5.5*	*0.4*	*100.0*
	1998 Emission	Mt C equiv	11.9	1.4	1.0	0.9	0.1	15.3
	1998 Percentage	%	*78.1*	*9.2*	*6.6*	*5.7*	*0.4*	*100.0*
	Change C equiv 90/98	%	*-17.7*	*-14.1*	*7.4*	*9.2*	*2.1*	*-14.8*
HFC	1990 Emission	Mt C equiv	3.1	0.0	0.0	0.0	0	3.1
	1990 Percentage	%	*100.0*	*0.0*	*0.0*	*0.0*	*0*	*100.0*
	1995 Emission	Mt C equiv	4.1	0.03	0.02	0.008	0	4.1
	1995 Percentage	%	*98.7*	*0.7*	*0.4*	*0.2*	*0*	*100.0*
	1998 Emission	Mt C equiv	5.3	0.09	0.05	0.03	0	5.5
	1998 Percentage	%	*97.0*	*1.6*	*0.9*	*0.5*	*0*	*100.0*
	Change C equiv 90/98	%	*72.2*	*407065*	*286240*	*171882*	*0*	*77.4*
PFC	1990 Emission	Mt C equiv	0.44	0.07	0.11	0.00	0	0.62
	1990 Percentage	%	*70.5*	*11.3*	*17.9*	*0.3*	*0*	*100.0*
	1995 Emission	Mt C equiv	0.13	0.14	0.03	0.00	0	0.3
	1995 Percentage	%	*44.2*	*46.3*	*9.5*	*0.1*	*0*	*100.0*
	1998 Emission	Mt C equiv	0.08	0.07	0.03	0.00	0	0.2
	1998 Percentage	%	*45.7*	*37.1*	*17.0*	*0.2*	*0*	*100.0*
	Change C equiv 90/98	%	*-81.5*	*-6.3*	*-72.7*	*-84.2*	*0*	*-71.4*
SF_6	1990 Emission	Mt C equiv	0.16	0.02	0.02	0.00	0	0.20
	1990 Percentage	%	*78.9*	*9.8*	*10.1*	*1.2*	*0*	*100.0*
	1995 Emission	Mt C equiv	0.26	0.03	0.02	0.00	0	0.31
	1995 Percentage	%	*83.9*	*8.9*	*6.4*	*0.8*	*0*	*100.0*
	1998 Emission	Mt C equiv	0.30	0.02	0.02	0.00	0	0.35
	1998 Percentage	%	*86.4*	*6.3*	*6.4*	*0.9*	*0*	*100.0*
	Change C equiv 90/98	%	*94.8*	*15.5*	*13.3*	*28.3*	*0*	*78.0*
GWP	1990 Emission	Mt C equiv	159.5	23.8	13.4	6.6	7.6	210.9
	1990 Percentage	%	*75.6*	*11.3*	*6.4*	*3.1*	*3.6*	*100.0*
	1995 Emission	Mt C equiv	142.1	23.2	13.2	6.7	8.0	193.2
	1995 Percentage	%	*73.5*	*12.0*	*6.8*	*3.5*	*4.1*	*100.0*
	1998 Emission	Mt C equiv	142.1	23.0	12.4	6.3	8.2	192.0
	1998 Percentage	%	*74.0*	*12.0*	*6.4*	*3.3*	*4.3*	*100.0*
	Change C equiv 90/98	%	*-10.9*	*-3.0*	*-7.8*	*-5.2*	*7.0*	*-9.0*

Table 2 Summary of Greenhouse Gas Emissions as GWP weighted Equivalent Mass of CO_2

Greenhouse Gas		England	Scotland	Wales	Northern Ireland	Un-allocated	United Kingdom
CO_2	1990 Emission	459.4	73.2	39.5	18.1	25.7	616.0
	1995 Emission	416.6	72.3	40.1	18.6	27.2	574.7
	1998 Emission	416.4	72.3	36.7	16.5	28.2	570.2
Methane[1]	1990 Emission	58.6	7.5	5.8	3.2	2.0	77.2
	1995 Emission	44.8	6.8	4.8	3.1	1.7	61.3
	1998 Emission	39.9	6.4	4.5	3.2	1.5	55.6
N_2O	1990 Emission	53.1	6.0	3.4	2.9	0.2	65.7
	1995 Emission	43.1	5.3	3.4	3.0	0.2	55.1
	1998 Emission	43.7	5.2	3.7	3.2	0.2	56.0
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
PFC	1990 Emission	1.61	0.26	0.41	0.01	0	2.28
	1995 Emission	0.48	0.51	0.10	0.001	0	1.09
	1998 Emission	0.30	0.24	0.11	0.001	0	0.65
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	1.11	0.08	0.08	0.01	0	1.29
GWP	1990 Emission	584.7	87.1	49.2	24.3	28.0	773.2
	1995 Emission	520.9	85.1	48.5	24.7	29.2	708.4
	1998 Emission	521.1	84.5	45.3	23.0	29.9	703.9

