National Atmospheric Emissions Inventory

Report

Air Quality Pollutant Inventories for England, Scotland, Wales and Northern Ireland: 1990 – 2008

A report of the National Atmospheric Emissions Inventory, AEA Group

October 2010

Air Quality Pollutant Inventories for England, Scotland, Wales and Northern Ireland: 1990 – 2008

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Executive Summary

This is the Air Quality Pollutant Inventory Report for England, Scotland, Wales and Northern Ireland. The report presents emission inventories for the constituent countries of the UK for the period 1990 to 2008, for the following priority Air Quality (AQ) pollutants:

- Ammonia (NH_3)
- Carbon monoxide (CO)
- Nitrogen oxides (NO_X as NO_2)
- Non-methane volatile organic compounds (NMVOCs)
- Sub-10 micron particulate matter (PM_{10})
- Sulphur dioxide (SO_2)
- Lead (Pb)

These inventories are compiled on behalf of the UK Department for Environment, Food & Rural Affairs, the Scottish Government, the Welsh Assembly Government and the Department of Environment for Northern Ireland, by the UK emission inventory teams at AEA and North Wyke Research.

Data Sources and Inventory Methodology

The constituent country inventories are compiled by disaggregating the UK emission totals presented within "UK Emissions of Air Pollutants 1970 to 2008" (Murrells *et al.*, 2010), derived from the National Atmospheric Emissions Inventory (NAEI) database. The emission estimates for each pollutant are presented in NFR format, to be consistent with the UK inventory submissions to the United Nations Economic Commission for Europe (UNECE), which follow international inventory reporting guidelines.

The method for disaggregating UK emission totals across the constituent countries draws on a combination of point source data (e.g. Pollution Inventory[1] data for industrial emissions) and sub-national and local datasets such as:

- DECC sub-national statistics on energy use
- Other regional energy use data for specific industries or regional data on raw material consumption or sector-specific production
- Major road traffic count data
- Domestic and international flight data for all major UK airports
- Rail company fuel use estimates
- Regional housing, employment, population and consumption data
- Agricultural surveys (livestock numbers, crop production, fertiliser application)
- Land use survey data

Emissions from the offshore oil & gas exploration and production sector are not attributed to a specific country inventory, but are reported within an "unallocated" category. Note, however, that emissions from onshore oil & gas terminals are assigned to the appropriate country inventories.

The disaggregation of air quality (AQ) pollutant emissions across the four constituent countries of the UK has been conducted four times previously, using the 1990-2003, 1990-2005, 1990-2006 and 1990-2007 NAEI datasets. This report presents the results from a programme of ongoing data and methodology improvement, to provide emission inventories for the Devolved Administrations (DAs). This programme spans both GHG and AQ emission inventories, and is driven by the developing requirements for sub-national reporting against emission targets and DA policy development.

[1] The term "Pollution Inventory" is used here to represent the industrial emissions databases of the UK environmental regulators (The Environment Agency of England & Wales, the Scottish Environment Protection Agency and the Northern Ireland Department of Environment), which comprise annual emission estimates from all IPC/IPPC-regulated processes under their authority.

For many sources of AQ pollutants, the data available for constituent country emissions are less detailed than for the UK as a whole, and for some sources, country-level data are not available at all. In particular, complete sets of fuel consumption data are not available for England, Scotland, Wales and Northern Ireland.

Sub-national energy statistics are published annually by the Department for Energy and Climate Change (DECC) within the quarterly Energy Trends[2] publication. These statistics are limited in their detail when compared to UK-level energy statistics, but do provide estimated fuel use data for England, Scotland, Wales and Northern Ireland for the following source sectors:

- Industry (1A2) & Commercial (1A4a)
- Agriculture (4)
- Residential (1A4b)

The DECC sub-national energy statistics have been developed in recent years to provide estimates of fuel use and CO_2 emissions data at Local Authority (LA) level across the UK. The latest available data include LA solid and liquid fuel use estimates for 2003 to 2007, with gas and electricity data also being available up to 2008.

The DECC data at local and regional level are derived from analysis of gas and electricity meter point data, supplemented by additional research to estimate the distribution of solid fuels and petroleum-based fuels across the UK. Since the initial study and presentation of experimental data for 2003 and 2004, each annual revision to the local and regional data has included data improvements through targeted sector research. These DECC sub-national energy statistics continue to evolve and improve, reducing data inaccuracies, but nevertheless are subject to greater uncertainty and less detail than the UK energy statistics presented within DUKES (and used to underpin the UK air quality pollutant inventories). However, they are regarded as the best dataset available to inform the patterns of fuel use across the Devolved Administrations and are therefore used to underpin the pollutant emission estimates from fuel combustion sources within the inventories presented here, in conjunction with other data sources such as EU ETS fuel use data for large industrial sites and other DA-specific energy data.

For other significant emission sources there are more reliable and complete country-level datasets available, although some of these are less detailed than data used for the UK Inventory:

- Industrial process emissions are based on plant operator estimates reported to environmental agencies under regulatory systems such as Integrated Pollution Prevention and Control (IPPC). Major sources include power stations, cement and lime kilns, iron & steelworks, aluminium and other non ferrous metal plant, chemical industries. These data are not available across the full time-series from 1990, as the regulatory reporting regimes developed in the late 1990s;

- Emissions from oil and gas terminals and offshore platforms and rigs, are based on operator estimates reported to the DECC Oil and Gas team in Aberdeen through the Environmental Emissions Monitoring System, EEMS.

- Agricultural emissions are based on UK emission factors and annual survey data across each of the Devolved Administrations, including estimates of arable production and livestock numbers;

- Land Use, Land Use Change and Forestry estimates are based on emission factors and regional survey data of land use;

[2] The latest available data are taken from the March 2010 Energy Trends, http://www.decc.gov.uk/assets/decc/statistics/publications/trends/1_20100324115020_en;e_@@_trendsmar10.pdf

- Emissions from waste disposal activities are estimated based on modelled emissions from the UK air quality inventories, split out across the DAs based on local authority waste disposal activity reporting which provides an insight into the local shares of UK activity for recycling, landfilling, incineration and other treatment and disposal options.

For some sources where regional data are not available, current local mapping grids have been used; these mapping grids are commonly based on census and other survey data that are periodically updated and used within UK emissions mapping and modelling work. For many sources, there is insufficient local data available back to 1990, and assumptions and extrapolations of available datasets have frequently been used to present a time-series of air quality pollution emissions.

As a result of the more limited DA-specific activity and emission factor data, the emission estimates for the England, Scotland, Wales and Northern Ireland inventories are subject to greater uncertainty than the equivalent UK estimates. There are step-changes in data availability during the time-series, such as installation-specific fuel use data from major industrial plant under EUETS (from 2005 onwards) and sites regulated under IPC/IPPC (1998 onwards for England and Wales, 1999 onwards for Northern Ireland, and in 2002 and from 2004 onwards for Scotland). These data sources are used where possible to inform back-casting of emission estimates, but there remains a greater level of uncertainty in emission estimates from the earlier part of the time-series compared to more recent years. Furthermore, the data quality from these environmental regulatory systems has evolved over the years, as monitoring, reporting and quality checking methods and protocols have developed. This also impacts upon the accuracy of the reported emissions of AQ pollutants which are used within inventory compilation, such that more recent data are likely to be more accurate.

Air Quality Emission Inventories: Key Findings

The main findings of this report are summarised below:

Carbon monoxide (CO)

UK emissions in 2008 are estimated at 2.8 Mt, representing a 69% reduction on the emissions in 1990 (90.1 Mt). Emissions of CO are dominated by those from road transport (1A3b) (54% of UK emissions in 2008). The UK-wide estimates of road transport CO emissions have been revised in the 1990-2008 inventory cycle to reflect recent research to update vehicle emission factors and revise assumptions of catalyst failure rates for different vehicle types. Higher emission factors, especially for cars and light duty vehicles, have led to higher CO emission estimates from road transport across the time series, compared to previous inventories. The change in emissions between 1990 and 2008 is dominated by the reduction in emissions from the road transport sector (1A3b), caused by the increased use of three-way catalysts in cars; this trend is evident for all DAs. Across Scotland, Wales and Northern Ireland, residential emissions have declined by 69%, 66% and 80% respectively, primarily to a decrease in the use of solid fuels. In Wales, combustion and process emissions from the iron and steel industry account for 36% of total emissions in 2008, despite having reduced by 48% since 1990.

Non-methane volatile organic compounds (NMVOCs)

UK emissions of NMVOC are estimated as 2.6 Mt for 1990 and 0.94 Mt for 2008, a decrease of 63%. The observed decrease arises primarily from the road transport (1A3b) and industrial sectors, due to the impact of tighter European vehicle emission standards and fuel quality directives, as well as the impact of the Solvent Emissions Directive. Across the UK, the estimated overall reductions are broadly similar, ranging from a decrease of 57% since 1990 in Northern Ireland, 61% reduction in Scotland, 62% reduction in Wales, to a 65% reduction in England. Each country has its own mix of high-emitting sectors in 2008, though. In England, road transport (1A3b) accounts for 14% of the inventory and oil & gas sector (NFR 1B2) is 14% of the total. In Scotland the oil and gas sector accounts for 23% in 2008, whilst the food and drink sector (mainly whisky maturation) accounts for 34% of 2008 emissions. In Wales the road transport sector (1A3b) accounts for 14% of 2008 emissions and the oil and gas sector a further 22%. In Northern Ireland the residential sector accounts for 33% of the 2008 total due to the higher incidence of solid fuel use compared to GB, whilst road transport (1A3b) accounts for 12% and the food and drink industry a further 7%.

Nitrogen oxides reported as nitrogen dioxide (NO_X as NO_2)

UK emissions of NO_X were 2.7 Mt in 1990, and have fallen by 49% to 1.4 Mt in 2008. This is primarily a consequence of abatement measures in road transport (1A3b) and at coal-fired power stations, and the increased use of other fuels for power generation (1A1a). Emissions from road transport and coal combustion together account for 48% of UK emissions in 2008. Emissions from all of the DAs have declined since 1990, ranging from a 38% reduction in Wales, 48% reduction in Scotland, 49% reduction in Northern Ireland and a 51% reduction in England.

Across all of the constituent countries of the UK, emissions from the power generation sector (1A1a) have had a dominant effect, both in overall reductions since 1990 and determining more recent trends that have resulted from changes in the fuel mix used for generation and the installation of over-fire air NO_X abatement at a majority of UK coal-fired power stations since 2007. In England, power sector NO_X emissions are down 66% since 1990; between 2007 and 2008, coal-fired generation declined by 12%, gas-fired generation increased by 10% and overall NO_X emissions reduced by 29%, reflecting the abatement impacts at coal-fired stations. The picture is very similar in Scotland where since 1990 the power sector NO_X emissions are down 62%, with 2007-8 trends down 21%, following a 15% reduction in coal-fired generation but a 7% increase in gas generation. Power sector NO_X emissions in Northern Ireland have declined by 80% since 1990, reflecting an underlying shift away from coal-fired and oil-fired generation to gas-fired generation since the gas pipeline was completed to Northern Ireland in 1996. 2007 to 2008 emissions show an 8% reduction, despite a 12% increase in generation from coal-fired plant and a 1% reduction in gas-fired generation. In Wales, power sector NO_X emissions have declined by 25% since 1990, with large increases in power generation (1A1a) evident in recent years as Wales increasingly generates electricity that is exported and used in England. Trends over the last few years have been greatly affected by a plant shut-down at Aberthaw in 2007 to retro-fit 2 units with Flue Gas Desulphurisation abatement. Coal-fired generation over 2006, 2007 and 2008 in Wales has varied from 8859 GWh down 40% to 5121 GWh and then increasing again by over 80% to 9364 GWh in 2008 as Aberthaw was back online. This is the underlying reason why overall NO_X emissions in Wales have increased by 54% between 2007 and 2008.

Road transport (1A3b) is another very significant source of NO_X emissions across all DAs, and over 2007 to 2008 all DAs show a reduction in emissions of around 10%, which reflects shifts in engine technology across the fleet and the down-turn in UK economic activity. In England in 2008, road transport accounts for 35% of total emissions, down 59% since 1990. The sector in Scotland is 28% of the total NO_X inventory in 2008, down 58% since 1990. In Wales emissions are down 61% since 1990 and represent a lower share of the overall NO_X inventory at 20%, reflecting Wales' greater share of manufacturing and energy industries and hence higher NO_X emissions from those sources. In Northern Ireland, road transport is estimated to account for 42% of the total NO_X emissions, down 37% on 1990.

Sulphur dioxide (SO_2)

UK emissions of sulphur dioxide have fallen from 3.7 Mt in 1990 to 0.5 Mt in 2008, representing a decrease of 86%. Between 2007 and 2008, an overall reduction of 14% in SO_2 emissions is reported, and this is driven largely by efforts in the refining industry to reduce the sulphur content of petroleum-based fuels, shifts in power generation fuel mix and the installation of Flue Gas Desulphurisation abatement on power stations. These changes are reflected across the DA inventories; similar to the NO_X inventories, the reported trends in the DA inventories are dominated by emissions from the power generation (1A1a) sector. In Wales, the installation of Flue Gas Desulphurisation abatement at the Aberthaw coal-fired power station led to a 58% reduction in SO_2 emissions from the sector between 2007 and 2008, which underpinned the overall 2007 to 2008 reduction of 24% in Wales.

The contribution of emissions from industrial combustion sources (NFR 1A2) ranges from 8% of the SO_2 inventory total in 2008 for both Scotland and Wales, to 16% in Northern Ireland and 17% in England, reflecting the variable fuel mix and greater use of solid fuels and fuel oil in England (including one major coal-fired autogeneration plant) and Northern Ireland. A similar issue arises when considering the relatively high SO_2 emissions from the domestic sector (1A4b) in Northern

Ireland (14% of the 2008 total, compared to a UK average of 5%) which is again primarily due to the greater use of oil and solid fuels, which is a consequence of the less mature gas network.

Reductions in SO_2 emissions from road transport sources (1A3b) are evident across the UK, with all constituent countries of the UK achieving a 98% reduction in emissions from road transport between 1990 and 2008. Recent trends from the impacts from the Sulphur Content of Liquid Fuels Directive are illustrated by SO_2 reductions from road transport declining by over 30% in all constituent countries of the UK between 2007 and 2008. This has been achieved through efforts in the refinery sector to reduce the average sulphur content of petroleum fuels. Data from the refinery trade association, UKPIA, shows that for premium unleaded petrol the average UK sulphur content declined by 22% between 2007 and 2008, whilst average content of sulphur in diesel more than halved in the one year. Small changes in sulphur content are also evident for kerosene, aviation fuels (9% increase in sulphur content), medium and heavy fuel oil, whilst gas oil (for non-transport markets) has also shown a reduction in sulphur content of around 39% between 2007 and 2008.

Ammonia (NH_3)

The total UK emission of ammonia for 2008 is estimated at 0.28 Mt, compared to the 1990 estimate of 0.37 Mt, representing a 23% reduction. The agricultural sector dominates ammonia emissions, with over 88% of UK emissions coming from agricultural sources. Agricultural emissions have declined by 27% since 1990, most notably in England, due primarily to reductions in livestock numbers, especially cattle and pigs. Agricultural emissions dominate all of the DA inventories in 2008, contributing 86% of the total in England, 92% in Scotland, 93% in Wales, and 96% in Northern Ireland. Agricultural emission reductions since 1990 have been greatest in England (down 31%), then Wales (down 25%) and Scotland (down 24%), whilst reductions in Northern Ireland are estimated at around 8%.

Emissions from road transport (1A3b) have increased since 1990 due to the increased use of catalytic converter technology in petrol cars, although emissions are now declining due to the introduction of second generation catalysts which emit less NH_3. These increases are more than offset by the impacts of reducing livestock numbers. Across each of the constituent countries of the UK, the overall significance of the emissions from cars reflects some differences in reported vehicle fleets and vehicle kilometre data for different vehicle sub-groups. In Scotland and Wales, cars account for 3% of total ammonia emissions in 2008. In Northern Ireland where diesel vehicles are a larger fraction of the vehicle fleet, the emissions from cars are only 1% of the 2008 ammonia emissions, whilst in England the share is 5%.

Ammonia emissions from sewage sludge decomposition and composting are around 1% each from all of the DAs, whilst in England there is also 2% of 2008 ammonia emissions which arise from chemical industry production and use of ammonia.

Sub-10 micron Particulate Matter (PM_{10})

UK emissions of PM_{10} have declined by 53% from 0.28 Mt in 1990 to 0.13 Mt in 2008. This reflects a trend away from coal use particularly by domestic users. There are a wide range of sources of PM_{10} that contribute of the order of 1 to 10% of the inventory total, but the most significant sources are domestic combustion (14% of UK emissions of PM_{10} in 2008) and particulate from (1A3b) sources (18% of UK emissions in 2008).

Across the constituent countries of the UK, emissions from England show proportionally higher emissions from the road transport sector (1A3b) (20% of the total in 2008) with Scotland and Northern Ireland around the UK average at 15% and 13% respectively, whereas in Wales only 11% of the total is from road transport due to higher emissions from industry (2) sites such as iron and steelworks. Northern Ireland has proportionally higher emissions from the domestic sector (1A4b) (45% compared to 14% UK-wide in 2008) due to the more extensive use of solid fuels, although it must be noted that the DA domestic energy data estimates are amongst the most uncertain activity data in the inventory. Estimates for Wales and Scotland indicate that the domestic sector contributes around 22% of the 2008 total, whilst in England only 10% comes from domestic sources.

Other sources of note include mobile agricultural machinery which contributes 4 to 5% in Wales, Scotland and Northern Ireland and 2% in England in 2008. Quarrying emissions range from 2% in Northern Ireland to 6% in England and 7% in each of Scotland and Wales in 2008. Iron and steelworks contribute 5% of England PM_{10} emissions and 13% of Wales emissions in 2008 (very low or no emissions in Scotland or Northern Ireland). Industrial coating account for 4% in England, 1% in Northern Ireland and 2% in each of Scotland and Wales. Emissions from poultry broilers is a notably higher proportion of the inventory in Northern Ireland at over 7%, whereas in Wales the figure is 3%, Scotland 4% and England 5% of the 2008 total. Small-scale waste burning estimates are highly uncertain at both UK and DA level, but the current estimates for 2008 PM_{10} emissions indicate that they contribute 1% of emissions in Northern Ireland, 2% in Wales and 3% in Scotland and England.

Lead (Pb)

UK lead emissions are estimated at 67 tonnes in 2008, compared to 2,890 tonnes in 1990, representing a 98% reduction. The largest source of lead until 1999 was from anti-knock lead additives in petrol. The lead content of leaded petrol was reduced from 0.34 g/l to 0.143 g/l in 1986. From 1987 sales of unleaded petrol increased, particularly as a result of the increased use of cars fitted with three-way catalysts, and leaded petrol was phased out from general sale at the end of 1999. As a result, a very large decline in emissions from the road transport sector (1A3b) is evident across each of the constituent countries of the UK since the late 1990s.

The major sources of lead that remain in 2008 are primarily those from sinter plant and other metal production processes. There has been some reduction in emissions from iron and steel production processes due to improved abatement, with a 43% reduction from iron and steel sources between 1990 and 2008. Emissions from steelworks account for 81% of lead emissions in Wales in 2008, whilst in England the sector accounts for 48% of total emissions. Wales iron and steel emissions account for 15% of the total UK inventory, and the England iron and steel emissions another 36% of the UK total. As a result, England accounts for almost 76% of total UK emissions, whilst Wales accounts for approximately 19% of total UK lead emissions, and in contrast Scotland emits only 4% and Northern Ireland approximately 2% of UK lead releases in 2008.

In Scotland and Northern Ireland, the 2008 inventories indicate that the domestic sector (1A4b) combustion of solid fuels is the largest emission source. In total, the domestic sector (1A4b) accounts for 31% of the Scottish lead inventory and just under 43% of the Northern Ireland inventory, but as mentioned above the domestic sector energy data are associated with high uncertainty.

Other lead emission sources of note in 2008 include non-ferrous metal processes such as: the alkyl lead industry (7% of the England inventory and 0.6% of the Wales inventory), copper alloy industry (ranging from 0.6% of the Wales inventory to around 2% of the lead emissions in Scotland, England and Northern Ireland), secondary lead processes (negligible in Wales, 1% in Northern Ireland and 2% of lead emissions in Scotland and England) and foundries (1% in Wales in Northern Ireland but nearly 8% of total England emissions and over 10% of lead emissions in Scotland). Power sector emissions account for 1% of the Wales inventory, 5% of emissions in England, 7% of emissions in Northern Ireland and 11% of Scottish lead emissions in 2008. Refinery emissions in Scotland account for 8% of the total, with 2% and 3.2% of emissions in Wales and England, which reflects the overall higher inventory totals in Wales and England due to the iron and steel sector emissions.

The DA inventories of lead emissions are strongly influenced by the annual emissions data reported by the UK environmental regulatory agencies. In many industrial sectors regulated under IPC/IPPC, the annual reporting of lead emissions to the Pollution Inventory, SPRI and ISR shows a greater degree of variability than for many other pollutants; compared to the other pollutants covered in this report, the data for lead emissions from regulated processes tends to be more scarce, with occasional gaps in data and noticeably greater variation in year-to-year emissions reported by specific installations. This is likely to be partly due to the greater difficulty in emissions measurement for species such as lead, for which standard methods are typically discrete (i.e. periodic, rather than continuous). Consequently, the annual operator estimates submitted to regulators may be based on a more limited dataset of stack emissions measurements that may not represent all phases of non-continuous (batch) processes, or may not be representative of fuels that may have a variable lead

elemental composition (such as coal). The lead inventory estimates from these sources are based on the best available data from IPPC regulated installations, which are subject to a managed system of quality checking by the environmental regulatory agencies. Furthermore, the emissions of lead are expected to show more variation than for other pollutants, as the lead content of raw materials will vary, and emissions will be affected by this and other factors of plant performance over time. However, the lead emission estimates are regarded as more uncertain than for other pollutants reported here, such as NO_X and SO_2 that are more commonly estimated based on analysis from Continuous Emission Monitoring Systems and are less dependent on raw material composition.

Contacts

This work forms part of the Atmosphere & Local Environment (ALE) Programme of the Department for Environment, Food and Rural Affairs. AEA compiles emission estimates for the energy, industrial process, solvents and waste sectors. The Centre for Ecology and Hydrology (Edinburgh) provides emission estimates for land use, land use change and forestry sources. North Wyke Research provides the estimates of agricultural emissions.

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A copy of this report and related data may be found on the website maintained by AEA for Defra: http://www.naei.org.uk

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1 Introduction

1.1 BACKGROUND TO INVENTORY DEVELOPMENT FOR THE DEVOLVED ADMINISTRATIONS

This study to develop AQ pollutant datasets for each of the constituent countries of the UK has been commissioned by Defra in order to better inform energy and environmental policy-makers within the Devolved Administrations in their pursuit of objectives set by the Air Quality Strategy for England, Scotland, Wales and Northern Ireland (AQS for ESWNI). These objectives also contribute to the UK's targets as a whole in terms of meeting both national and international targets on both local and transboundary air pollution.

The provision of DA-level datasets and subsequent identification of key sources at more regional and local levels is a key step to enable prioritisation of local action and to highlight the potential impacts of specific policies and measures. The time-series of AQ pollutant emissions provides an insight into the effects of environmental policies introduced since 1990, and may help to identify where win-win policies could be pursued to achieve both AQ and GHG policy goals.

1.1.1 Air quality emission reduction drivers

Overall air quality in the UK is currently estimated to be better than at any time since the industrial revolution. However air pollution is still estimated to reduce the life expectancy of every person in the UK by an average of 7-8 months (AQS, 2008). A number of policies are currently in place in the UK, which aim to improve air quality. This includes the national air quality strategy for England, Scotland, Wales and Northern Ireland.

Air Quality Strategy for England, Scotland, Wales and Northern Ireland

The original National Air Quality Strategy (NAQS) published in 1997 (DOE 1997) set out a framework of standards and objectives for the air pollutants of most concern (SO_2, PM_{10}, NO_X, CO, lead, benzene, 1,3-butadiene and tropospheric ozone). The aim of the strategy was to reduce the air pollutant impact on human health by reducing airborne concentrations.

The NAQS identified air quality standards for 8 priority pollutants based on the recommendations of the Expert Panel on Air Quality Standards (EPAQS) or World Health Organisation (WHO) guidance where no EPAQS recommendation existed. The NAQS has been subject to periodic review, with consultation documents being published in 1998 and 2001 (DETR 1998a, Defra 2001), and has subsequently evolved into the Air Quality Strategy for England, Scotland, Wales and Northern Ireland (AQS for ESWNI), with the same goals. A second edition of the strategy was published in 2000 (DETR 2000), identifying further revisions and focused on the incorporation of air quality limit values in European Directives, and the impacts of devolution. On 17 July 2007 a new Air Quality Strategy was published by Defra and the Devolved Administrations. The details of this AQS can be found on the Defra website at: http://www.defra.gov.uk/environment/airquality/strategy/index.htm

The new Air Quality Strategy supersedes previous versions and covers the whole of the UK, therefore including DA-specific objective values that were previously detailed in addenda to the previous AQS.

EU Air Quality Framework Directive

The EU air quality framework directive (96/62/EC) established a framework for setting limit values, assessing concentrations and managing air quality to avoid exceeding the limits for air pollutants known to be harmful to human health and the environment through a series of four Daughter Directives. However, in 2008, the Framework Directive and first three Daughter Directives were consolidated in a new EU air quality Directive (2008/50/EC), the 4th Daughter Directive. The new Directive also introduced a new regulatory framework for $PM_{2.5}$.

At present, under 2008/50/EC and the 4th Daughter Directive, limit values are set for twelve pollutants, including NO_X, SO_2, PM and CO, and member states are required to submit annual reports to the European Commission on whether the limits have been achieved within their respective areas.

UN/ECE's Convention on Long-Range Transboundary Air Pollution
The UK is committed to reducing acidifying gas and ozone precursor emissions and is a party to several protocols under the UNECE's Convention on Long-Range Transboundary Air Pollution.

Under the Second Sulphur Protocol, the UK must reduce its total SO_2 emissions by 50% by 2000, 70% by 2005 and 80% by 2010 (all from a 1980 baseline).

The NMVOC Protocol requires the UK to achieve a 30% reduction of anthropogenic NMVOC emissions by 1999 from a 1988 baseline. The emission estimates given in the 1999 version of the emissions inventory indicated that this was achieved.

The NO_X Protocol required that the total emissions of NO_X in 1994 should be no higher than they were in 1987; UK emissions were 11% lower in 1994 than in 1987 and have fallen substantially since 1994.

In 1996, the UNECE started negotiating a new multi-effect, multi-pollutant protocol on nitrogen oxides and related substances. This was aimed at addressing photochemical pollution, acidification and eutrophication. The Protocol to Abate Acidification, Eutrophication and Ground-level Ozone was adopted in Gothenburg in December 2000, where it was signed by the UK. The multi-pollutant protocol incorporates several measures to facilitate the reduction of emissions:

- Emission ceilings are specified for sulphur, nitrogen oxides, NH_3 and NMVOCs;
- Emission limits are specified for sulphur, nitrogen oxides and NMVOCs from stationary sources;
- Emission limits are indicated for CO, hydrocarbons, nitrogen oxides and particulates from new mobile sources;
- Environmental specifications for petrol and diesel fuels are given;
- Several measures to reduce NH_3 emissions from the agriculture sector (4) are required.

The Gothenburg Protocol forms a part of the Convention on Long-range Transboundary Air Pollution. More detailed information on both of the Gothenburg protocol and the Convention may be found at the UNECE web site: www.unece.org/env/lrtap/

National Emissions Ceilings Directive
Within the EU, the National Emission Ceilings Directive was agreed in 2001. It sets emission ceilings to be achieved from 2010 onwards for each Member State for the same 4 pollutants as in the Gothenburg Protocol. A number of member states (including the UK for SO_2 and NO_X) reduced their ceilings somewhat below the levels included in the Protocol.

Large Combustion Plant Directive
Within the UK, the implementation of the EC's Large Combustion Plant Directive and other associated policy measures has led to substantial reductions in acidifying pollutants, specifically NO_X, SO_2 and dust from power plants and industrial sources.

Sulphur Content of Liquid Fuels Directive
The EC's Directive to limit sulphur content in gas oil and fuel oil has been transposed into UK regulations which were initially established in 2000 but were updated with Statutory Instruments brought into force across the DAs via the Sulphur Content of Liquid Fuel Regulations 2007 (England and Wales: SI79/2007; Scotland: SI 27/2007; Northern Ireland: SI 272/2007). The main impact of these regulations has been to gradually drive down the maximum sulphur content of refinery products, with the 2007 Regulations requiring that gas oil has a maximum 0.1% content Sulphur by mass from January 2008 onwards. The impacts of this change are evident within the recent emission

trends of the UK and DA inventories as SO_2 emissions have declined significantly between 2007 and 2008 from road transport (1A3b) and other sources where petroleum-based fuels are dominant.

UN/ECE Heavy Metals Protocol
The Convention on Long-range Transboundary Air Pollution was signed in 1979 and came into force in 1983. Since its entry into force, the Convention has been extended by a number of protocols, including the 1998 Protocol on Heavy Metals. This Protocol is given in outline below; more information may be found at the UN/ECE web site, located at: http://www.unece.org/env/lrtap/
The UK has signed this protocol.

The UN/ECE Protocol on Heavy Metals targets three particularly harmful substances: lead, cadmium and mercury. Countries are obliged to reduce their emissions of these three metals below their levels in 1990 (or an alternative year between 1985 and 1995). The protocol aims to cut emissions from industrial sources (iron and steel industry, non-ferrous metal industry), combustion processes (power generation, road transport) and waste incineration.

The protocol specifies limit values for emissions from stationary sources and requires the use of Best Available Technology (BAT)) to minimise emissions from these sources, through the application of special filters or scrubbers for combustion sources, or mercury-free processes. The protocol also required countries to phase out leaded petrol. Under the protocol, measures are introduced to lower heavy metal emissions from other products e.g. mercury in batteries, and examples are given of management measures for other mercury containing products, such as electrical components (thermostats, switches), measuring devices (thermometers, manometers, barometers), fluorescent lamps, dental amalgam, pesticides and paint.

1.2 INVENTORY METHOLODOGY & DATA AVAILABILITY

This report presents emission inventories for the constituent countries of the UK for the period 1990 to 2008, for the following priority Air Quality (AQ) pollutants:

- Ammonia (NH_3)
- Carbon monoxide (CO)
- Nitrogen oxides (reported as nitrogen dioxide) (NO_X as NO_2)
- Non-methane volatile organic compounds (NMVOC)
- Sub-10 micron particulate matter (PM_{10})
- Sulphur dioxide (SO_2)
- Lead (Pb)

The estimates have been compiled by disaggregating the UK emission totals presented within "UK Emissions of Air Pollutants 1970 to 2008" (Murrells *et al.*, 2010a), derived from the National Atmospheric Emissions Inventory database. The UK data is compiled annually in accordance with the requirements of United Nations Economic Commission for Europe (UNECE) reporting guidelines using the NFR reporting format and submitted to the Convention on Long-Range Transboundary Air Pollution (CLRTAP). In addition to the UK Emissions of Air Pollutants 1970 to 2008 report, in 2010 an additional report, the Informative Inventory Report (Murrells *et al.,* 2010b), was produced which provides an overview of time-series revisions.

1.2.1 Background: Data Availability and Inventory Uncertainty

The method for disaggregating UK emission totals across the constituent countries draws on a combination of point source data (e.g. Pollution Inventory[3] data for industrial emissions) and sub-national and local datasets such as:

[3] The term "Pollution Inventory" is used here to represent the industrial emissions databases of the UK environmental regulators (The Environment Agency of England & Wales, the Scottish Environment Protection Agency and the Northern Ireland Department of Environment) which comprise annual emission estimates from all IPC/IPPC-regulated processes under their authority.

- DECC sub-national statistics on energy use
- Other regional energy use data for specific industries or regional data on raw material consumption or sector-specific production
- Major road traffic count data
- Domestic and international flight data for all major UK airports
- Rail company fuel use estimates
- Regional housing, employment, population and consumption data
- Agricultural surveys (livestock numbers, crop production, fertiliser application)
- Land use survey data

Emissions from the offshore oil & gas exploration and production sector are not attributed to a specific country inventory, but are reported within an "unallocated" category. Note, however, that emissions from onshore oil & gas terminals are assigned to the appropriate country inventories.

The disaggregation of air quality (AQ) pollutant emissions across the four constituent countries of the UK has been conducted four times previously, using the 1990-2003, 1990-2005, 1990-2006 and 1990-2007 NAEI datasets. This report presents the results from a programme of ongoing data and methodology improvement, to provide emission inventories for the Devolved Administrations (DAs). This programme spans both GHG and AQ emission inventories, and is driven by the developing requirements for sub-national reporting against emission targets and DA policy development.

For many emission sources of AQ pollutants, the data available for constituent country emissions are less detailed than for the UK as a whole, and for some sources country-level data are not available at all. For this reason, a "top-down" approach using UK inventory data as the core dataset has been adopted, and percentage splits of the UK total have been derived for each of the constituent countries using available regional data.

In particular, energy balance data (i.e. fuel production, transformation and sector-specific consumption data) are not available for England, Wales and Scotland. Sub-national energy statistics are published annually by the Department for Energy and Climate Change (DECC) within the quarterly Energy Trends[4] publication. These sub-national statistics are limited in their detail when compared to UK-level energy statistics, but do provide estimated fuel use data for England, Scotland, Wales and Northern Ireland for the following source sectors:

- Industry (2) & Commercial
- Agriculture (4)
- Residential (1A4b)

The DECC sub-national energy statistics have been developed in recent years to provide estimates of fuel use and CO_2 emissions data at Local Authority (LA) level across the UK. The latest available data include LA solid and liquid fuel use estimates for 2003 to 2007, with gas and electricity data also being available up to 2008.

The DECC data at local and regional level are derived from analysis of gas and electricity meter point data, supplemented by additional research to estimate the distribution of solid fuels and petroleum-based fuels across the UK. Since the initial study and presentation of experimental data for 2003 and 2004, each annual revision to the local and regional data has included data improvements through targeted sector research. These DECC sub-national energy statistics continue to evolve and improve, reducing data inaccuracies, but nevertheless are subject to greater uncertainty and less detail than the UK energy statistics presented within DUKES (and used to underpin the UK air quality pollutant inventories). However, they are regarded as the best dataset available to inform the patterns of fuel use across the Devolved Administrations and are therefore used to underpin the pollutant emission estimates from fuel combustion sources within the inventories presented here, in conjunction with other data sources such as EU ETS fuel use data for large industrial sites and other DA-specific energy data.

[4] The latest available data are taken from the December 2008 Energy Trends, http://www.berr.gov.uk/files/file49202.pdf

For other significant emission sources there are more reliable and complete country-level datasets available, although some of these are less detailed than data used for the UK Inventory:

- Industrial process emissions are based on plant operator estimates reported to environmental agencies under regulatory systems such as Integrated Pollution Prevention and Control (IPPC). Major sources include power stations, cement and lime kilns, iron & steelworks, aluminium and other non ferrous metal plant, chemical industries. These data are not available across the full timeseries from 1990, as the regulatory reporting regimes developed in the late 1990s;

- Emissions from oil and gas terminals and offshore platforms and rigs, are based on operator estimates reported to the DECC Oil and Gas team in Aberdeen through the Environmental Emissions Monitoring System, EEMS;

- Agricultural emissions are based on UK emission factors and annual survey data across each of the Devolved Administrations, including estimates of arable production and livestock numbers;

- Land Use, Land Use Change and Forestry estimates are based on emission factors and regional survey data of land use;

- Emissions from waste disposal activities are estimated based on modelled emissions from the UK air quality inventory, split out across the DAs based on local authority waste disposal activity reporting which provides an insight into the local shares of UK activity for recycling, landfilling, incineration and other treatment and disposal options.

- For some sources where regional data are not available, current local mapping grids have been used; these mapping grids are commonly based on census and other survey data that are periodically updated and used within UK emissions mapping and modelling work.

In many source sectors, there is insufficient local data available back to 1990 or earlier, and assumptions and extrapolations of available datasets have frequently been used to present a time-series of air quality pollution emissions.

As a result of the more limited country-specific activity and emission factor data, the emission estimates for the England, Scotland, Wales and Northern Ireland inventories are subject to greater uncertainty than the equivalent UK estimates. There are step-changes in data availability during the time-series, such as installation-specific fuel use data from major industrial plant under EUETS (from 2005 onwards) and sites regulated under IPC/IPPC (1998 onwards for England and Wales, 1999 onwards for Northern Ireland, and in 2002 and from 2004 onwards for Scotland). These data sources are used where possible to inform back-casting of emission estimates, but there remains a greater level of uncertainty in emission estimates from the earlier part of the time-series compared to more recent years. Furthermore, the data quality from these environmental regulatory systems has evolved over the years, as monitoring, reporting and quality checking methods and protocols have developed. This also impacts upon the accuracy of the reported emissions of AQ pollutants which are used within inventory compilation, such that more recent data are likely to be more accurate. The uncertainties in the DA air quality inventories are discussed in more detail in Chapter 3.

1.2.2 Inventory Compilation Method

A comprehensive list of all sources and UK emissions for the target pollutants (CO, NO_X, SO_2, VOC, NH_3, PM_{10}, Pb) during the study period of 1990-2008 is available from the NAEI database. From these data, the key sources for each of the AQ pollutants can be determined. The DA share of the UK emissions from each source category are then determined using the best available regional data, which may range from good quality emissions or activity data, to the use of proxy data (e.g. production or employment indices, population data) to provide a “best estimate” of the DA share of the UK emissions from a given source.

There are a number of resources that have been used to analyse the DA share of UK emissions for each emission source, including:

- NAEI point source database;
- Emissions mapping grid data;
- Regional data derived from analysis of activity data trends, taken from research to develop DA Greenhouse Gas (GHG) Inventories;
- Generic parameters and proxy data such as population or regional GDP data.

The development of more consistent reports and datasets between different scales (national-regional-local) derived from the NAEI database is a key improvement that this study has enabled. The main resources used within the DA air quality pollutant inventory analysis are outlined below.

1.2.2.1 NAEI Point Source Database

Operators of all IPC/IPPC-regulated industrial plant are required to submit annual emission estimates of a range of pollutants (including all of those pertinent to this study) to their local UK environmental regulatory agency, and these emission estimates are subject to established procedures of Quality Assurance and Quality Checking prior to publication. These industrial point-source pollution inventories (held by the Environment Agency, the Scottish Environment Protection Agency and the Northern Ireland Environment Agency) are emission datasets that have been developing and improving since their inception in the mid-1990s. Robust and reliable data for installations in England and Wales have been widely available since around 1998, whilst the equivalent datasets in Scotland and Northern Ireland became available from the early 2000s.

NAEI point source data have been improved over recent years through the increasing quality and availability of these IPC/IPPC-regulated industrial pollution emission datasets, as well as through the availability of site-specific fuel use data for sites that operate within the EU Emissions Trading Scheme (EUETS), which has been running since 2005. Annual data requests are also made directly to plant operators in key sectors such as power stations, refineries, cement & lime manufacture, iron & steel manufacture, chemical industry and waste treatment and disposal, in order to procure more detailed emissions data and other parameters (e.g. production data).

As part of the Devolved Administrations Inventory Improvement Programme, a research study was undertaken in early 2010 to source more detailed information on emissions sources at a number of petrochemical and industrial sites across the UK. The study included consultation with Environment Agencies responsible for each of the respective Devolved Administrations and site visits to review further details of applications and reports submitted in relation to permitted activities.

Through analysis of the time-series of data and review of the latest emission estimates, the point source data is amended as appropriate to fill in gaps and rectify any errors. These finalised data are then used as the basis for the NAEI industrial emissions estimates. The location of each site is known and therefore the point-source database can be queried to extract all emissions information relevant to a given geographical area, and hence the DA-level inventories can partly be populated in this way.

Although the use of this dataset can only provide a limited time-series of emissions from a given source sector, it is nevertheless a useful tool for deriving recent regional emissions data for a broad range of pollutants, including CO, NO_X, SO_2, VOC, Pb, NH_3 and PM_{10}. The NAEI point-source database is most useful for industries that are dominated by large IPC/IPPC-authorised plant, such as power stations, refineries, iron & steel manufacturing, cement and lime kilns and so on. For these sectors, the point source database covers nearly 100% of emissions, and is regarded to be the best available dataset for such sources, as it is largely based on energy use and emissions data derived from regulatory agency sources that are subject to quality checking and (in the case of EUETS data) independent verification.

Annual revisions to the NAEI point source database are conducted when new data become available and/or when installation-level data are revised by operators, regulators or through enquiry by the AEA inventory team to resolve data discrepancies which may be evident between reporting mechanisms.

In the 1990-2008 dataset, data have been revised for a range of industrial sites where the Phase II EUETS data (from 2008) enabled clarification of energy use patterns at industrial installations that had previously not reported under EUETS. Part of the DA Inventory Improvement Programme focussed on improved analysis of the EUETS dataset from 2008, and the results of this study are available on the NAEI website at:

http://www.naei.org.uk/reports.php?list=DA

1.2.2.2 NAEI Emission Mapping Grids

Emission maps for the whole of the UK are routinely produced as part of the NAEI for 25 pollutants, including all of the pollutants considered in this study. The maps are compiled at a 1km resolution and are produced annually for the most recent NAEI database (2008 in this case). The mapped emissions data are made freely available on the NAEI web site at:

http://www.naei.org.uk/mapping/mapping_2008.php

The emission maps are used by AEA and other organisations for a variety of Government policy support work at the national scale. In particular, the maps are used as input into a programme of air pollution modelling studies.

The geographical distribution of emissions across the UK is built up from distributions of emissions in each source sector. These source sector distributions are developed using a set of statistics appropriate to that sector. For large industrial 'point' sources, emissions are compiled from a variety of official UK sources (Environment Agency, Scottish Environment Protection Agency, Northern Ireland Environment Agency Local Authority data). For sources that are distributed widely across the UK (known as 'area' sources), a distribution map is generated using appropriate surrogate statistics for that sector. The method used for each source varies according to the data available, but is commonly based on either local activity statistics such as raw material use, energy use, industrial production and employment data, housing and population data, road vehicle and fuel sales data, periodic census or socio-economic survey data.

Periodic surveys and censuses of industrial, commercial, domestic, and other economic sectors provide indicators regarding the location and scale of a wide variety of activity data that can be used to disaggregate emissions totals, and these are commonly utilised within the NAEI mapping grids. For a more detailed description of the integration of point source data analysis and the development of UK emission maps, see Chapter 3 of *UK Emission Mapping Methodology 2008* (Bush et al., 2010). Appendix B of this report provides a summary table of the mapping grid data availability for each UNECE sector. In the latest cycle of emissions mapping research, revisions have been made to the emission maps for domestic combustion sources and landfill waste emissions, and this has led to revisions in the air quality emission estimates for each of the Devolved Administrations within this report, when compared to the emission distributions reported within the 1990-2007 DA Air Quality Inventory Report, published in October 2009.

The key limitation to the use of mapping grids within inventory development is the difficulty in obtaining an accurate time-series of emissions from a given sector, as the mapping grids are typically only updated every few years as more survey data becomes available. The data availability limitations inevitably impact upon the reliability of emission inventory estimates. In this study we have endeavoured to focus resources on ensuring that the most significant sources are assessed most accurately across the time-series, whilst less significant source sectors may be subject to a single mapping-grid-based disaggregation across all years.