Table 3 Summary of Greenhouse Gas Emissions

Greenhouse Gas			England	Scotland	Wales	Northern Ireland	Un-Allocated	United Kingdom
CO_2	1990 Emission	Mt	459.4	73.2	39.5	18.1	25.7	616.0
	1995 Emission	Mt	416.6	72.3	40.1	18.6	27.2	574.7
	1998 Emission	Mt	416.4	72.3	36.7	16.5	28.2	570.2
Methane[1]	1990 Emission	Mt	2.791	0.359	0.277	0.153	0.097	3.677
	1995 Emission	Mt	2.135	0.325	0.227	0.148	0.083	2.917
	1998 Emission	Mt	1.902	0.303	0.216	0.152	0.072	2.646
N_2O	1990 Emission	Mt	0.171	0.019	0.011	0.010	0.0007	0.212
	1995 Emission	Mt	0.139	0.017	0.011	0.010	0.0006	0.178
	1998 Emission	Mt	0.141	0.017	0.012	0.010	0.0007	0.181
HFC	1990 Emission	Mt	0.973	0.000	0.000	0.000	0	0.973
	1995 Emission	Mt	1.836	0.065	0.036	0.019	0	1.956
	1998 Emission	Mt	3.292	0.193	0.109	0.061	0	3.656
PFC	1990 Emission	kt	0.233	0.037	0.060	0.001	0	0.331
	1995 Emission	kt	0.069	0.073	0.015	0.000	0	0.157
	1998 Emission	kt	0.043	0.035	0.016	0.000	0	0.094
SF_6	1990 Emission	kt	0.024	0.003	0.003	0.0004	0	0.030
	1995 Emission	kt	0.040	0.004	0.003	0.0004	0	0.047
	1998 Emission	kt	0.047	0.003	0.003	0.0005	0	0.054

1 Sum of gas leakage emissions for England, Scotland, Wales in 1998 exceeds the published UK estimate due to a more recent regional estimate. The published total is 2.636 Mt CH_4 or 15.096 kt C equiv.

Contents

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). The first UK programme, published in *Climate Change: the UK Programme (DOE, 1994)*, includes national inventories for greenhouse gases from anthropogenic sources for 1990 disaggregated by sector. The second UK programme, published in *Climate Change: the UK Programme (DOE, 1997)*, includes national inventories for greenhouse gases from anthropogenic sources for 1990 to 1994 disaggregated by sector.

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 and to form the basis of any negotiation on future emission reductions. Therefore, the DETR 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 report updates and revises the earlier study and presents separate GHG Inventories for England, Scotland, Wales and Northern Ireland for the years 1990, 1995 and 1998. 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 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, 2000). This report follows the convention used in Salway (2000) 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 presents the regional greenhouse gas emissions for the years 1990, 1995 and 1998 and discusses the reasons for the trends. Table 1 in the Executive Summary gives the regional summary data for these years and includes global warming potential (GWP) weighted emissions as well as actual emissions. 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 4 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 1 and 2 are expressed in equivalent masses of CO_2 and carbon.

Table 4 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

The IPCC Sectoral Tables are given in Appendix 2. Table 3 has been omitted because this reports VOCs which are not relevant to this study. Also, only Table 7A is reported for the Unallocated Emissions. In IPCC Tables, emissions are reported in Gigagrammes (Gg).[1]

Appendix 1 describes in detail the methodology of the estimates and how the regional inventories relate to the UK GHGI. Figures 1-8 summarise the emissions.

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

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 (MAFF)
- Land Use Change and Forestry (Institute of Terrestrial Ecology)
- 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 was provided for this work. The Digest of UK Energy Statistics (DTI, 2000) reports some regional data such as coal production, domestic gas consumption 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 were able to provide a set of gas sales statistics disaggregated by region and consumer size. The steel industry is well covered by Iron and Steel Industry Statistics (ISSB, 1999) 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 was 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 and 1998. 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 Miscellaneous 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 and 1998 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, Scotland and Wales around 9% of the 1998 CO_2 emissions occur in sources where data had to be estimated from surrogates. For Northern Ireland the proportion is 25%. 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.

Certain changes have been made to the estimates since the earlier study (Salway *et al*, 1999). These are:

- Emissions from power generation in England and Wales in 1995 have been revised due to better data on gas fired generation. Emissions in Wales have decreased as a result.
- Emissions from natural gas consumption and natural gas leakage have been revised due to new data from Transco. The sum of gas leakage emissions for England, Scotland, Wales in 1998 exceeds the published UK estimate due to a more recent regional estimate. The published total is 2.636 Mt CH_4 or 15.096 kt C equiv.
- Domestic emissions from gas oil, burning oil and LPG consumption in Northern Ireland have been revised to obtain better agreement with the Housing Conditions Survey.
- Process emissions from the metal industries have been revised to take account of non-ferrous metal production. This has resulted in a reduction in CO_2 emissions in Wales and an increase in England.

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 1998 inventory (Salway, 2000) and are given in Table 5.

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 5. The N_2O distribution is heavily skewed, so that 5% and 95% confidence limits are quoted.

Table 5. Estimated Uncertainties[2] in the Regional Inventories

		England	Scotland	Wales	N Ireland	UK
CO_2	±%	2	19	7	4	3
Methane	±%	18	16	15	16	16
N_2O	Lower Gg	21.5	0.9	0.6	0.5	24.2
	Upper Gg	91.0	16.0	11.4	9.1	127.4
HFC	±%	25[1]				25
PFC	±%	19[1]				19
SF6	±%	8[1]				8
GWP	±%	12	23	24	41	14

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 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.

Emissions in England

CARBON DIOXIDE

Figure 1 shows the emissions of carbon dioxide for 1990 to 1998 broken down by major IPCC source category. Total emissions were around 73% of the UK total in 1998 and have declined by 9% 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 contributed around 29% of the total emission which is slightly 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 have decreased by 28% since 1990 in contrast with a fall of 25% 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 9% reduction in the English total emission over the period.