1.2.2.3 Other Regional Data

In recent years, the NAEI team has aimed to develop a consistent time-series of detailed datasets to inform DA and local emission inventories (back to 1990) and pollutant mapping campaigns. Examples of such datasets that have been used in this study include:

- Regional fuel use data for natural gas, solid fuel and petroleum-based fuels, from UK Transco, other gas network operators, the Coal Authority and the Department of Energy and Climate Change (DECC). The AEA energy mapping team has been involved in the ongoing development of the DECC sub-national energy statistics which provide limited data from 2004 to 2008. These data are used to underpin many of the AQ pollutant emission estimates from small-scale (non-regulated) combustion sources such as domestic, commercial, public administration and small-scale industrial sectors. Back-casting the fuel use trends to 1990 has drawn upon available UK-level data and trends supplemented by analysis of additional data, such as Housing Condition Survey data, to ensure that significant changes are represented in the inventories (e.g. to reflect the development of the gas supply infrastructure in Northern Ireland since 1999).

- The Road Transport (1A3b) emissions database uses local traffic count data from the Department for Transport (DfT), the Northern Ireland Department of Regional Development (DRDNI), fuel use datasets (DECC), vehicle fleet data (DfT, DRDNI) and emission factors from European research sources (COPERT III, IV) to derive detailed emission estimates for a wide range of pollutants across the UK.

- Aircraft emissions are derived from the Civil Aviation Authority's (CAA) database of flight movements, fuel use data (DECC), aircraft fleet information (CAA) and emission factors from international guidance and research (Intergovernmental Panel on Climate Change, IPCC) to derive emission estimates for aircraft cruise, take-off and landing cycles.

- Regional quarry production data and quarry location information (British Geological Survey, BGS).

- Regional iron & steel production data, and regional fuel use data in the iron & steel industry (Corus, Iron & Steel Statistics Bureau).

- Site-specific emissions data split by combustion and process sources for all UK refineries, and refinery production capacities (UKPIA),

- Site-specific cement production capacities, and UK-wide cement industry fuel use data (British Cement Association).

- Regional railway diesel consumption data (local train operating companies, including freight, intercity and local passenger services).

- Regional housing & population data (Department of Communities and Local Government)

- Regional economic activity & industrial production indices (Office of National Statistics)

1.3 REPORT STRUCTURE

This report is structured as follows:

Main body of the report: This part of the report presents and discusses the inventories for England, Scotland, Wales and Northern Ireland, providing air quality pollutant emissions data for the years 1990, 1995, and 1998 to 2008. Emission inventories for PM_{10}, CO, NMVOCs, NH_3, NO_X, SO_2 and Pb are included in Chapter 2. Where appropriate, the reasons for any significant trends in emissions, issues regarding data availability and uncertainty estimates are provided for each inventory. A qualitative assessment of the uncertainty in the DA air quality inventories is presented in Chapter 3.

Appendix A: This appendix provides National Reporting Format sector code descriptions.

Appendix B: This appendix provides a summary of the disaggregation methods and mapping grids used in this study, for each UNECE sector.

Appendix C: Devolved Administration Emission Inventories for PM_{10}, 1990-2008 in NFR format.

Appendix D: Devolved Administration Emission Inventories for CO, 1990-2008 in NFR format.

Appendix E: Devolved Administration Emission Inventories for NO_X, 1990-2008 in NFR format.

Appendix F: Devolved Administration Emission Inventories for SO_2, 1990-2008 in NFR format.

Appendix G: Devolved Administration Emission Inventories for NMVOC, 1990-2008 in NFR format.

Appendix H: Devolved Administration Emission Inventories for NH_3, 1990-2008 in NFR format.

Appendix I: Devolved Administration Emission Inventories for Pb, 1990-2008 in NFR format.

2 Air Quality Pollutants

Inventories for England, Scotland, Wales and Northern Ireland for ammonia (NH_3), carbon monoxide (CO), nitrogen oxides (NO_X), non-methane volatile organic compounds (NMVOCs), sub-10 micron particulate matter (PM_{10}), sulphur dioxide (SO_2) and lead (Pb) are discussed in the following sections. These data have been derived by disaggregation of the UK figures using point source, mapping and regional datasets as appropriate (see Appendix B for details).

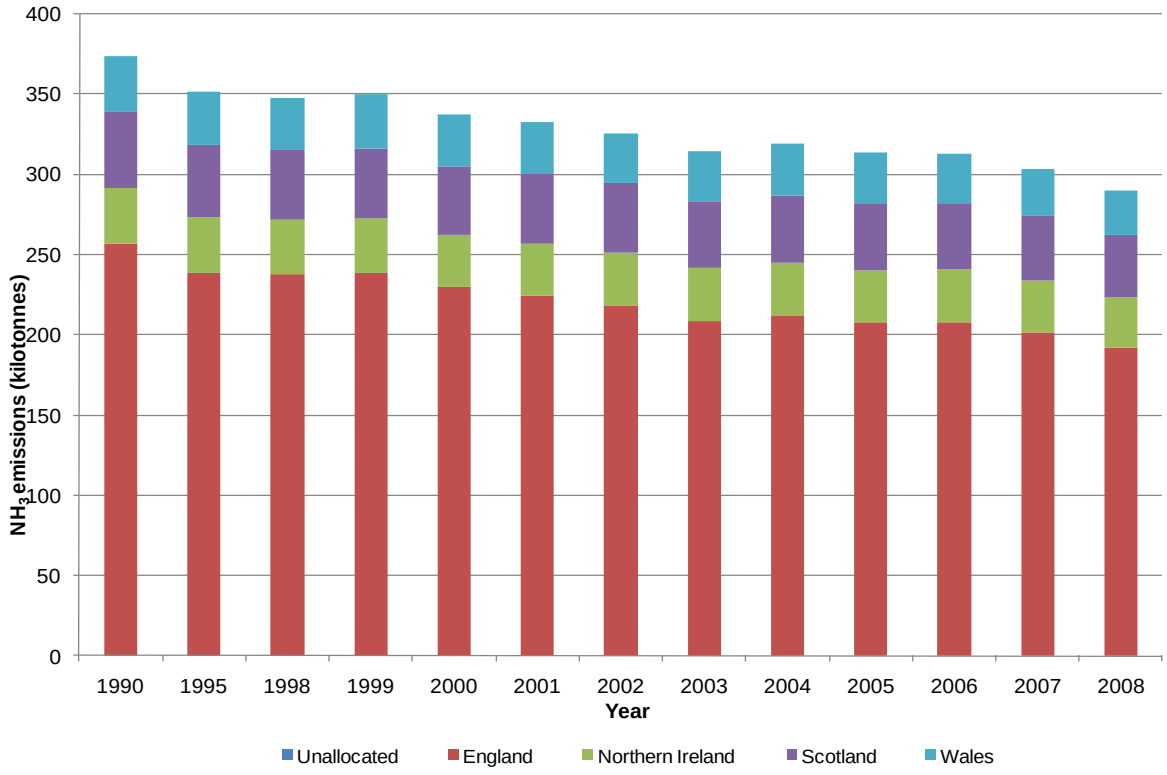
For information on the main sources & emission trends of Air Quality Pollutants in the UK National Atmospheric Emissions Inventory (NAEI) as well as supplementary information on particulate size & composition, monitoring and epidemiological evidence regarding effects on human health, please see Chapter 2 of *"UK Emissions of Air Pollutants 1970 to 2008"* (Murrells *et al*., 2010).]

2.1 AMMONIA

Ammonia (NH_3) emissions play an important role in a number of different environmental issues including acidification, eutrophication and changes in biodiversity. The atmospheric chemistry of NH_3 and NH_4^+ is such that transport of the pollutants can vary greatly, and that as a result, NH_3 emissions can exert impacts on a highly localised level, as well as contributing to the effects of long-range pollutant transport.

UK emission estimates for NH_3 are only available from 1990 onwards, because earlier data from the most significant industrial sources are not available for use in emission inventory estimates. UK ammonia emissions in 2008 represent a decrease of 23% on the 1990 emissions (Figure 2.1).

Figure 2-1 UK Ammonia Emissions by Constituent Country, 1990-2008



The main source of NH_3 emissions in the UK is livestock manure management, and in particular cattle manure management. These emissions derive mainly from the decomposition of urea in animal wastes and uric acid in poultry wastes. Emissions from nitrogen fertiliser use on grassland and arable crops are also a significant source and included in the ammonia inventory. Emissions are affected by a large number of factors, including animal species, age, weight, diet, housing and manure management systems, and environmental conditions. As such, the interpretation and extrapolation of experimental data is problematic, making emission estimates uncertain. Estimates are based on official livestock datasets, annual fertiliser use surveys, farm management practice surveys and detailed emission factors from recent literature sources. The methodology for compiling the inventory of ammonia emissions from agriculture (4) follows that of Webb and Misselbrook (2004) for manure management sources and Misselbrook et al (2004) for fertiliser sources, with annual revisions to input data, emission factors and other parameters as described in the annual Informative Inventory Report.

Decreasing livestock numbers (cattle in particular) and fertiliser use in the UK since 1990 have led to reductions in UK ammonia emissions, and it is this trend in agricultural sources that influences the DA-level inventories most significantly.

Non-agricultural sources of ammonia comprise a number of diverse sources. Emission estimates for these sources are often highly uncertain due to a lack of activity and emission factor data. Emissions from road transport (1A3b) (although relatively insignificant compared to agricultural emissions) increased in the 1990's as a result of the increasing number of three way catalysts in the vehicle fleet. However, emissions are now falling as the second generation of catalysts (which emit less NH_3 than first generation catalysts) penetrate the vehicle fleet.

Emissions of ammonia for England, Wales, Scotland and Northern Ireland are summarised in the tables and graphs below, with more detailed inventory tables in Appendix H. Table 2.1 shows how the estimated total UK NH_3 emissions are split between the 4 constituent countries.

Table 2-1 - Proportion of UK Ammonia Emissions by Constituent Country

Year	England	Scotland	Wales	N Ireland	Unallocated
1990	69%	12%	9%	9%	0%
2008	67%	13%	9%	11%	0%

2.1.1 England Ammonia Inventory by NFR Sector, 1990-2008

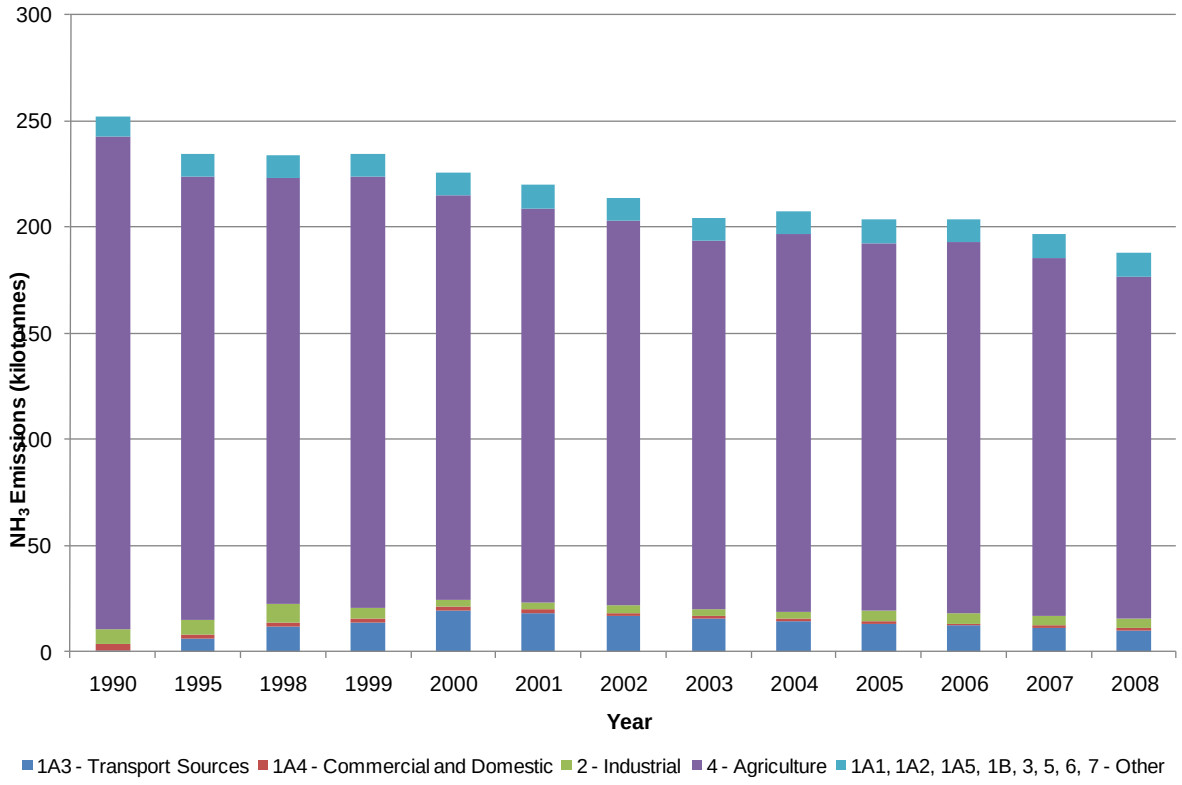
The table and graph below give a summary of the ammonia emissions in England by broad NFR sector categories. The detailed data are available in Appendix H.

Table 2-2 - England Emissions of Ammonia by NFR Source Sector

NFR Code	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2008%
1A3 - Transport Sources	0.7	5.9	11.9	13.8	19.4	18.1	16.9	15.3	14.3	13.1	12.2	11.2	10.1	5%
1A4 - Commercial and Domestic	2.8	2.0	1.9	2.0	1.6	1.6	1.3	1.1	1.1	1.0	0.9	1.0	1.1	1%
2 - Industrial	7.1	7.2	8.8	4.8	3.5	3.6	3.5	3.2	3.1	5.3	5.0	4.8	4.2	2%
4 - Agriculture	231	209	200	203	190	185	181	174	178	173	175	169	161	86%
1A1,1A2,1B,3,6, 7 - Other	9.3	10.6	10.5	10.8	10.9	10.9	11.0	10.8	10.7	10.9	10.9	11.1	11.6	6%
Total	252	234	233	235	226	220	214	204	207	203	204	197	188	100%

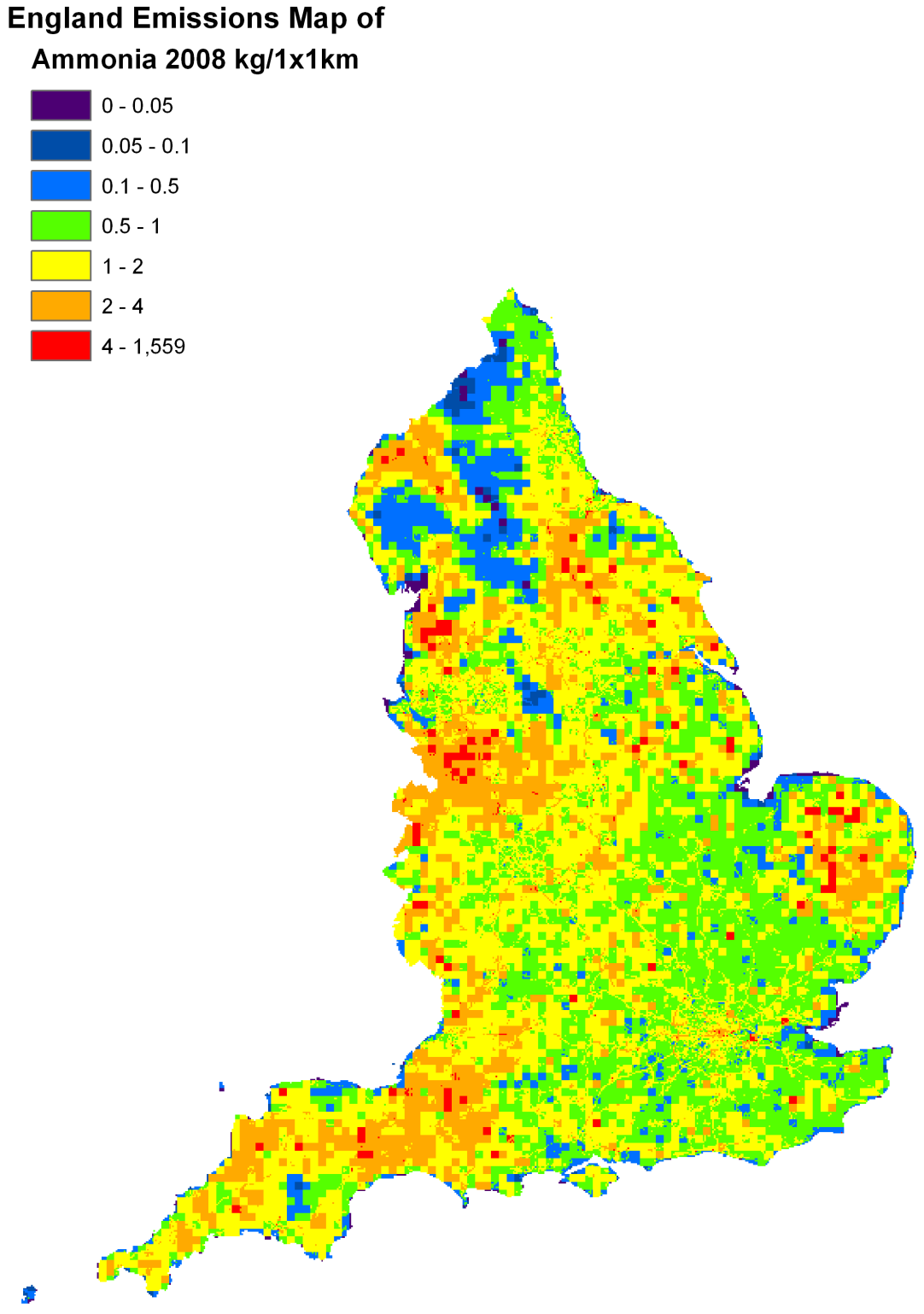
Units: kilotonnes

Figure 2-2 England Ammonia Emissions by Source, 1990-2008



England's NH_3 emissions have declined by 25% since 1990 and currently account for 67% of the UK total. The inventory is dominated by emissions from agricultural sources with 74% of the total in 2008 coming from manure management (4B: down 26% since 1990). 41% of the English total is from cattle manure management alone (4B1: down 22% since 1990). Other sources of note include transport emissions (1A3: 6% of the England total in 2008) and waste treatment and disposal (6: 5% of the England total in 2008).

Figure 2-3 Map of Ammonia Emissions in England, 2008



2.1.2 Scotland Ammonia Inventory by NFR Sector, 1990-2008

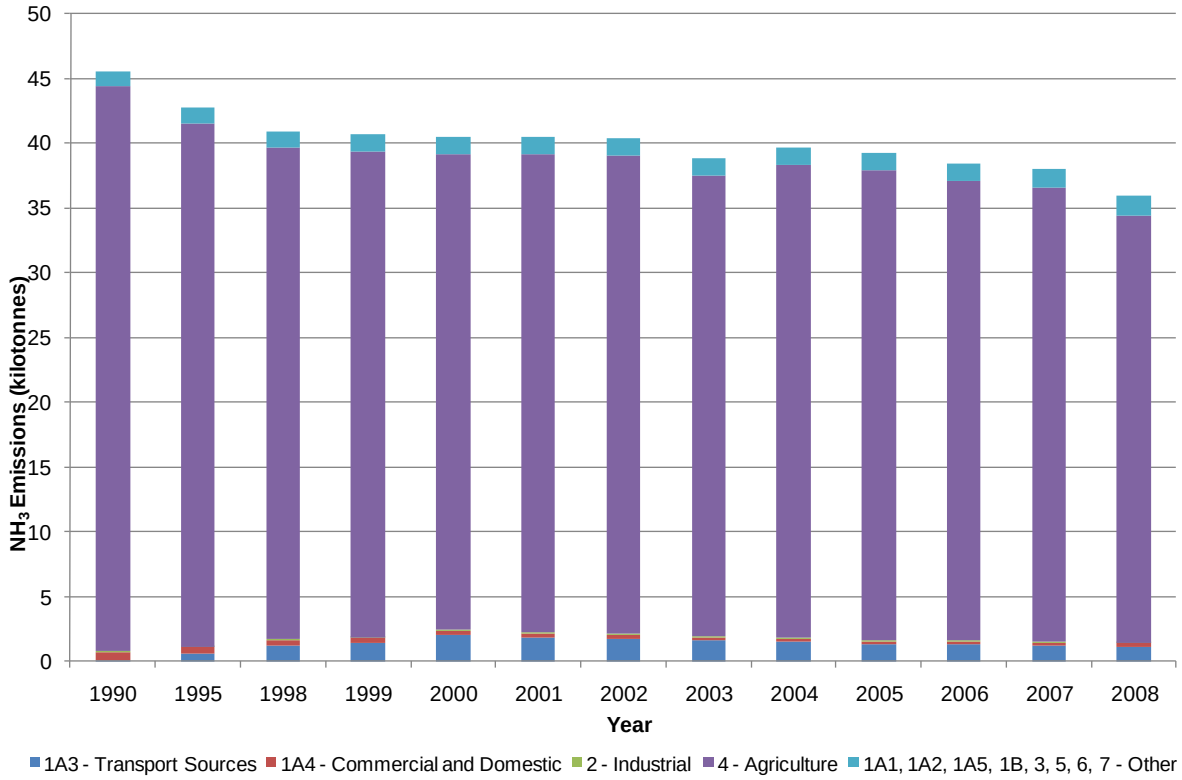
The table and graph below give a summary of the ammonia emissions in Scotland by broad NFR sector categories. The detailed data are available in Appendix H.

Table 2-3 - Scotland Emissions of Ammonia by NFR Source Sector

NFR Code	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2008 (%)
1A3 - Transport Sources	0.1	0.6	1.2	1.4	2.0	1.9	1.7	1.6	1.5	1.3	1.3	1.2	1.1	3%
1A4 - Commercial and Domestic	0.6	0.4	0.4	0.4	0.3	0.3	0.3	0.2	0.2	0.2	0.3	0.3	0.3	1%
2 - Industrial	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0%
4 - Agriculture	43.6	40.3	38.0	37.5	36.8	36.9	36.9	35.6	36.5	36.3	35.4	35.0	32.9	92%
1A1,1A2,1B,3,6,7 - Other	1.2	1.3	1.3	1.3	1.4	1.4	1.4	1.3	1.3	1.4	1.4	1.5	1.6	4%
Total	45.5	42.8	40.9	40.7	40.5	40.5	40.4	38.8	39.7	39.3	38.5	38.0	35.9	100%

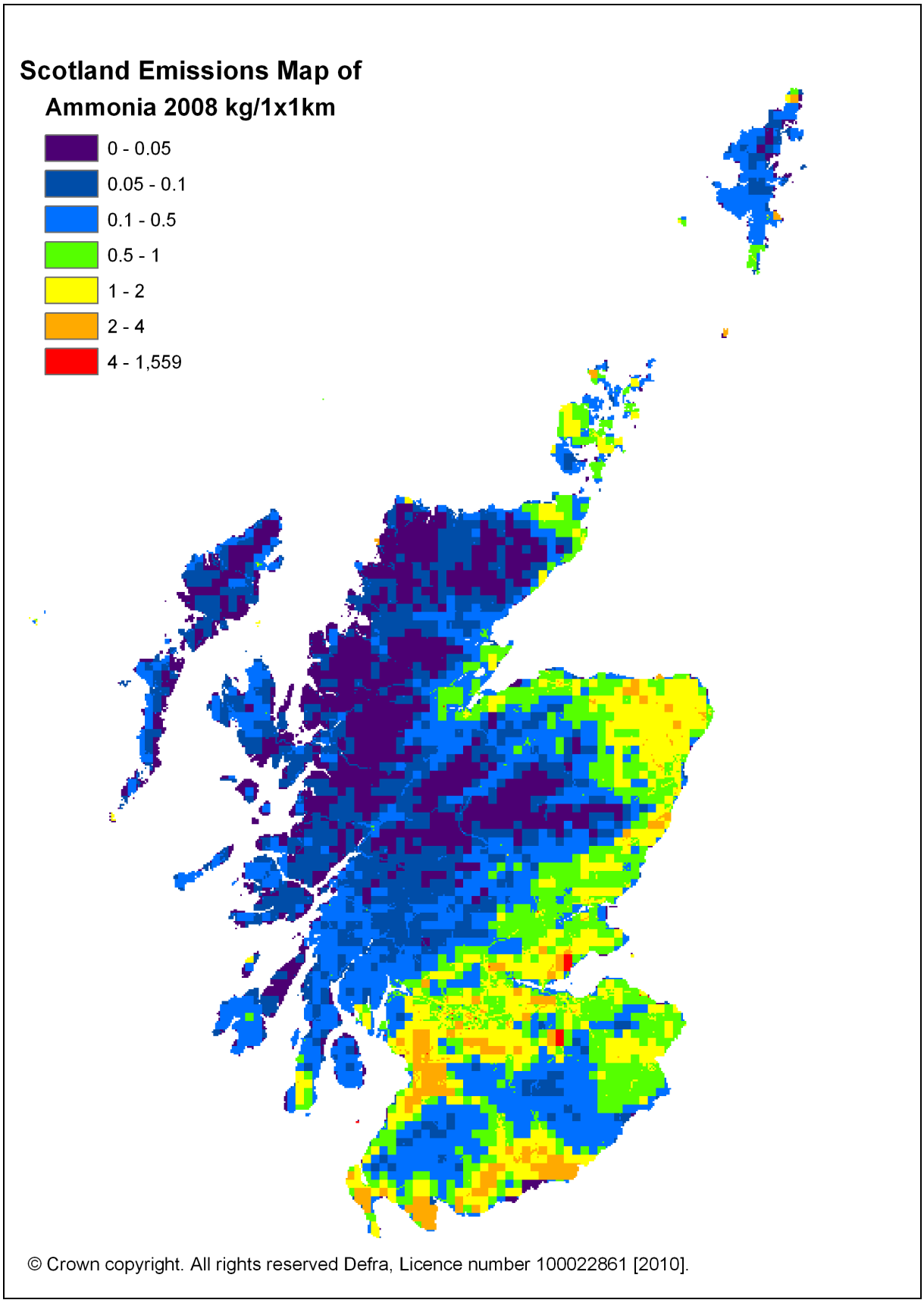
Units: kilotonnes

Figure 2-4 Scotland Ammonia Emissions by Source, 1990-2008



Scotland's NH_3 emissions have declined by 21% since 1990 and accounted for 13% of the UK total in 2008. The inventory is dominated by emissions from agricultural sources, with 78% of the total in 2008 estimated to originate from manure management (4B: down 14% since 1990). Other sources of note include transport emissions (1A3: 3% of the Scotland total in 2008) and waste treatment and disposal (6: 4% of the Scotland total in 2008).

Figure 2-5 Map of Ammonia Emissions in Scotland, 2008



2.1.3 Wales Ammonia Inventory by NFR Sector, 1990-2008

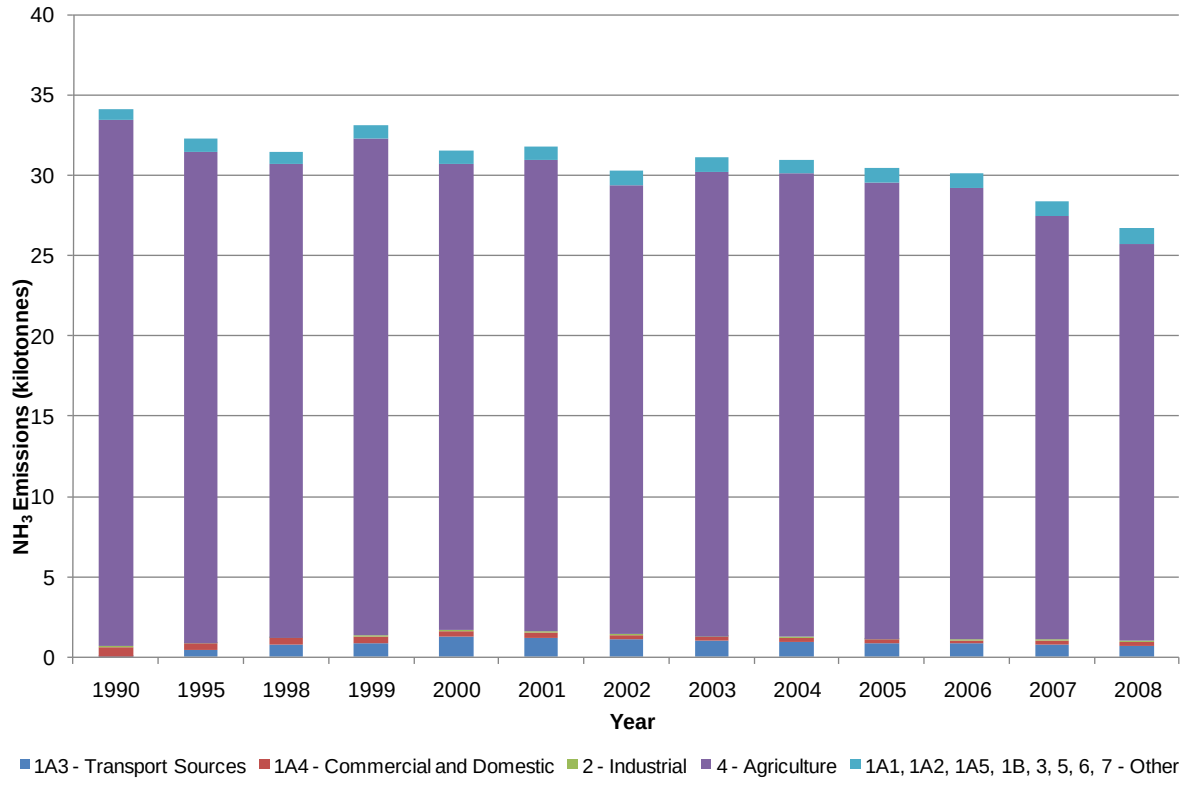
The table and graph below give a summary of the ammonia emissions in Wales by broad NFR sector categories. The detailed data are available in Appendix H.

Table 2-4 - Wales Emissions of Ammonia by NFR Source Sector

NFR Code	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2008 (%)
1A3 - Transport Sources	0.0	0.4	0.8	0.9	1.3	1.2	1.1	1.0	1.0	0.9	0.8	0.8	0.7	2.6%
1A4 - Commercial and Domestic	0.6	0.4	0.4	0.4	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.3	0.3	1.0%
2 – Industrial	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.2%
4 – Agriculture	32.8	30.6	29.5	31.0	29.0	29.4	27.9	28.9	28.9	28.4	28.1	26.4	24.7	93%
1A1,1A2,1B,3, 6, 7 - Other	0.7	0.8	0.8	0.8	0.8	0.9	0.9	0.9	0.8	0.9	0.9	0.9	1.0	3.6%
Total	34.1	32.3	31.5	33.1	31.5	31.8	30.3	31.1	31.0	30.4	30.1	28.4	26.7	100%

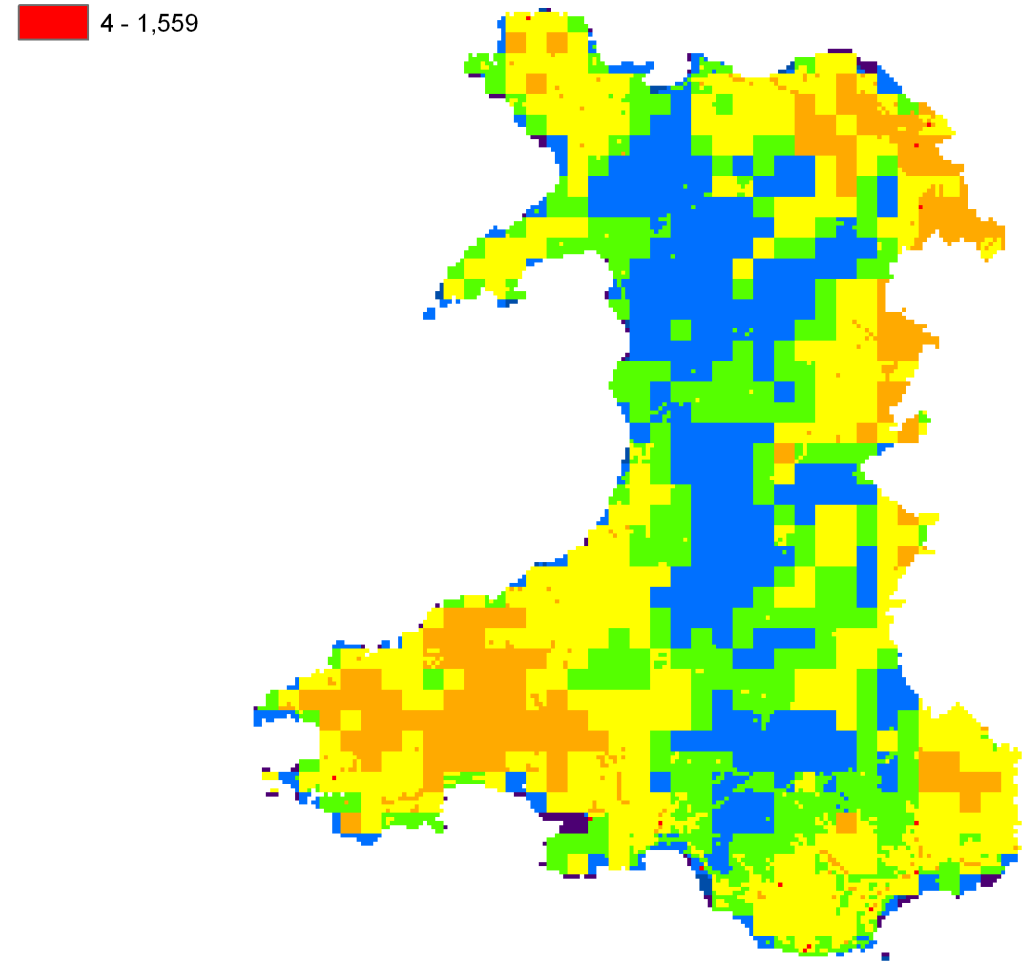
Units: kilotonnes

Figure 2-6 Wales Ammonia Emissions by Source, 1990-2008



NH_3 emissions in Wales have declined by 22% since 1990 and accounted for 9% of the UK total in 2008. The inventory is dominated by emissions from agricultural sources with 81% of the total in 2008 coming from manure management (4B: down 17% since 1990). In 2008, 57% of emissions from Wales is estimated to originate from cattle manure management alone (4B1: down 13% since 1990). Other sources of note include transport emissions (1A3: 3% of the Wales total in 2008) and waste treatment and disposal (6: 3% of the Wales total in 2008).

Figure 2-7 Map of Ammonia Emissions in Wales, 2008



2.1.4 Northern Ireland Ammonia Inventory by NFR Sector, 1990-2008

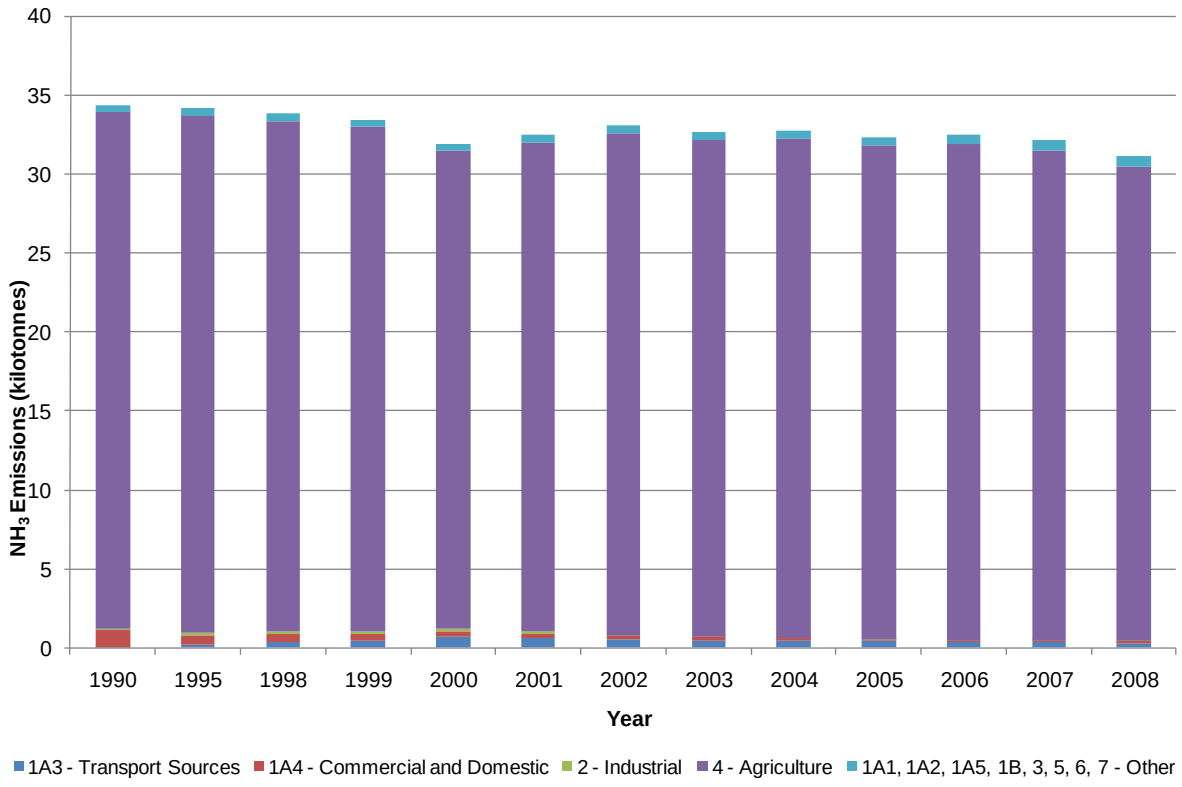
The table and graph below give a summary of the ammonia emissions in Northern Ireland by broad NFR sector categories. The detailed data are available in Appendix H.

Table 2-5 - Northern Ireland Emissions of Ammonia by NFR Source Sector

NFR Code	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2008 (%)
1A3 - Transport Sources	0.0	0.2	0.4	0.5	0.7	0.6	0.5	0.5	0.5	0.4	0.4	0.4	0.3	1.0%
1A4 - Commercial and Domestic	1.1	0.6	0.5	0.4	0.4	0.3	0.3	0.2	0.1	0.1	0.1	0.1	0.1	0.4%
2 - Industrial	0.2	0.2	0.2	0.2	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0%
4 - Agriculture	32.7	32.8	32.3	32.0	30.3	30.9	31.8	31.5	31.6	31.3	31.4	31.0	30.0	96%
1A1,1A2,1B,3,6, 7 - Other	0.4	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.6	0.6	0.7	2.2%
Total	34.3	34.2	33.8	33.5	31.9	32.5	33.1	32.7	32.7	32.3	32.5	32.1	31.1	100%

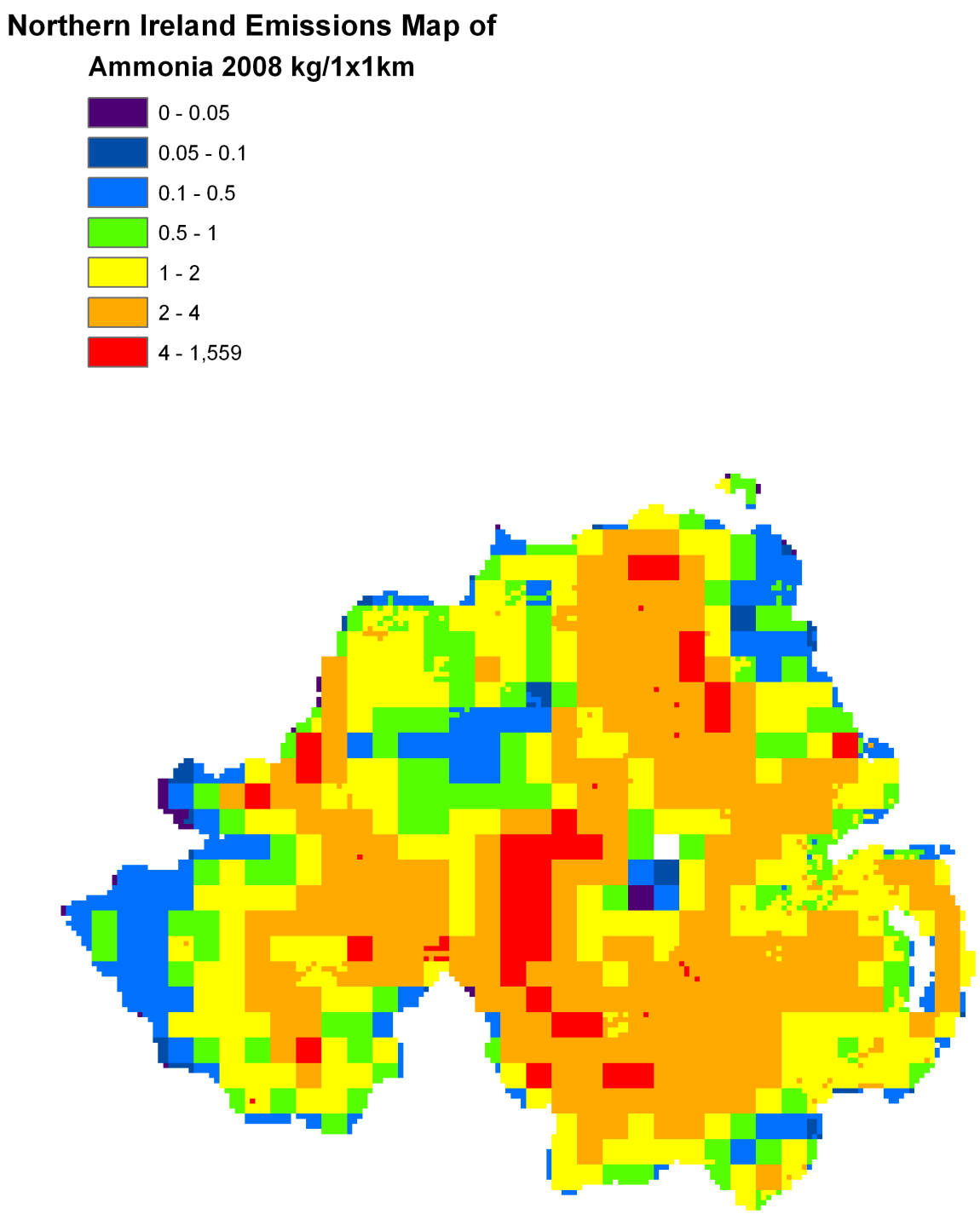
Units: kilotonnes

Figure 2-8 Northern Ireland Ammonia Emissions by Source, 1990-2008



Northern Ireland's NH_3 emissions have declined by 9% since 1990 and currently account for 11% of the UK total. The inventory is dominated by emissions from agricultural sources (4) with 87% of the total in 2008 coming from manure management (4B: down 1% since 1990). In 2008, 67% of the Northern Ireland total is from cattle manure management alone (4B1: up 12% since 1990). Other sources of note include transport emissions (1A3: 1% of the Northern Ireland total in 2008), commercial and domestic combustion (1A4: 0.4 % of the Northern Ireland total in 2008), and waste treatment and disposal (6: 2% of the Northern Ireland total in 2008).