Petroleum refining constitutes a similar proportion of national emissions at 4% compared with 4% for the UK. Emissions have increased by 23% 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 by 65% 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 account for around 16% of the English total compared with 16% for the UK. The iron and steel industry in England accounts for 54% of UK Iron and Steel combustion emissions. The other industry category is around 82% of the UK total.

Road transport is the largest single source after power generation and contributes around 24% to the total. Its contribution to UK road transport emissions is 87% which is slightly more than that which would be expected from England's population (83% of UK population). The emission has risen by 7.5% over the period compared with a 5.9 % rise for the UK. Emissions were estimated from road fuel sales data. The estimates for 1995 and 1998 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, commercial and public sectors. These are fairly uncertain due to lack of data. Domestic emissions are around 17% of the total. As a proportion of UK domestic emissions they are 83% 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 constituting 1.2% of the total with smaller emissions from glass, ammonia, aluminium, iron and steel production. Together, these processes emitted around 2.4% of the total in 1998. 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 - industrial emissions from combustion 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 0.24% of the total English emission and contribute only around 4% of the UK LUCF emission. In 1998 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 and 1998. The reporting of emissions from 5D CO_2 Emissions and Removals from Soils is slightly anomalous since these changes from a source in 1990 to a sink in 1998. 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 1998. Milne (Salway, 2000) discusses the assumptions underlying these emissions in more detail. In 1998 a carbon sink 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 29% of UK removals.

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 32% from 1990 to 1998.

The largest source of methane emissions in England is waste disposal. This contributes around 35% 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 31% because of increasing use of methane recovery systems, though this reduction assumes the UK trend. Emissions from wastewater treatment are around 1.7% of the total and comprise 92% of UK wastewater emissions. Emissions reflect treatment methods 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 22%. Emissions are dependent on the numbers of

livestock and have fallen by 8% over the period 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. 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 high 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 emissions coal mining contributes 12%, natural gas distribution 18% and oil and gas terminals 0.5% of the English total. Coal mining emissions have declined by 68% 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 has been revised since the last study and is now based on Transco data. The reduction in leakage between 1990 and 1998 is around 8%.

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

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 1998 broken down by major IPCC source category. Total emissions were around 78% of the UK total in 1998 and have declined by 18% since 1990.

Of the total emission of 141 kt in 1998, around 62 kt of this was from agriculture representing around 44% 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
- atmospheric deposition of NH_3 and NO_x
- ploughing in crop residues
- 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. English agricultural emissions are around 65% of UK agricultural emissions and have fallen by around 6% since 1990.

Unlike other parts of the UK, a substantial proportion of England's nitrous oxide emissions are produced by chemical processes, namely adipic acid production and to a lesser extent nitric acid

production. These processes constitute around 41% of England's emissions and 98% of UK industrial process emissions. These emissions depend mainly on production rates and vary year to year accordingly. There has been some reduction in emissions due to abatement measures on the adipic acid plant and one nitric acid plant.

The remaining 20 kt (14%) of nitrous oxide emissions result from fuel combustion. Just over 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 2.4 over the period. This is a result of the increasing use of catalytic converters on cars.

HYDROFLUOROCARBONS

The largest source of HFCs is 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.

Refrigeration is the next largest source and contributes 10% of total HFC GWP. Here emissions arise from losses from refrigeration and air conditioning equipment during its manufacture and lifetime. Aerosols contribute 6% to the total HFC GWP emission, and it is assumed that all the fluid is emitted in the year of manufacture. 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. The total GWP emission has 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.

PERFLUOROCARBONS

The largest source of perfluorocarbons in England is aluminium production which contributed around 36% of the PFC total (as CO_2 equivalent) in 1998. Aluminium production plant are also located in Scotland and Wales, with the result that England's contribution to UK aluminium production emissions is 48%. 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 PFC total GWP. 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 emissions are 46% of the UK PFC total (as CO_2 equivalent). Emissions of PFC have declined by 81% mainly as a result of better control measures in aluminium production.

SULPHUR HEXAFLUORIDE

The main source of sulphur hexafluoride emissions is from use as a cover gas in magnesium production. This accounted for around 60% of total emissions in 1998. Magnesium production is largely concentrated in England and accounts for 93% of the UK magnesium production emission. The next largest source of sulphur hexafluoride is emissions from electrical switchgear used in power transmission. This accounts for around 16% of total emissions. The remaining emissions are leakage from the soles of certain brands of training shoes and consumption by the

electronics industry. Overall emissions are 86% of the UK total. Emissions of SF_6 have increased by 95% as a result of increasing use in trainers, magnesium production and switchgear.

Emissions in Scotland

CARBON DIOXIDE

Figure 1 shows emissions of carbon dioxide for 1990 to 1998 broken down by major IPCC source category. Total emissions were around 13% of the UK in 1998 with an estimated reduction of 1% since 1990.

The largest emission source in Scotland is from Land Use Change and Forestry (LUCF). This constitutes around 32% of the total emission and contributes around 87% 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 18% over the period. Milne discusses the assumptions underlying these emissions in more detail. (See Salway (2000)). The Scottish Executive has commissioned new research to develop a more robust process-based approach to estimating CO_2 emissions and removals from UK soils following land use change, which will address these uncertainties. LUCF emissions are much less significant in other parts of the UK and overall, LUCF emissions constitute around 5% 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 next largest source is Energy Industries, which includes power generation, refineries, solid fuel transformation processes and the oil and gas industry. Electricity Generation contributed around 24% of the total emission (35% of the non-LUCF emission) which is slightly lower than 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 20% since 1990 in contrast with a fall of 25% 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 4% for the UK. The other energy emissions are relatively small and are mostly gas consumption at oil and gas terminals and gas separation plant. Only those emissions arising from on-shore installations in Scotland have been included. These emissions have however increased by 53% over the period, though the 1990 estimates for terminals are highly uncertain.

Emissions from manufacturing industry account for around 13% of the non-LUCF total compared with 16% for the UK. Emissions have declined over the period by 33% largely as a result of the Ravenscraig Steel Plant closing.

Road transport is the largest single source after power generation and comprises around 16% 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 1.6% 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 9% which is consistent with the population.

Around 1% of non-LUCF emissions arise from oil and gas fugitives, mainly from flaring at terminals. Flaring has fallen by 67% 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 1998. Since 1990 emissions from iron and steel processes have been absent resulting in a 48% reduction in these sources.

Carbon dioxide emissions from waste incineration are not significant

Over the period the total non-LUCF emission has fallen by 2.8%.

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 15% from 1990 to 1998.

The largest source of methane emissions in Scotland is agriculture. Emissions arise from enteric fermentation in livestock and the treatment of their wastes. Around 54% of Scottish emissions arise from agriculture with cattle responsible for 37%. 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 17% 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 on Scottish landfills reflected that of the UK. Landfill emissions have fallen by 30% because of increasing use of methane recovery systems, though this reduction assumes the UK trend. Emissions from wastewater treatment are around 2% of UK emissions which seems low compared with the other regions. This is because of the use of sea dumping in Scotland over the period. This should cease at the end of 1998, when other disposal routes will be adopted. This could increase emissions from this source.

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 18% 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 7%, oil and gas terminals 2% and natural gas distribution 9% of the Scottish total. Coal mining emissions have declined by 22% over the period due to the decline in the coal industry. Terminal emissions have decreased by 48% over the period. 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 1998 was around 8%.

Fuel combustion emissions of methane are not important and only account for 3.5%. Most of these emissions are from domestic coal combustion.

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 1998 broken down by major IPCC source category. Total emissions were around 9% of the UK in 1998 and have declined by 14% since 1990.

Of the total emission of 17 kt in 1998, around 15 kt of this was from agriculture. Most of this was 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
- 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 (0.8 kt) is emitted from the treatment of agricultural wastes. Scottish agricultural emissions are around 15% of UK agricultural emissions and have fallen by around 9% since 1990.

The remaining 2 kt (8%) 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 2.7 over the period. This is a result of the increasing use of catalytic converters on cars.

In 1990 around 1.8 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 main factor producing the reduction in emissions.

HYDROFLUOROCARBONS

Total emissions of HFCs were 2% of the UK total (as CO_2 equivalent) in 1998. 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 63% 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 36% 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.

PERFLUOROCARBONS

The largest source of perfluorocarbons in Scotland is consumption by the electronics industry which contributed around 81% of the total emission (as CO_2 equivalent) in 1998. Electronics production is concentrated in Scotland and contributes around 52% of UK electronics emissions and 30% of the UK PFC total (as CO_2 equivalent). Aluminium production also makes an important contribution accounting for 17% 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 37% of the UK total (as CO_2 equivalent).

SULPHUR HEXAFLUORIDE

The main source of sulphur hexafluoride is emissions from the electronics industry which accounts for 40% of the total emission for Scotland in 1998. 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 6% of the UK total.

Emissions in Wales

CARBON DIOXIDE

Figure 1 shows emissions of carbon dioxide for 1990 to 1998 broken down by major IPCC source category. Total emissions were around 6% of the UK total in 1998 and have decreased by 7% since 1990.

The largest source is Energy Industries, which includes power generation, refineries and solid fuel transformation processes. Electricity generation contributed around 12% of the total emission in 1998 which is lower than 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 stations. Fossil fuel generation is from conventional coal stations and a gas fired CCGT. Emissions have decreased by 55% since 1990 in contrast with a fall of 25% in UK emissions. 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. Power generation emissions are around 3% of UK power generation emissions.

Petroleum refining constitutes a larger proportion of national emissions at 8% compared with 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 total. There are no significant emissions from oil and gas production.

Combustion emissions from manufacturing industry account for around 37% of the 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 45% of UK Iron and Steel combustion emissions. The other industry category is around 5% of the UK total. Iron and Steel combustion emissions have increased by 37% 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 14% of the total. Its contribution to UK emissions is 4.5% which is around that which would be expected from Wales' population (5% of UK population). The estimate for 1995 and 1998 is 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, commercial and public sectors. These are fairly uncertain due to lack of data. Domestic emissions are around 12% of the 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 and account for around 2% of the total.

Emissions from Land Use Change and Forestry (LUCF) constitute around 3% of the total emission and contribute around 4% 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 total in 1998. The Welsh industrial process emission is around 15% 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.

Over the period the total emissions have decreased by 6% with the main decreases occurring in the electricity supply industry and increases in the iron and steel industry and other industry.

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 22% from 1990 to 1998.

The largest source of methane emissions in Wales is agriculture. Emissions arise from enteric fermentation in livestock and the treatment of their wastes. Around 65% of Wales' emissions arise from agriculture with cattle responsible for 38% and sheep 26%. 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 18% 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 31% 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 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 13% 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 emissions coal mining contributes 4%, coking 2% and natural gas distribution 8% to the Welsh total. Coal mining emissions have declined by 84% 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 extrapolated from the UK estimate using gas sales data. This estimate is uncertain since leakage is not directly related to gas throughput, and it assumes that changes in the Welsh system reflect those of the UK.