Figure 2-9 Map of Ammonia Emissions in Northern Ireland, 2008

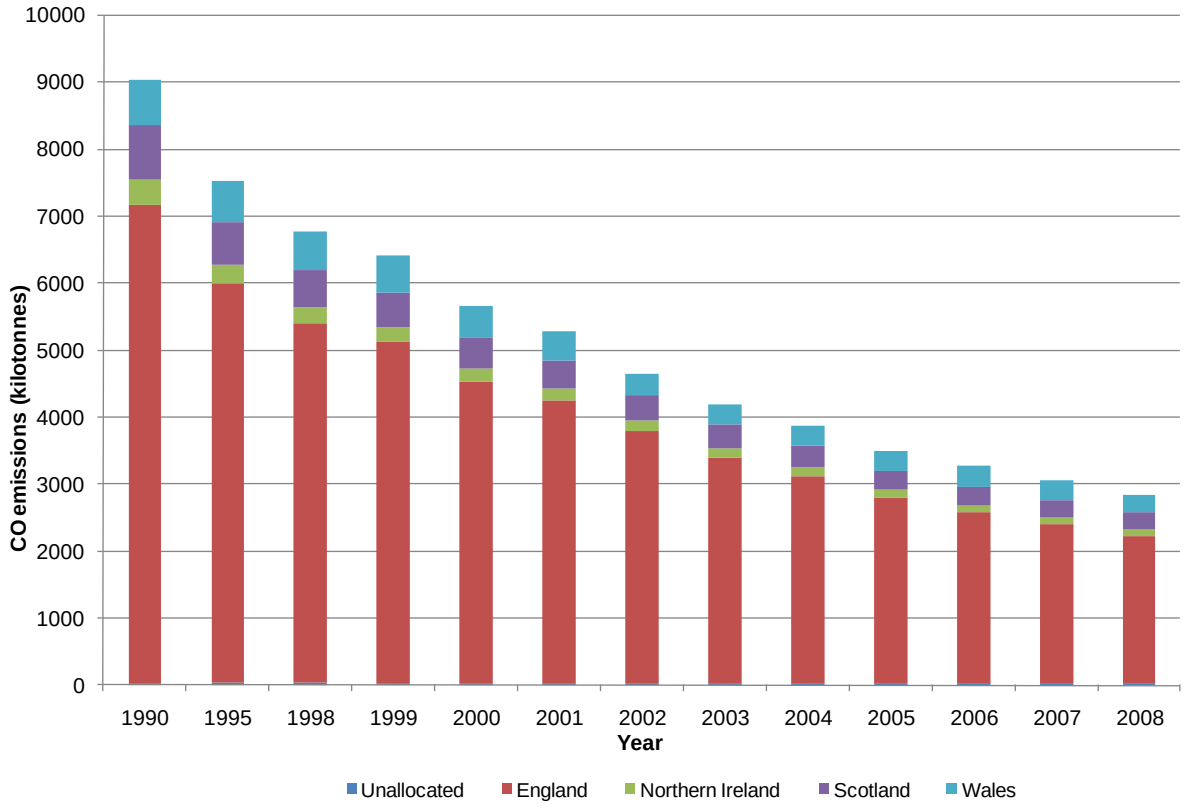


2.2 CARBON MONOXIDE

Carbon monoxide (CO) arises from incomplete fuel-combustion and is of concern mainly due to its toxicity and its role in tropospheric ozone formation. In terms of human health, CO combines with haemoglobin in blood, decreasing the uptake of oxygen by the lungs, with symptoms varying from nausea to asphyxiation depending upon the level of exposure.

Across the UK, over the period 1990-2008 emissions decreased by 69% reflecting significant reduction in emissions from road transport (1A3b), agricultural field burning (4F) and the domestic sector (1A4b). The UK-wide estimates of road transport CO emissions have been revised in the 1990-2008 inventory cycle to reflect recent research to update vehicle emission factors and revise assumptions of catalyst failure rates for different vehicle types. Higher emission factors, especially for cars and light duty vehicles, have led to higher CO emission estimates from road transport across the time series, compared to previous inventories. The change in emissions between 1990 and 2008 is dominated by the reduction in emissions from the road transport sector (1A3b), caused by the increased use of three-way catalysts in cars; this trend is evident for all DAs.

Figure 2-10 UK Carbon Monoxide Emissions by Constituent Country, 1990-2008



The main sources of CO are outlined below:

- **Road Transport (1A3b).** Petrol engines are the main source of CO emissions, especially from cold start engine cycles. Since 1990, emissions from road transport sources have reduced by around 76% due to the development of more efficient engine combustion technology, the increased use of catalytic converters and the growth in diesel engine use.

- **Off-road transport and machinery.** In the UK, just over 10% of CO emissions arise from off-road mobile industrial, residential and agricultural machinery such as portable generators,

forklift trucks, lawnmowers and tractors. Recent studies have been aimed at improving these estimates, but the quality of CO emission estimates from such machinery remains uncertain due to the lack of activity data and the resultant use of survey data and assumptions regarding equipment numbers and utilisation.

- **Domestic combustion (1A4b)**. Around 11% of CO emissions in 2008 arise from residential combustion sources, namely non-electric domestic heating. Reductions in emissions have been significant, due to the switch from solid fuels to the use of gas and electricity, with a 77% reduction in UK emissions since 1990.

Other sources of CO emissions are small compared with transport and off-road sources. Industrial combustion emissions have decreased by 49% since 1970, reflecting fuel switching from solid fuels to gas, similar to the domestic sector (1A4b). The sudden decline in emissions from the agricultural sector reflects the banning of stubble burning in 1993 in England and Wales, whilst power generation (1A1a) accounts for only 3% of UK emissions in 2008.

Emissions of CO for England, Wales, Scotland and Northern Ireland are summarised in the tables and graphs below, with more detailed inventory tables in Appendix D. Table 2.6 shows how total UK CO emissions are split between the 4 constituent countries.

Table 2-6 - Proportion of UK Carbon Monoxide Emissions by Constituent Country

Year	England	Scotland	Wales	N Ireland	Unallocated
1990	79%	9%	7%	4%	0%
2008	78%	9%	9%	4%	1%

2.2.1 England Carbon Monoxide Inventory by NFR Sector, 1990-2008

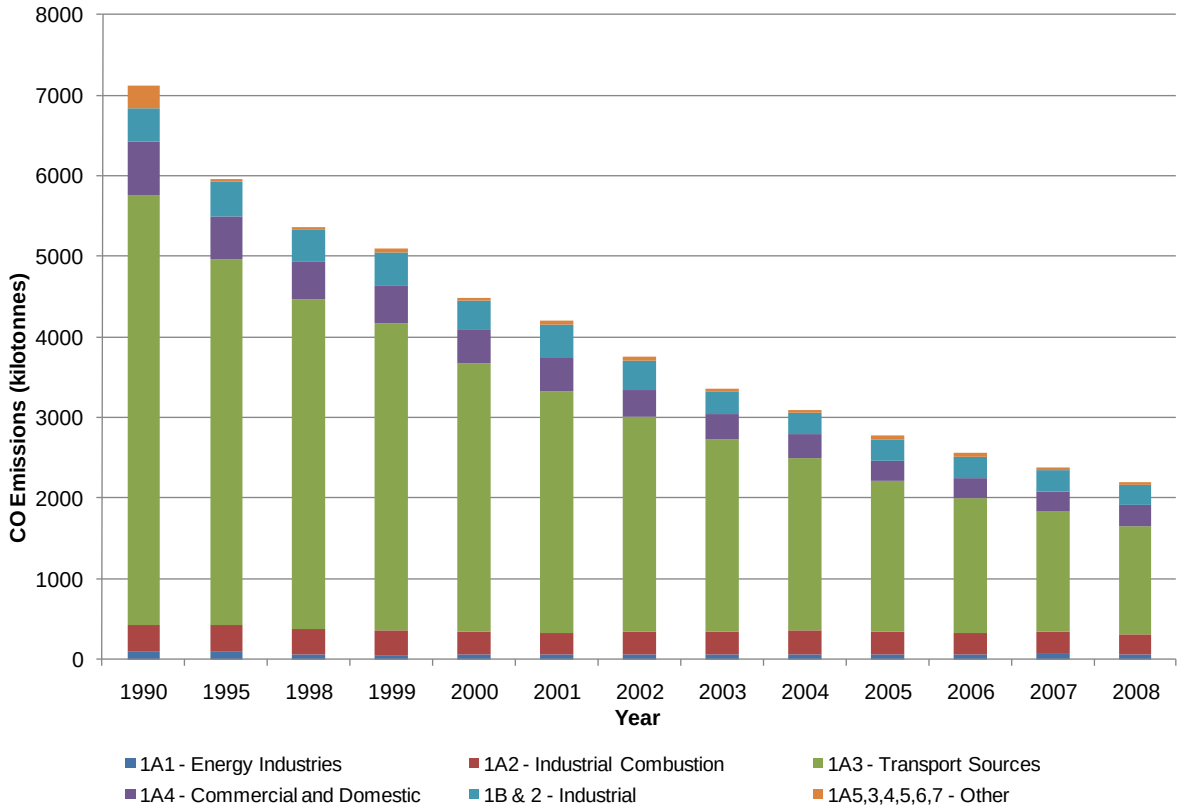
The table and graph below give a summary of the CO emissions in England by broad NFR sector categories. The detailed data are available in Appendix D.

Table 2-7 - England Emissions of Carbon Monoxide by NFR Source Sector

NFR Code	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2008 (%)
1A1 - Energy Industries	99.0	92.8	56.2	50.4	59.2	57.9	56.3	64.4	61.9	67.2	66.9	69.9	63.4	3%
1A2 - Industrial Combustion	322	340	324	310	282	275	282	283	290	267	267	269	242	11%
1A3 - Transport Sources	5337	4534	4085	3808	3332	2991	2666	2388	2139	1875	1671	1487	1343	61%
1A4 - Commercial and Domestic	670	527	474	474	411	413	342	309	299	258	245	251	261	12%
1B & 2 - Industrial	412	426	392	410	365	412	365	275	264	266	268	263	252	12%
1A5,4,5,6,7 - Other	288.1	39.4	38.0	38.5	37.6	53.9	38.4	39.2	38.0	37.1	37.4	37.3	37.4	2%
Total	7127	5959	5368	5091	4487	4203	3749	3358	3091	2771	2555	2377	2199	100%

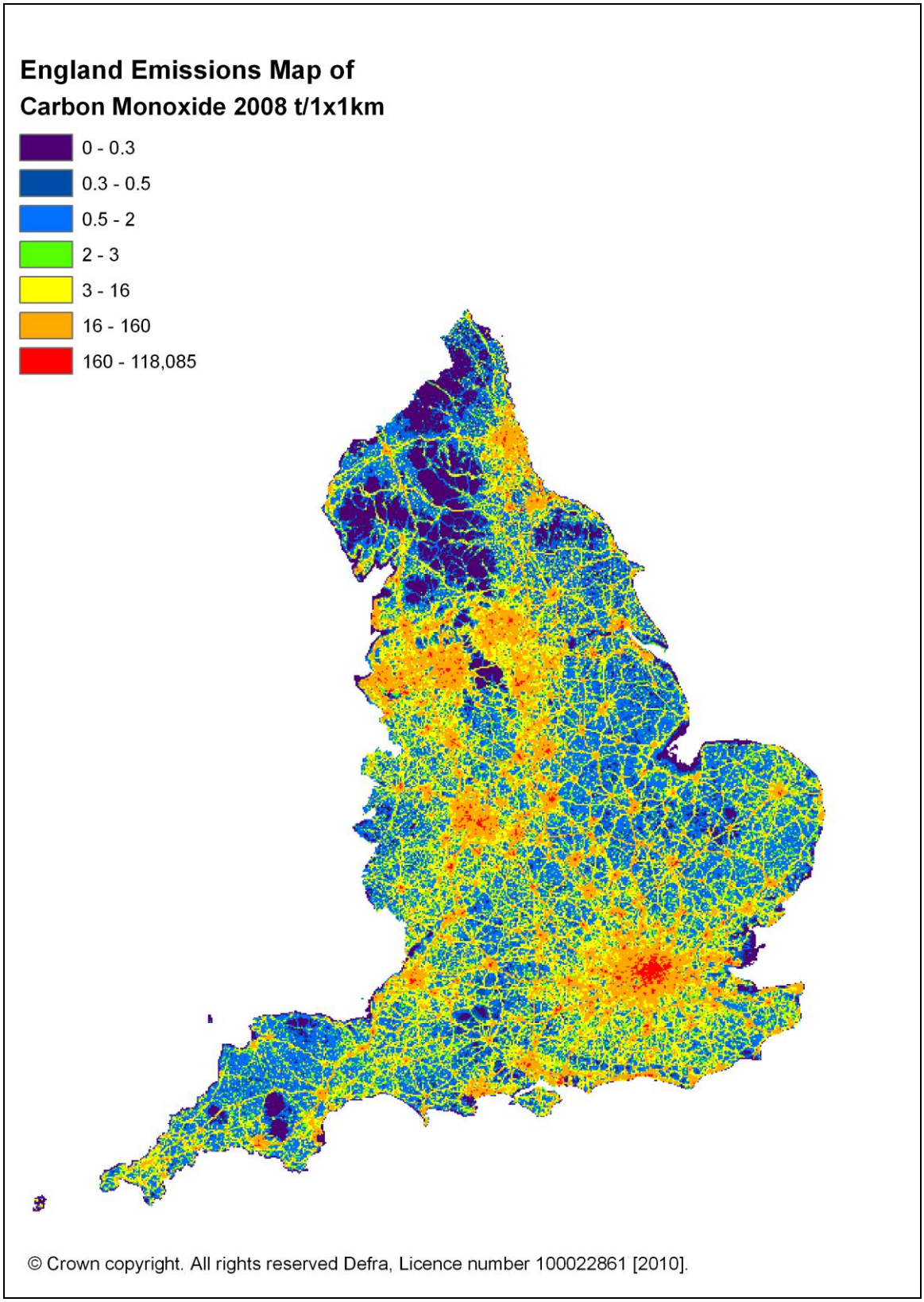
Units: kilotonnes

Figure 2-11 England Carbon Monoxide Emissions by Source, 1990-2008



England's CO emissions have declined by 69% since 1990 and account for 78% of the UK total. In 2008, 59% of CO emissions in England stem from road transport combustion sources (1A3bi-iv: down by 76% since 1990), whilst 11% stem from industrial combustion (1A2: down 25% since 1990) and 12% from commercial and residential combustion (1A4: down 61% since 1990). Notable increasing trends in emissions arise from the non-road transport sources, such as railways (1A3c: up by 20% since 1990) and national navigation (1A3dii: up by 44% since 1990). However, the levels of emissions from these sources are small relative to emissions that arise from road transport (1A3b) sources.

Figure 2-12 Map of Carbon Monoxide Emissions in England, 2008



2.2.2 Scotland Carbon Monoxide Inventory by NFR Sector, 1990-2008

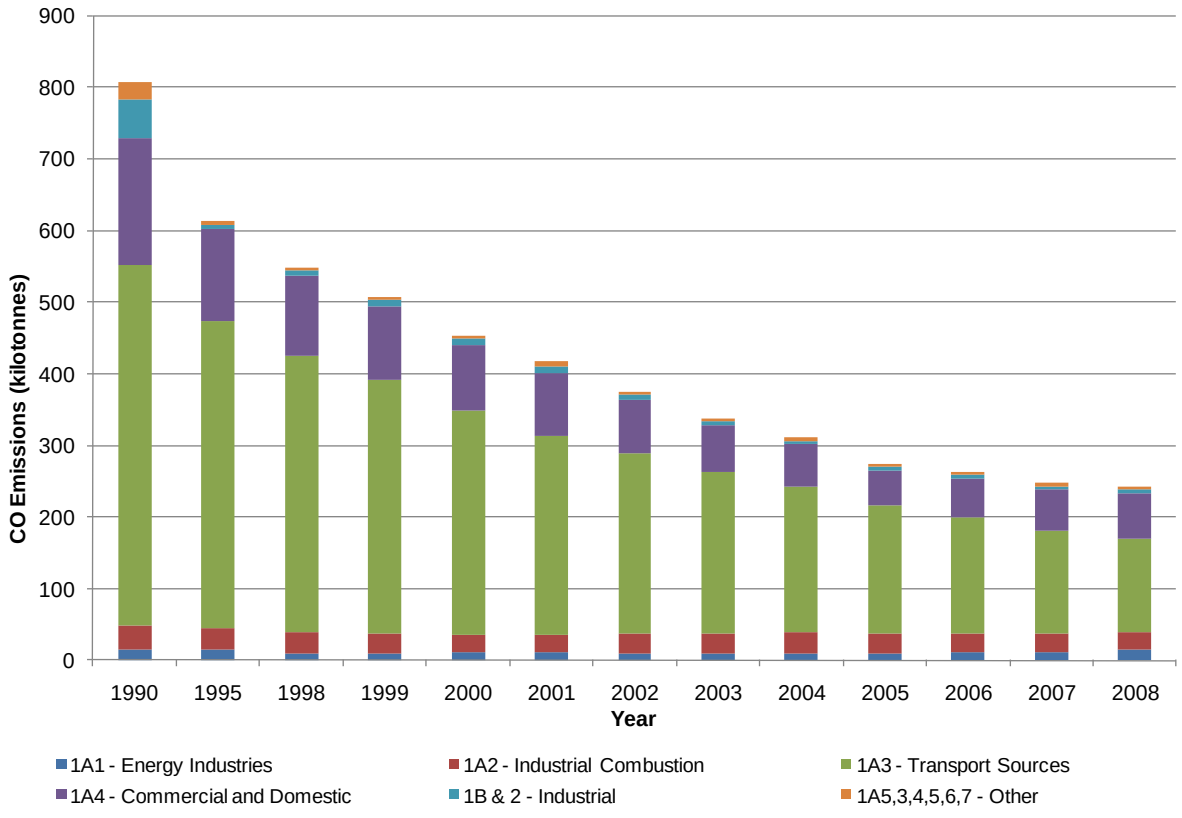
The table and graph below give a summary of the CO emissions in Scotland by broad NFR sector categories. The detailed data are available in Appendix D.

Table 2-8 - Scotland Emissions of Carbon Monoxide by NFR Source Sector

NFR Code	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2008 (%)
1A1 - Energy Industries	14.6	14.6	9.9	9.1	10.8	10.5	10.0	9.5	10.0	9.8	11.8	11.2	14.2	6%
1A2 - Industrial Combustion	34.3	31.0	29.0	27.8	25.3	25.0	27.6	27.3	28.6	27.0	26.2	27.0	25.0	10%
1A3 - Transport Sources	503	428	386	355	312	279	251	227	204	179	162	144	131	54%
1A4 - Commercial and Domestic	177	129	113	104	93.0	87.4	74.6	65.7	59.7	49.8	53.2	56.2	62.5	26%
1B & 2 - Industrial	55	6.3	6.4	7.7	7.8	8.6	8.2	4.4	4.4	4.4	5.0	5.3	5.5	2%
1A5,4,5,6,7 - Other	23	4.3	4.1	4.1	4.0	8.2	4.1	4.1	4.0	3.9	4.0	3.9	4.0	2%
Total	807	613	548	507	453	418	375	338	311	274	263	247	242	100%

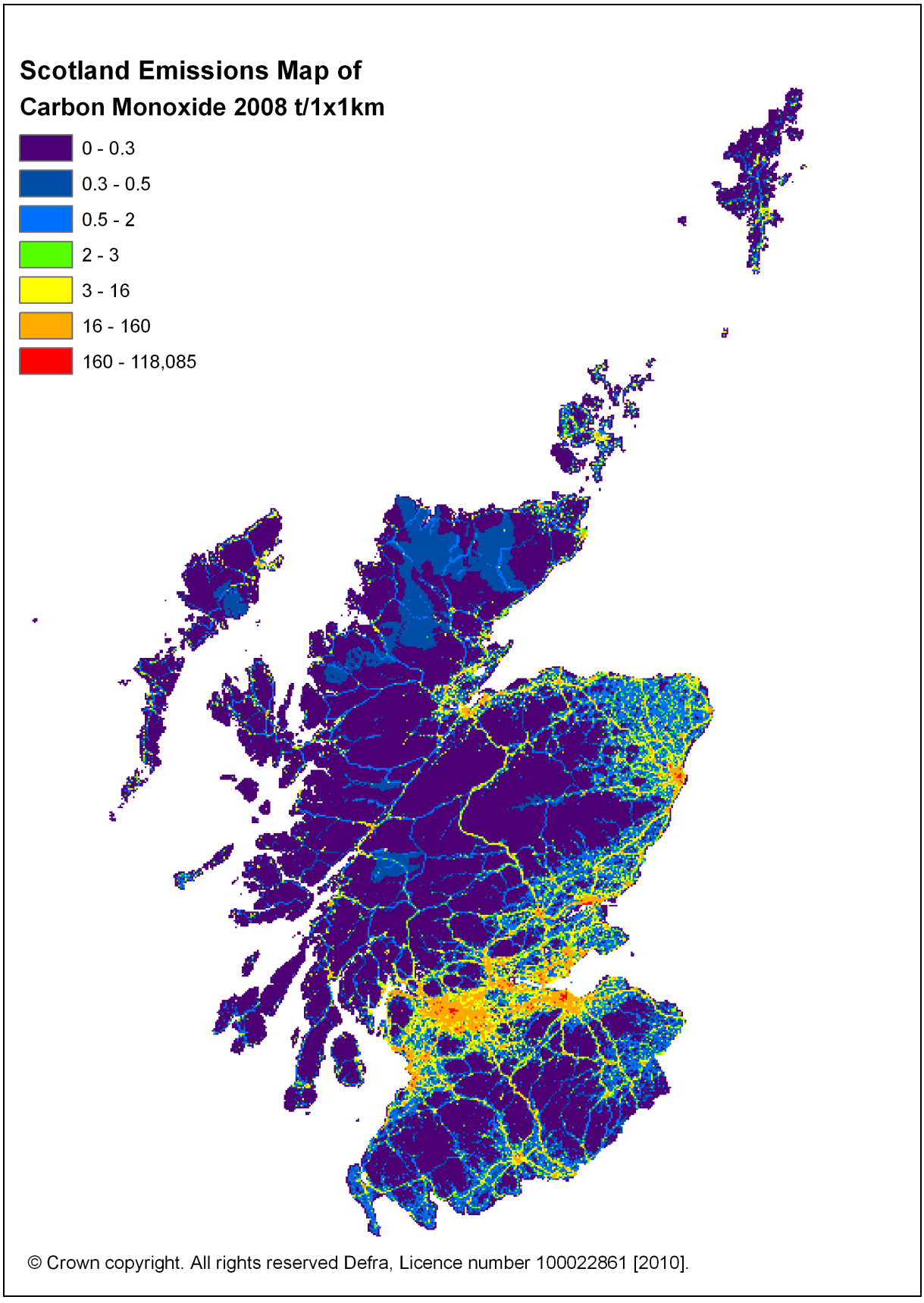
Units: kilotonnes

Figure 2-13 Scotland Carbon Monoxide Emissions by Source, 1990-2008



Scotland's CO emissions have declined by 70% since 1990 and account for 9% of the UK total. In 2008, 51% of CO emissions in Scotland stem from road transport combustion sources (1A3bi-iv: down by 75% since 1990), whilst 10% stem from industrial combustion (1A2: down 27% since 1990) and 26% from commercial and residential combustion (1A4: down 65% since 1990).

Figure 2-14 Map of Carbon Monoxide Emissions in Scotland, 2008



2.2.3 Wales Carbon Monoxide Inventory by NFR Sector, 1990-2008

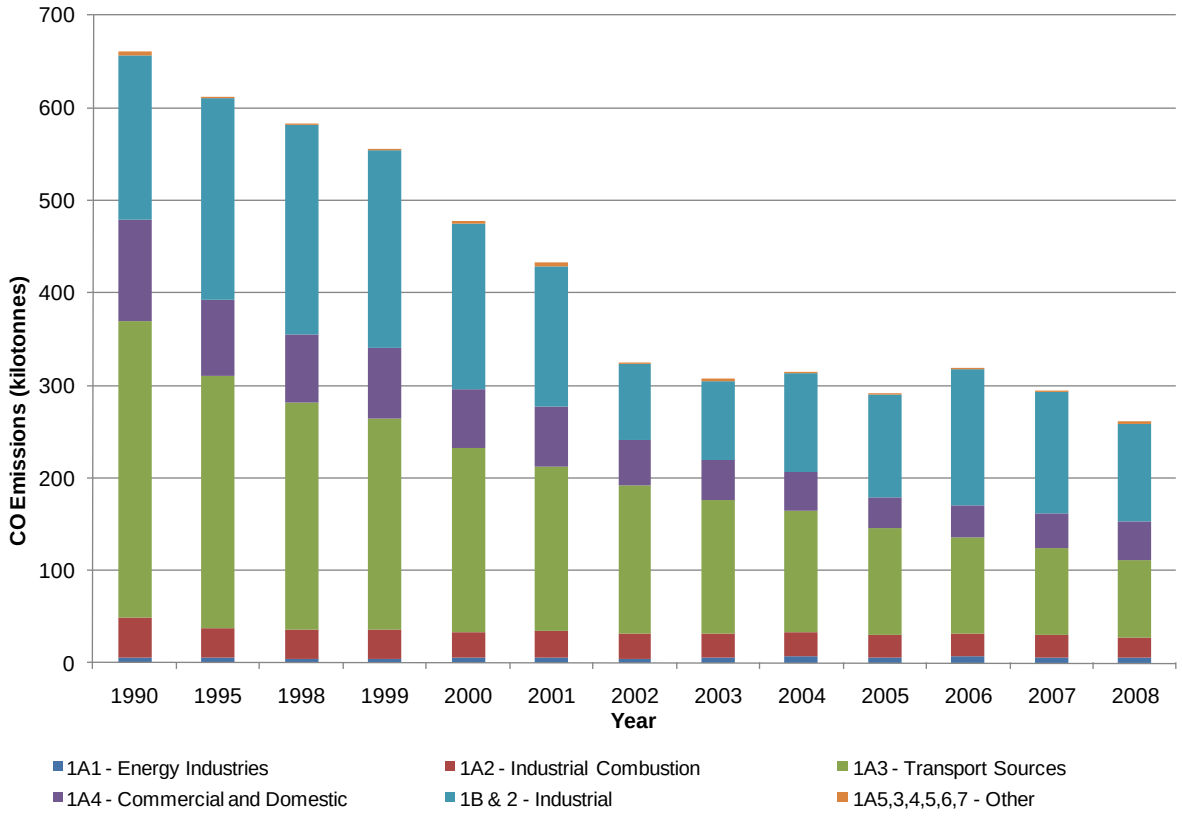
The table and graph below give a summary of the CO emissions in Wales by broad NFR sector categories. The detailed data are available in Appendix D.

Table 2-9 - Wales Emissions of Carbon Monoxide by NFR Source Sector

NFR Code	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2008 (%)
1A1 - Energy Industries	6.3	6.2	4.4	3.9	5.2	5.9	4.8	5.2	6.9	6.2	6.8	5.7	6.5	2.5%
1A2 - Industrial Combustion	42.0	30.7	32.0	32.0	28.4	28.1	26.3	25.9	26.1	23.7	24.9	24.4	20.4	7.8%
1A3 - Transport Sources	321	272	245	227	199	178	160	144	131	115	104	93.1	84.8	33%
1A4 - Commercial and Domestic	110	83.6	73.8	76.5	63.0	64.5	49.6	43.4	42.0	34.0	34.8	37.9	40.9	16%
1B & 2 - Industrial	178	217	226	213	180	152	82.0	85.8	107	110	147	131	106	41%
1A5,4,5,6,7 - Other	4.2	2.1	2.0	2.0	2.0	3.2	2.0	2.1	2.0	1.9	1.9	1.9	1.9	1%
Total	661	612	583	555	477	432	325	307	314	291	319	294	261	100%

Units: kilotonnes

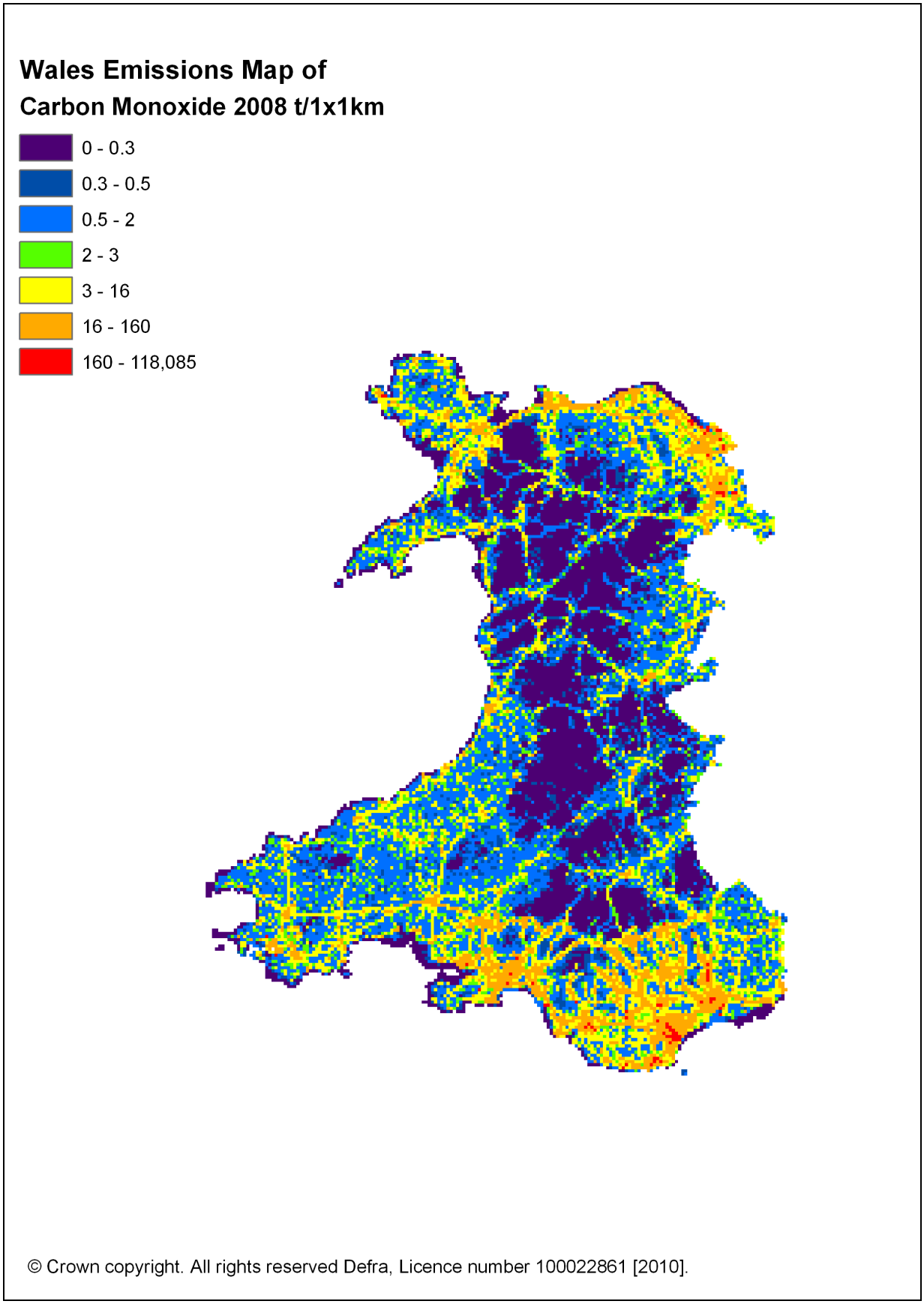
Figure 2-15 Wales Carbon Monoxide Emissions by Source, 1990-2008



Wales CO emissions have declined by 61% since 1990 and account for 9% of the UK total. The iron & steel industry (1A2a) contributes a very significant emission to the Welsh total, with a total of 8% of CO from industrial combustion (1A2: down 52% since 1990). In 2008, 31% of CO emissions in Wales stem from road transport combustion sources (1A3bi-iv: down by 75% since 1990), whilst 16% stem from commercial and residential combustion (1A4: down 63% since 1990). Total CO emissions increased between 2005 and 2006, as a result of additional emissions from the iron & steel industry (1A2), solid fuel transformation (1B1b) and metal production (2C). This increase in emissions was attributed to additional industrial output from Wales during 2006, but more recent trends show a decline in industrial emissions since 2006.

Energy Industries (NFR sector 1A1) make a relatively small contribution to emissions of CO in Wales, at 3% of the total in 2008. However, trends in power generation (1A1a) have had noticeable impact on emissions of CO from the sector in recent years; emissions of CO from the power generation decreased by 16% between 2006 and 2007 followed by a 21% increase in 2008. These changes in emissions are primarily due to the trends in coal-fired power generation over 2006 to 2008 due to the plant shut-down at Aberthaw during 2007 to retro-fit Flue Gas Desulphurisation abatement.

Figure 2-16 Map of Carbon Monoxide Emissions in Wales, 2008



2.2.4 Northern Ireland Carbon Monoxide Inventory by NFR Sector, 1990-2008

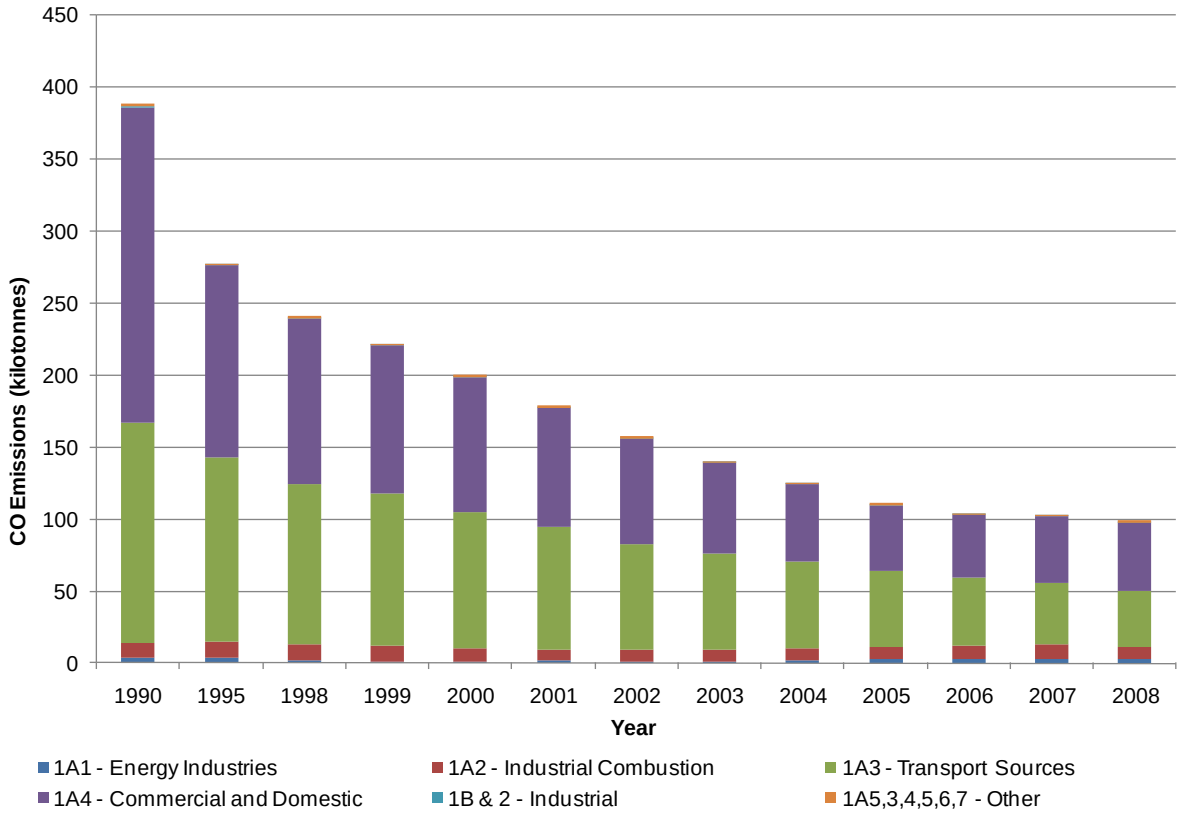
The table and graph below give a summary of the CO emissions in Northern Ireland by broad NFR sector categories. The detailed data are available in Appendix D.

Table 2-10 Northern Ireland Carbon Monoxide Emissions by NFR Source Sector

NFR Code	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2008 (%)
1A1 - Energy Industries	4.1	3.8	2.2	1.4	1.3	1.5	1.1	1.1	2.1	2.8	2.9	2.7	2.6	3%
1A2 - Industrial Combustion	10.1	11.1	10.5	10.1	8.7	8.1	8.2	8.1	8.4	8.5	9.4	9.9	8.7	9%
1A3 - Transport Sources	153	128	112	106	95.2	85.0	72.9	66.4	60.3	53.2	46.9	43.4	39.0	39%
1A4 - Commercial and Domestic	219	133	115	103	93.5	82.5	73.4	63.2	53.2	45.4	43.6	45.7	47.4	48%
1B & 2 - Industrial	0.2	0.2	0.2	0.4	0.4	0.4	0.4	0.1	0.1	0.0	0.0	0.0	0.0	0%
1A5,3,4,5,6,7 - Other	2.5	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1%
Total	389	278	241	222	200	179	157	140	125	111	104	103	99.0	100%

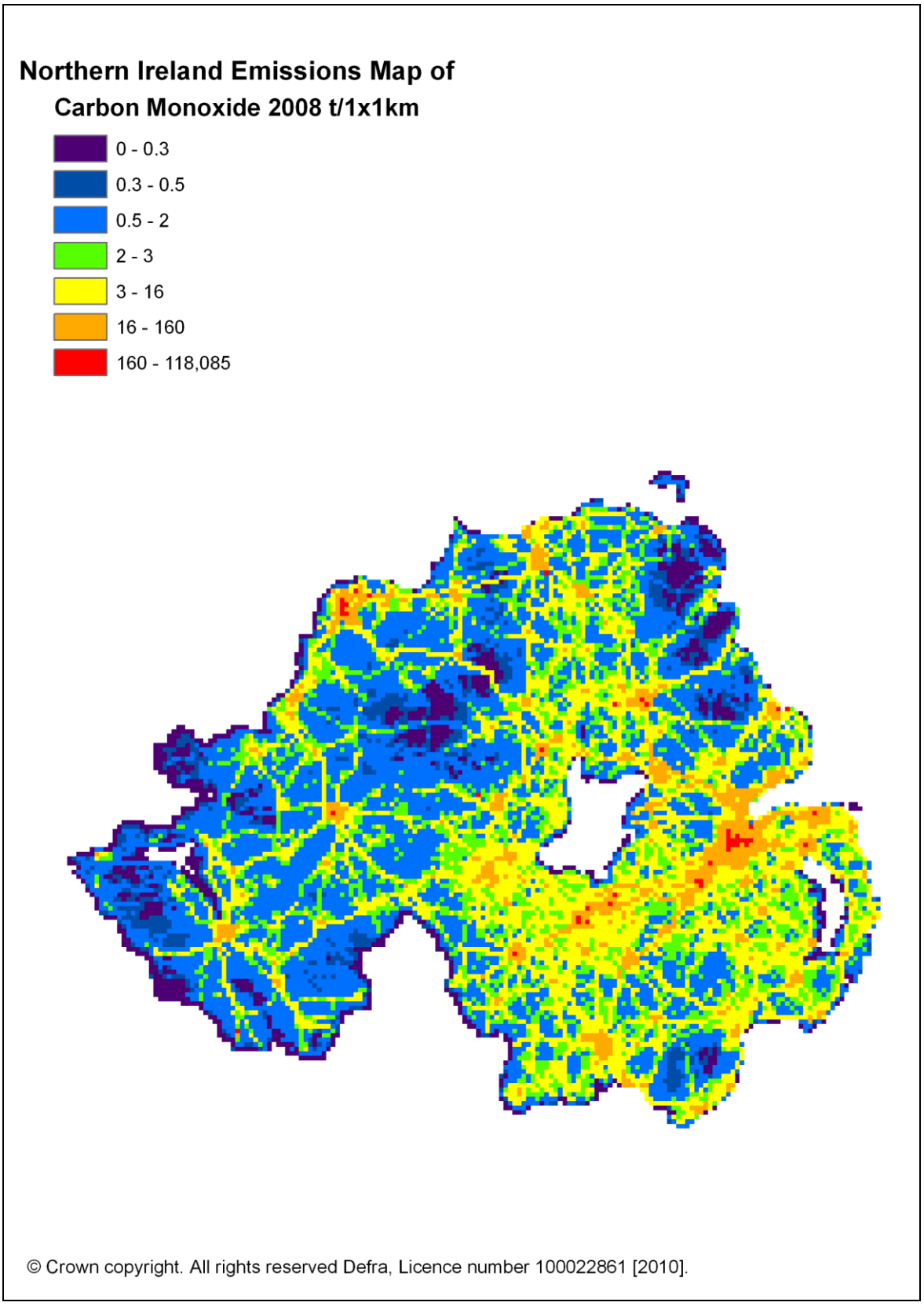
Units: kilotonnes

Figure 2-17 Northern Ireland Carbon Monoxide Emissions by Source, 1990-2008



Northern Ireland's CO emissions have declined by 75% since 1990 and accounted for 4% of the UK total in 2008. 38% of CO emissions in Northern Ireland stem from road transport combustion sources (1A3bi-iv: down by 75% since 1990), whilst only 9% come from industrial combustion sources (1A2: down 13% since 1990). In 2008, 48% of the Northern Ireland total emission comes from commercial and residential combustion (1A4: down 78% since 1990), which is a much higher contribution than in other DAs (commercial and residential emissions contribute 12%, 26% and 16% within England, Scotland and Wales respectively) due to the greater use of solid fuels in domestic heating combined and the significantly lower industrial emissions in the region.

Figure 2-18 Map of Carbon Monoxide Emissions in Northern Ireland, 2008



2.3 NITROGEN OXIDES

Across the UK, emissions of oxides of nitrogen (NO_X) arise primarily from combustion sources. The estimation of these emissions is complex since the nitrogen can be derived from either the fuel or atmospheric nitrogen. The emission is dependent on the conditions of combustion, in particular temperature and excess air ratio, which can vary considerably. Thus combustion conditions, load and even state of maintenance are important. The main three combustion sources of NO_X are:

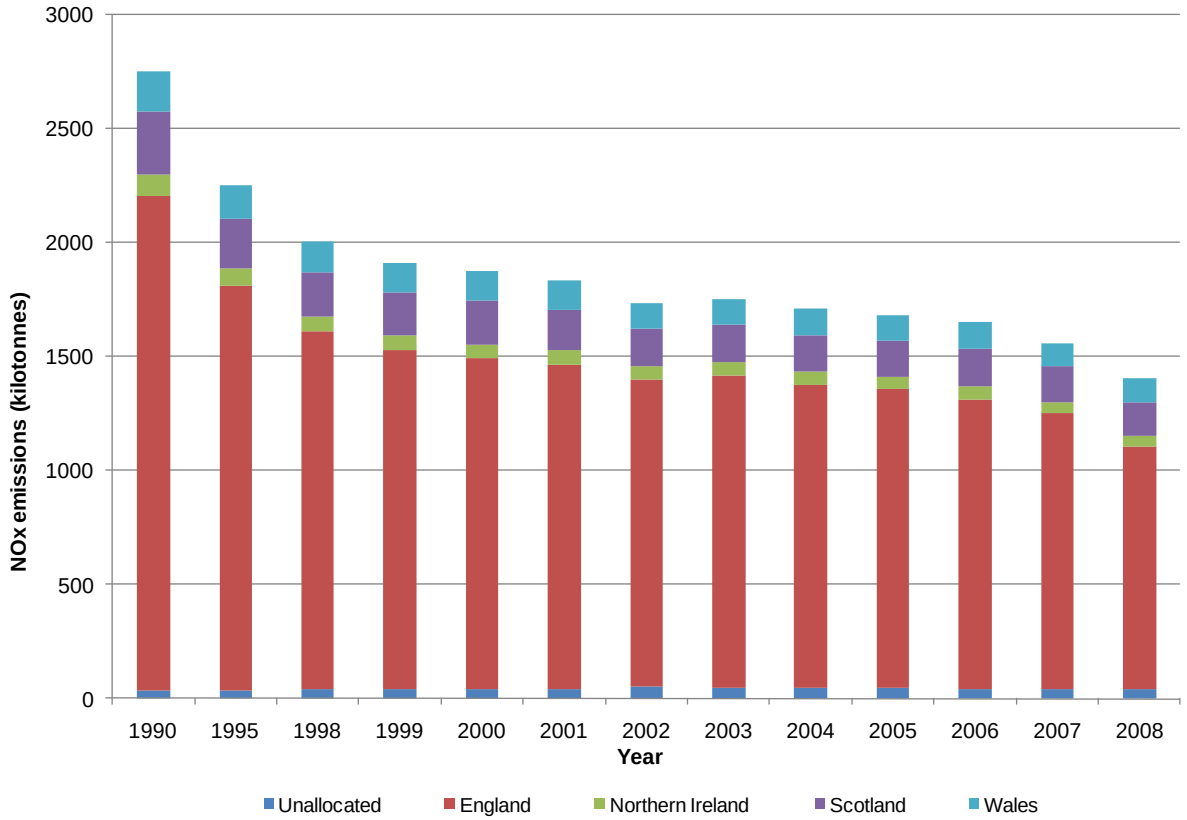
- **Transport (1A3).** In 2008 road vehicles contributed 32% of total UK NO_X emissions. Since 1990 there has been a steady decline in emissions due to the introduction of catalytic converters on cars and stricter regulations on truck emissions. Research indicates that conurbations and city centres show high localised emissions due to the combination of road transport (1A3b), residential and commercial combustion sources. Similarly, around airports, ports and major terminals, significant localised emissions arise from aviation, shipping, railway locomotives and road vehicles.