Combustion emissions are not an important source of methane. Altogether they account for around 3% of the total. Most of this comes from sintering in the iron and steel industry and domestic combustion of coal and anthracite.

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 1998 broken down by major IPCC source category. Total emissions were around 7% of the UK in 1998 and have increased by 7% since 1990.

Of the total emission of 11.8 kt in 1998, around 10.5 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
- histosols (i.e. high organic content soils)
- cultivation of legumes
- field burning (discontinued in 1993)

A relatively small proportion (0.5 kt) is emitted from the treatment of agricultural wastes. Welsh agricultural emissions are around 11% of UK agricultural emissions and have increased by 5% since 1990.

The remaining 1.3kt (11%) of nitrous oxide emissions result from fuel combustion. The main sources are power generation, road transport 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.

HYDROFLUOROCARBONS

In 1998 the total HFC emission in Wales was 0.9% of the UK HFC total (as CO_2 equivalent). Refrigeration is the largest source and contributes 63% to the total (as CO_2 equivalent). Here emissions arise due to losses from refrigeration and air conditioning equipment during its manufacture and lifetime. Aerosols contribute 36% 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.

PERFLUOROCARBONS

The largest emission source of perfluorocarbons in Wales is the electronics industry which contributed around 31% of the total Welsh PFC emission (as CO_2 equivalent) in 1998. This is around 9% of UK electronics emissions. Aluminium production also makes an important contribution accounting for 67% of Wales' PFC emission (as CO_2 equivalent) and 33% of UK aluminium production emissions. The remaining sources are fire extinguishers, refrigeration and leakage from the soles of certain brands of training shoes. Overall, emissions are 17% of the UK PFC total (as CO_2 equivalent). Emissions of PFC have decreased by 73% mainly as a result of improved control measures in the aluminium industry.

SULPHUR HEXAFLUORIDE

Welsh emissions of sulphur hexafluoride were 6% of the UK total in 1998. The main source of emissions is from use as a cover gas in magnesium production. These account for around 58% of total emissions and comprise 7% of the UK magnesium production emission. The next largest sources of sulphur hexafluoride are leakage from the soles of certain brands of training shoes and emissions from the electrical switchgear used in electricity transmission. Together these account for 36% of the total. The remaining emissions are from the electronics industry and are around 7% of total Welsh emissions.

Emissions in Northern Ireland

CARBON DIOXIDE

Figure 1 shows emissions of carbon dioxide for 1990 and 1998 broken down by major IPCC source category. Total emissions in Northern Ireland were around 3% of the UK total in 1998 and have decreased by 9% 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 36% 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. Emissions from electricity generation increased by 11% over the period but have declined by 11% since 1995. The recent decline is largely due to the conversion to natural gas.

Combustion emissions from manufacturing industry account for around 13% of the total 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 total, and has declined by about 5% over the period since 1990.

Road transport is the largest single source after power generation and residential, and comprises around 13% of the total. Its contribution to UK emissions is 2% which is less that which would be expected from Northern Ireland's population (2.5% of the UK). The emission has fallen by 28% over the period contrary to the UK trend of a 6% increase. 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 south of the border. IPCC (1997) guidelines require that carbon dioxide emissions in a country be based on fuel sales 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 emissions are around 20% of the total and are the largest source after power generation. As a proportion of UK domestic emissions they are 4% which is higher than would be consistent with the population. The reason for this is the non-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 significant. 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 process source of carbon dioxide are two cement plants and a glass factory which contribute around 2.5% to the total. Waste incineration is not a significant source of CO_2.

Emissions from Land Use Change and Forestry (LUCF) constitute around 9% of the total emission and contribute around 6% of the UK LUCF Emission. Around 0.97 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 -0.64 Mt CO_2 arises from 5A Changes in Forests and Other Woody Biomass. These emissions have fallen by around 26% over the period.

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 1998.

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 81% of Northern Ireland's emissions arise from agriculture with cattle responsible for 68%. Emissions are dependent on the numbers of livestock and have increased by 8% over the period 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. This contributes around 15% 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 29% 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 significant source of methane emissions. Altogether they account for around 4% of the total. Most of this comes from the domestic combustion of coal and anthracite.

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 1998 broken down by major IPCC source category. Total emissions were around 6% of the UK emission in 1998 and have increased by 9% since 1990.

Of the total emission of 10 kt in 1998, around 8 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. Agricultural emissions in Northern Ireland are around 9% of UK agricultural emissions and have increased by 7% since 1990.

Around 1.3 kt of nitrous oxide were emitted from a nitric acid plant contributing 13% to the total emission.

The remaining 0.8 kt (8%) of nitrous oxide emissions result from fuel combustion. Around 0.3 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 over the period. This is a result of the increasing use of catalytic converters on cars.

HYDROFLUOROCARBONS

Total emissions of HFCs in 1998 were 0.5% of the UK Total (as CO_2 equivalent). The main sources are aerosols and refrigeration (including air conditioning) each contributing around half of the 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. The remaining emission source, fire fighting was negligible. The total emission has increased from virtually zero in 1990.

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. New data suggests that the use of PFCs in the electronics industry in Northern Ireland is not significant hence the revision since the previous inventory.