- **Power Generation (1A1a).** Since 1988 the electricity generators have adopted a programme of progressively fitting low-NO_X burners to their 500 MWe (megawatt electric) or larger coal fired units. More recently the increased use of nuclear generation and the introduction of CCGT (Combined Cycle Gas Turbine) plant burning natural gas have further reduced NO_X emissions. The emissions from the low-NO_X turbines used are much lower than those of pulverised coal fired plant even when low-NO_X burners are fitted. Assuming that these trends continue, power station emissions are expected to fall further. An additional factor has been the recent retrofitting of Boosted Over Fire Air (BOFA) systems to reduce NO_X formation and ensure compliance with the Large Combustion Plant Directive. Between 2007 and 2008, there was a 30% decrease in the emissions from coal burning power stations due to the use of BOFA, as well as the decreased consumption of coal. Further reductions in NO_X emissions are expected during 2009 as a result of additional BOFA systems coming on stream.

- **Industrial Combustion (1A2).** The emissions from industrial combustion have declined by 66% since 1970 and they currently contribute 16% to total UK emissions. This is primarily due to the decline in coal use in favour of gas and electricity.

As can be seen in Figure 2.19, total UK emissions of NO_X have decreased by 49% since 1990.

Figure 2-19 UK Nitrogen Oxides Emissions by Constituent Country, 1990-2008



Emissions of NO_X for England, Wales, Scotland and Northern Ireland are summarised in the tables and graphs below, with more detailed inventory tables in Appendix E. Table 2.11 shows how total UK NO_X emissions are split between the 4 constituent countries.

Table 2-11 - Proportion of UK Nitrogen Oxides Emissions by Constituent Country

Year	England	Scotland	Wales	N Ireland	Unallocated
1990	79%	10%	6%	3%	1%
2008	76%	10%	8%	3%	3%

2.3.1 England Nitrogen Oxides Inventory by NFR Sector, 1990-2008

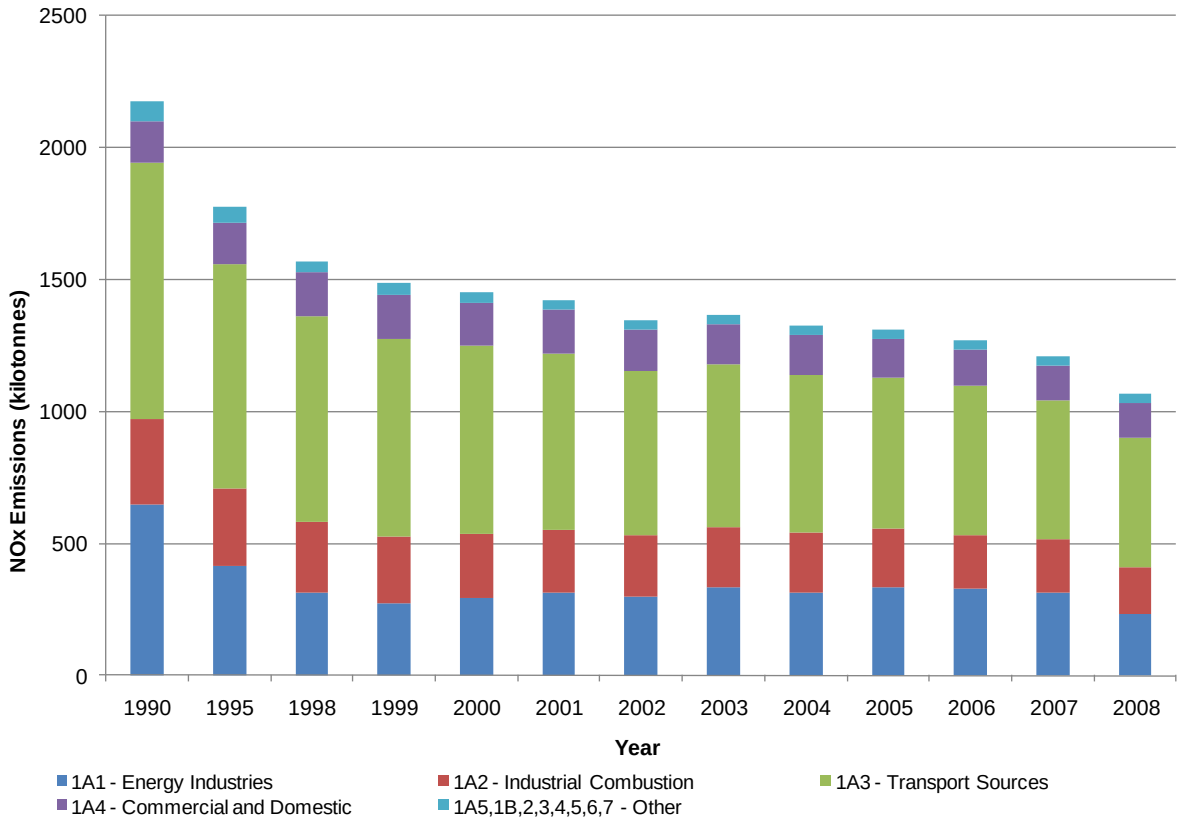
The table and graph below give a summary of the NO_X emissions in England by broad NFR sector categories. The detailed data are available in Appendix E.

Table 2-12 - England Emissions of Nitrogen Oxides by NFR source sector

NFR Code	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2008 (%)
1A1 - Energy Industries	648	414	312	275	292	314	300	336	316	336	326	315	231	22%
1A2 - Industrial Combustion	321	295	267	253	246	236	229	225	226	219	207	203	179	17%
1A3 - Transport Sources	974	845	782	749	713	670	626	615	594	574	565	527	492	46%
1A4 - Commercial and Domestic	158	161	166	164	161	163	154	153	153	145	136	128	128	12%
1A5,1B,2,4,5,6 - Other	71.8	59.4	41.4	43.4	40.0	39.8	35.3	37.8	39.3	36.6	35.8	36.0	35.3	3%
Total	2172	1775	1568	1484	1451	1423	1344	1367	1327	1311	1269	1208	1065	100%

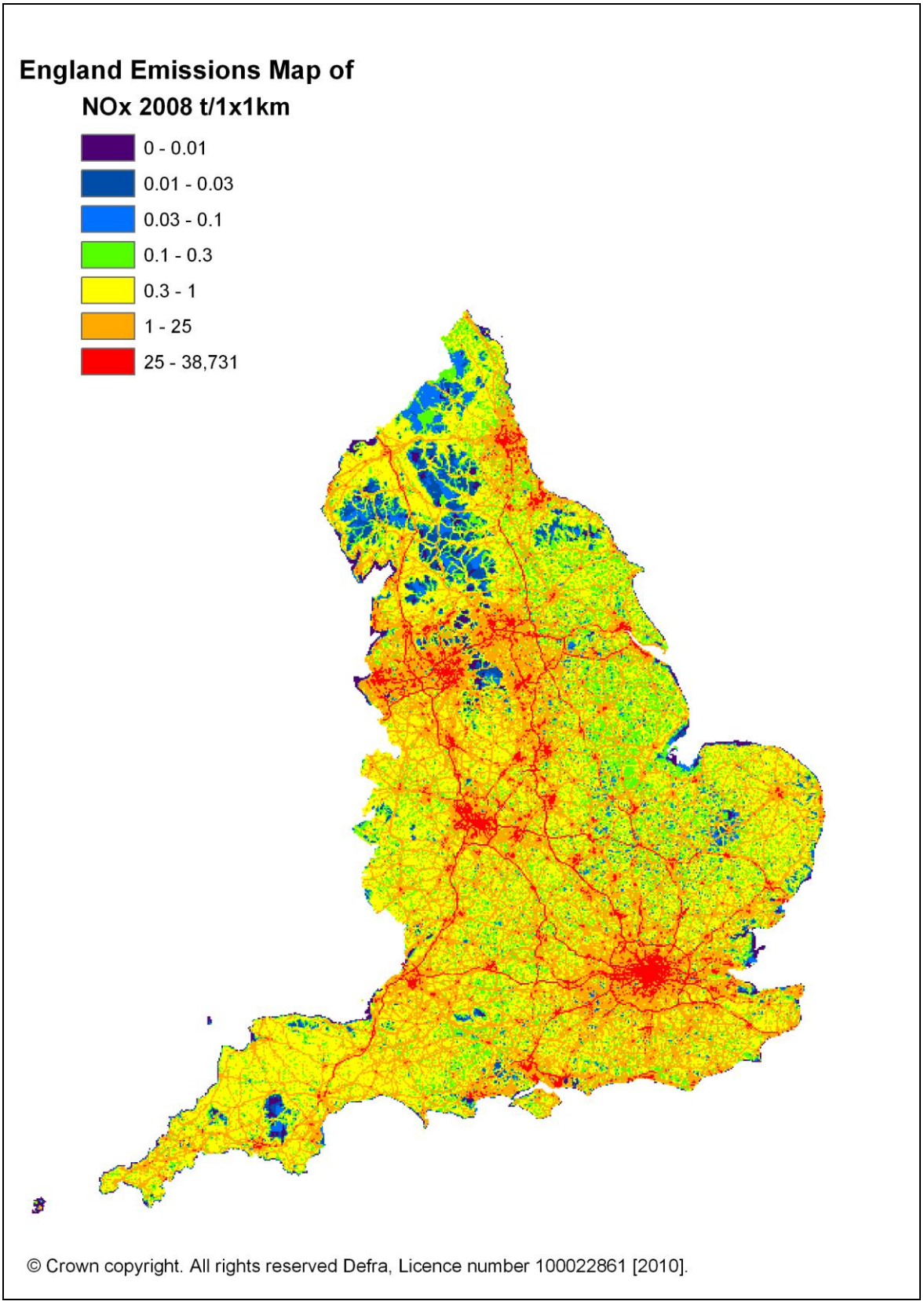
Units: kilotonnes

Figure 2-20 England Nitrogen Oxides Emissions by Source, 1990-2008



England's NO_X emissions have declined by 51% since 1990 and account for 76% of the UK total. Power generation (1A1a) is a very significant source, accounting for 20% of the England total in 2008, although emissions from this source have reduced by 66% since 1990. In 2008, 35% of NO_X emissions in England stem from road transport combustion sources (1A3bi-iv: down by 59% since 1990), whilst 17% stem from industrial combustion (1A2: down 44% since 1990). Notable increases in emissions arise from railways (1A3c: up by 96% since 1990 accounting for 3% of the 2008 England total emission) and from national navigation (1A3dii: up 44% since 1990 accounting for 8% of the 2008 England total emission).

Figure 2-21 Map of Nitrogen Oxides Emissions in England, 2008



2.3.2 Scotland Nitrogen Oxides Inventory by NFR Sector, 1990-2008

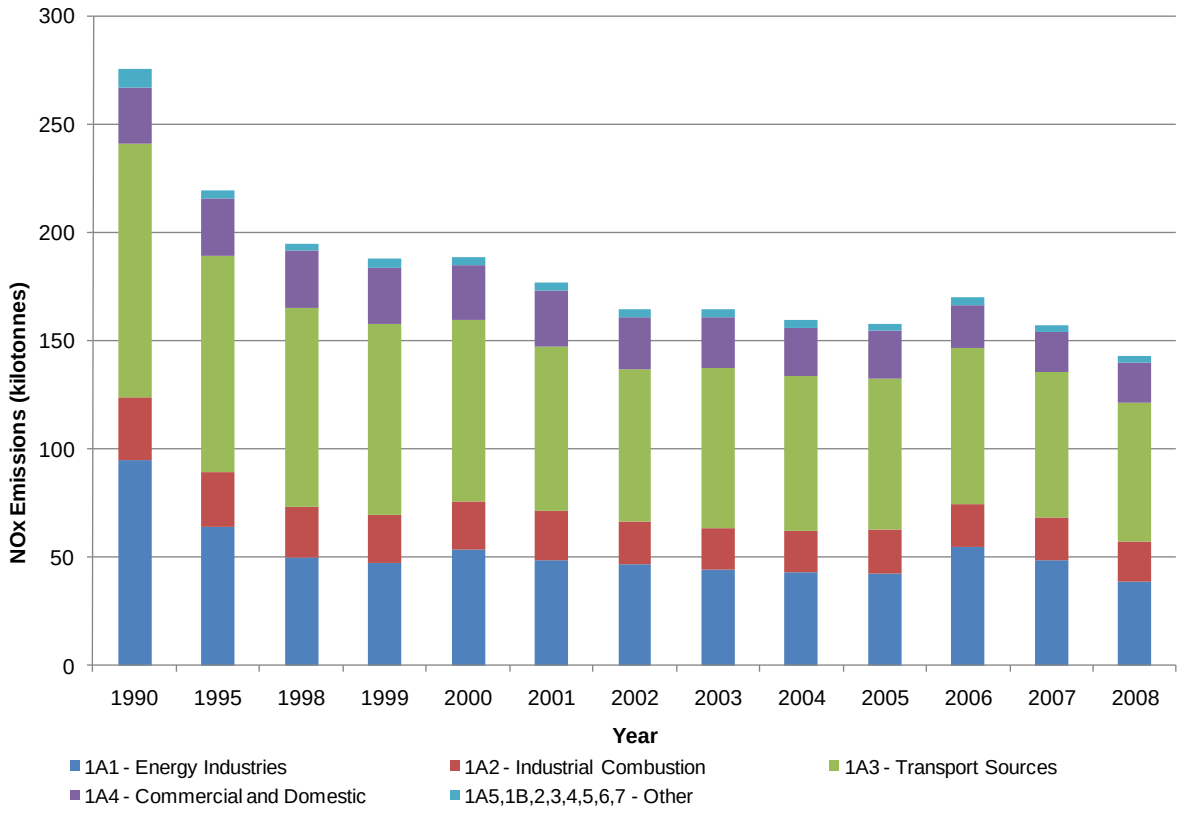
The table and graph below give a summary of the NO_X emissions in Scotland by broad NFR sector categories. The detailed data are available in Appendix E.

Table 2-13 - Scotland Emissions of Nitrogen Oxides by NFR source sector

NFR Code	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2008 (%)
1A1 - Energy Industries	95.0	64.1	49.8	47.0	53.6	48.7	46.6	44.4	42.8	42.5	54.9	48.3	38.9	27%
1A2 - Industrial Combustion	30.9	26.2	24.0	22.7	22.5	22.8	20.0	19.0	19.7	19.9	19.5	19.9	18.3	13%
1A3 - Transport Sources	117	100	92.0	88.4	83.8	76.4	70.5	74.1	71.0	70.1	72.1	67.2	64.4	45%
1A4 - Commercial and Domestic	26.2	26.5	26.5	26.1	25.2	25.5	24.0	23.3	22.6	21.8	20.0	18.6	18.2	13%
1A5,1B,2,4,5,6 - Other	8.3	4.1	3.3	3.9	3.9	4.0	3.7	3.8	3.7	3.6	3.4	3.1	3.3	2%
Total	278	221	196	188	189	177	165	165	160	158	170	157	143	100%

Units: kilotonnes

Figure 2-22 Scotland Nitrogen Oxides Emissions by Source, 1990-2008

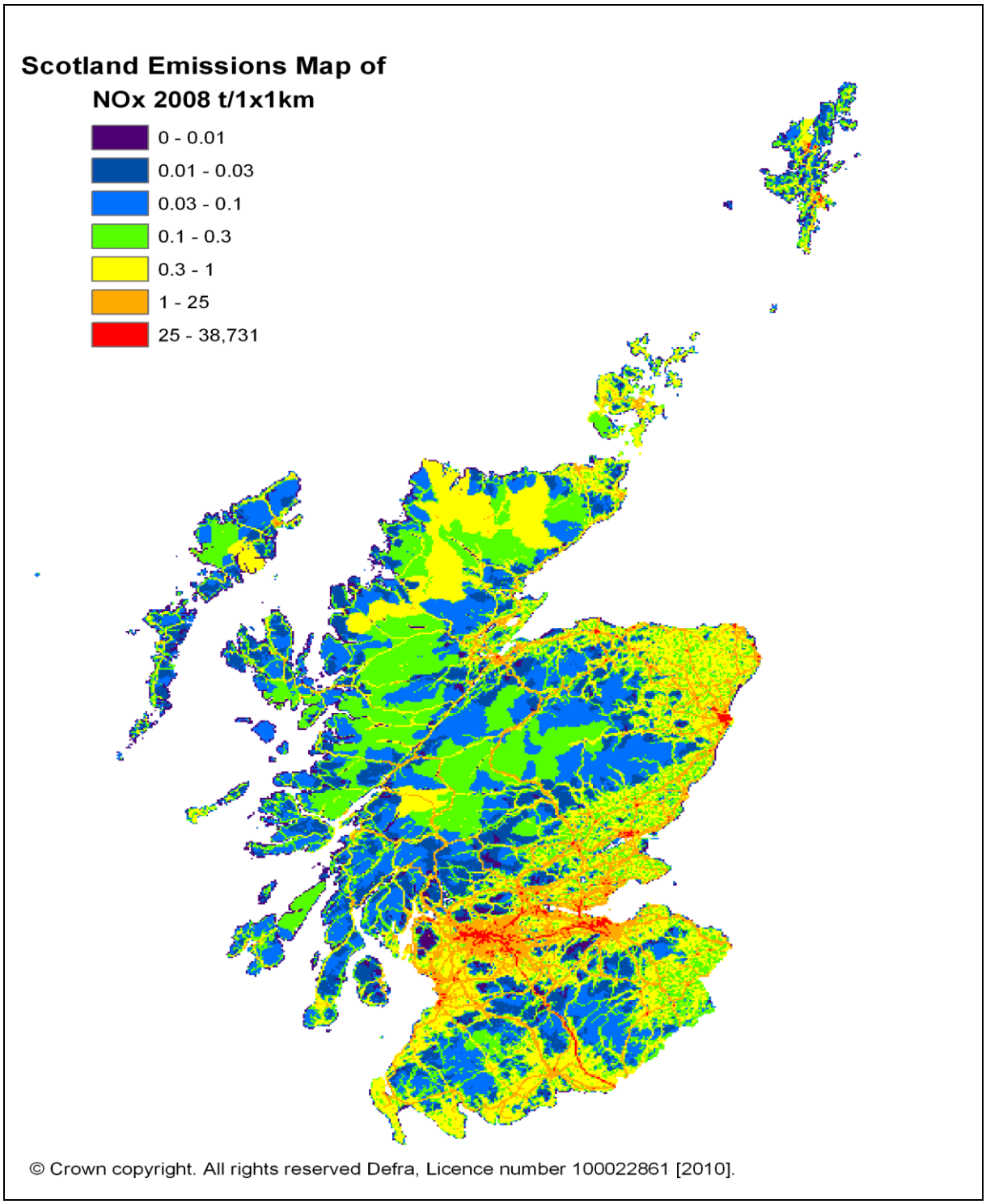


Scotland's NO_X emissions have declined by 48% since 1990 (Figure 2-22) and currently account for 10% of the UK total. Power generation (1A1a) is a very significant source of NO_X emissions, accounting for 23% of the Scotland total in 2008; although emissions from this source have reduced by 62% since 1990. *(Note that is the figure above, the sector 1A1 includes power generation, petroleum refining and other energy industries such as collieries and gas processing.)*

Recent trends in electricity generation have dominated the overall trends the inventory. In Scotland, coal-fired generation increased to a peak in 2006 (17,488 GWh), and have since declined by over 33% between 2006 and 2008 (to 11,692 GWh). Between 2007 and 2008, coal-fired generation declined by 15%, whilst gas-fired generation increased by 7.3% to 9,594 GWh. However, due in part to the use of over-fire air abatement on the coal-fired plant, overall emissions of NO_X from the sector

declined by 21% in just that one year. A further 28% of NO_X emissions in Scotland arise from road transport sources (1A3bi-iv: down by 58% since 1990), 13% stem from industrial combustion (1A2: down 41% since 1990) and 6% is from residential combustion sources (1A4bi: down 2% since 1990). Increases in emissions are only apparent in relatively minor source sectors such as domestic and international aviation landing and take off (LTO) (1A3ai(i): up by 172% since 1990 and 1A3aii(i): up by 43% since 1990 in 2008). Combined, these sources account for less than 1% of the emissions in Scotland in 2008.

Figure 2-23 Map of Nitrogen Oxides Emissions in Scotland, 2008



2.3.3 Wales Nitrogen Oxides Inventory by NFR Sector, 1990-2008

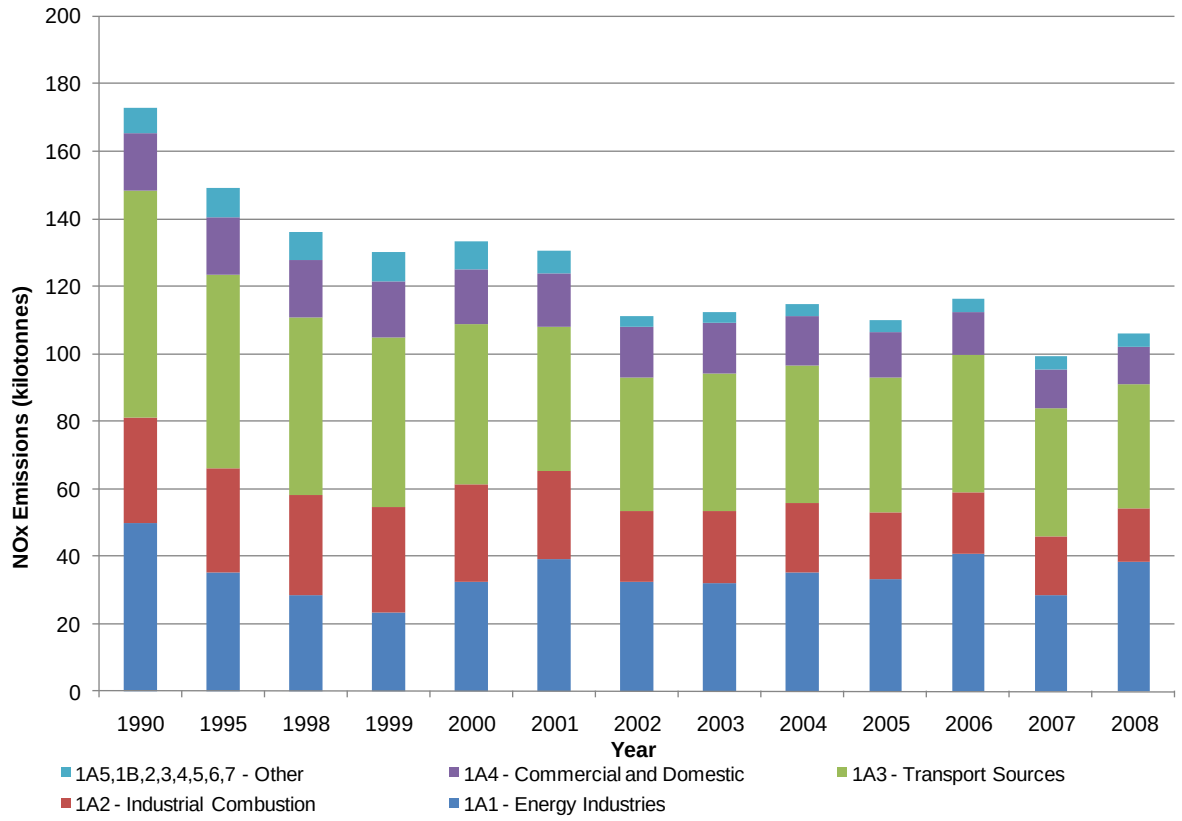
The table and graph below give a summary of the NO_X emissions in Wales by broad NFR sector categories. The detailed data are available in Appendix E.

Table 2-14 - Wales Emissions of Nitrogen Oxides by NFR source sector

NFR Code	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2008 (%)
1A1 - Energy Industries	49.8	35.2	28.6	23.2	32.6	39.3	32.3	32.2	35.0	33.4	40.6	28.4	38.3	36%
1A2 - Industrial Combustion	28.7	29.4	28.7	31.0	28.4	25.8	20.9	20.9	20.7	19.5	18.3	17.5	15.8	15%
1A3 - Transport Sources	67.1	57.2	52.8	50.2	47.7	42.7	39.6	40.9	40.8	40.0	40.9	37.9	36.8	35%
1A4 - Commercial and Domestic	16.9	17.0	16.9	16.7	16.1	16.0	15.3	14.9	14.5	13.6	12.6	11.5	11.2	11%
1A5,1B,2,4,5,6 - Other	7.9	8.8	8.4	8.6	8.3	6.4	3.0	3.4	3.8	3.6	4.1	4.0	4.0	4%
Total	170	148	135	130	133	130	111	112	115	110	117	99	106	100%

Units: kilotonnes

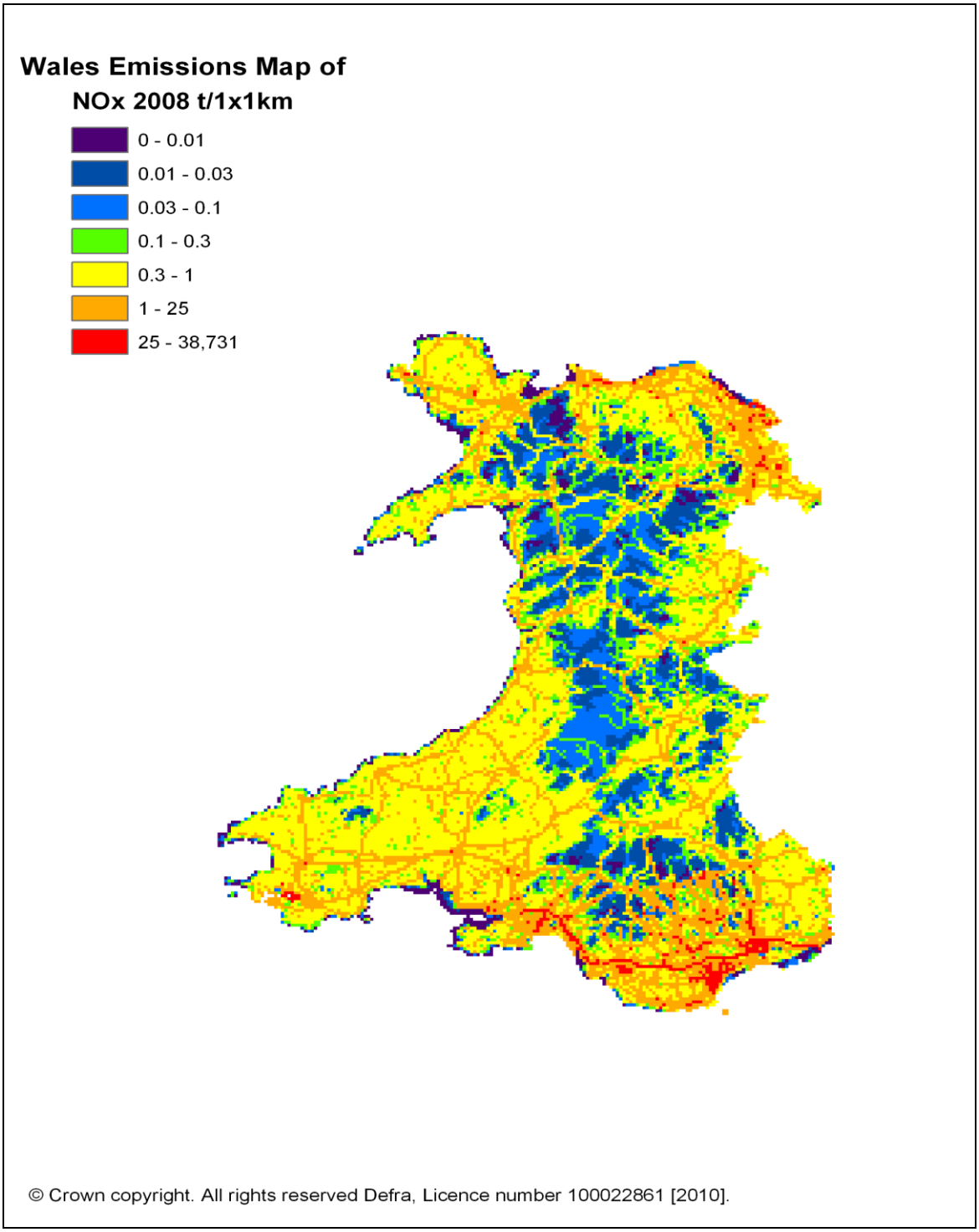
Figure 2-24 Wales Nitrogen Oxides Emissions by Source, 1990-2008



Wales NO_X emissions have declined by 38% since 1990 and accounted for 8% of the UK total in 2008. Power generation (1A1a) accounts for 30% of the Wales NO_X inventory total in 2008; emissions from this source have reduced by 25% since 1990. Recent trends in electricity generation have dominated the overall trends in the Wales NO_X inventory, with large fluctuations in coal-fired generation in particular (due to a plant shut-down at Aberthaw during 2007 to retro-fit 2 units with Flue Gas Desulphurisation abatement). Coal-fired generation increased by over 30% between 2005 and 2006 (to 8,859 GWh), and then reduced by over 40% between 2006 and 2007 (to 5,121 GWh). Between 2007 and 2008, coal-fired generation increased again by nearly 83% (up to 9,364 GWh) once Aberthaw came back on-line, whilst gas-fired generation fell by 5% to 14,746 GWh. As a result, the overall NO_X emissions from the sector increased by 54% between 2007 and 2008 (Figure 2-24).

A further 20% of NO_X emissions in Wales stem from road transport combustion sources (1A3bi-iv: down by 61% since 1990), 15% stem from industrial combustion (1A2: down 45% since 1990) and 5% of emissions are from residential combustion sources (1A4bi: down 3% since 1990). Notable increases in significant emissions arise from railways (1A3c: up by 54% since 1990 to 3% of the 2008 Wales total) and from national navigation (1A3dii: up 25% since 1990 to 11% of the 2008 Wales total).

Figure 2-25 Map of Nitrogen Oxides Emissions in Wales, 2008



2.3.4 Northern Ireland Nitrogen Oxides Inventory by NFR Sector, 1990-2008

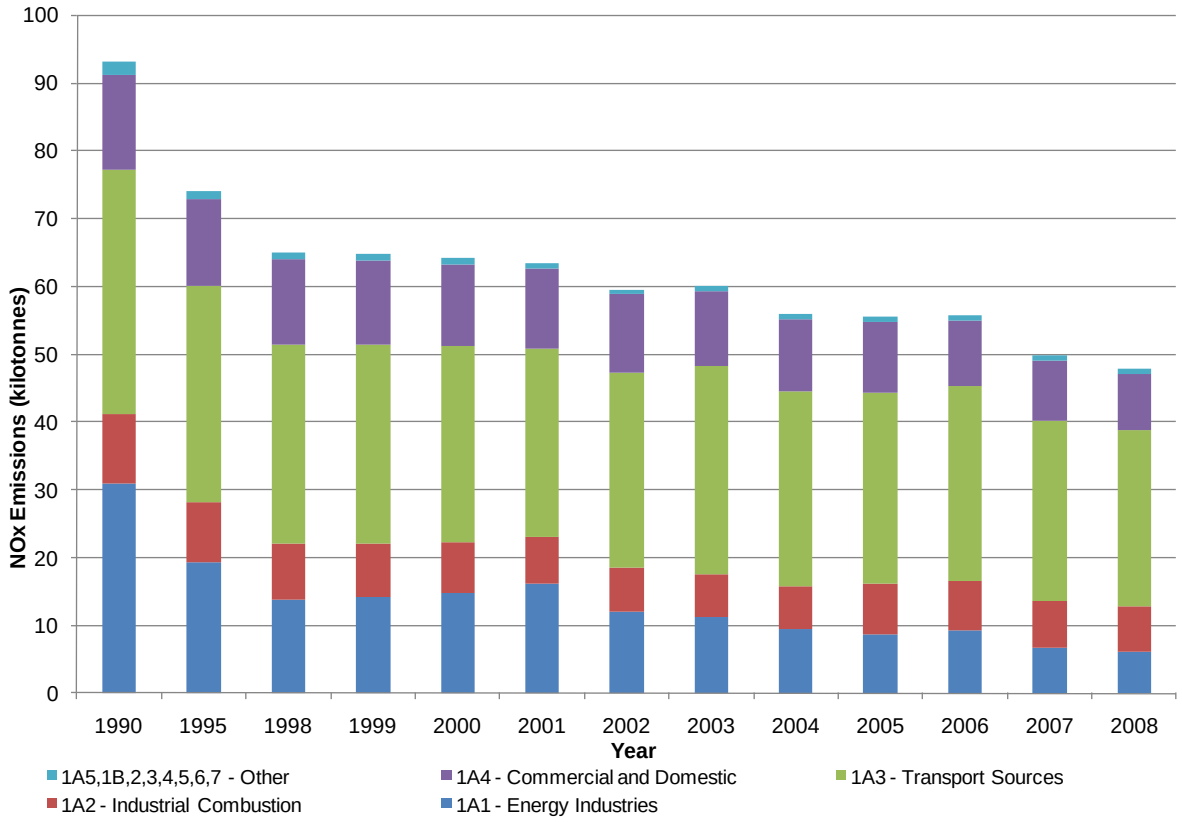
The table and graph below give a summary of the NO_X emissions in Northern Ireland by broad NFR sector categories. The detailed data are available in Appendix E.

Table 2-15 - Northern Ireland Emissions of Nitrogen Oxides by NFR source sector

NFR Code	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2008(%)
1A1 - Energy Industries	30.9	19.2	13.8	14.1	14.8	16.2	12.0	11.3	9.4	8.6	9.3	6.6	6.1	13%
1A2 - Industrial Combustion	11.4	10.1	8.8	8.2	7.6	7.3	6.8	6.5	6.5	7.5	7.2	7.0	6.8	14%
1A3 - Transport Sources	36.0	31.9	29.4	29.3	29.0	27.7	28.8	30.6	28.7	28.2	28.7	26.5	25.9	54%
1A4 - Commercial and Domestic	14.2	12.7	12.7	12.5	12.0	11.8	11.5	11.1	10.8	10.4	9.7	8.9	8.4	18%
1A5,1B,2,4,5,6 - Other	1.8	1.2	1.0	1.1	1.0	0.9	0.7	0.8	0.8	0.7	0.7	0.7	0.7	2%
Total	94.2	75.1	65.7	65.2	64.4	63.8	59.7	60.3	56.2	55.5	55.7	49.8	47.9	100%

Units: kilotonnes

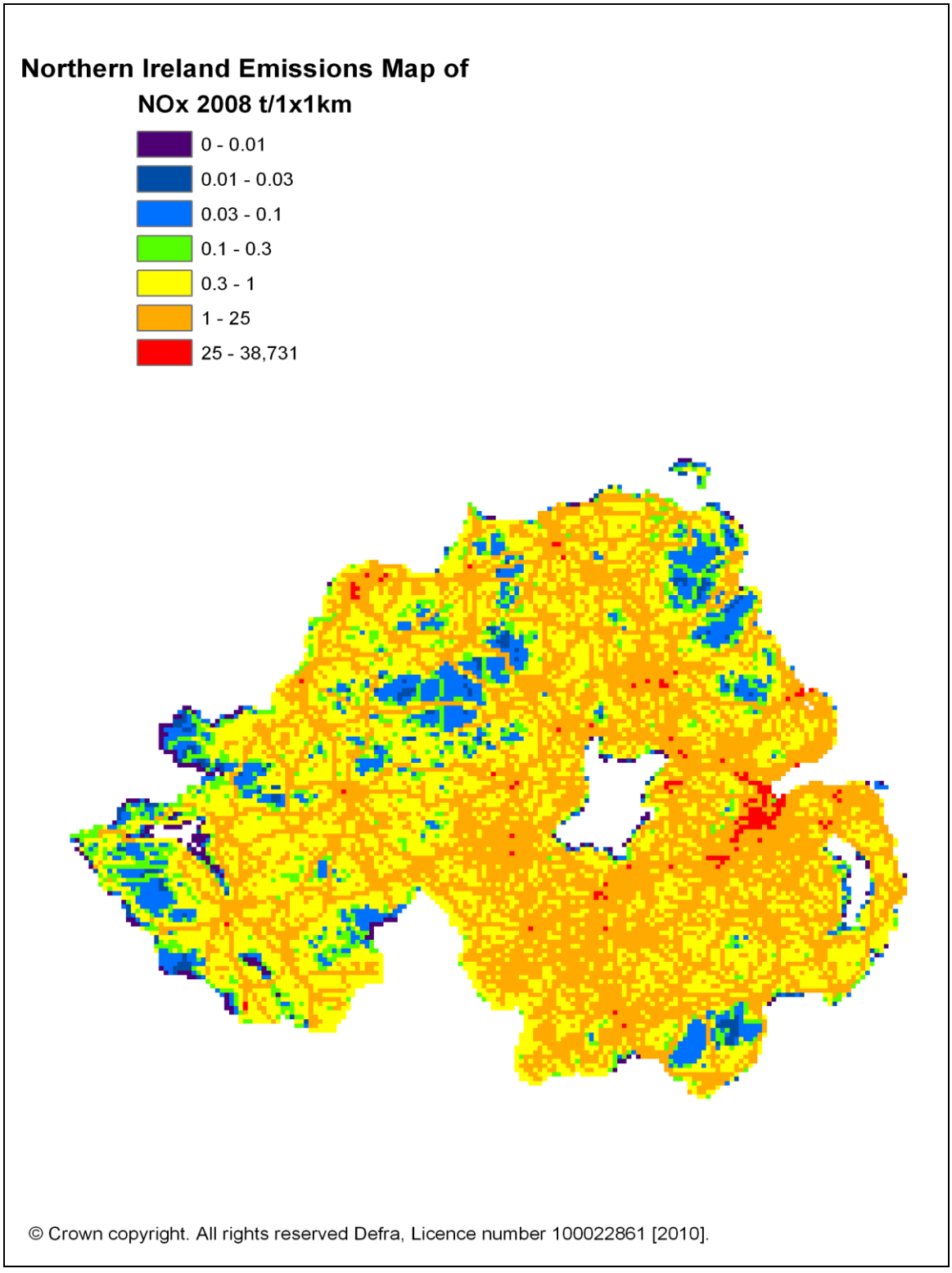
Figure 2-26 Northern Ireland Nitrogen Oxides Emissions by Source, 1990-2008



Northern Ireland's NO_X emissions have declined by 49% since 1990 and account for only 3% of the UK total. Power generation (1A1a) accounts for 13% of the Northern Irish total in 2008; emissions from this source have reduced by 80% since 1990. 42% of NO_X emissions in Northern Ireland stem from road transport combustion sources (1A3bi-iv: down by 37% since 1990), whilst 14% stem from industrial combustion (1A2: down 40% since 1990) and 8% are from residential combustion sources (1A4bi: down 13% since 1990). Notable increases in emissions arise from national navigation (1A3dii: up 48% since 1990 to 10% of the 2008 Northern Irish total) and from very minor sources sector such as domestic and international aviation LTO (1A3ai(i): up by 431% since 1990 and 1A3aii(i): up by

112% since 1990). However, combined these two sources account for less than 1% of the Northern Ireland total emission in 2008.

Figure 2-27 Map of Nitrogen Oxides Emissions in Northern Ireland, 2008



2.4 NON-METHANE VOLATILE ORGANIC COMPOUNDS

Non-Methane Volatile Organic Compounds (NMVOCs) are emitted to air as combustion products, as vapour arising from handling or use of petroleum distillates, solvents or chemicals, and from numerous other sources. The diversity of processes which emit NMVOCs is huge, covering not only many branches of industry, but also transport (1A3), agriculture (4) and domestic sources.

UK emissions inventory data indicate that only 25% of the NMVOC emissions arise from combustion sources (unlike SO_2 and NO_X where the contribution from combustion sources is much higher). Of these emissions from combustion sources, it is the transport (1A3) sector that dominates. NMVOC emissions are dependent on vehicle speed and are higher on minor and urban major roads than on the high-speed motorways and major roads.

A large proportion of emissions are caused either as a result of the activities of people in and around their homes (e.g. domestic solvent use or domestic combustion), or by widespread industrial activities such as small-scale industrial coating processes, dry cleaners and small bakeries.

- **Solvent and other product use (3).** This sector comprises industrial and domestic solvent applications (cleaning, degreasing), as well as the manufacturing and processing of chemical products. It represents 42% of the UK total NMVOC emission in 2008. During the 1990s, industrial NMVOC emissions have fallen as a result of emission controls, technological changes, and reduced manufacturing output in some sectors. Emissions from the chemical industry have reduced during the 1990s as tighter emission controls have been introduced. Domestic solvent emissions have also fallen due to a trend towards formulating products such as paints and aerosols with lower solvent contents.

- **Stationary Combustion.** This sector includes emissions from public electricity and heat production as well as those from petroleum refining and the manufacture of iron and steel. Emissions from the petroleum-refineries have fallen significantly due to a reduction in refinery capacity and tighter emission regulations during the 1990s.

- **Production processes**. This sector includes emissions from metal production, road construction, and non-fuel mining. These processes are estimated to comprise approximately 3% of the UK total emission in 2008.

- **Processes in wood, paper pulp and food & drink.** Emissions from the food and drink industry comprised approximately 9% of the total NMVOC emission in 2008. The largest source is whisky maturation although bread baking, animal feed manufacture, fat and oil processing and barley malting are also important sources.

- **Transport (1A3).** Emissions from transport sources are currently responsible for 15% of NMVOC emissions, with road transport (1A3b) accounting for 14% of UK emissions in 2008. During the 1990s, these emissions have declined significantly due to the increased use of catalytic converters and fuel switching from petrol to diesel cars.

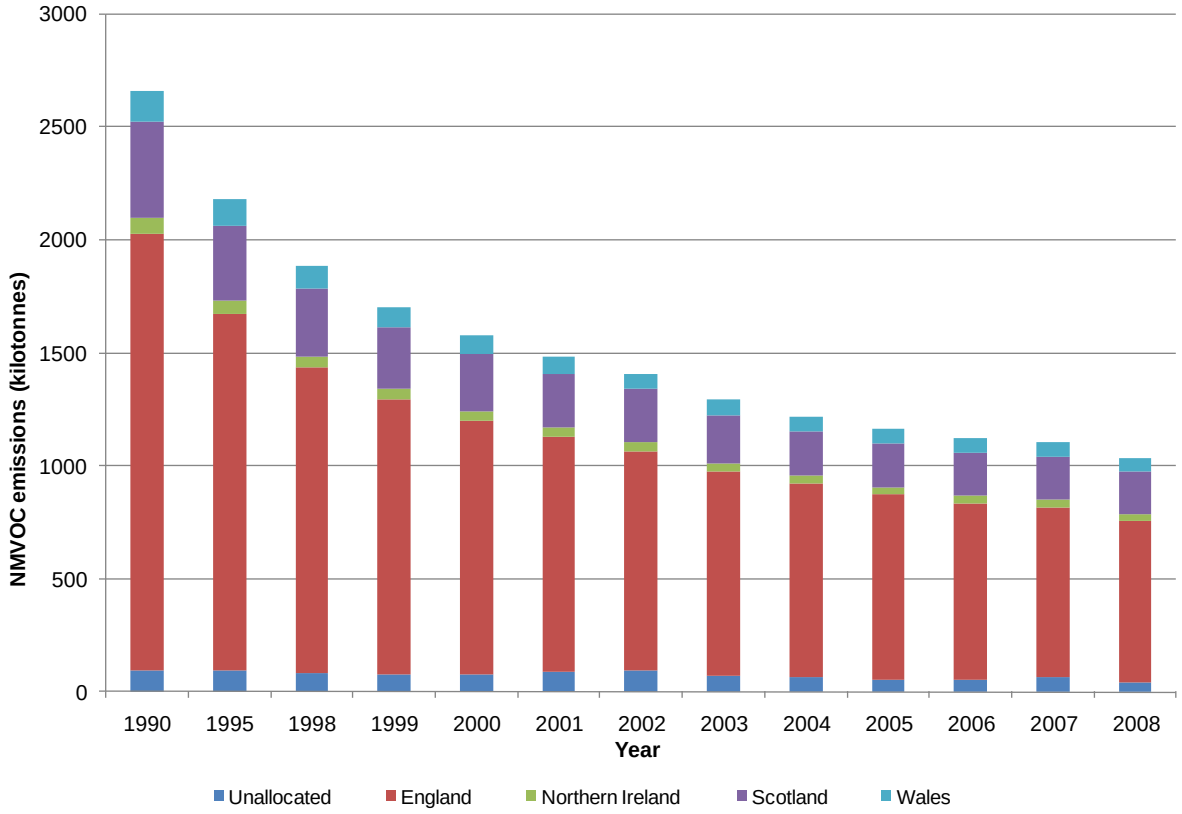
- **Offshore oil and gas.** Emissions from this sector have increased substantially with the growth of the UK's offshore activities, and stem primarily from tanker loading / unloading.

Other sources of NMVOCs include:

- Gas leakage from the national gas distribution networks.
- Evaporative losses from the distribution and marketing of petrol.
- Waste treatment and disposal contribute.
- Natural and agricultural sources.

UK emissions of NMVOC fell by 63% between 1990 and 2008, primarily due to reductions in road transport sources through the use of catalytic converters and fuel switching to diesel technology.

Figure 2-28 UK NMVOC Emissions by Constituent Country, 1990-2008



Emissions of NMVOCs for England, Wales, Scotland and Northern Ireland are summarised in the tables and graphs below, with more detailed inventory tables in Appendix G. Table 2.16 shows how total UK NMVOC emissions are split between the 4 constituent countries.

Table 2-16 - Proportion of UK NMVOC Emissions by Constituent Country

Year	England	Scotland	Wales	N Ireland	Unallocated
1990	74%	15%	5%	3%	4%
2008	71%	16%	5%	3%	5%

2.4.1 England NMVOC Inventory by NFR Sector, 1990-2008

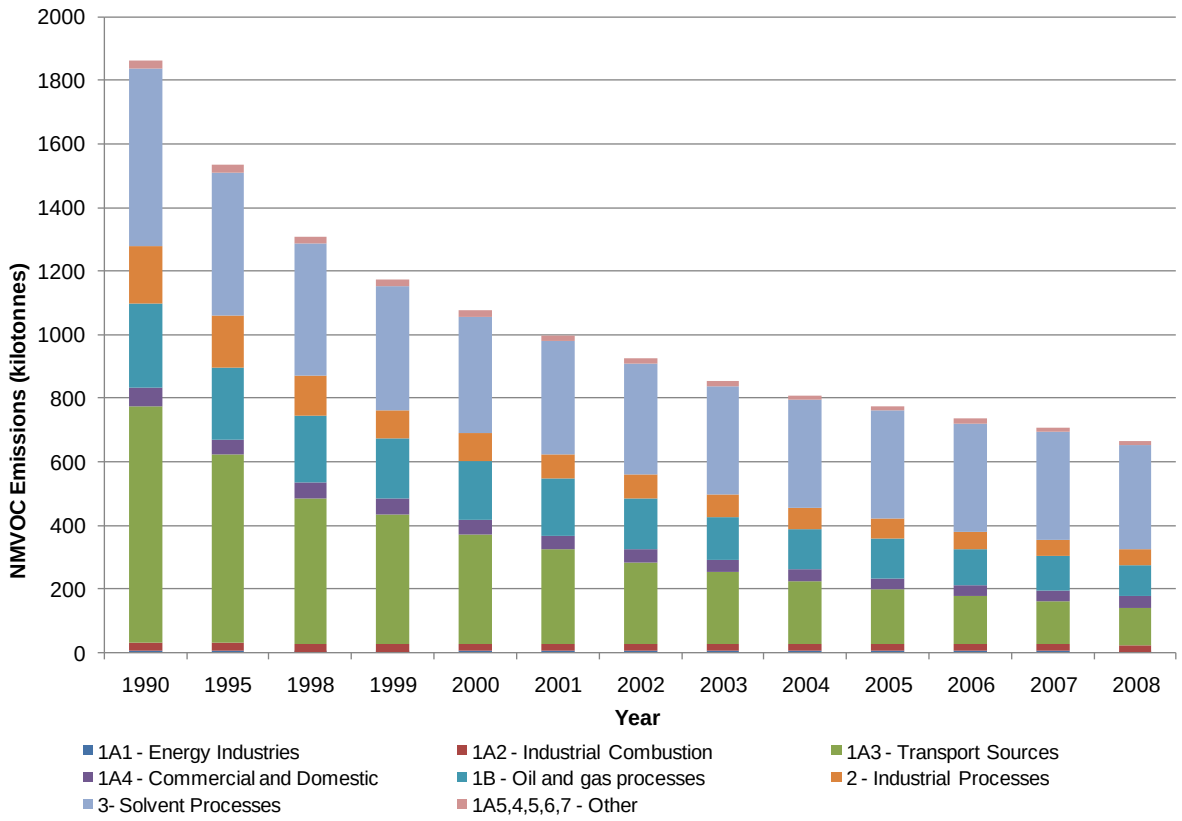
The table and graph below give a summary of the NMVOC emissions in England by broad NFR sector categories. The detailed data are available in Appendix G.

Table 2-17 - England Emissions of NMVOC by NFR Source Sector

NFR Code	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2008 (%)
1A1 - Energy Industries	5.9	6.2	3.1	3.3	4.1	3.7	4.3	3.5	3.9	3.6	4.3	3.8	3.3	1%
1A2 - Industrial Combustion	23.1	23.8	24.0	23.6	23.1	23.2	22.7	22.4	22.8	22.7	22.0	22.1	19.4	3%
1A3 - Transport Sources	745	593	458	409	345	297	258	227	196	171	152	135	119	18%
1A4 - Commercial and Domestic	60.0	47.8	48.5	50.0	43.6	41.5	38.4	37.6	37.6	36.8	35.3	35.7	36.3	5%
1B - Oil and gas processes	264	224	210	187	187	182	161	136	129	125	113	107	96.5	14%
2 - Industrial Processes	181	164	129	89.6	85.2	76.9	77.9	72.6	64.3	62.5	54.0	51.8	49.0	7%
3- Solvent Processes	557	450	416	391	368	355	345	341	341	341	341	339	329	49%
1A5,4,6 - Other	52.9	26.4	23.0	22.0	21.0	19.5	18.6	17.7	16.9	16.6	16.6	16.4	16.3	2%
Total	1889	1535	1311	1176	1078	998	926	857	811	779	737	710	669	100%

Units: kilotonnes

Figure 2-29 England NMVOC Emissions by Source, 1990-2008

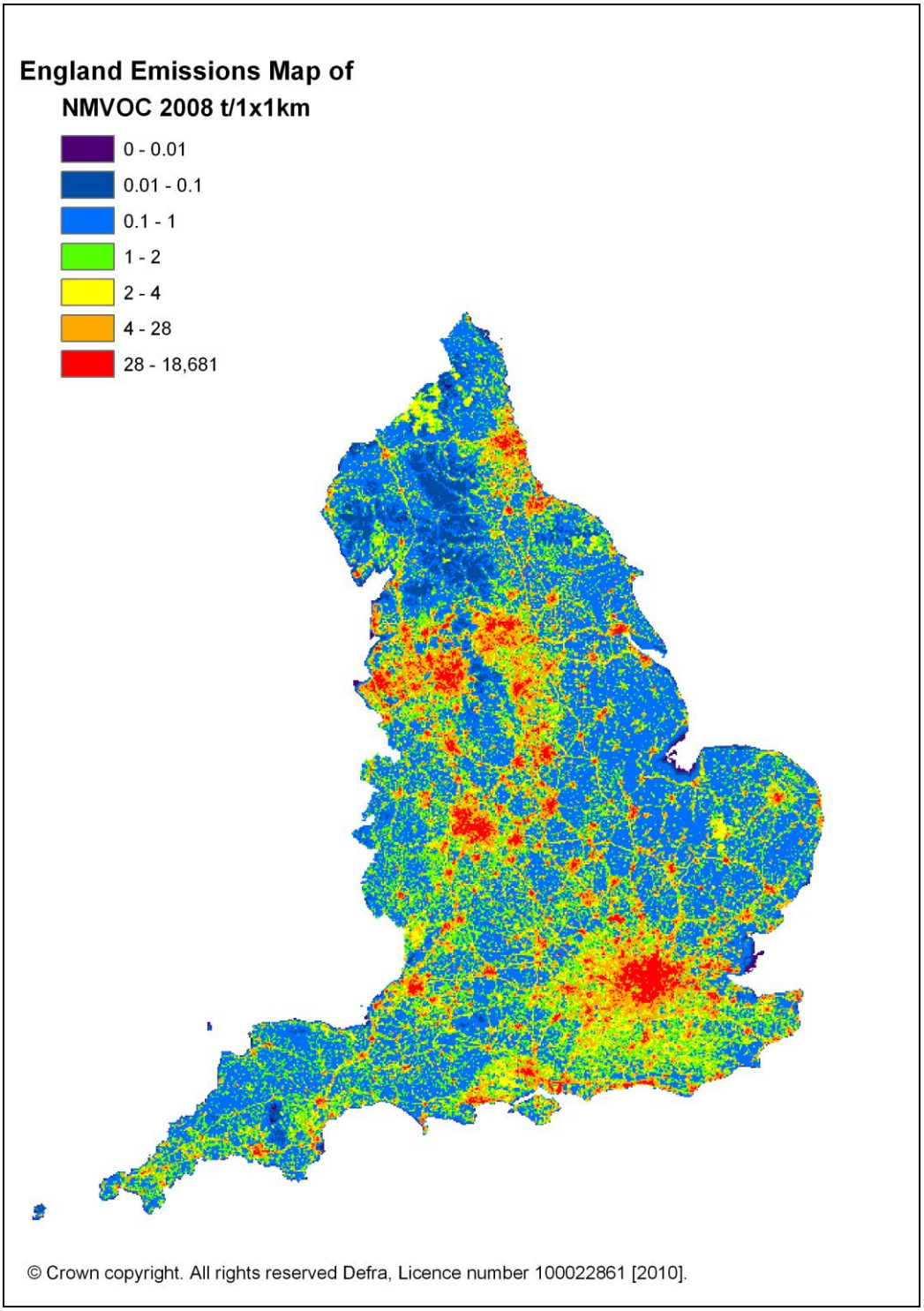


England's NMVOC emissions have declined by 65% since 1990 and account for 71% of the UK total. Significant sources include:

- Road transport sources, including evaporative losses (1A3bi-v: 17% of the total in 2008, down 85% since 1990)

- Oil & gas processes (1B: 14% of the total in 2008, down 63% since 1990)
- Industrial processes (2: 7% of the total in 2008, down 73% since 1990)
- Solvent processes (3: 49% of the total in 2008, down 41% since 1990)

Figure 2-30 Map of NMVOC Emissions in England, 2008



2.4.2 Scotland NMVOC Inventory by NFR Sector, 1990-2008

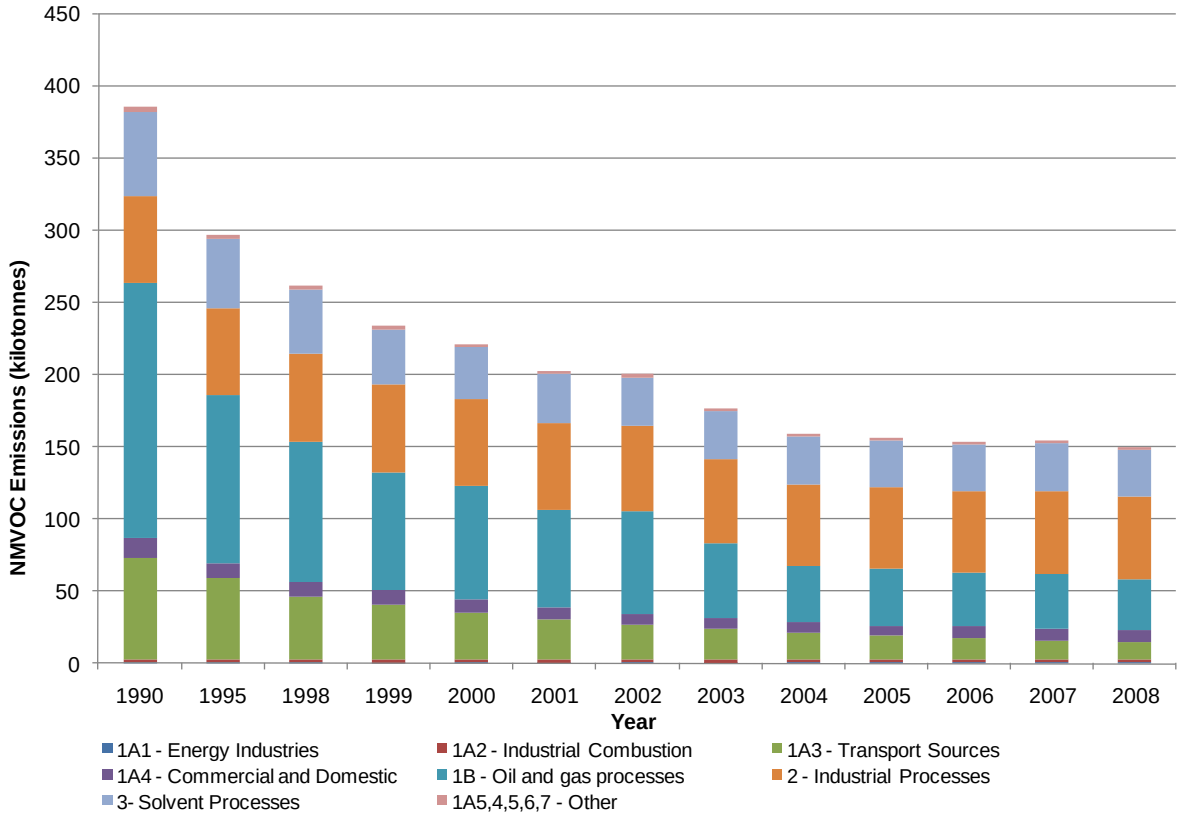
The table and graph below give a summary of the NMVOC emissions in Scotland by broad NFR sector categories. The detailed data are available in Appendix G.

Table 2-18 - Scotland Emissions of NMVOC by NFR Source Sector

NFR Code	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2008(%)
1A1 - Energy Industries	0.8	0.9	0.6	0.4	0.6	0.5	0.5	0.5	0.6	0.5	0.7	0.5	0.5	0%
1A2 - Industrial Combustion	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.1	2.1	2.1	2.0	2.1	1.8	1%
1A3 - Transport Sources	70.5	56.5	43.6	38.5	32.7	28.0	24.5	21.8	19.0	16.6	15.1	13.4	12.1	8%
1A4 - Commercial and Domestic	13.5	9.9	9.8	9.7	8.5	7.9	7.2	7.1	6.8	6.7	8.0	8.3	8.8	6%
1B - Oil and gas processes	176	116	97.7	81.3	78.7	68.1	71.2	52.2	38.9	40.0	37.0	37.4	34.7	23%
2 - Industrial Processes	59.9	59.6	60.6	60.9	60.2	59.5	59.2	57.9	56.6	55.9	56.1	57.8	57.5	38%
3- Solvent Processes	59.0	48.0	44.7	38.3	36.0	34.6	33.5	33.0	32.9	32.8	32.8	32.9	32.1	21%
1A5,4,6 - Other	5.7	3.5	3.0	2.8	2.7	2.4	2.3	2.2	2.1	2.1	2.2	2.2	2.2	2%
Total	388	297	262	234	222	203	201	177	159	157	154	155	150	100%

Units: kilotonnes

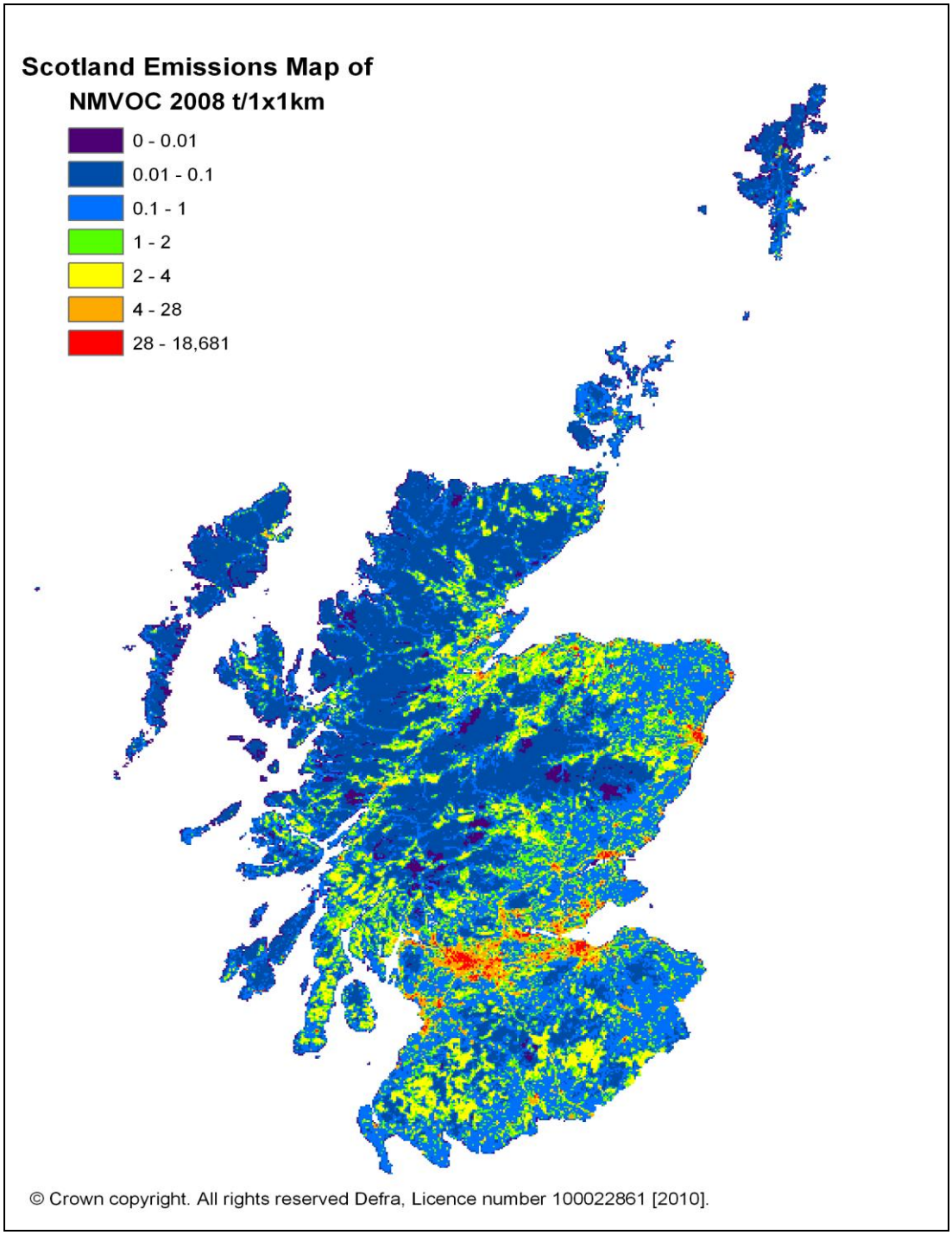
Figure 2-31 Scotland NMVOC Emissions by Source, 1990-2008



Scotland's NMVOC emissions have declined by 61% since 1990 and account for 16% of the UK total. Significant sources include:

- Road transport sources, including evaporative losses (1A3bi-v: 7% of the total in 2008, down 85% since 1990)
- Oil & gas processes (1B: 23% of the total in 2008, down 80% since 1990)
- Industrial processes (2: 38% of the total in 2008, down 4% since 1990), including food & drink emissions (2D2: dominated by brewers and distilleries, 34% of the Scottish total in 2008, up 21% since 1990)
- Solvent processes (3: 21% of the total in 2008, down 46% since 1990)

Figure 2-32 Map of NMVOC Emissions in Scotland, 2008



2.4.3 Wales NMVOC Inventory by NFR Sector, 1990-2008

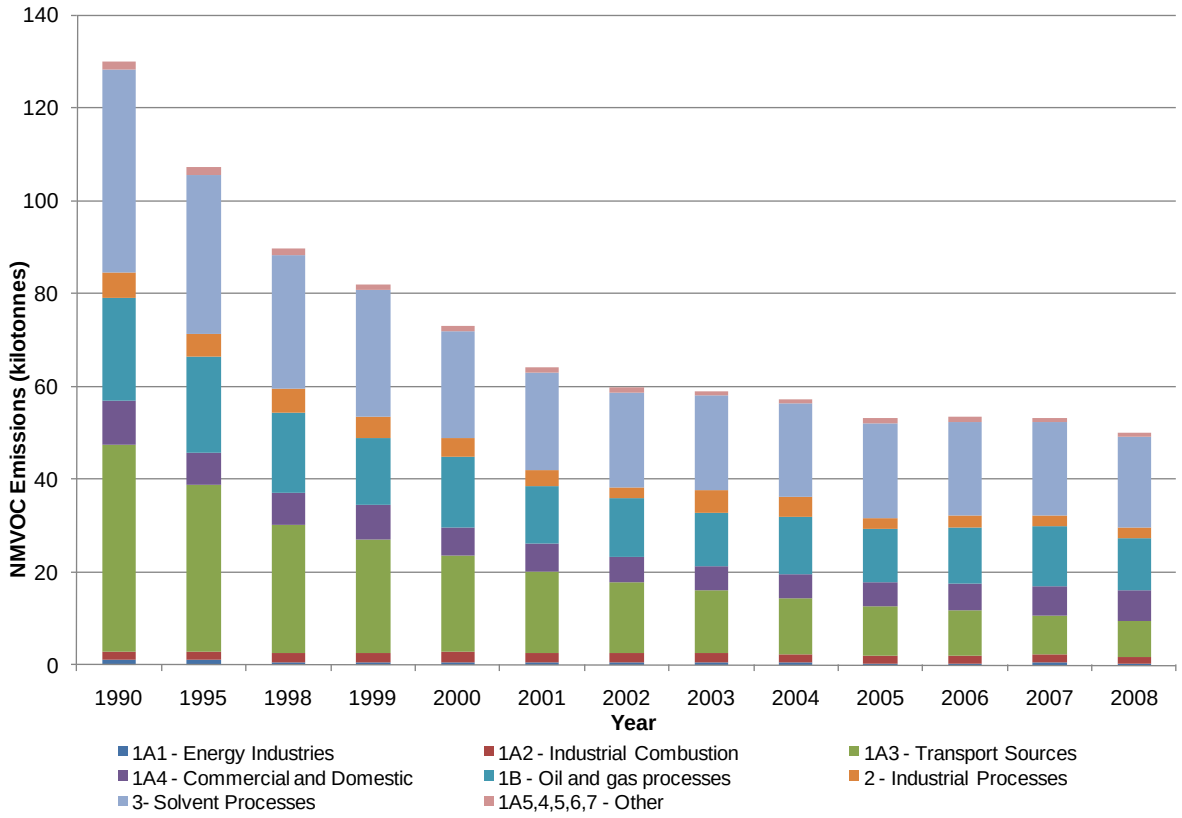
The table and graph below give a summary of the NMVOC emissions in Wales by broad NFR sector categories. The detailed data are available in Appendix G.

Table 2-19 - Wales Emissions of NMVOC by NFR Source Sector

NFR Code	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2008 (%)
1A1 - Energy Industries	1.0	1.1	0.6	0.5	0.6	0.5	0.6	0.5	0.4	0.4	0.4	0.5	0.3	1%
1A2 - Industrial Combustion	1.8	1.9	1.9	2.0	2.1	2.0	1.9	2.0	1.8	1.7	1.7	1.7	1.5	3%
1A3 - Transport Sources	44.6	35.8	27.5	24.5	20.8	17.7	15.5	13.8	12.2	10.6	9.6	8.6	7.7	15%
1A4 - Commercial and Domestic	9.4	6.9	7.2	7.6	6.2	5.8	5.2	5.1	5.2	5.3	5.9	6.3	6.7	13%
1B - Oil and gas processes	22.4	20.7	17.2	14.2	15.2	12.5	12.8	11.6	12.3	11.4	12.1	12.7	11.3	23%
2 - Industrial Processes	5.4	5.1	5.2	4.6	4.0	3.3	2.3	4.8	4.2	2.3	2.4	2.3	2.2	4%
3- Solvent Processes	43.7	34.2	28.8	27.3	22.8	21.2	20.5	20.3	20.2	20.5	20.4	20.1	19.5	39%
1A5,4,6 - Other	2.0	1.6	1.4	1.3	1.3	1.2	1.1	1.0	1.0	1.0	1.0	1.0	1.0	2%
Total	130	107	89.7	82.0	73.1	64.3	59.8	59.1	57.3	53.2	53.5	53.2	50.1	100%

Units: kilotonnes

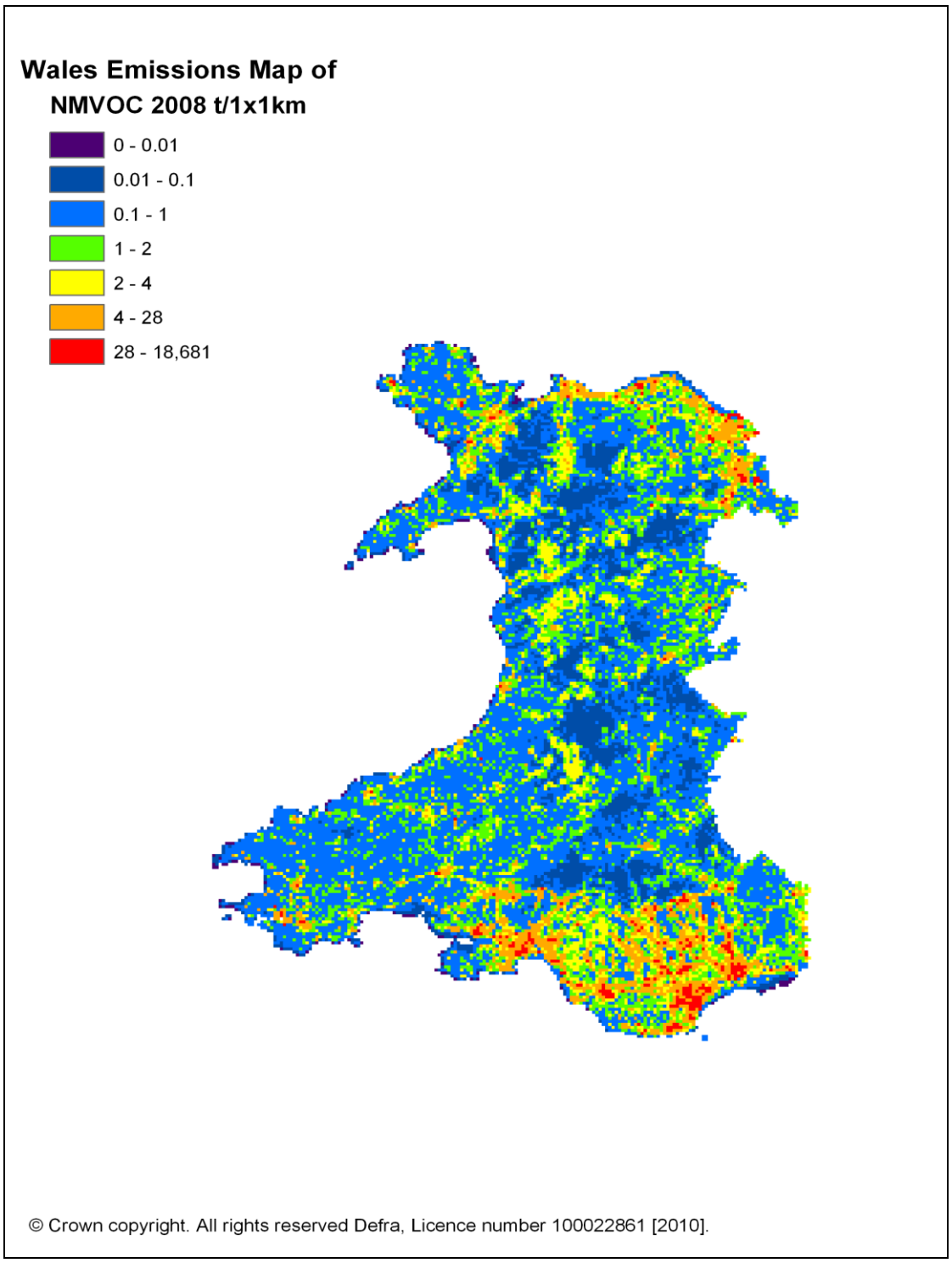
Figure 2-33 Wales NMVOC Emissions by Source, 1990-2008



Wales' NMVOC emissions have declined by 62% since 1990 and account for 5% of the UK total. Significant sources include:

- Road transport sources, including evaporative losses (1A3bi-v: 14% of the total in 2008, down 84% since 1990)
- Oil & gas processes (1B: 22% of the total in 2008, down 50% since 1990)
- Industrial processes (2: 4% of the total in 2008, down 59% since 1990)
- Solvent processes (3: 39% of the total in 2008, down 55% since 1990)

Figure 2-34 Map of NMVOC Emissions in Wales, 2008



2.4.4 Northern Ireland NMVOC Inventory by NFR Sector, 1990-2008

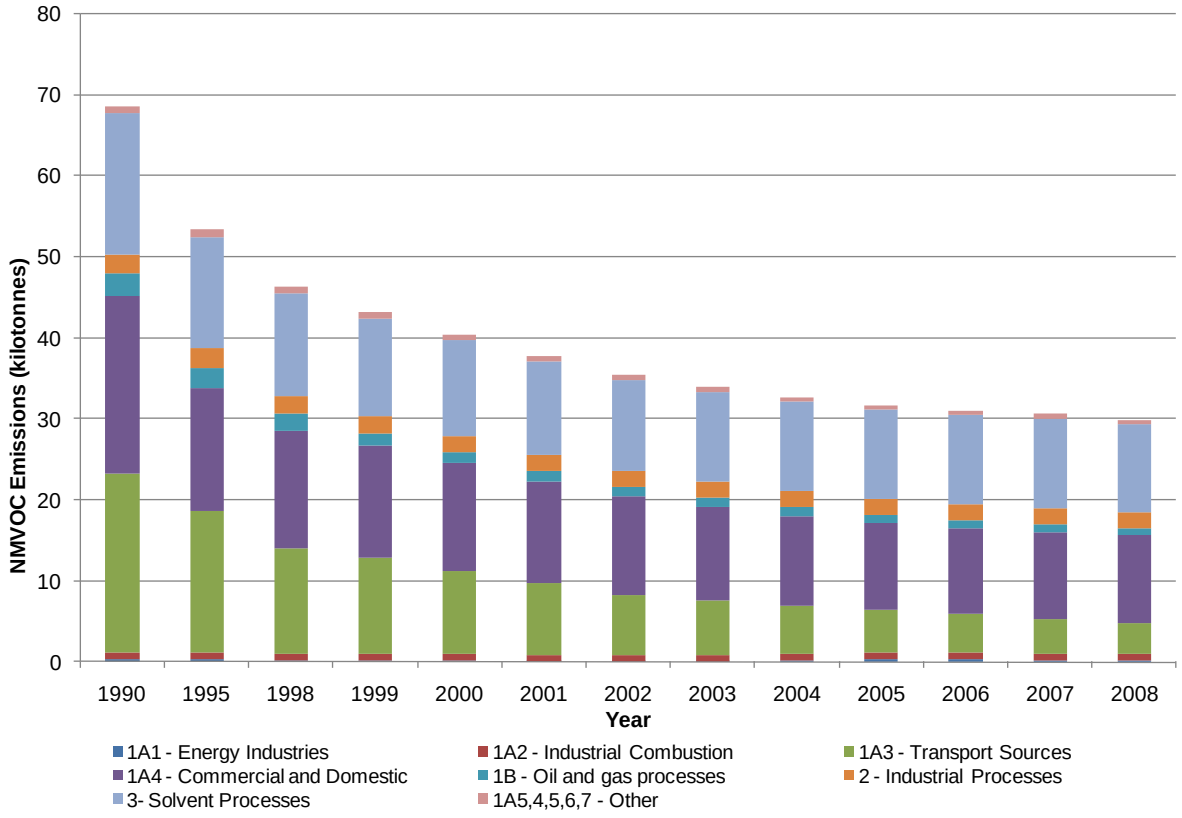
The table and graph below give a summary of the NMVOC emissions in Northern Ireland by broad NFR sector categories. See Appendix G for more detailed data.

Table 2-20 - Northern Ireland Emissions of NMVOC by NFR Source Sector

NFR Code	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2008 (%)
1A1 - Energy Industries	0.3	0.4	0.2	0.2	0.2	0.0	0.0	0.0	0.2	0.3	0.4	0.1	0.2	1%
1A2 - Industrial Combustion	0.8	0.8	0.9	0.8	0.8	0.7	0.7	0.8	0.8	0.8	0.8	0.8	0.7	2%
1A3 - Transport Sources	22.0	17.5	13.0	11.9	10.3	8.9	7.5	6.8	6.0	5.3	4.7	4.3	3.8	13%
1A4 - Commercial and Domestic	21.9	15.2	14.4	13.8	13.2	12.6	12.1	11.5	11.0	10.7	10.6	10.8	10.9	37%
1B - Oil and gas processes	2.8	2.5	2.2	1.6	1.5	1.4	1.2	1.2	1.1	1.0	0.9	0.9	0.7	3%
2 - Industrial Processes	2.4	2.4	2.2	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.1	7%
3- Solvent Processes	17.4	13.8	12.8	12.2	11.8	11.4	11.2	11.1	11.0	11.0	11.1	11.1	10.7	36%
1A5,4,6 - Other	1.2	1.0	0.8	0.8	0.8	0.7	0.7	0.6	0.6	0.6	0.6	0.6	0.6	2%
Total	68.9	53.5	46.4	43.2	40.5	37.8	35.5	34.0	32.7	31.7	31.1	30.7	29.9	100%

Units: kilotonnes

Figure 2-35 Northern Ireland NMVOC Emissions by Source, 1990-2008

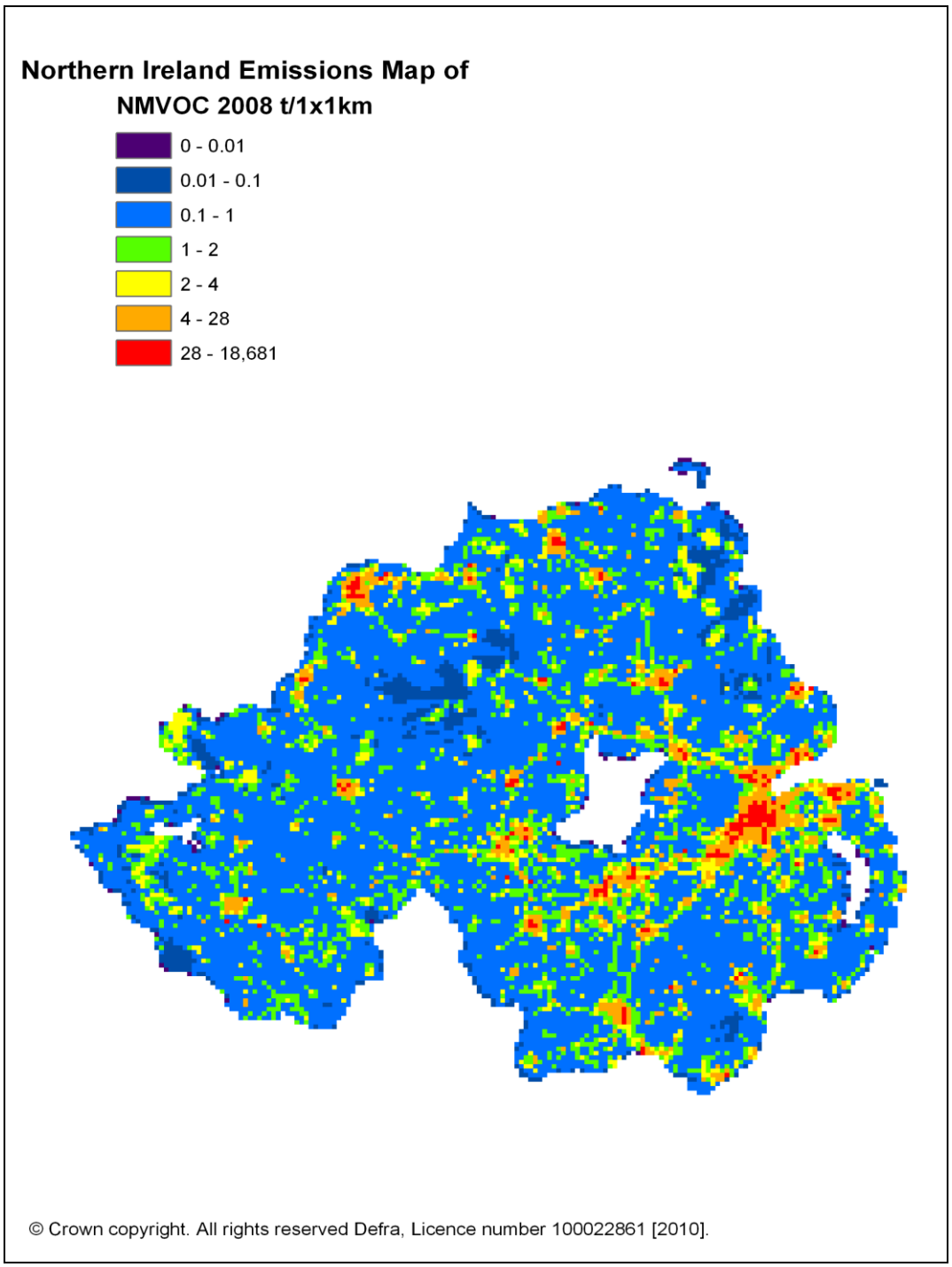


Northern Ireland's NMVOC emissions have declined by 57% since 1990 and account for 3% of the UK total. Significant sources include:

- Road transport sources, including evaporative losses (1A3bi-v: 12% of the total in 2008, down 84% since 1990)

- Oil & gas processes (1B: 2% of the total in 2008, down 74% since 1990)
- Commercial & domestic combustion (1A4: 37% of the total in 2008, down 50% since 1990)
- Solvent processes (3: 36% of the total in 2008, down 38% since 1990)
- Food & drink sector (2D2: 7% of the total in 2008, up 10% since 1990).

Figure 2-36 Map of NMVOC Emissions in Northern Ireland, 2008



2.5 PARTICULATE MATTER AS PM_{10}

PM_{10} is a measure of the size distribution of the particles emitted to air and represents the proportion material with an aerodynamic diameter less than 10 micro meters. PM_{10} in the atmosphere arises from primary and secondary sources:

Primary Sources
Direct emissions of particulate matter into the atmosphere arise from a wide range of sources such as fuel combustion, surface erosion and wind blown dusts and mechanical break-up in, for example, quarrying and construction sites.

Secondary Sources
Particulate matter may be formed in the atmosphere through reactions of other pollutants such as sulphur dioxide, nitrogen oxides and ammonia to form solid sulphates and nitrates, as well as organic aerosols formed from the oxidation of NMVOCs.

These inventories only consider primary sources. For further information on secondary particulates see the Air Quality Expert Group's Report on particulate matter in the United Kingdom (AQEG, 2005) http://www.defra.gov.uk/environment/airquality/publications/particulate-matter/index.htm

The main sources of primary PM_{10} are briefly described below:

- **Road Transport (1A3b).** Diesel engines typically emit a greater mass of particulates per vehicle kilometre than petrol engines. Particulate emissions also arise from all vehicles through brake and tyre wear as well as from the re-entrainment of dust from road surfaces caused by vehicle movements.

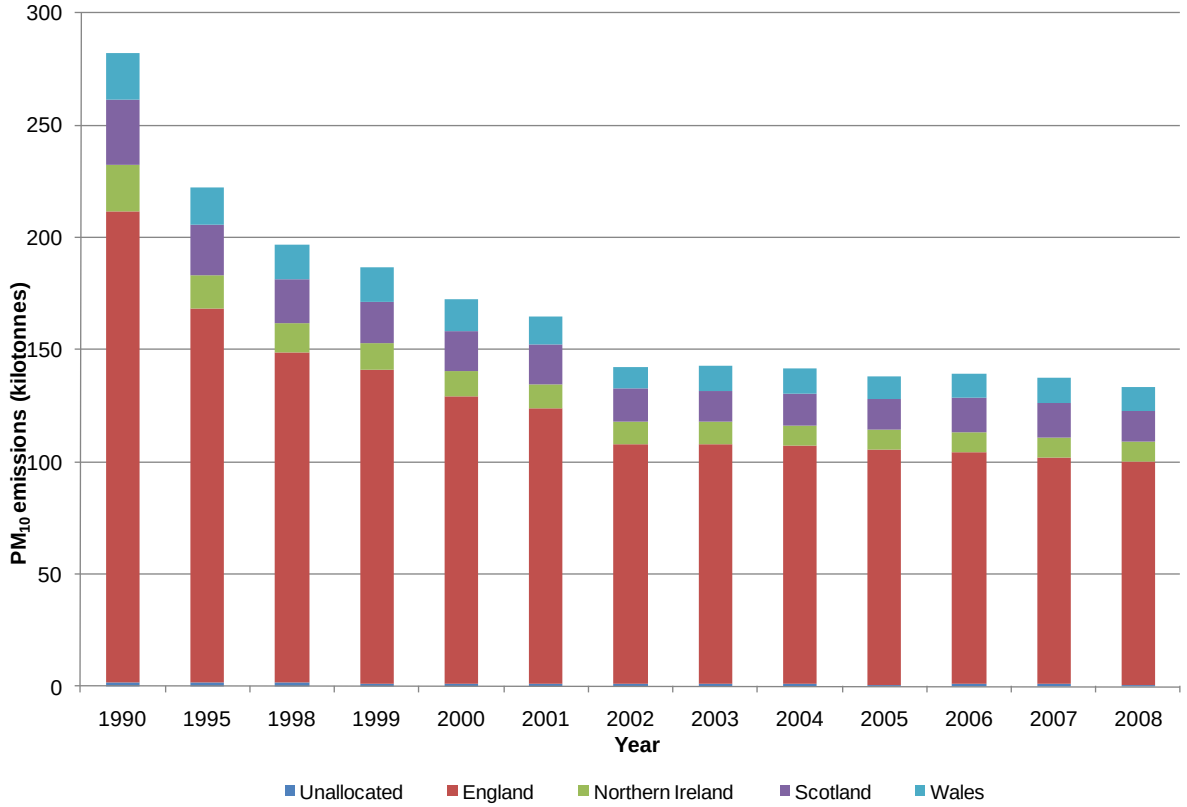
- **Stationary Combustion.** Domestic coal combustion has historically been the main source of particulate emissions in the UK, but restrictions in the use of coal for domestic combustion through the Clean Air Acts has lead to other sources becoming more important nationally. Domestic coal is still a significant source in Northern Ireland, some smaller towns and villages, and in areas associated with the coal industry. Other fossil fuels emit PM_{10}, with combustion of wood, gas oil and fuel oil all contributing significantly to UK emissions. In general, particles emitted from fuel combustion are of a smaller size than from other sources.