SULPHUR HEXAFLUORIDE

Overall emissions were 0.9% of the UK total in 1998. 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. New data suggest that the use of SF_6 in the electronics industry in Northern Ireland is negligible hence the revision since the previous inventory.

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 1998 UK total they account for carbon dioxide 5%; methane 3% and nitrous oxide 0.4%. There were no unallocated emissions of halocarbons and sulphur hexafluoride.

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Figure 1 Emissions of Carbon Dioxide

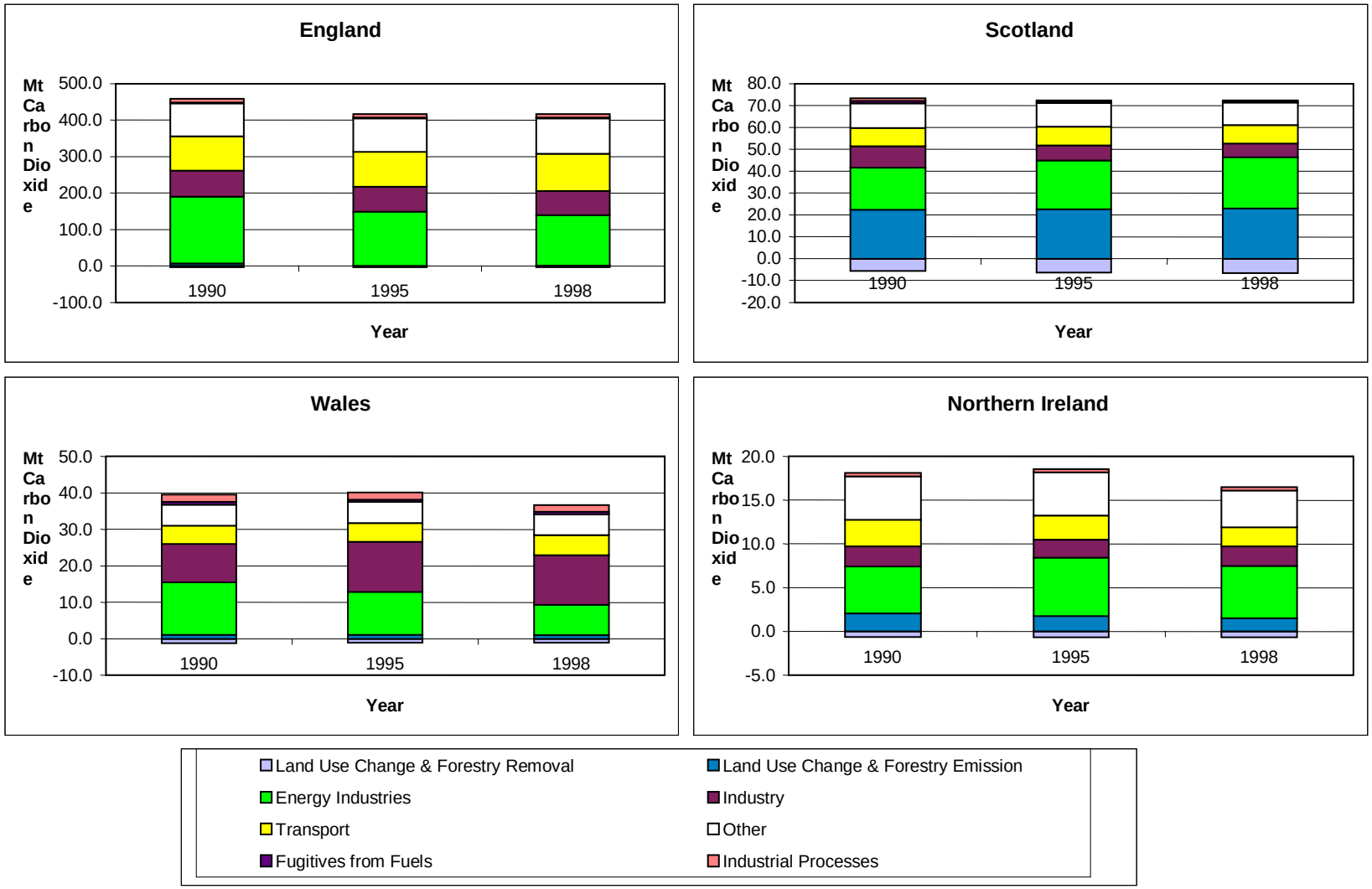