- **Industrial Processes (2).** Particulates are emitted from a wide range of industrial processes including: the production of metals, cement, lime, coke & chemicals, bulk handling of dusty materials, construction, mining and quarrying. Whilst emission monitoring results are now widely available for stack and other point-source emissions of particulates from regulated industrial processes, the quantification of diffuse & fugitive emissions from industrial sources is more difficult. Few UK measurements are available for these fugitive releases but there have been substantial improvements in the estimation of PM_{10} emissions from industrial processes in recent years.

2.5.1 UK Trends in PM_{10} Emissions

Emissions of PM_{10} from across the UK have declined significantly since 1970, mainly due to improved abatement of industrial and power generation (1A1a) emission sources and a general reduction in coal use as an energy source across many economic sectors. For example, emissions in the domestic and commercial sector have fallen from 245 ktonnes (50% of the total emission) in 1970 to 20 ktonnes (14%) in 2008.

Figure 2-37 UK PM_{10} Emissions by Constituent Country, 1990-2008



Emissions from power stations have declined despite a significant growth in electricity generation capacity, due to a shift in the fuel mix for power generation from coal to natural gas, nuclear and renewable generation, and also due to abatement being fitted at coal-fired power stations. For example, the installation of flue gas desulphurisation (FGD) at a number of plants has reduced particulate matter emissions substantially. Emissions from road transport have varied across the time-series as a number of factors have combined. The main source of road transport emissions is exhaust gases from diesel engines. Emissions from diesel vehicles have been growing due to the growth in heavy-duty vehicle traffic and the move towards more diesel cars. Since around 1992, however, emissions from diesel vehicles have been decreasing due to the penetration of new vehicles meeting tighter PM_{10} emission regulations ("Euro standards" for diesel vehicles were first introduced in 1992).

Among the non-combustion and non-transport sources, the major emissions are from industrial processes (2), the most important of which is quarrying whose emission rates have remained fairly constant. Other industrial processes, including the manufacture of steel, cement, lime, coke, and primary and secondary non-ferrous metals, are collectively important sources of particulate matter although emissions from individual sectors are relatively insignificant.

Emissions of PM_{10} for England, Wales, Scotland and Northern Ireland are summarised in the tables and graphs below, with more detailed inventory tables in Appendix C. Table 2.21 shows how total UK PM_{10} emissions are split between the 4 constituent countries.

Table 2-21 - Proportion of UK PM_{10} Emissions by Constituent Country

Year	England	Scotland	Wales	N Ireland	Unallocated
1990	74%	10%	7%	8%	1%
2008	74%	10%	8%	7%	1%

2.5.2 England PM_{10} Inventory by NFR Sector, 1990-2008

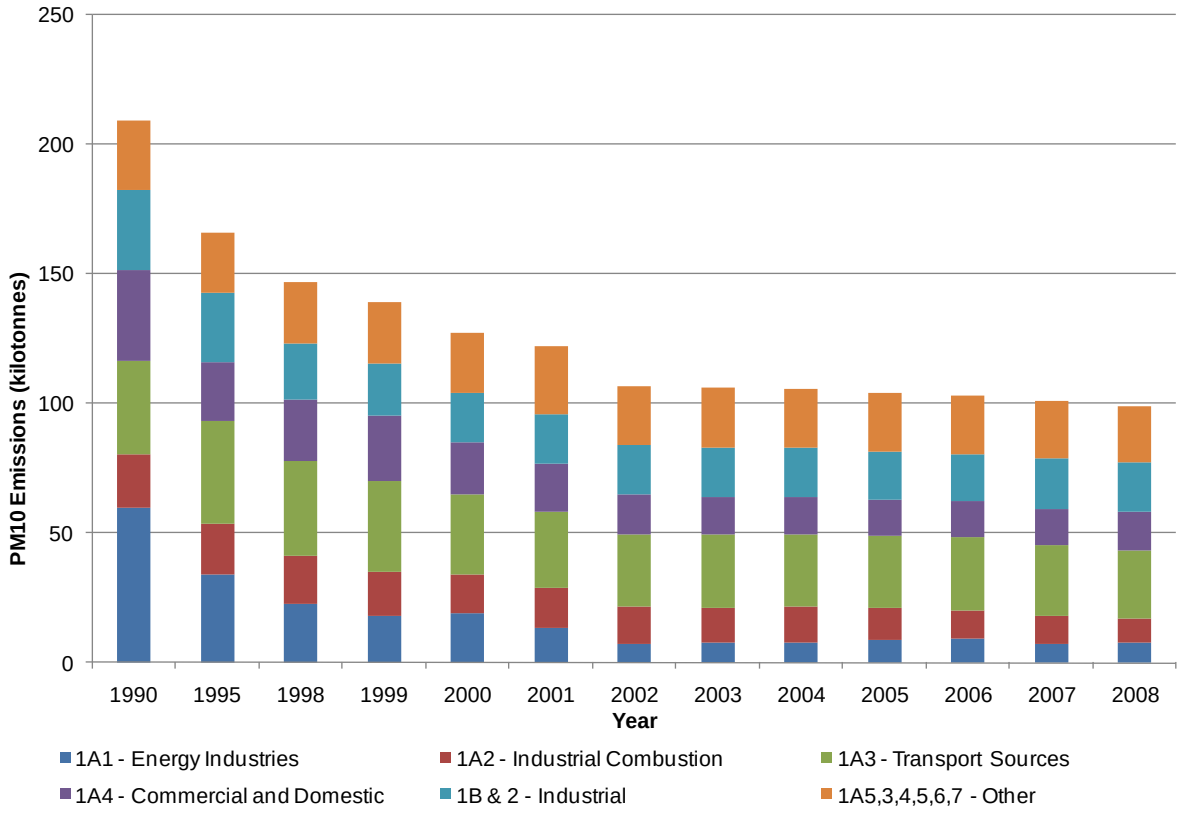
The table and graph below give a summary of the PM_{10} emissions in England by broad NFR sector categories. The detailed data are available in Appendix C.

Table 2-22 - England Emissions of PM_{10} by NFR Source Sector

NFR Code	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2008 (%)
1A1 - Energy Industries	59.8	33.9	22.4	18.2	19.0	13.4	7.4	7.6	7.9	8.8	9.0	7.4	7.5	7%
1A2 - Industrial Combustion	20.6	19.8	18.5	16.9	15.2	15.3	14.2	13.6	13.6	12.4	11.1	10.6	9.3	9%
1A3 - Transport Sources	36.1	39.4	36.6	35.1	30.9	29.6	27.8	28.0	27.9	27.7	28.3	27.1	26.3	27%
1A4 - Commercial and Domestic	34.9	23.0	23.7	25.0	19.8	18.4	15.6	14.9	14.5	14.0	13.7	14.2	14.9	15%
1B & 2 - Industrial	31.0	26.7	21.9	20.2	19.1	19.2	18.9	19.0	18.7	18.6	18.1	19.5	19.0	19%
1A5,3,4,5,6,7 - Other	26.4	23.2	23.8	23.8	23.3	26.0	22.4	23.1	22.9	22.5	22.6	21.9	22.0	22%
Total	209	166	147	139	127	122	106	106	106	104	103	101	99.0	100%

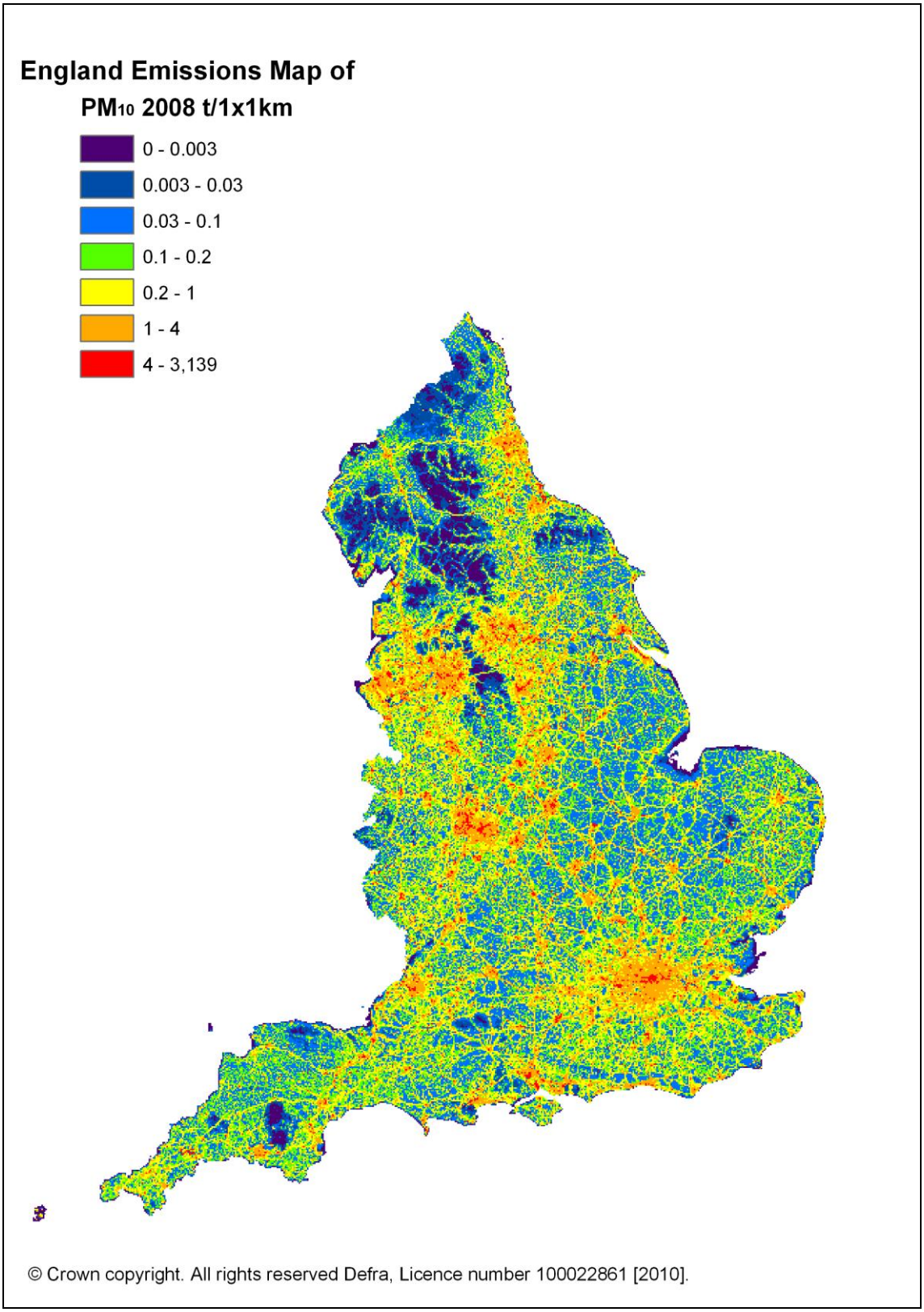
Units: kilotonnes

Figure 2-38 England PM_{10} Emissions by Source, 1990-2008



England's PM_{10} emissions have declined by 53% since 1990 and account for 74% of the UK total. 27% of PM_{10} emissions in England come from transport (1A3) sources (down by 27% since 1990), whilst 15% stem from commercial and residential combustion (mainly of coal and solid fuels, down by 57% since 1990). Emissions from power generation (1A1a) were 28% of the England total emission in 1990, but have been significantly reduced to 7% of the England total in 2008.

Figure 2-39 Map of PM_{10} Emissions in England, 2008



2.5.3 Scotland PM_{10} Inventory by NFR Sector, 1990-2008

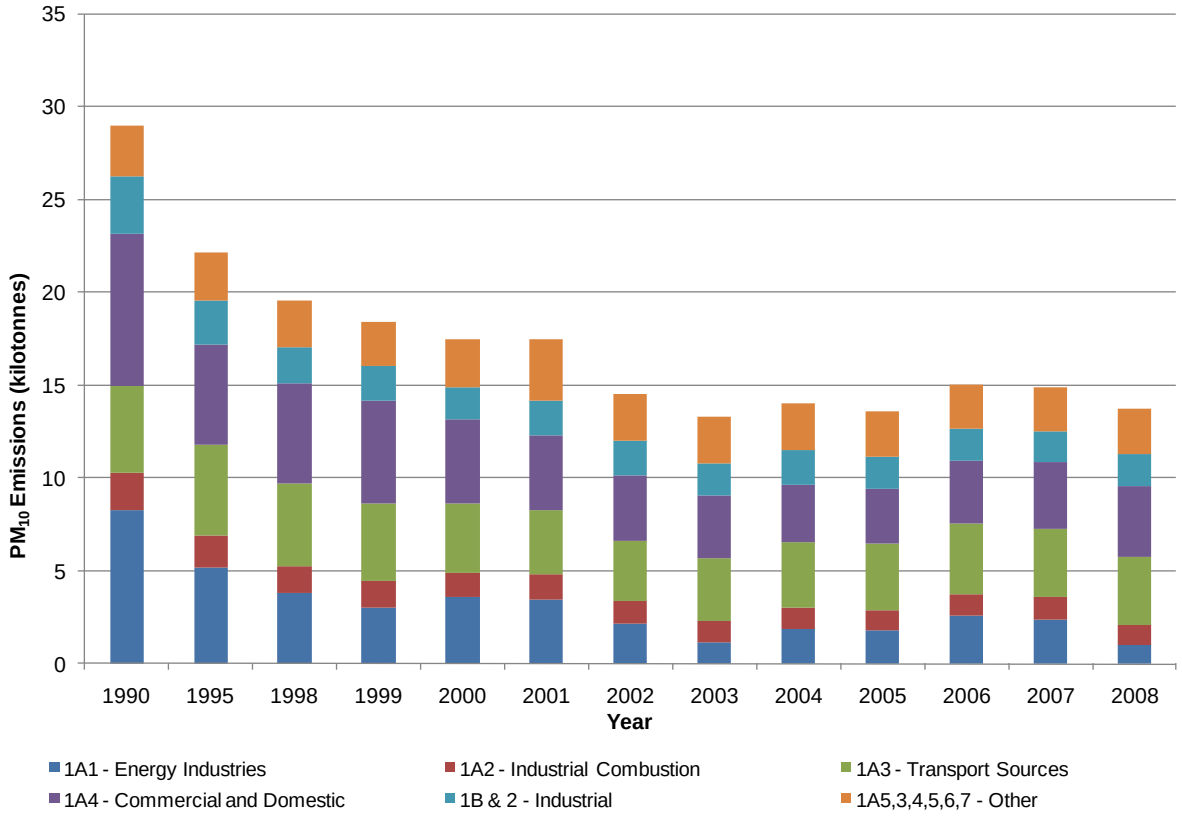
The table and graph below give a summary of the PM_{10} emissions in Scotland by broad NFR sector categories. The detailed data are available in Appendix C.

Table 2-23 - Scotland Emissions of PM_{10} by NFR Source Sector

NFR Code	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2008(%)
1A1 - Energy Industries	8.3	5.2	3.8	3.0	3.6	3.5	2.2	1.1	1.8	1.8	2.6	2.4	1.0	7%
1A2 - Industrial Combustion	2.0	1.7	1.5	1.4	1.3	1.4	1.2	1.2	1.2	1.1	1.1	1.2	1.1	8%
1A3 - Transport Sources	4.7	4.9	4.4	4.2	3.7	3.4	3.2	3.4	3.5	3.6	3.8	3.7	3.7	27%
1A4 - Commercial and Domestic	8.2	5.4	5.4	5.5	4.5	4.1	3.5	3.3	3.1	2.9	3.4	3.6	3.9	28%
1B & 2 - Industrial	3.1	2.4	1.9	1.9	1.8	1.8	1.9	1.7	1.8	1.8	1.7	1.7	1.7	13%
1A5,3,4,6,7 - Other	2.8	2.6	2.5	2.4	2.5	3.3	2.5	2.5	2.5	2.4	2.4	2.4	2.4	18%
Total	29.0	22.2	19.5	18.4	17.5	17.5	14.5	13.3	14.1	13.6	15.1	14.9	13.7	100%

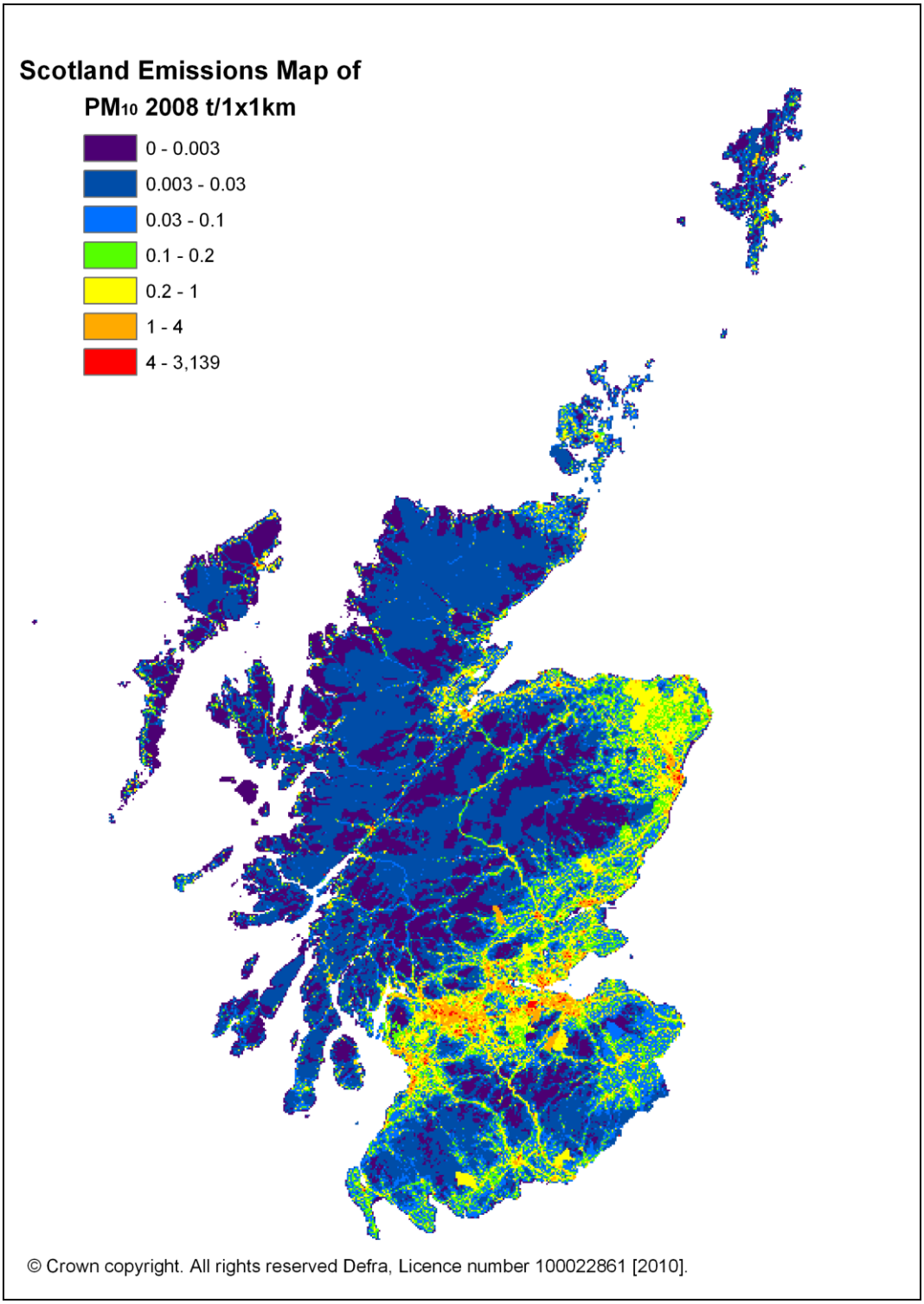
Units: kilotonnes

Figure 2-40 Scotland PM_{10} Emissions by Source, 1990-2008



Scotland's PM_{10} emissions have declined by 53% since 1990 and account for 10% of the UK total. 27% of PM_{10} emissions in Scotland come from transport (1A3) sources (down by 23% since 1990), whilst 28% stem from commercial and residential combustion (mainly of coal and solid fuels, down by 53% since 1990). Emissions from power generation (1A1a) were 25% of the Scotland total emission in 1990, but have been reduced to 6% of the Scotland total in 2008.

Figure 2-41 Map of PM_{10} Emissions in Scotland, 2008



2.5.4 Wales PM_{10} Inventory by NFR Sector, 1990-2008

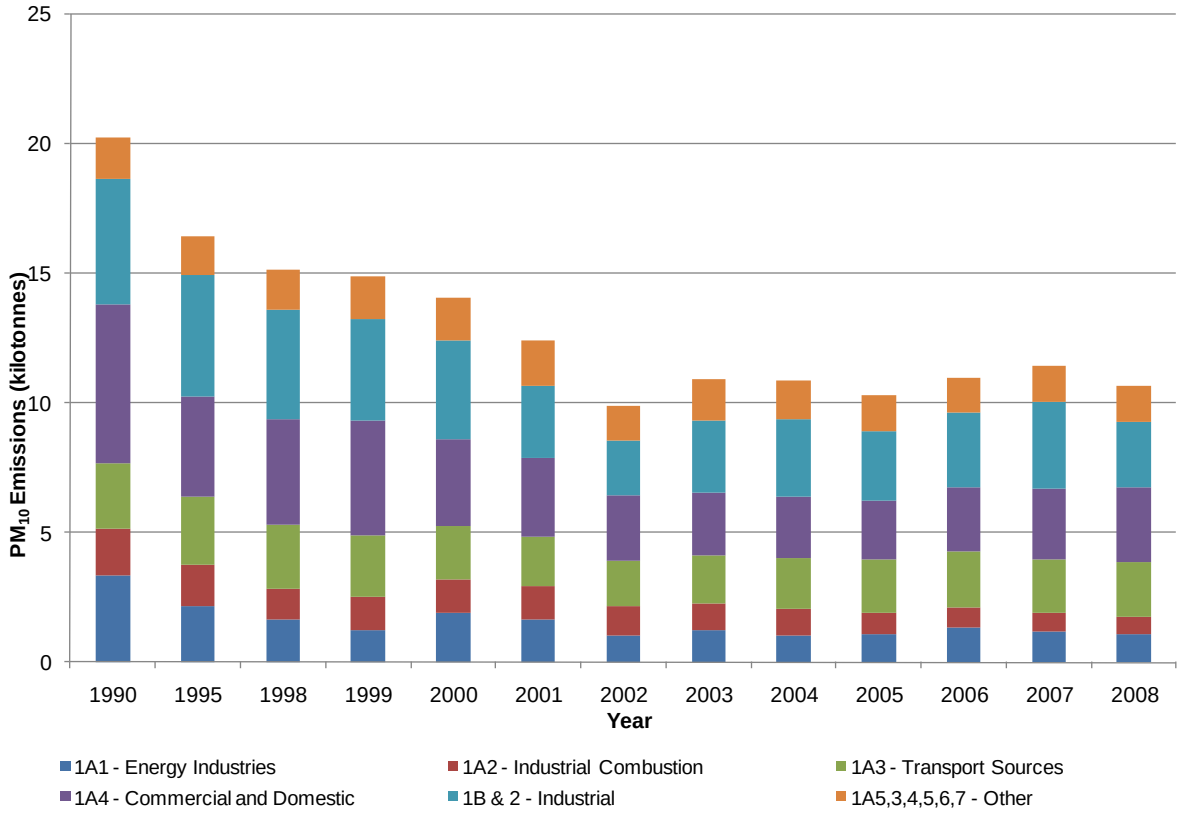
The table and graph below give a summary of the PM_{10} emissions in Wales by broad NFR sector categories. The detailed data are available in Appendix C.

Table 2-24 - Wales Emissions of PM_{10} by NFR Source Sector

NFR Code	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2008 (%)
1A1 - Energy Industries	3.3	2.2	1.6	1.2	1.9	1.6	1.0	1.2	1.0	1.1	1.3	1.2	1.1	10%
1A2 - Industrial Combustion	1.7	1.5	1.2	1.3	1.3	1.3	1.1	1.0	1.0	0.8	0.8	0.7	0.6	6%
1A3 - Transport Sources	2.5	2.7	2.5	2.3	2.0	1.9	1.8	1.9	2.0	2.0	2.2	2.1	2.1	20%
1A4 - Commercial and Domestic	6.2	3.9	4.1	4.4	3.4	3.1	2.5	2.4	2.4	2.3	2.5	2.7	2.9	27%
1B & 2 - Industrial	4.8	4.7	4.2	3.9	3.8	2.8	2.1	2.8	3.0	2.7	2.9	3.4	2.5	23%
1A5,3,4,6,7 - Other	1.6	1.5	1.5	1.6	1.6	1.7	1.3	1.6	1.5	1.4	1.3	1.4	1.4	13%
Total	20.2	16.4	15.1	14.9	14.0	12.4	9.8	10.9	10.8	10.3	11.0	11.4	10.7	100%

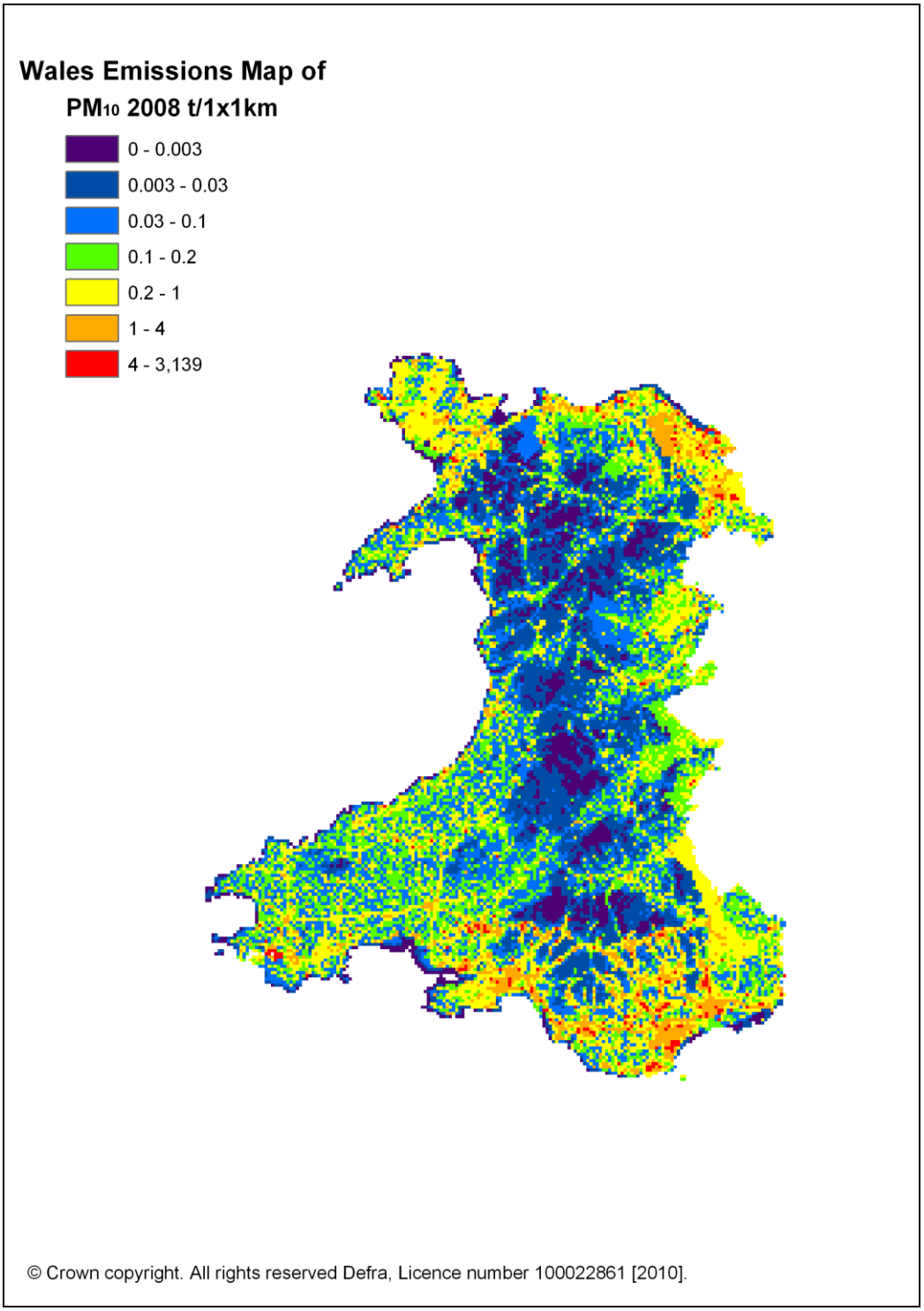
Units: kilotonnes

Figure 2-42 Wales PM_{10} Emissions by Source, 1990-2008



Wales PM_{10} emissions have declined by 47% since 1990 and accounted for 8% of the UK total in 2008. Commercial and domestic sources accounted for 27% of Welsh emissions in 2008, mainly from combustion of solid fuels; these emissions have declined by 53% since 1990. In 2008, 20% of PM_{10} emissions in Wales come from transport (1A3) sources (down by 17% since 1990), whilst emissions from power generation (1A1a) accounted for 8% of the Wales total in 2008, down 69% on 1990 emissions. Heavy industry plays a more significant role in the Wales PM_{10} inventory than in other parts of the UK, with key contributions to the 2008 total from quarrying and mining (7%), iron & steel production (13%), other manufacturing combustion (6%).

Figure 2-43 Map of PM_{10} Emissions in Wales, 2008



2.5.5 Northern Ireland PM_{10} Inventory by NFR Sector, 1990-2008

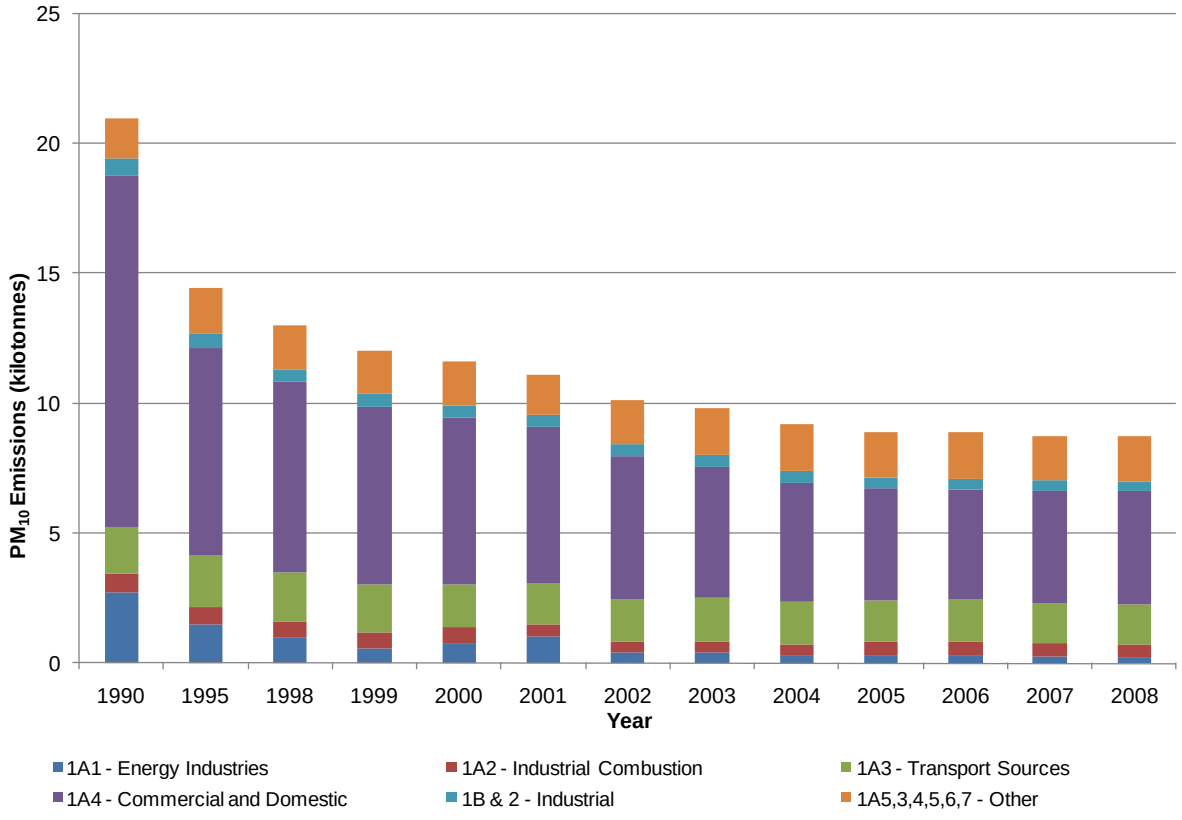
The table and graph below give a summary of the PM_{10} emissions in Northern Ireland by broad NFR sector categories. The detailed data are available in Appendix C.

Table 2-25 - Northern Ireland Emissions of PM_{10} by NFR Source Sector

NFR Code	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2008 (%)
1A1 - Energy Industries	2.7	1.5	1.0	0.6	0.8	1.0	0.4	0.4	0.3	0.3	0.3	0.3	0.2	3%
1A2 - Industrial Combustion	0.9	0.8	0.7	0.7	0.7	0.6	0.5	0.4	0.5	0.6	0.6	0.5	0.5	6%
1A3 - Transport Sources	1.8	2.0	1.9	1.8	1.7	1.6	1.6	1.7	1.6	1.6	1.7	1.6	1.6	18%
1A4 - Commercial and Domestic	13.5	8.0	7.4	6.9	6.4	6.0	5.5	5.0	4.6	4.3	4.2	4.3	4.4	50%
1B & 2 - Industrial	0.6	0.6	0.5	0.5	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4	5%
1A5,3,4,6,7 - Other	1.5	1.7	1.7	1.7	1.7	1.6	1.7	1.8	1.8	1.7	1.8	1.7	1.7	20%
Total	21.1	14.6	13.1	12.1	11.7	11.2	10.2	9.9	9.3	8.9	9.0	8.8	8.8	100%

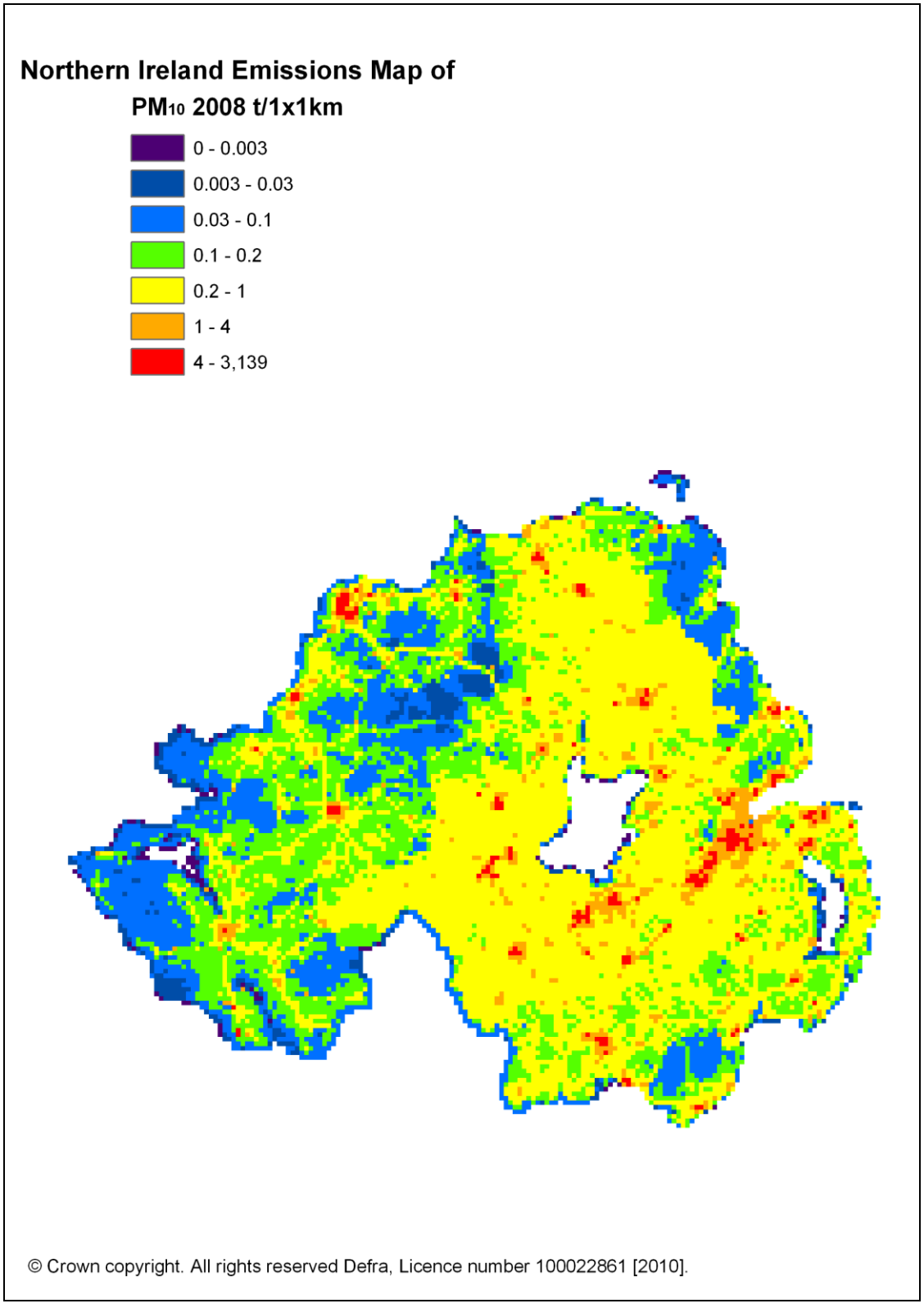
Units: kilotonnes

Figure 2-44 Northern Ireland PM_{10} Emissions by Source, 1990-2008



Northern Ireland's PM_{10} emissions have declined by 58% since 1990 and accounted for 7% of the UK total in 2008. 18% of PM_{10} emissions in Northern Ireland come from transport (1A3) sources (down by 14% since 1990), whilst 50% stem from commercial and residential combustion (mainly of coal and solid fuels), down by 68% since 1990. Emissions from power generation (1A1a) were 13% of the total emissions in 1990, but have been reduced to 3% of the Northern Ireland total in 2008.

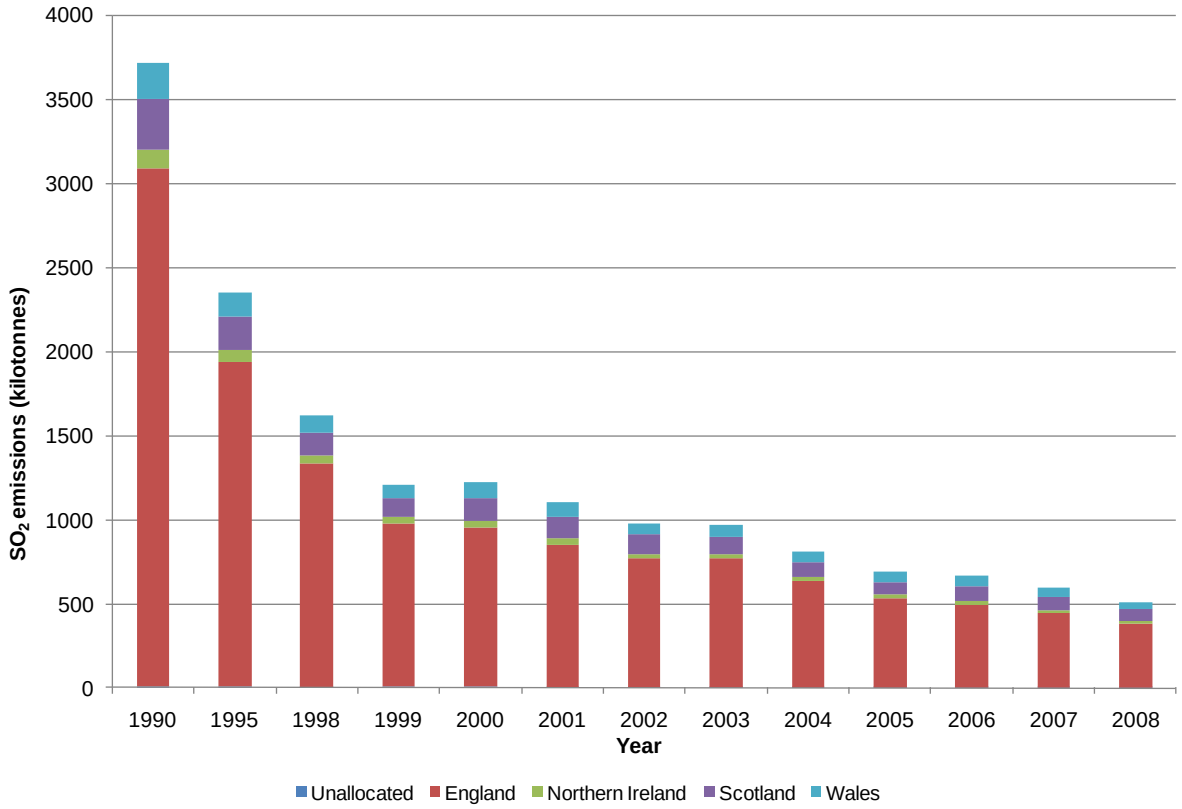
Figure 2-45 Map of PM_{10} Emissions in Northern Ireland, 2008



2.6 SULPHUR DIOXIDE

Since 1970 there has been a substantial overall reduction of more than 92% in SO_2 emissions from across the UK, mainly due to a decline in emissions from combustion of sulphur-containing solid fuels and petroleum products.

Figure 2-46 UK Sulphur Dioxide Emissions by Constituent Country, 1990-2008



Emissions from combustion of petroleum products have fallen significantly due to the decline in fuel oil use and the reduction in the sulphur content of gas oil and DERV (diesel fuel specifically used for road vehicles). The reduced sulphur content of gas oil is particularly significant in sectors such as domestic heating, commercial heating and off-road sources where gas oil is used extensively.

Fuel combustion accounts for more than 90% of total UK SO_2 emissions with the sulphur arising from the fuel itself. The SO_2 emission can be calculated from knowledge of the sulphur content of the fuel and from information on the amount of sulphur retained in the ash. Published fuel consumption data (DECC, 2009), sulphur contents of liquid fuels (McPherson, 2009) and data from coal producers regarding sulphur contents of coals enable reliable estimates to be produced. The main combustion sources are:

- **Power generation (1A1a).** Power stations account for 42% of UK SO_2 emissions in 2008. Historically coal-fired stations have been the most important source, but the gradual change in fuel mix of UK power stations (to more nuclear and gas-fired plant) and improvements in generation efficiency and these reductions will continue in the near future as more CCGT stations are built and FGD is fitted to more coal fired power plant.

- **Industrial Combustion (1A2).** Emissions of SO_2 from industry result from the combustion of coal and oil, some refinery processes and the production of sulphuric acid and other chemicals. Between 1970 and 2008 emissions from combustion sources have fallen by 81%, primarily due to the decline in energy-intensive heavy industries such as iron & steel

manufacturing. In addition, UK industry has gradually switched from coal and oil-based fuels in favour of natural gas, as it provides a cleaner, cheaper energy source.

In 2008, road transport (1A3b) emissions account for less than 1% of the total SO_2 emissions. Previously this source was more significant, but a tightening of fuel standards during the 1990s and more recently due to the 2007 Sulphur Content of Liquid Fuels Regulations has led to a significant decline in emissions due to the reduction in the sulphur content of DERV. The reduction in the sulphur content of gas oil (to 0.1% by mass from January 2008 onwards) has also reduced emissions from off-road vehicles.

Emissions from domestic (1A4b), commercial & institutional sectors (1A4a) have also declined since 1970, reflecting the major changes in fuel mix from oil and coal to gas. Emissions from waste incinerators have reduced significantly during the 1990s due to the introduction of stricter emission standards forcing the closure of old-design incinerators and their replacement with more modern plant with improved abatement.

Emissions of SO_2 for England, Wales, Scotland and Northern Ireland are summarised in the tables and graphs below, with more detailed inventory tables in Appendix F. Table 2.26 shows how total UK SO_2 emissions are split between the 4 constituent countries.

Table 2-26 - Proportion of UK Sulphur Dioxide Emissions by Constituent Country

Year	England	Scotland	Wales	N Ireland	Unallocated
1990	83%	8%	5%	3%	0%
2008	74%	13%	8%	4%	0%

2.6.1 England Sulphur Dioxide Inventory by NFR Sector, 1990-2008

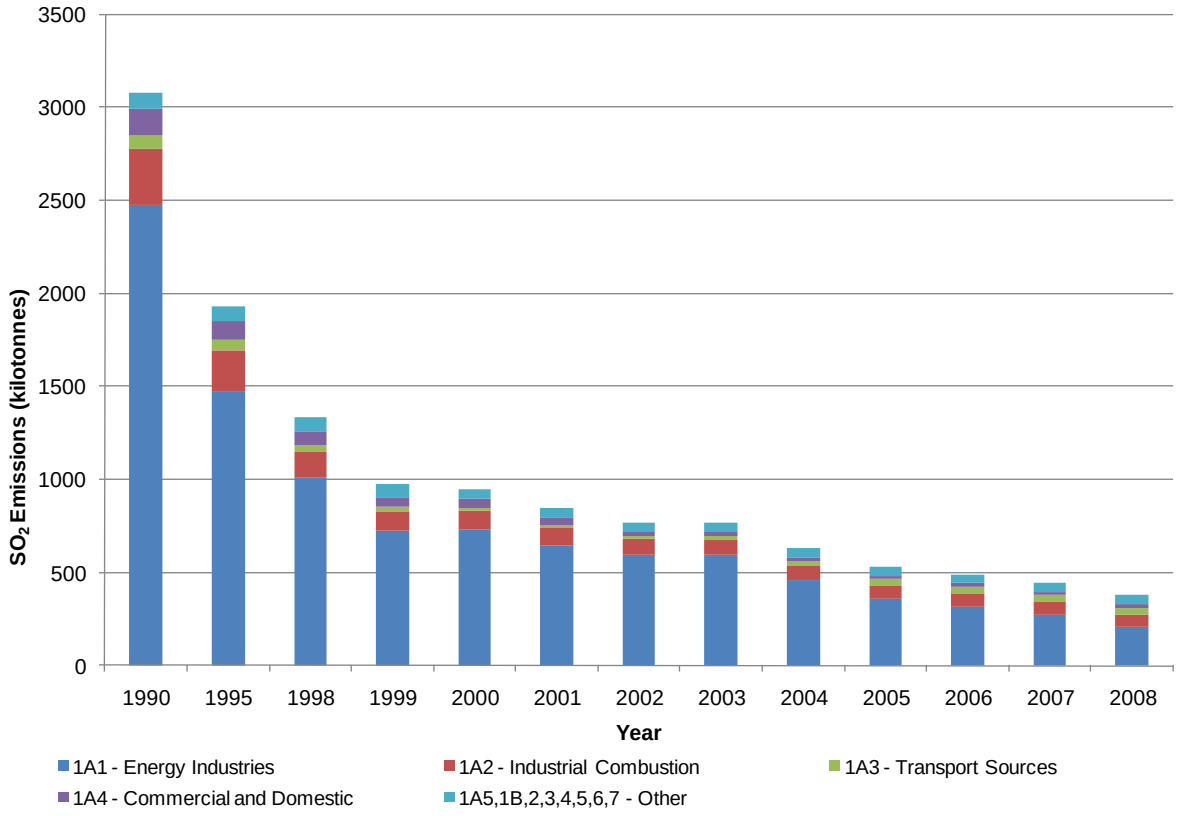
The table and graph below give a summary of the SO_2 emissions in England by broad NFR sector categories. The detailed data are available in Appendix F.

Table 2-27 - England Emissions of Sulphur Dioxide by NFR Source Sector

NFR Code	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2008 (%)
1A1 - Energy Industries	2478	1473	1011	723	733	643	594	597	456	355	315	271	208	55%
1A2 - Industrial Combustion	310	224	136	105	310	224	136	104	96.3	98.2	85.8	78.1	79.6	17%
1A3 - Transport Sources	72.1	62.9	37.6	27.7	20.2	16.1	14.5	21.5	25.7	29.8	39.2	37.6	40.0	11%
1A4 - Commercial and Domestic	144	99.3	72.6	52.7	44.7	40.2	27.3	23.8	22.0	18.2	18.1	18.6	19.5	5%
1A5,1B,2,6 - Other	88.1	81.1	76.4	66.1	55.2	51.8	45.6	48.1	50.2	48.5	47.7	48.5	47.8	13%
Total	3092	1939	1334	974	949	849	767	769	633	530	491	446	379	100%

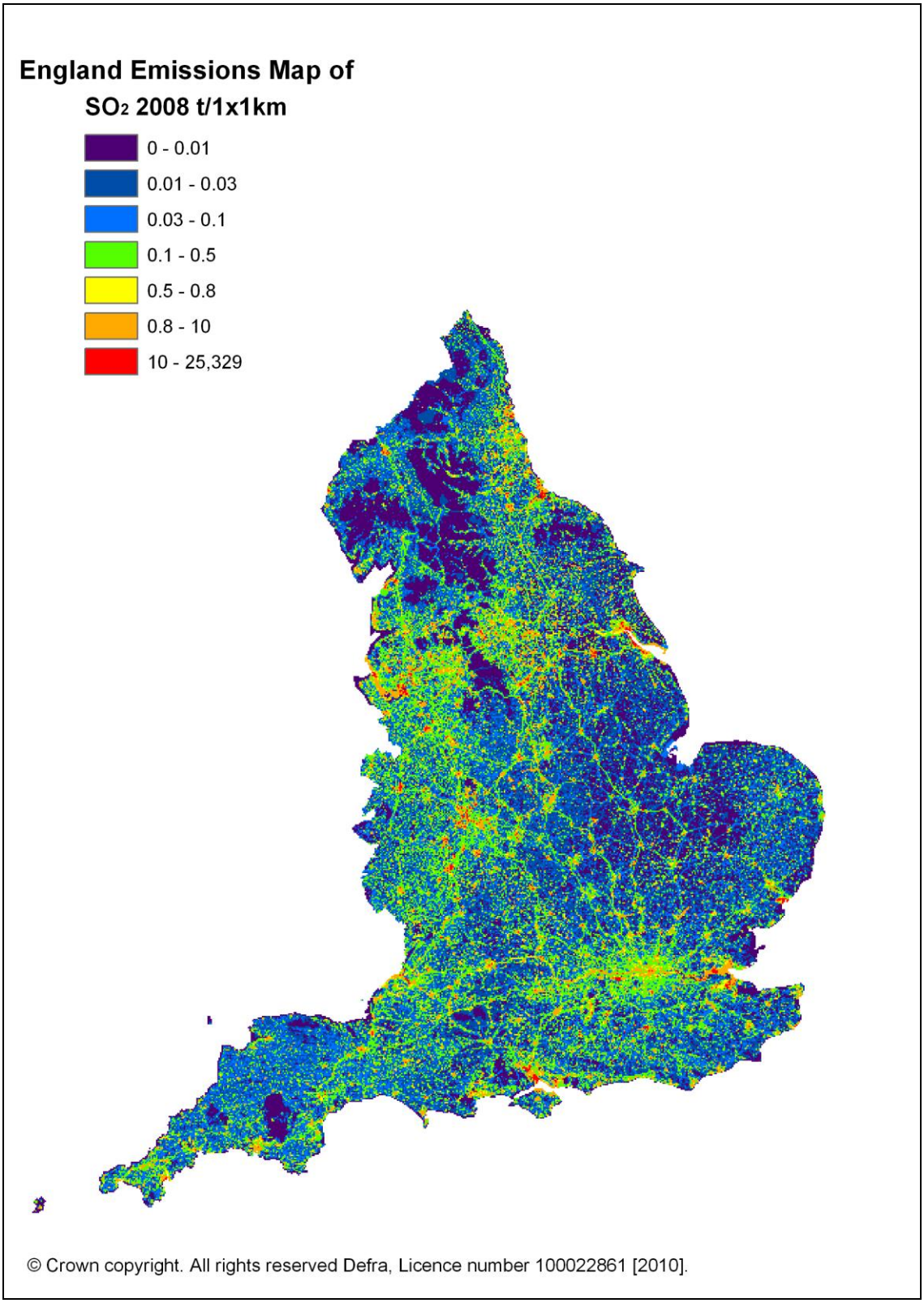
Units: kilotonnes

Figure 2-47 England Sulphur Dioxide Emissions by Source, 1990-2008



England's SO_2 emissions have declined by 88% since 1990 and accounted for 74% of the UK total in 2008. Power generation (1A1a) is by far the most significant source, accounting for 40% of the England total in 2008 (mainly from the sulphur in coal and fuel oil), but due to the growth in gas & nuclear fuel use and the installation of FGD plant at a number of coal-fired power stations, emissions from this source have reduced by 94% since 1990. 17% of SO_2 emissions in England are from industrial combustion (1A2: down by 79% since 1990), 14% from refineries (1A1b: down 46% since 1990) whilst national navigation and residential combustion contribute 10 and 4% of the total respectively. Reductions in SO_2 emissions across all sectors are also due to the progress towards production of low-sulphur petroleum-based fuels such as gas oil (diesel) and burning oil.

Figure 2-48 Map of Sulphur Dioxide Emissions in England, 2008



2.6.2 Scotland Sulphur Dioxide Inventory by NFR Sector, 1990-2008

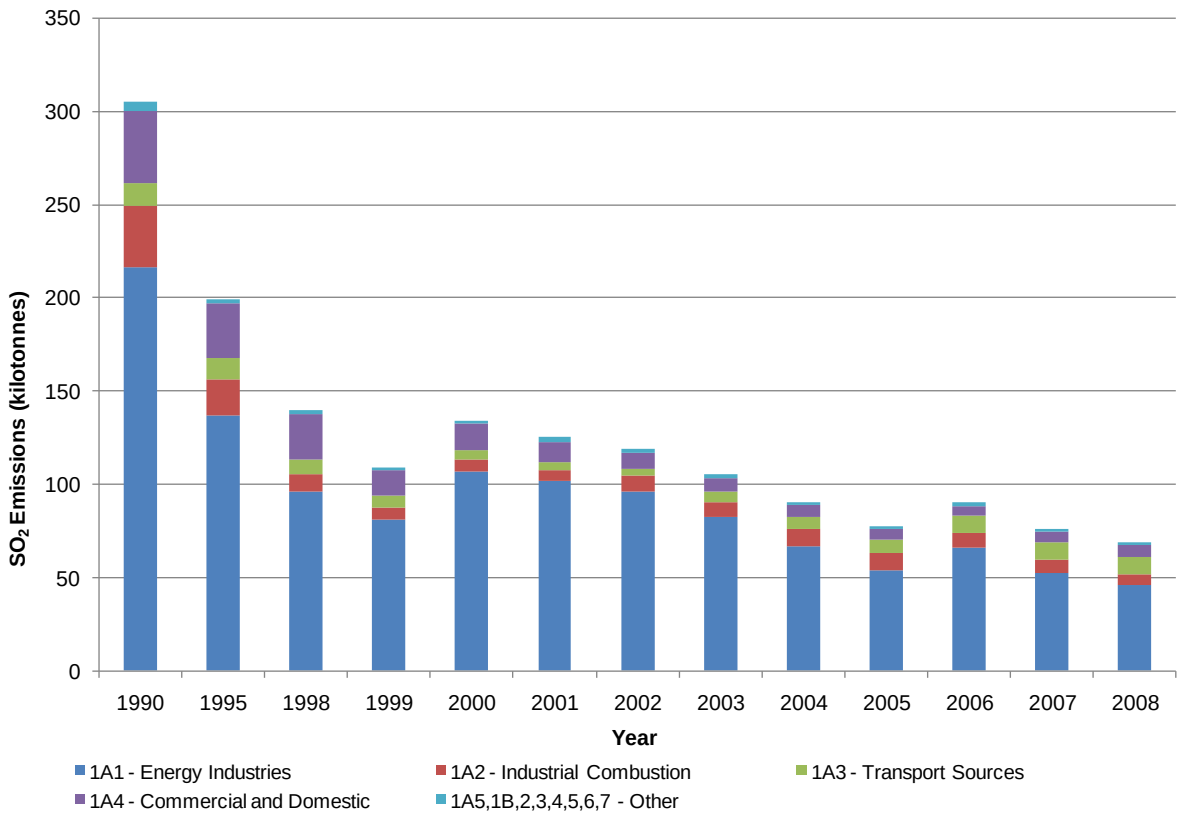
The table and graph below give a summary of the SO_2 emissions in Scotland by broad NFR sector categories. The detailed data are available in Appendix F.

Table 2-28 - Scotland Emissions of Sulphur Dioxide by NFR Source Sector

NFR Code	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2008 (%)
1A1 - Energy Industries	217	137	96	81	107	102	96	82	67	54	66	53	46	67%
1A2 - Industrial Combustion	32.4	18.5	8.9	6.3	5.8	5.9	8.8	8.5	9.1	9.6	7.8	7.0	5.3	8%
1A3 - Transport Sources	12.2	11.3	7.7	6.5	5.4	4.2	3.7	5.4	6.5	7.4	9.3	9.0	9.6	14%
1A4 - Commercial and Domestic	38.4	29.5	24.6	13.2	13.9	10.8	8.3	7.2	6.3	5.2	5.4	5.8	6.3	9%
1A5,1B,2,6 - Other	4.9	2.0	1.9	2.0	1.8	2.9	2.2	2.0	1.9	1.8	1.6	1.5	1.4	2%
Total	305	198	139	109	134	125	119	105	90.6	77.6	90.0	76.1	68.9	100%

Units: kilotonnes

Figure 2-49 Scotland Sulphur Dioxide Emissions by Source, 1990-2008

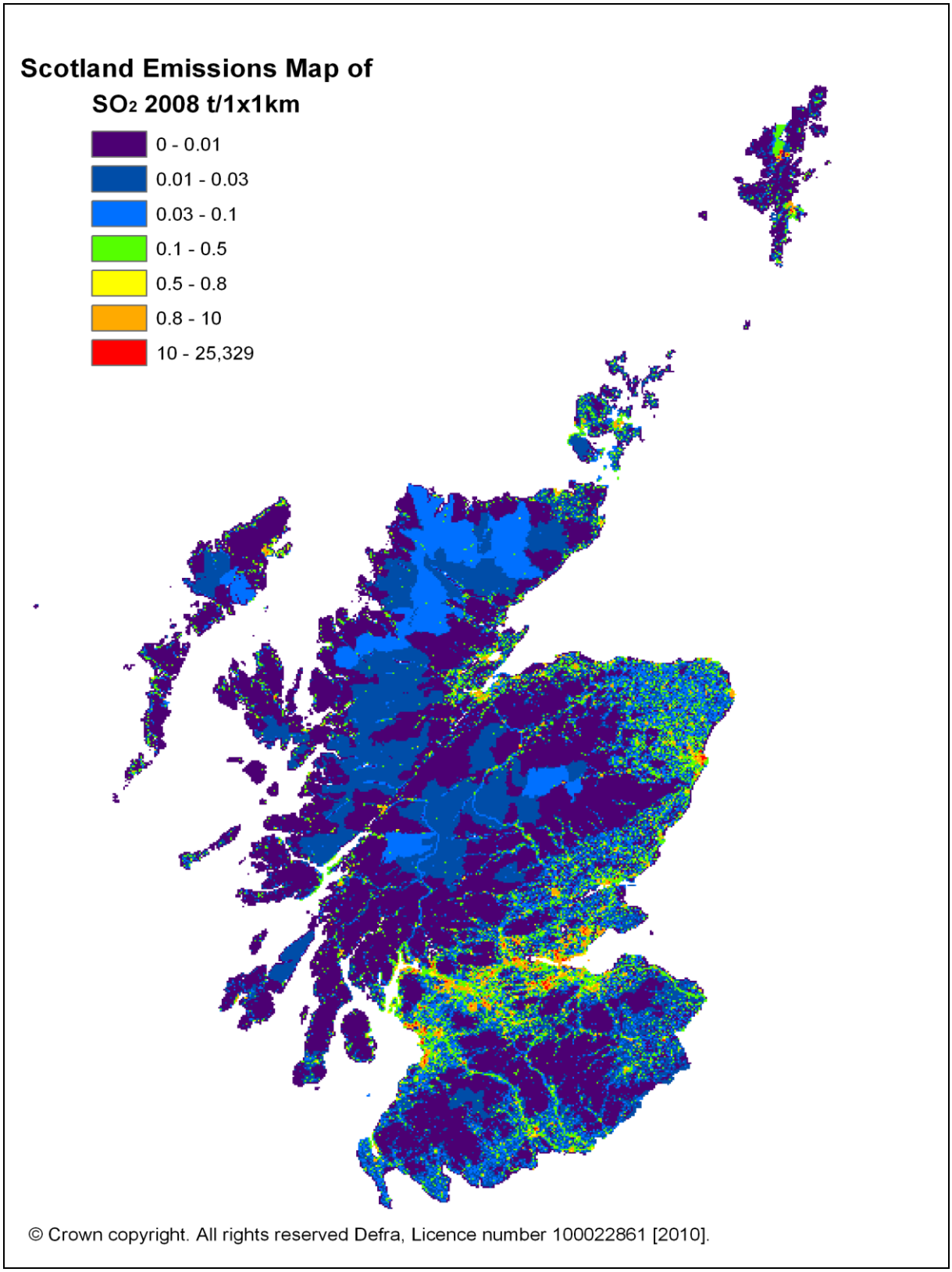


Scotland's SO_2 emissions have declined by 77% since 1990 and account for 13% of the UK total. Power generation (1A1a) is by far the most significant source, accounting for 58% of the Scotland total in 2008 (mainly from the sulphur in coal and fuel oil), but due to the growth in gas, renewable and nuclear fuel use, emissions from this source have reduced by 80% since 1990. However, in recent years, fluctuating trends in electricity generation have had a noticeable impact on emissions of SO_2 from power generation (1A1a) in Scotland. In 2006, coal-fired generation in Scotland increased by over 40% from 2005 (12,092 GWh to 17,488 GWh), and then declined by over 33% in 2008 (down to 11,692 GWh). The trends in coal-powered generation are reflected in the emissions of SO_2 from

the power sector in Scotland, which showed an increase in 2006 in comparison to preceding and following years (Figure 2-49). *(Note that is the figure above, the sector 1A1 includes power generation, petroleum refining and other energy industries such as collieries and gas processing.)*

In 2008, 8% of SO_2 emissions in Scotland are from industrial combustion (1A2: down by 84% since 1990), 9% from refineries (1A1b: down 70% since 1990) whilst national navigation and residential combustion contribute 13% and 8% of the total respectively. The overall downward trend in SO_2 emissions across all sectors is also due to the progressive introduction of low-sulphur petroleum-based fuels such as gas oil (diesel) and burning oil.

Figure 2-50 Map of Sulphur Dioxide Emissions in Scotland, 2008



2.6.3 Wales Sulphur Dioxide Inventory by NFR Sector, 1990-2008

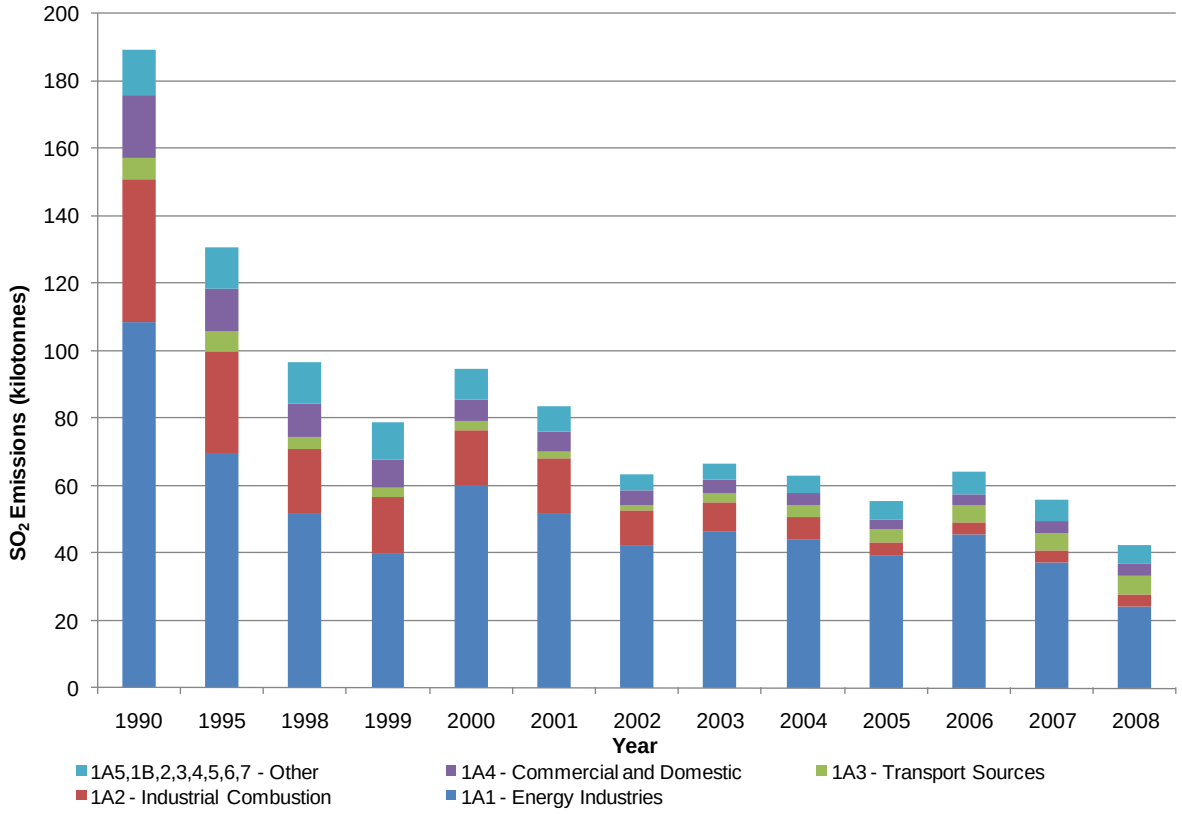
The table and graph below give a summary of the SO_2 emissions in Wales by broad NFR sector categories. The detailed data are available in Appendix F.

Table 2-29 - Wales Emissions of Sulphur Dioxide by NFR Source Sector

NFR Code	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2008 (%)
1A1 - Energy Industries	109	69.7	51.7	40.1	60.2	52.0	42.2	46.3	44.1	39.1	45.7	37.1	24.3	57%
1A2 - Industrial Combustion	42.2	30.1	19.0	16.3	16.3	16.2	10.5	9.0	6.5	4.0	3.5	3.8	3.5	8%
1A3 - Transport Sources	6.3	5.7	3.8	3.1	2.6	1.9	1.7	2.7	3.6	4.1	5.2	5.0	5.5	13%
1A4 - Commercial and Domestic	18.9	13.0	9.8	8.1	6.6	6.0	4.1	3.7	3.5	2.7	2.9	3.4	3.5	8%
1A5,1B,2,6 - Other	13.2	12.0	12.1	11.2	9.0	7.5	4.9	5.1	5.4	5.6	6.8	6.6	5.5	13%
Total	189	131	96.5	78.9	94.6	83.7	63.4	66.7	63.1	55.6	64.2	56.0	42.3	100%

Units: kilotonnes

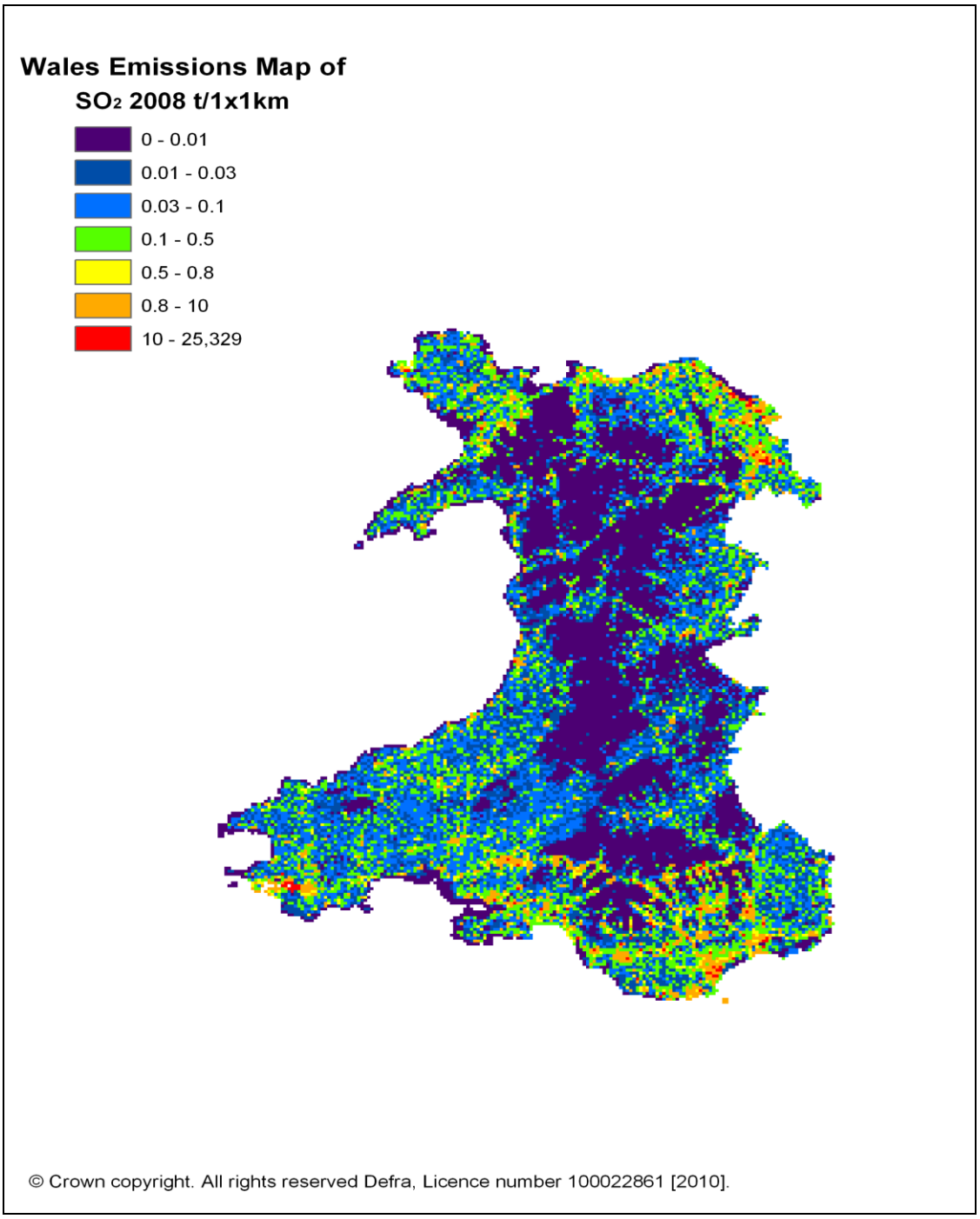
Figure 2-51 Wales Sulphur Dioxide Emissions by Source, 1990-2008



Wales SO_2 emissions have declined by 78% since 1990 and accounted for 8% of the UK total in 2008. In 2008, emissions from petroleum refineries are the most significant source in Wales, accounting for 34% of all SO_2 emissions (1A1b: down 35% since 1990). Previously the power generation (1A1a) sector was the highest emitter (40% of Wales emissions in 2007, and 49% in 2006) but the installation of Flue Gas Desulphurisation at the coal-fired Aberthaw station has significantly reduced the emissions from power generation to only 22% of the Wales total in 2008 (a reduction in emissions of 58% between 2007 and 2008).

In 2008, 8% of SO_2 emissions in Wales are from industrial combustion (1A2: down by 92% since 1990), 7% from residential combustion and 13% from national navigation (1A3dii: up 86% since 1990). Reductions in SO_2 emissions across all sectors are also due to the progress towards production of low-sulphur petroleum-based fuels such as gas oil (diesel) and burning oil.

Figure 2-52 Map of Sulphur Dioxide Emissions in Wales, 2008



2.6.4 Northern Ireland Sulphur Dioxide Inventory by NFR Sector, 1990-2008

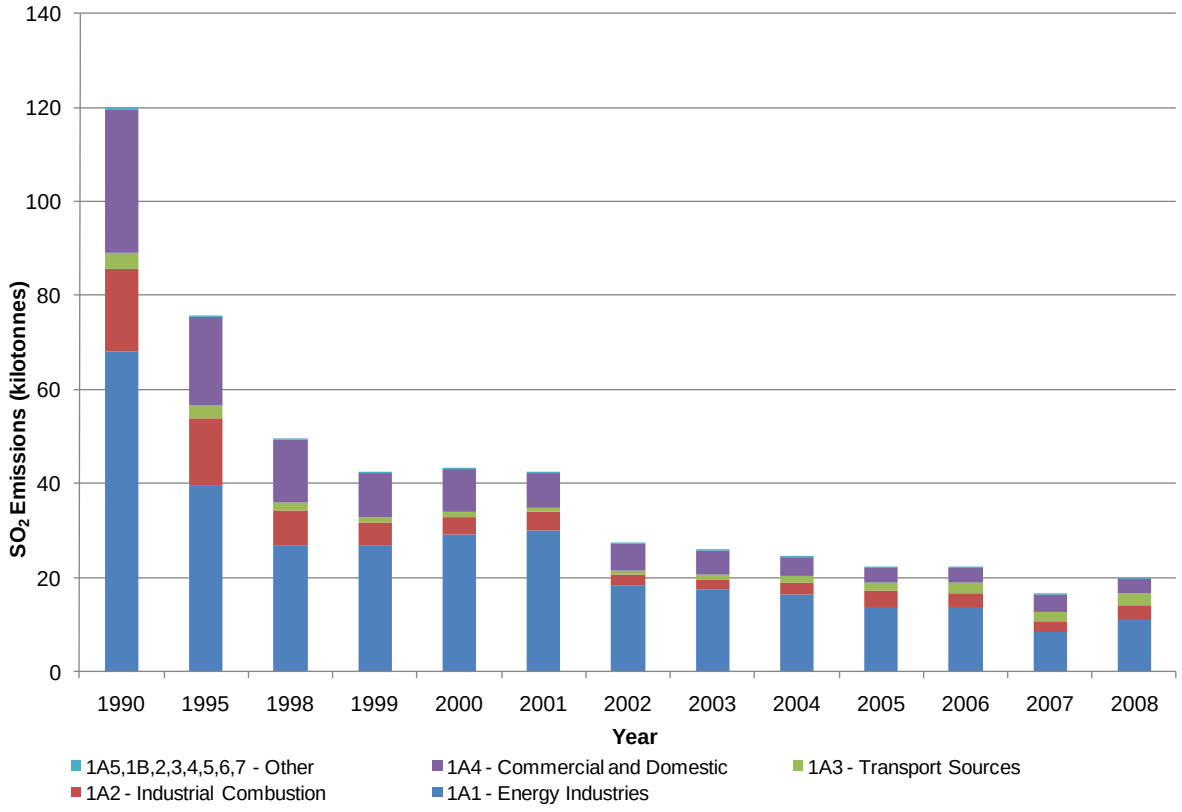
The table and graph below give a summary of the SO_2 emissions in Northern Ireland by broad NFR sector categories. The detailed data are available in Appendix F.

Table 2-30 - Northern Ireland Emissions of Sulphur Dioxide by NFR Source Sector

NFR Code	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2008 (%)
1A1 - Energy Industries	68.1	39.8	26.8	26.8	29.2	30.1	18.3	17.4	16.4	13.7	13.4	8.3	11.0	55%
1A2 - Industrial Combustion	17.6	14.0	7.6	4.8	3.8	4.0	2.3	2.1	2.5	3.6	3.2	2.3	3.2	16%
1A3 - Transport Sources	3.2	3.0	1.7	1.3	1.0	0.8	0.7	1.1	1.4	1.7	2.3	2.1	2.3	12%
1A4 - Commercial and Domestic	30.6	18.7	13.3	9.4	9.1	7.2	5.7	5.1	4.1	3.2	3.3	3.5	3.2	16%
1A5,1B,2,6 - Other	0.4	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	1%
Total	120	75.8	49.6	42.5	43.3	42.3	27.3	25.9	24.6	22.3	22.3	16.4	20.0	100%

Units: kilotonnes

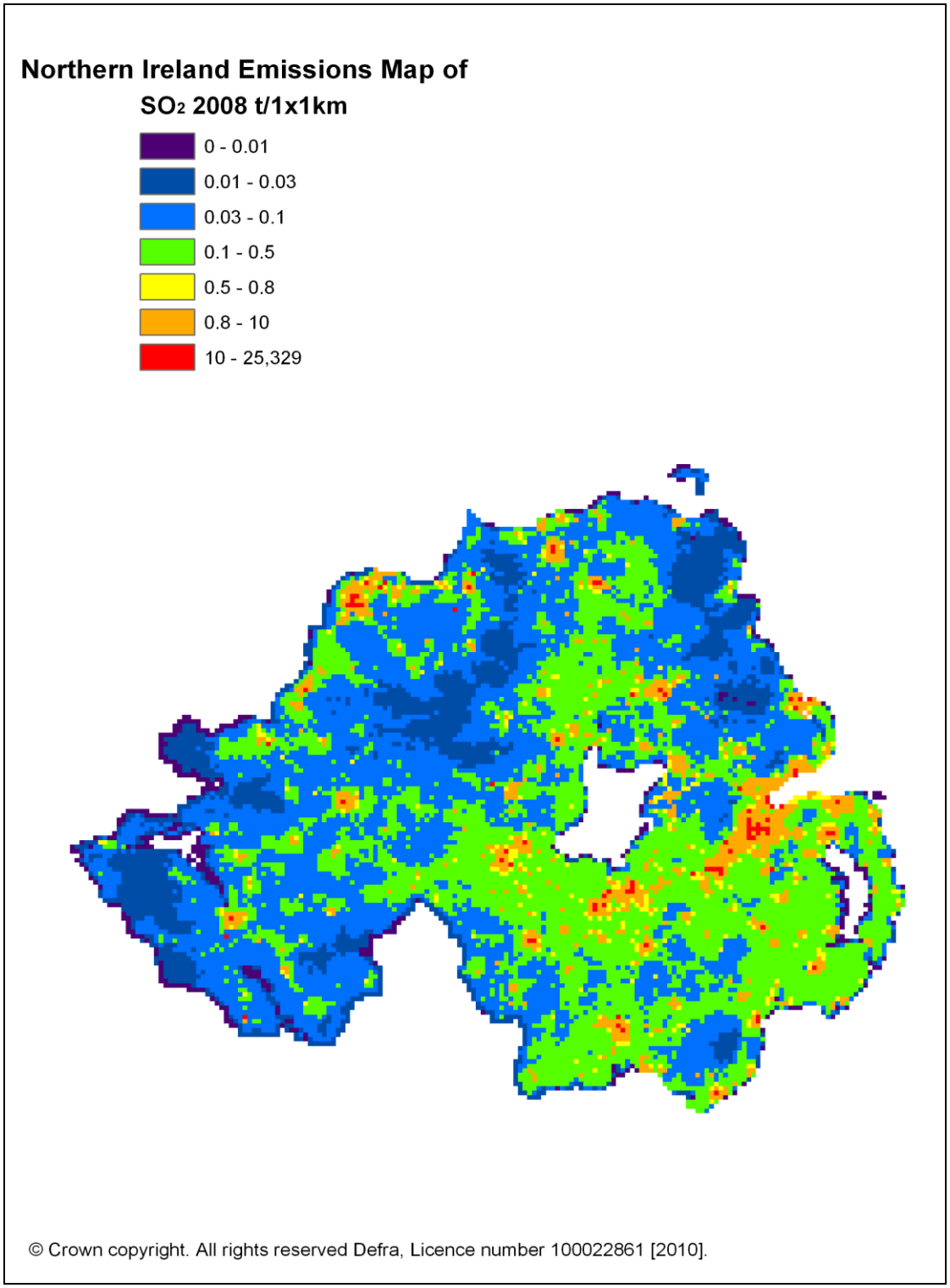
Figure 2-53 Northern Ireland Sulphur Dioxide Emissions by Source, 1990-2008



Northern Ireland's SO_2 emissions have declined by 83% since 1990 and they accounted for 4% of the UK total in 2008. Power generation (1A1a) is by far the most significant source, accounting for 55% of the Northern Irish total in 2008 (mainly from the sulphur in coal and fuel oil), but due to the growth in gas use, emissions from this source have reduced by 84% since 1990. 16% of SO_2 emissions in Northern Ireland are from industrial combustion (1A2: down by 82% since 1990), whilst 14% stems from residential combustion (1A4bi: down 88% since 1990) which is much higher than the rest of the UK, reflecting the higher use of coal and solid fuels in the domestic sector (1A4b) in this region. These emissions are expected to decline in the future as the gas supply network develops further

and solid fuel use is reduced. Reductions in SO_2 emissions across all sectors are due to the use of low-sulphur petroleum-based fuels such as gas oil (diesel) and burning oil.

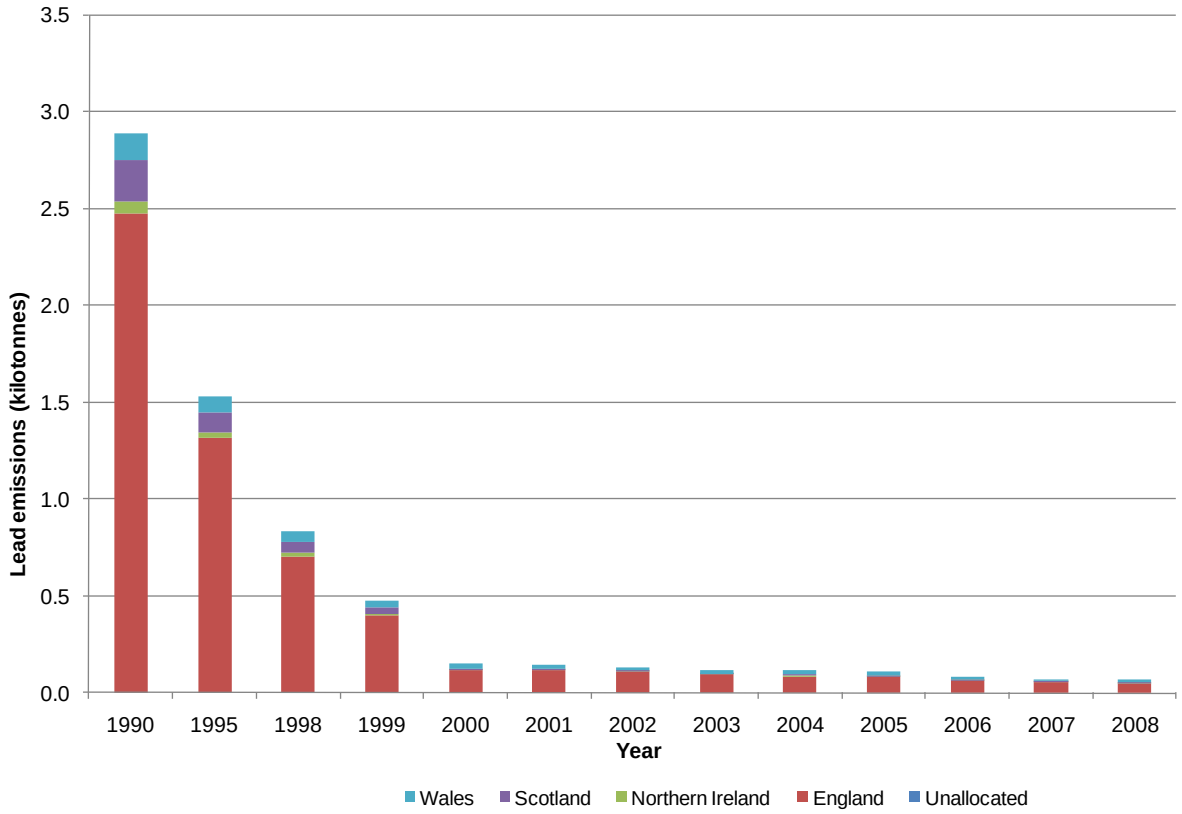
Figure 2-54 Map of Sulphur Dioxide Emissions in Northern Ireland, 2008



2.7 LEAD

Since 1970, emissions of lead to air in the UK have declined by 99%, with reductions in emissions occurring in most sectors. However, the decline has been mainly driven by the progressive phasing out of leaded petrol in the UK. The lead content of leaded petrol was reduced from around 0.34 g/l to 0.143 g/l in 1986. From 1987, sales of unleaded petrol increased, particularly as a result of the increased use of cars fitted with three-way catalyst and leaded petrol was then phased out from general sale at the end of 1999. The largest source of lead until 1999 was the road transport sector (1A3b).

Figure 2-55 UK Lead Emissions by Constituent Country, 1990-2008



In recent years, the main sources of lead emissions in the UK are from iron and steel combustion, metal production and combustion of lubricants in industry. There has been some reduction in emissions from iron and steel production processes due to improved abatement measures. Emissions have also declined as a result of the decreasing use of coal.

- **Iron and Steel Sector Production (2C1).** This sector is responsible for 51% of the lead emissions in the UK in 2008, of which sinter production accounts for over 99%. Emissions from sinter production have reduced by around 13% since 1990, but the proportion of annual UK lead emissions it accounts for has increased due to the decline in emissions from sectors such as transport (1A3).

- **Industrial Processes (2).** Emissions of lead from industry arise only from a few industries, dominated by metal production. Other sources include the chemical industry and solid fuel transformation. Between 1970 and 2008 emissions from metal production and the chemical industry have fallen by 94% and 96% respectively.

- **Waste Incineration (6C).** In 1990, lead emissions from waste incineration accounted for 8% (238t) of the overall emissions in the UK. Municipal Solid Waste (MSW) incinerators not

meeting regulatory standards were closed in the period leading up to December 1996. Improved combustion and flue gas controls, and developments in abatement technology in modern MSW incinerator design has resulted in emissions from waste incineration declining down to less than 0.1% of the UK total.

In 2008, transport (1A3) emissions accounted for 4% of the total lead emissions. Previously this source was the most significant, accounting for 86% of emissions in 1970. Emissions of lead for England, Wales, Scotland and Northern Ireland are summarised in the tables and graphs below, with more detailed inventory tables in Appendix F. Table 2.26 shows how total UK lead emissions are split between the 4 constituent countries.