Figure 2 Emissions of Methane

Figure 3 Emissions of Nitrous Oxide

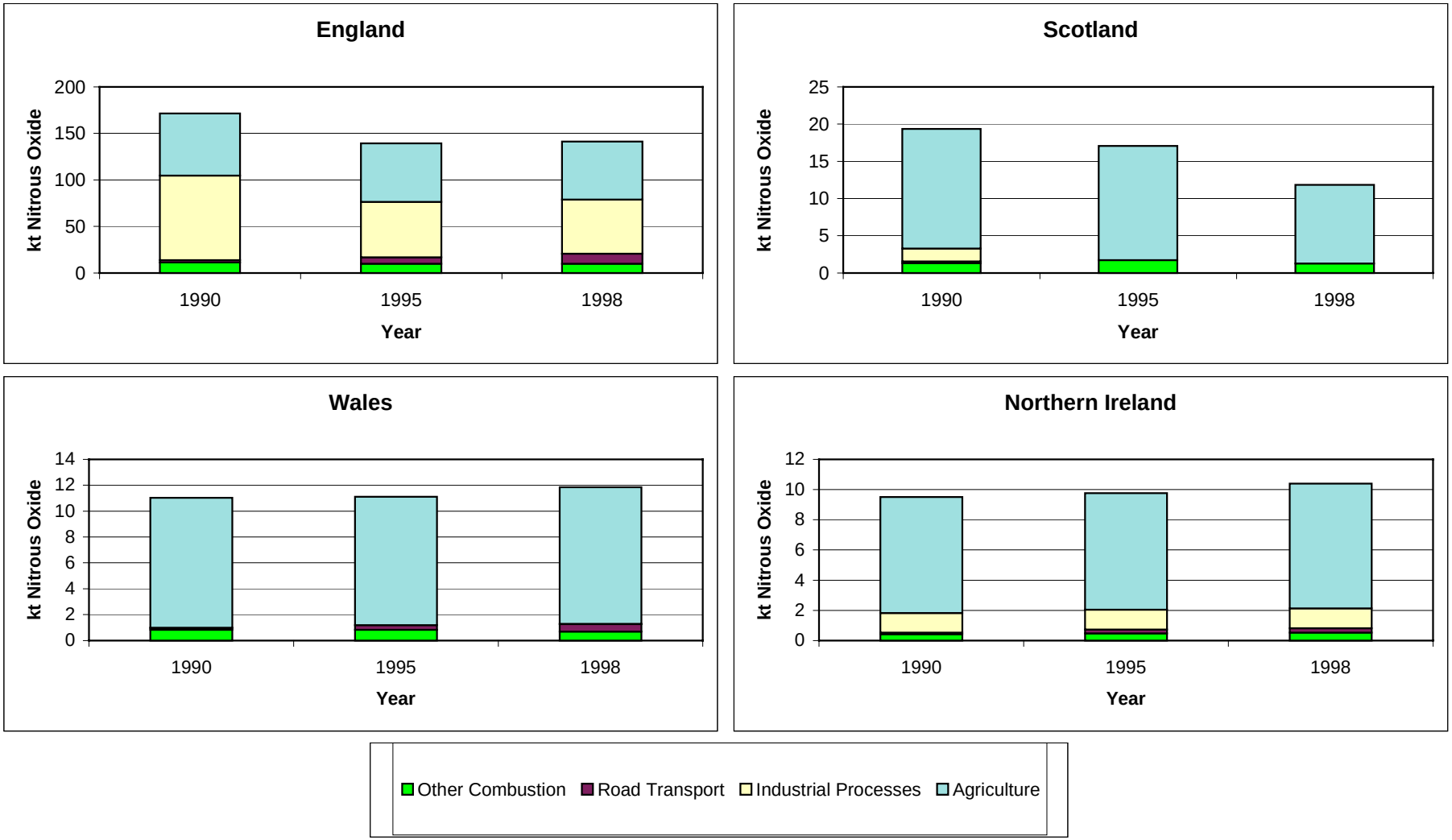

Figure 4 Emissions of HFCs

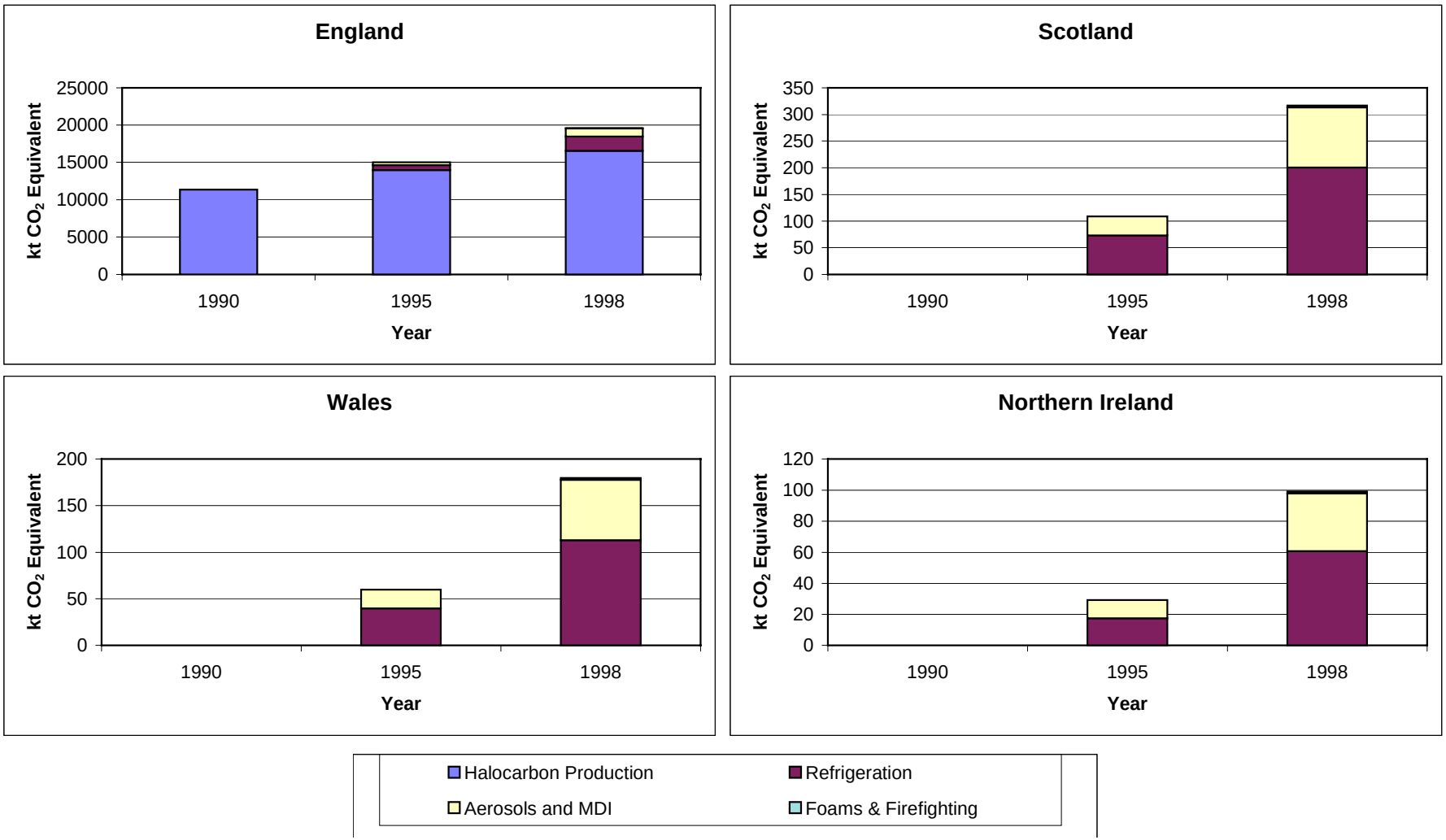

Figure 5 Emissions of PFCs

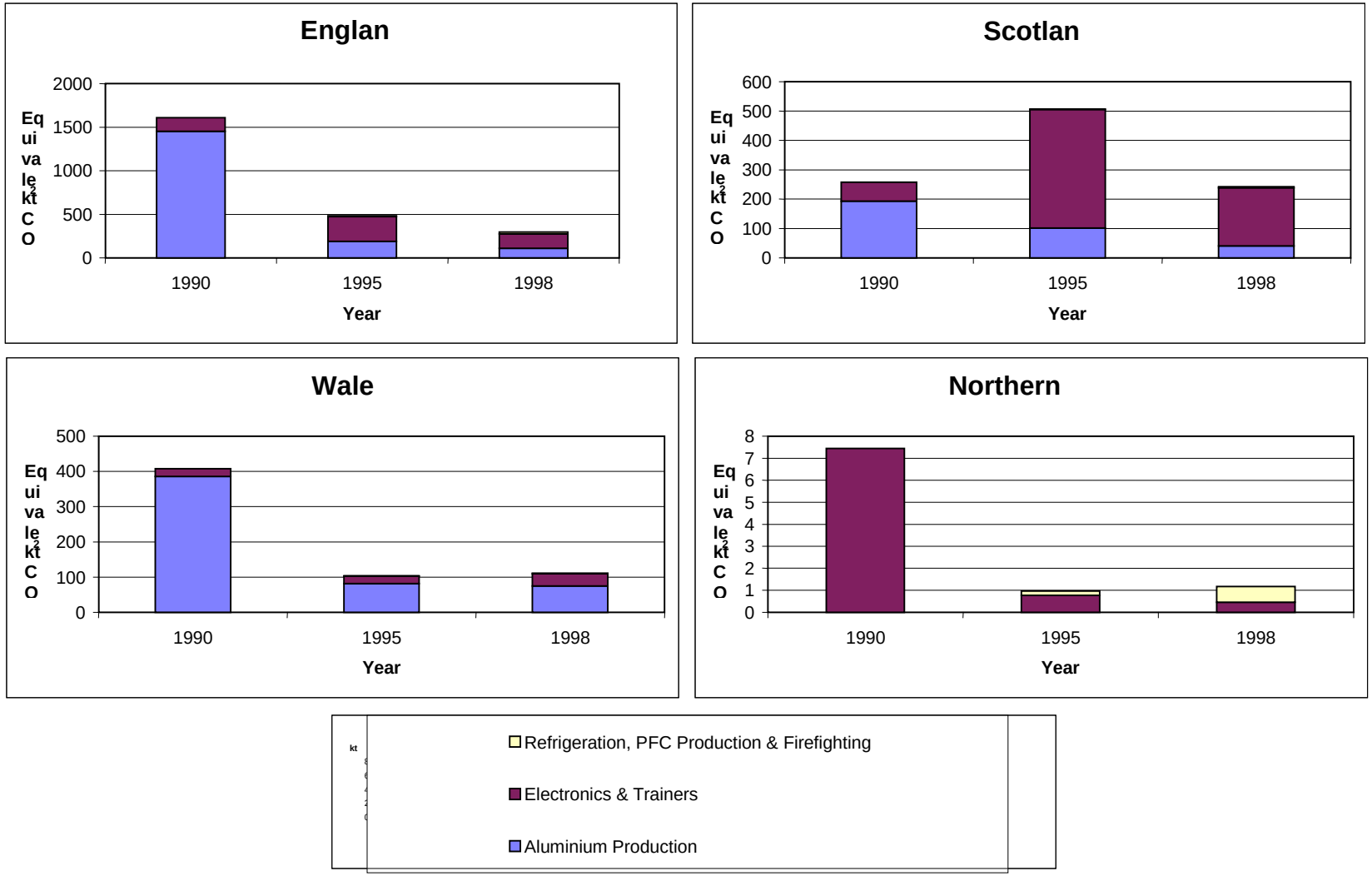

Figure 6 Emissions of Sulphur Hexafluoride