Table 2-31 - Proportion of UK Lead Emissions by Constituent Country

Year	England	Scotland	Wales	N Ireland	Unallocated
1990	86%	7%	5%	2%	0%
2008	76%	4%	19%	1%	0%

2.7.1 England Lead Inventory by NFR Sector, 1990-2008

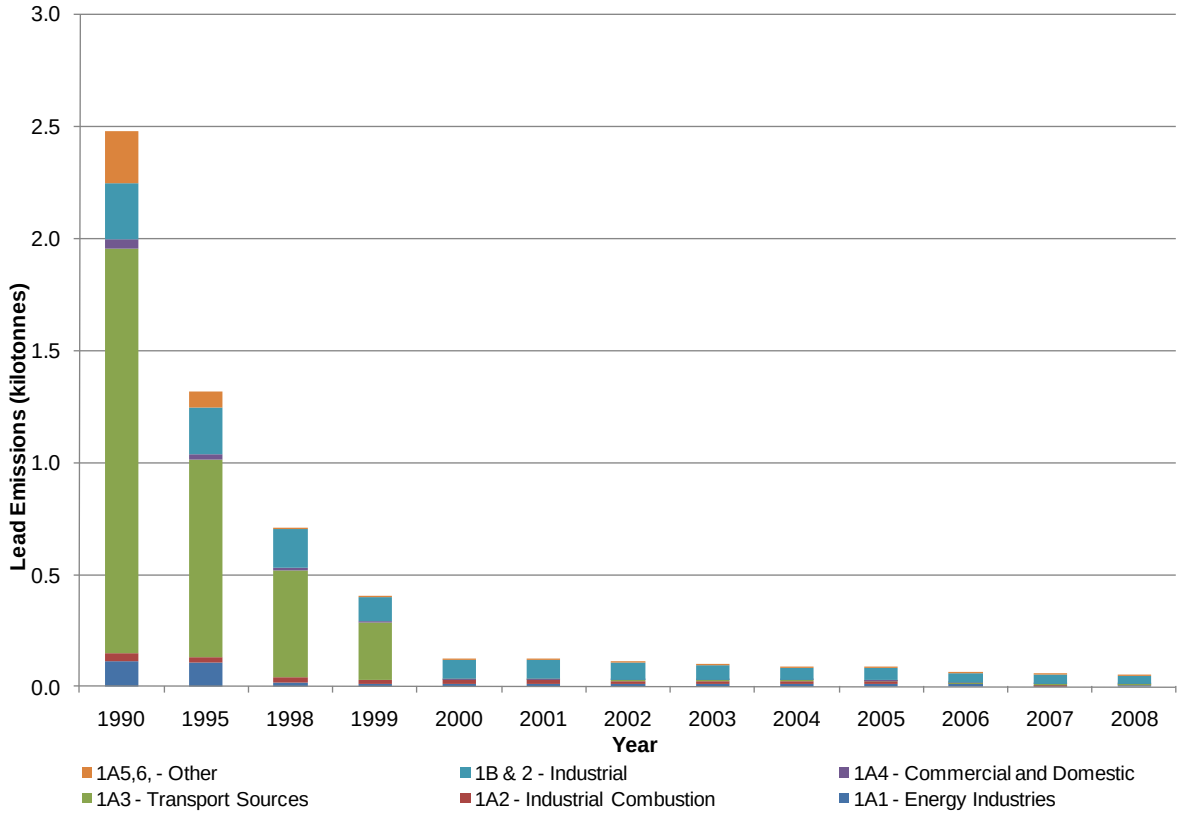
The table and graph below give a summary of the lead emissions in England by broad NFR sector categories. The detailed data are available in Appendix I.

Table 2-32 - England Emissions of Lead by NFR Source Sector (tonnes)

NFR Code	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2008 (%)
1A1 - Energy Industries	116	106	18	14	14	11	10	10	10	10	10	3	3	6%
1A2 - Industrial Combustion	33	27	21	18	15	16	16	16	16	13	5	5	5	10%
1A3 - Transport Sources	1805	881	482	254	2	2	2	2	2	2	2	2	2	4%
1A4 - Commercial and Domestic	44	24	10	9	6	6	5	4	4	3	3	3	3	6%
1B & 2 - Industrial	248	210	175	103	79	81	77	61	53	53	43	42	37	73%
1A5,6, - Other	230	67	0.8	1.1	1.1	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0%
Total	2476	1315	707	399	117	117	110	93	85	81	62	55	51	100%

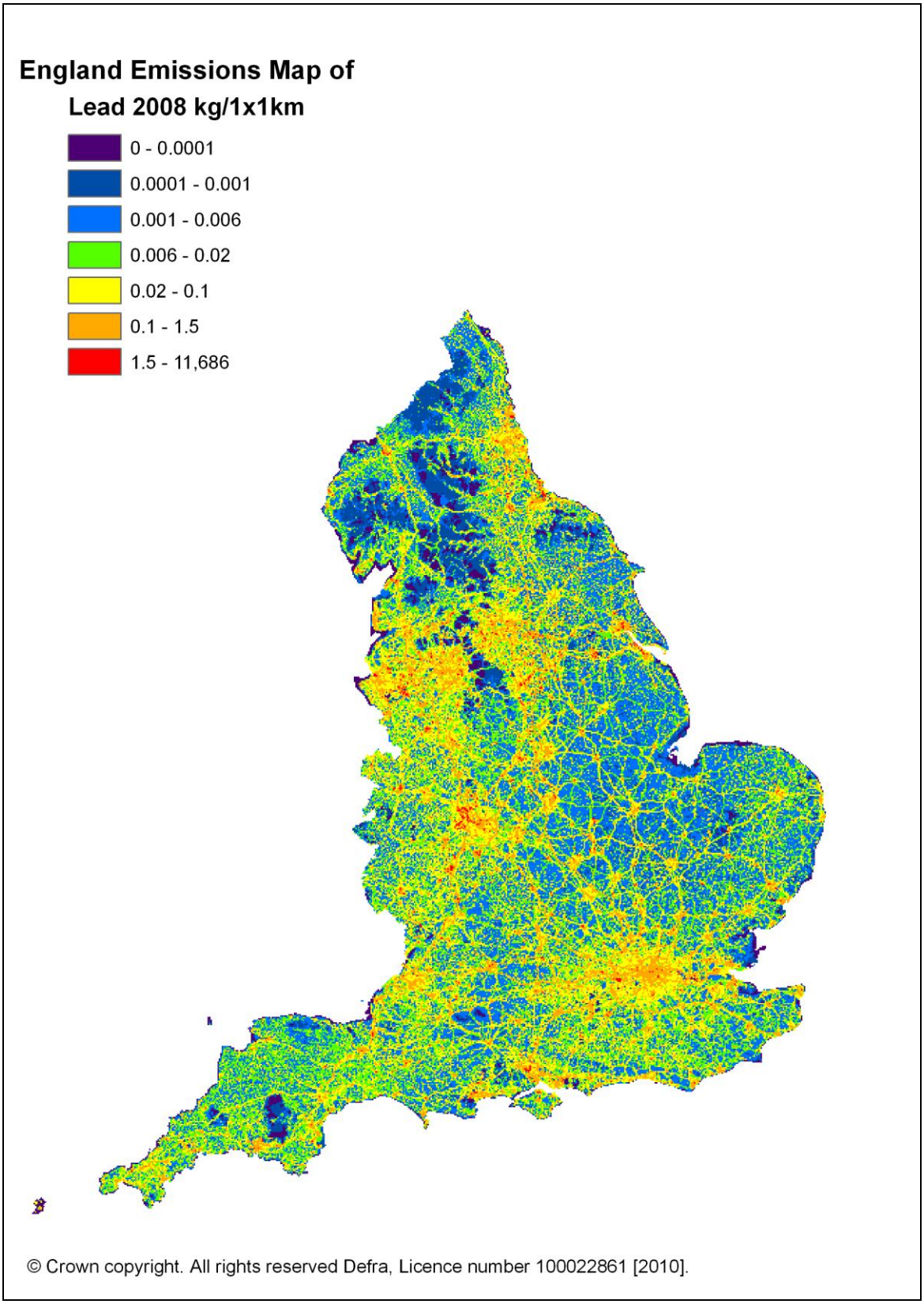
Units: tonnes

Figure 2-56 England Lead Emissions by Source, 1990-2008



England's lead emissions have declined by 98% since 1990 and accounted for 76% of the UK total in 2008. The emissions that arise due to the production in the iron and steel industries represent the most significant source, accounting for 48% of the England total in 2008. As a result, 61% of the overall emissions are from industrial production (2C3: aluminium production up 133% since 1990 and 2C5d: zinc production down 100% since 1990). Transport (1A3) sources used to dominate the emission of lead in England in 1990, accounting for 73%. However, as mentioned previously, due to the phase out of leaded petrol, transport sources (1A3) now only account for 4% of lead emissions in England.

Figure 2-57 Map of Lead Emissions in England, 2008



2.7.2 Scotland Lead Inventory by NFR Sector, 1990-2008

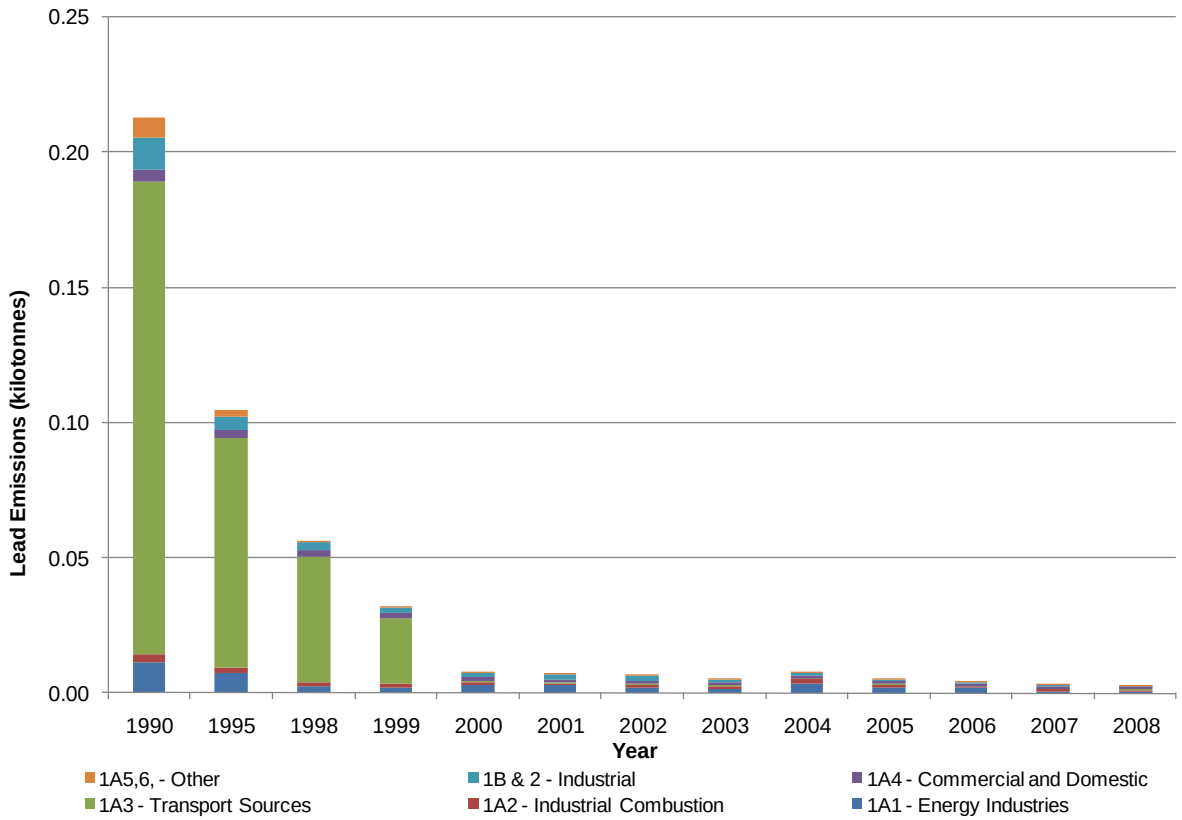
The table and graph below give a summary of the lead emissions in Scotland by broad NFR sector categories. The detailed data are available in Appendix I.

Table 2-33 - Scotland Emissions of Lead by NFR Source Sector (tonnes)

NFR Code	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2008 (%)
1A1 - Energy Industries	11.2	7.2	2.7	2.2	3.0	2.8	1.9	1.5	3.5	1.8	1.8	0.7	0.5	18%
1A2 - Industrial Combustion	3.1	2.0	1.4	1.2	0.9	0.7	1.1	1.0	1.8	1.4	0.5	0.5	0.5	18%
1A3 - Transport Sources	175	85.1	46.4	24.2	0.3	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3	11%
1A4 - Commercial and Domestic	4.9	2.9	2.1	2.0	1.6	1.4	1.2	1.1	0.9	0.8	0.8	0.8	1.0	36%
1B & 2 - Industrial	11.6	5.1	2.9	2.2	1.8	1.8	1.9	1.1	0.9	0.8	0.6	0.6	0.4	16%
1A5,6, - Other	7.35	2.40	0.07	0.10	0.10	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	1%
Total	213	105	55.6	31.9	7.7	7.0	6.5	5.0	7.4	5.0	4.0	3.0	2.7	100%

Units: tonnes

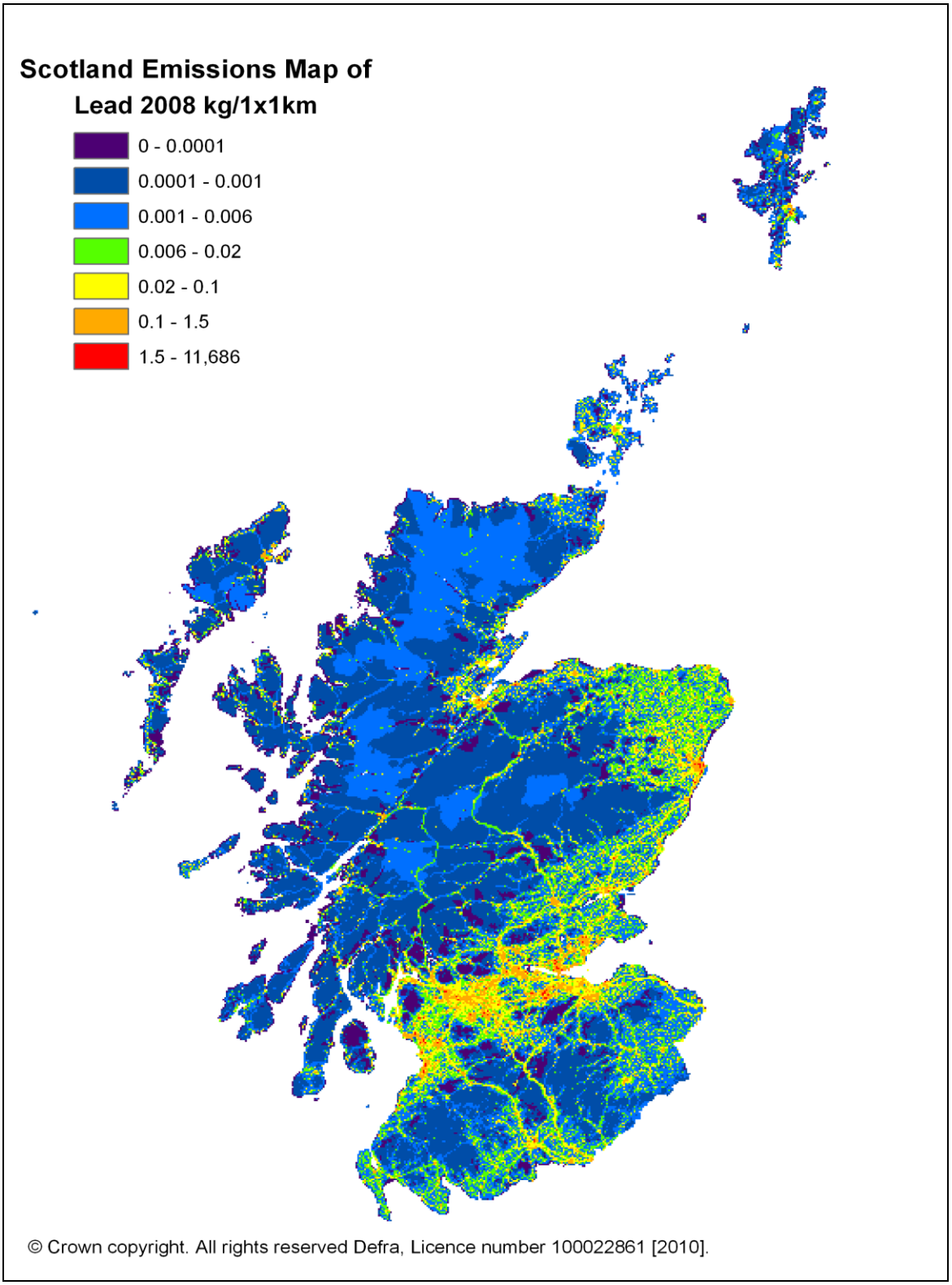
Figure 2-58 Scotland Lead Emissions by Source, 1990-2008



Scotland's lead emissions have declined by 99% since 1990 and accounted for 4% of the UK total in 2008. In Scotland, emission from domestic combustion is the most significant source, accounting for 31% of the Scotland total in 2008 (1A4bi: down 72% since 1990). 18% of lead emissions in Scotland come from energy industries (1A1: down 96% since 1990). Emissions from power generation (1A1a) accounted for 11% of the Scotland total emissions in 2008, but this is an increase in proportion of the overall emission relative to 1990 when it was only responsible for approximately 5% of overall

emissions. This is due to the decreased emissions from transport sources (1A3: down more than 99% since 1990).

Figure 2-59 Map of Lead Emissions in Scotland, 2008



2.7.3 Wales Lead Inventory by NFR Sector, 1990-2008

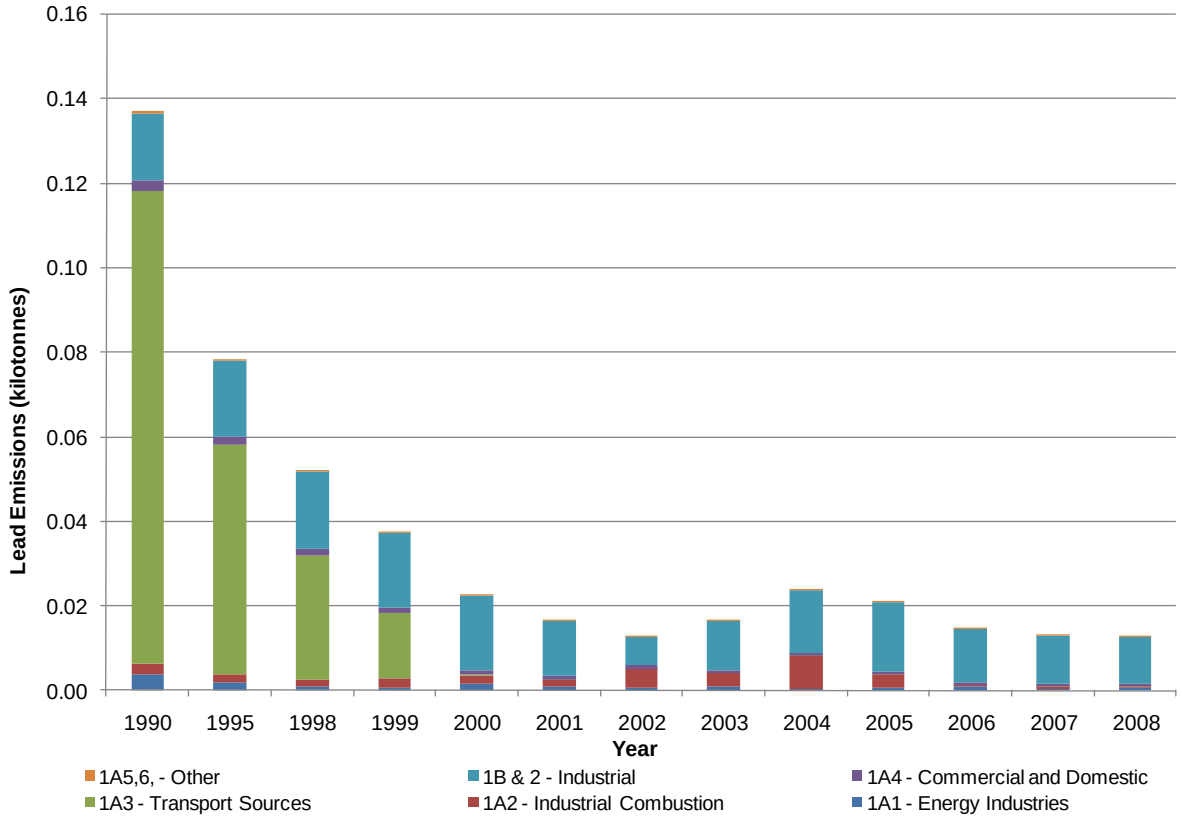
The table and graph below give a summary of the lead emissions in Wales by broad NFR sector categories. The detailed data are available in Appendix I.

Table 2-34 - Wales Emissions of Lead by NFR Source Sector (tonnes)

NFR Code	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2008 (%)
1A1 - Energy Industries	3.7	1.8	0.8	0.6	1.5	1.0	0.5	0.8	0.4	0.7	0.8	0.4	0.5	4%
1A2 - Industrial Combustion	2.6	2.1	1.6	2.2	2.1	1.4	4.5	3.1	7.7	2.9	0.4	0.4	0.4	3%
1A3 - Transport Sources	112	54.4	29.6	15.5	0.2	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	1%
1A4 - Commercial and Domestic	2.7	1.7	1.4	1.4	1.0	1.0	0.8	0.7	0.6	0.5	0.5	0.6	0.6	5%
1B & 2 - Industrial	15.9	18.2	18.6	17.6	17.8	12.8	6.8	11.7	14.9	16.5	12.5	11.4	10.8	86%
1A5,6, - Other	0.44	0.28	0.04	0.06	0.06	0.01	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0%
Total	137	78.4	52.0	37.3	22.5	16.4	12.7	16.5	23.9	20.9	14.5	12.9	12.5	100 %

Units: tonnes

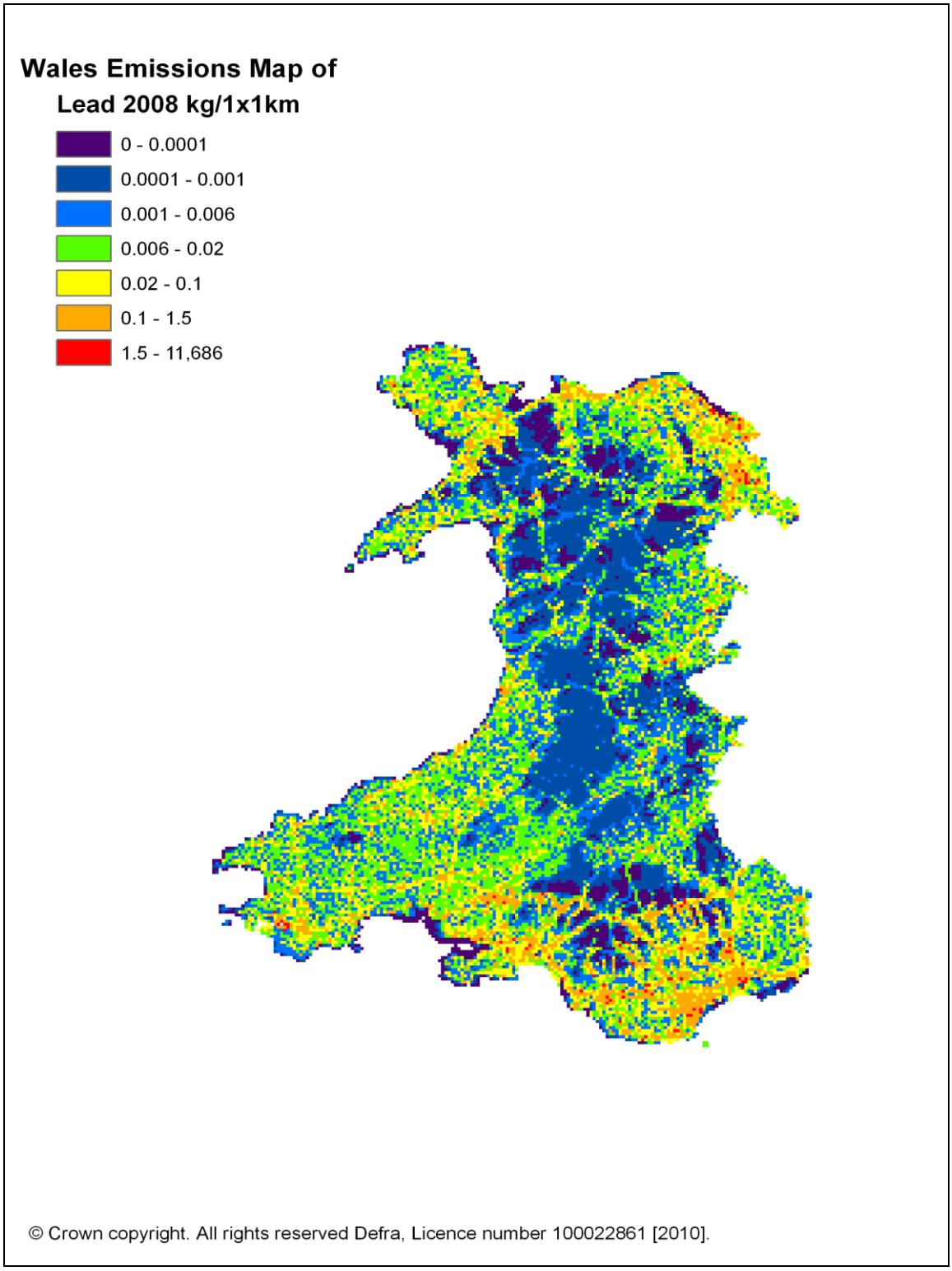
Figure 2-60 Wales Lead Emissions by Source, 1990-2008



Wales lead emissions have declined by 91% since 1990 and accounted for 19% of the UK total in 2008. The emissions that arise due to the production in the iron and steel industries are by far the most significant source, accounting for 81% of the Wales total in 2008. 84% of lead emissions in Wales are from industrial production (2C3: aluminium up 133% since 1990 and lead production 2C5b: down 87% since 1990), 5% from industrial processes and fugitive emissions from fuels (1A2 & 1B: down 86% since 1990), and 4% arise from energy industries (1A1: down by 87% since 1990) and transport sources (1A3: down more than 99% since 1990). The proportion of emissions from the industrial combustion sector is explained by the above average concentration of heavy industry within

the country. This is the main reason that reductions in lead emissions in Wales are less than those achieved in England, Scotland, and Northern Ireland.

Figure 2-61 Map of Lead Emissions in Wales, 2008



2.7.4 Northern Ireland Lead Inventory by NFR Sector, 1990-2008

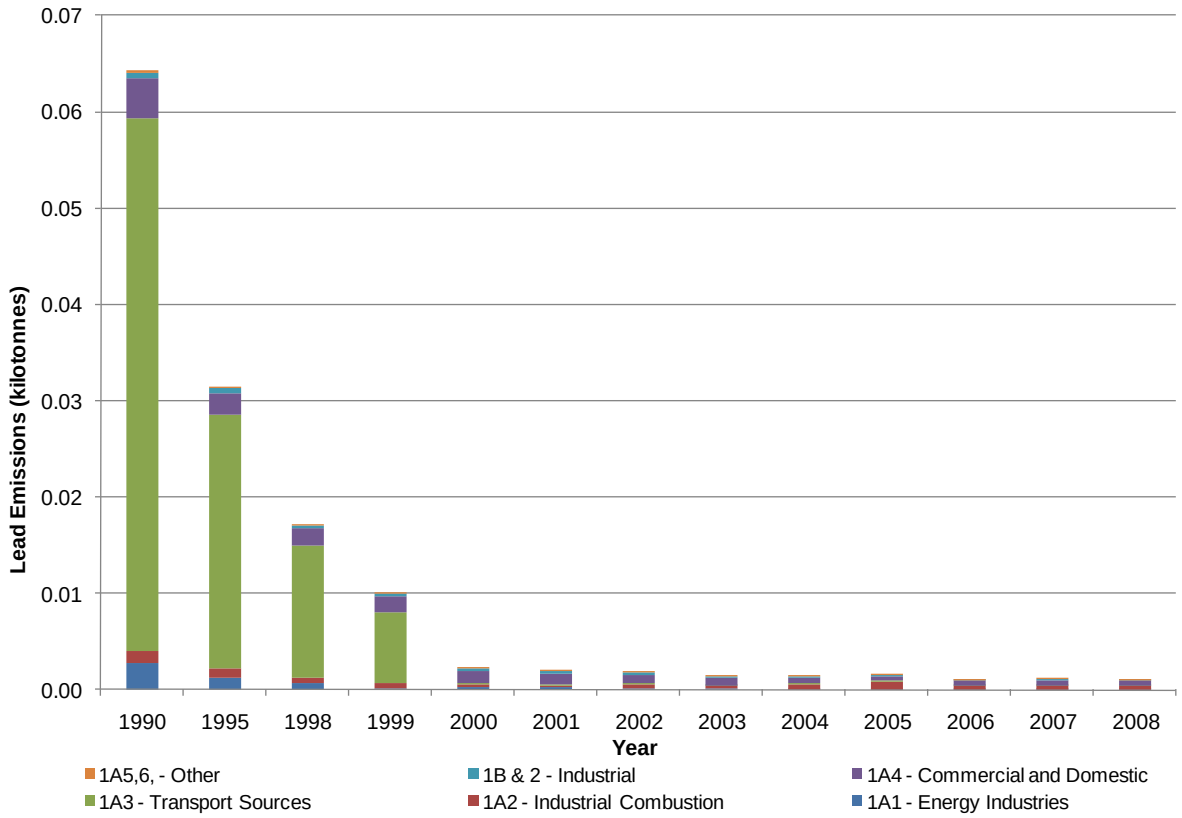
The table and graph below give a summary of the lead emissions in Northern Ireland by broad NFR sector categories. The detailed data are available in Appendix I.

Table 2-35 - Northern Ireland Emissions of Lead by NFR Source Sector (tonnes)

NFR Code	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2008 (%)
1A1 - Energy Industries	2.8	1.3	0.7	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	7%
1A2 - Industrial Combustion	1.2	0.8	0.6	0.5	0.3	0.3	0.4	0.2	0.5	0.8	0.3	0.3	0.3	30%
1A3 - Transport Sources	55.4	26.4	13.7	7.4	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	10%
1A4 - Commercial and Domestic	4.1	2.2	1.8	1.6	1.3	1.1	1.0	0.8	0.6	0.5	0.5	0.5	0.5	48%
1B & 2 - Industrial	0.6	0.5	0.3	0.3	0.3	0.3	0.3	0.1	0.1	0.1	0.1	0.1	0.04	8%
1A5,6, - Other	0.2	0.2	0.02	0.03	0.03	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0%
Total	64.3	31.4	17.1	10.0	2.3	2.0	1.9	1.3	1.4	1.5	1.0	1.1	1.0	100%

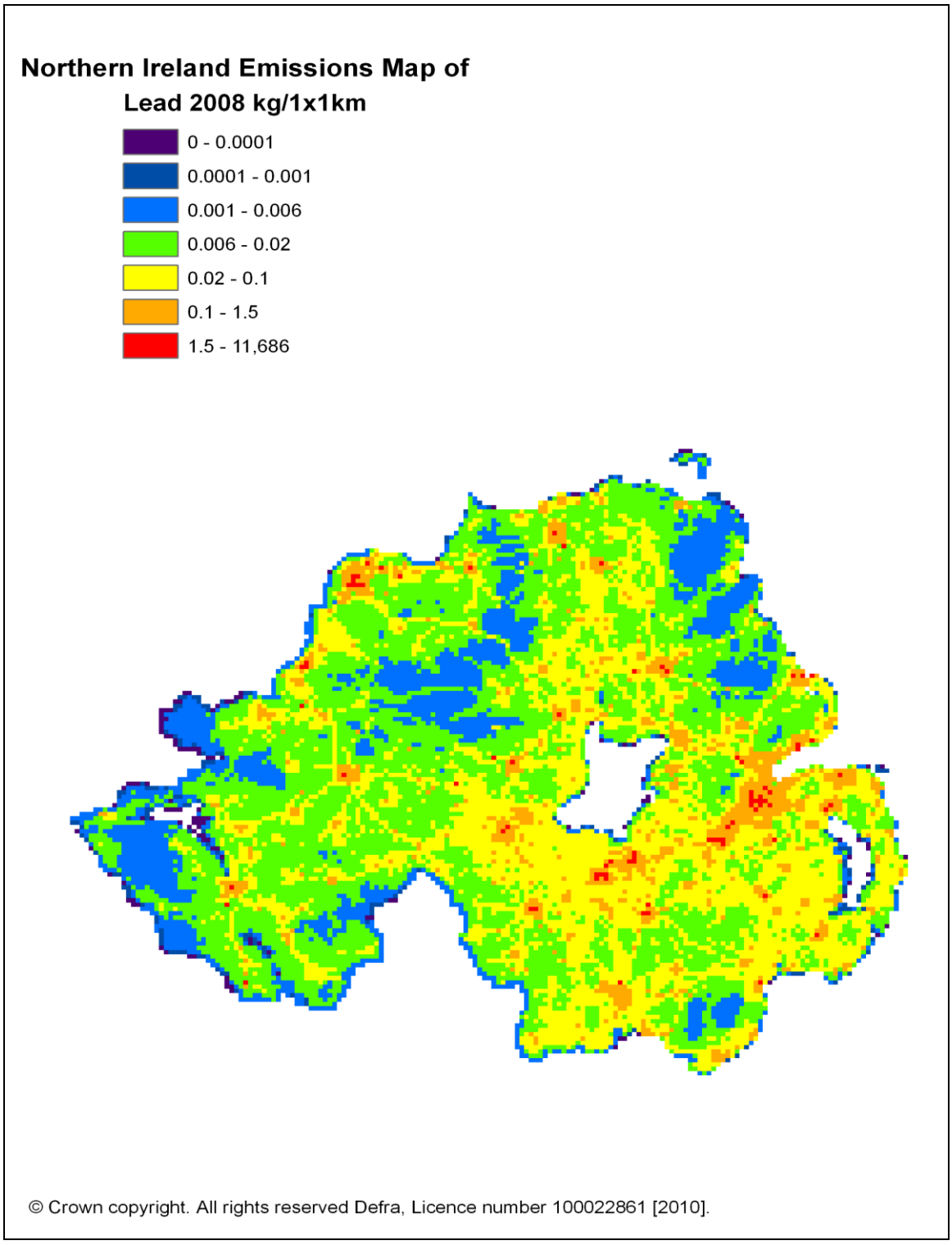
Units: tonnes

Figure 2-62 Northern Ireland Lead Emissions by Source, 1990-2008



Northern Ireland's lead emissions have declined by 98% since 1990 and accounted for 1% of the UK total in 2008. In Northern Ireland, emissions that arise from domestic combustion (1A4b) is the most significant source, accounting for 43% of the Northern Ireland total in 2008 (1A4bi: down 87% since 1990). 30% of lead emissions in Northern Ireland come from industrial combustion (1A2: down 75% since 1990), 10% from transport sources (1A3: down more than 99% since 1990) and 7% arise from energy industries (1A1: down by 98% since 1990).

Figure 2-63 Map of Lead Emissions in Northern Ireland, 2008



3 Uncertainties

As discussed in Section 1.2, the air quality pollutant inventories for England, Scotland, Wales and Northern Ireland are derived using a "top-down" approach whereby the UK inventory totals are disaggregated across the four countries. For most sources there is insufficient regional data to enable a comprehensive "bottom-up" calculation to be made, and hence available proxy data are used to estimate the country-specific share of UK activity for each emission source.

The calculated uncertainties of the UK inventories for AQ pollutants are shown in the table below:

Table 3.1 Uncertainty calculated for the UK Emission Inventories of AQ Pollutants

Pollutant	Estimated Uncertainty %
PM_{10}	- 20 to + 30
Carbon Monoxide	- 20 to + 30
Oxides of Nitrogen	+/- 10
Sulphur Dioxide	+/- 4
Non-Methane Volatile Organic Compounds	+/- 10
Ammonia	+/- 20
Lead	-30 to +50

(Source: *"UK Emissions of Air Pollutants 1970 to 2008"*, Murrells *et al*., 2010)

Further to these uncertainties in the UK datasets, there is an additional uncertainty inherent in the methodologies of disaggregating the UK emissions across the four countries. Further to this, there is greater uncertainty for emission estimates in the early years of the timeseries, as these estimates are frequently based on very limited historic data; in more recent years the development of environmental regulation and reporting has increased (e.g. through the development of annual reporting of emissions by operators of major industrial plant, now under IPPC).

The air quality pollutant inventories for England, Scotland, Wales and Northern Ireland are therefore subject to greater uncertainty than the equivalent UK estimates. The level of uncertainty is anticipated to reduce as further research is conducted and more data reporting at local and regional level is developed; one example of this is the ongoing DECC sub-national energy statistics work programme, which includes annual research tasks targeted to improve local and regional energy data in specific source sectors.

The key characteristics of each inventory are discussed below, by pollutant, with an indicative "Uncertainty Rating" provided in each case.

3.1 AMMONIA

Ammonia emission estimates are more uncertain than SO_2, NO_X and NMVOC inventories due largely to the nature of the major agricultural sources. Emissions depend on animal species, age, weight, diet, housing systems, waste management and storage techniques and environmental conditions. Hence emissions are affected by a large number of factors that make the interpretation of experimental data difficult and emission estimates uncertain (DOE, 1994). Emission estimates for non-agricultural sources such as wild animals are also highly uncertain. Unlike the case of NO_X and NMVOC, a few sources dominate the inventory and there is limited potential for error compensation.

Uncertainty Rating: **HIGH**

3.2 CARBON MONOXIDE

In 2008, 54% of the UK total from road transport sources (1A3b) alone, with 10% of UK carbon monoxide emissions were derived from the combustion of fuels. Emission estimates for road transport are highly uncertain, as the available dataset of emission measurements is small and shows significant variability. Emissions from stationary combustion processes are also variable and depend on the technology employed and the specific combustion conditions. Emission estimates from small and medium-sized installations are derived from emission factors based on relatively few measurements of emissions from different types of boiler. As a result of the high uncertainty in major sources, emission estimates for CO are much more uncertain than other pollutants such as NO_X, CO_2 and SO_2 which are also emitted mainly from combustion processes. Unlike the case of NO_x and NMVOC, a few sources dominate the inventory and there is limited potential for error compensation.

Uncertainty Rating: **HIGH**

3.3 NITROGEN OXIDES

NO_X emission estimates are less accurate than SO_2 because they are calculated using measured emission factors, which can vary widely with combustion conditions. Hence, emission factors given in the literature for combustion sources show large variations. In the case of road transport (1A3b) emissions, while the inventory methodology takes into account variations in the amount of NO_X emitted as a function of speed and vehicle type, significant variations in measured emission factors have been found even when keeping these parameters constant.

From the above, one might expect the NO_X inventory to be very uncertain, however the overall uncertainty is in fact lower than any pollutant other than SO_2 for a number of reasons:

While NO_X emission factors may be somewhat uncertain, activity data used in the NO_X inventory is very much more certain. This contrasts with inventories for pollutants such as volatile organic compounds and PM_{10}, which contain a higher degree of uncertainty.

The NO_X inventory is made up of a large number of emission sources with many of similar size and with none dominating. This leads to a large potential for error compensation, where an underestimate in emissions in one sector is very likely to be compensated by an overestimate in emissions in another sector.

Many of the larger point-source emission sources make up the bulk of the regional estimates, and these are commonly derived from extrapolation of on-line measurement data and hence are regarded to be good quality.

Uncertainty Rating: **LOW**

3.4 NON-METHANE VOLATILE ORGANIC COMPOUNDS

The NMVOC inventory is more uncertain than SO_2 and NO_X inventories. This is due in part to the difficulty in obtaining good emission factors or emission estimates for some sectors (e.g. fugitive sources of NMVOC emissions from industrial processes, and natural sources) and partly due to the absence of good activity data for some sources. As with NO_X, there is a high potential for error compensation, and this is responsible for the relatively low level of uncertainty compared with most other pollutants in the NAEI.

Uncertainty Rating: **MODERATE**

3.5 PM_{10}

The UK emission inventory for PM_{10} has undergone considerable revision over recent years through specific research into key source sectors to improve the veracity of emission factors and improve the "bottom-up" activity data such as fuel use. Nonetheless, the uncertainties in the PM_{10} emission estimates must still be considered high, due to persisting uncertainties in some sectors regarding emission factors, activity data and particulate size distribution profiles.

Emission factors are generally based on a few measurements on an emitting source that is assumed to be representative of all similar sources. Emission estimates for PM_{10} are based whenever possible on source-specific measurements of PM_{10}, but frequently the available data is emission measurement of total particulate matter and hence conversion to PM_{10} is required based either on the size distribution of the sample collected or (more usually) on literature data on typical size distributions.

Many sources of particulate matter are diffuse or fugitive in nature, such as emissions from coke ovens, metal processing, raw material stockpiles, loading and unloading activities, construction or quarrying sites. These emissions are difficult to measure and are often dependent on conditions that vary over time and between localities such as meteorology and topography and hence are also difficult to model accurately. In many such cases it is likely that no satisfactory estimates or measurements have ever been made.

Emission estimates for combustion of fuels are generally considered more reliable than those for industrial processes, quarrying and construction. All parts of the inventory would need to be improved before the overall uncertainty could be reduced to the levels seen in the inventories for CO_2, SO_2, NO_X, or NMVOC.

***Uncertainty Rating*: HIGH**

3.6 SULPHUR DIOXIDE

Sulphur dioxide emissions can be estimated with most confidence as they depend largely on the level of sulphur in fuels. Hence the DA inventories, being based upon comprehensive analysis of coals and fuel oils consumed by power stations and the agriculture (4), industry and domestic sectors, contain accurate emission estimates for the most important sources.

***Uncertainty Rating:* LOW**

3.7 LEAD

The lead inventory is more uncertain than SO_2 and NO_X inventories, and the certainty of the emissions varies over the time-series as different source sectors dominate at different times due to the very significant reductions in emissions from the key sources in 1990, notably road transport (1A3b). From the key sources in 1990, the lead emission estimates were based on measured concentrations of lead in the fuels, which were tightly regulated prior to being phased out in the late 1990s. This gives a high confidence in the estimates for those sources of fuel combustion, which dominated in the early 1990s but are now much reduced.

In more recent years, the level of emissions is estimated to be very much lower, and derived from a smaller number of sources. The metal processing industries are mainly regulated under IPPC and the estimates provided by plant operators to the regulatory agencies and used in the national inventories are based on emission measurements or emission factors that have been researched for the specific process type. There is a moderate level of uncertainty associated with these annual emission estimates due to the discrete nature of the stack emissions monitoring techniques and determination

of mass emission flow rates from point sources. Furthermore the variability of lead content of raw materials such as fuels (e.g. coal) is such that the discrete lead emission measurements provide a snap-shot of the process and plant performance, and there is some uncertainty as regards how representative that result may be for use in scaling up to provide annual emission estimates. These uncertainties are inherent within the inventories from environmental regulators of IPC/IPPC industries and are unavoidable; the emissions data from IPPC regulated installations used in the compilation of these DA inventories are subject to a managed process of quality checking by the environmental regulatory agencies and are regarded as the best data available for inventory compilation.

The observed year-to-year variations in emission estimates are based on actual trends reported by plant operators and may reflect changes in lead content of raw materials. The uncertainty in emission monitoring applies to all pollutants to some degree, but more so for pollutants such as lead for which (i) no continuous emission monitoring systems are available, and (ii) where fuel composition is known to be highly variable depending on the fuel source. This is not the case for species such as NO_X and SO_2 where many regulated sites will use Continuous Emission Monitoring Systems and the fuel elemental composition is either not a significant factor in process emissions or does not vary as much as for heavy metals and other trace contaminants. The emission estimates of lead from other smaller-scale combustion and process sources from industrial and commercial activities are less well documented and the estimates are based on emission factors that are less certain than those based on regulatory emissions monitoring and reporting.

Uncertainty Rating: **MODERATE**

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