National Atmospheric Emissions Inventory

Report

Air Quality Pollutant Inventories for England, Scotland, Wales and Northern Ireland: 1990 – 2009

A report of the National Atmospheric Emissions Inventory, AEA Group

October 2011

Air Quality Pollutant Inventories for England, Scotland, Wales and Northern Ireland: 1990 – 2009

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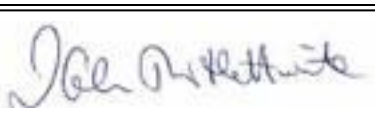
	Signature	
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Executive Summary

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 2009, 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 Government and the Department of Environment for Northern Ireland, by the UK emission inventory teams at AEA and Rothamsted 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 2009" (Murrells *et al.*, 2011), 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.

This report presents the results from a programme of Devolved Administration (DA) inventory data and methodology development, to continually improve the air quality (AQ) pollutant emission inventories for the 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 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.

[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.

In particular, detailed energy balances to provide annual fuel-specific consumption data by source sector 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 (combustion sources) (1A4c)
- 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 2005 to 2008, with gas and electricity data also being available up to 2009.

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 and are the best data available to inform the patterns of fuel use across the Devolved Administrations. They 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 Emissions Trading System (EUETS) fuel use data for large industrial sites and other DA-specific energy data.

For other significant emission sources there are 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 (in England, Wales and Northern Ireland) and early 2000s (in Scotland);

- 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 inventories, split out across the DAs based on local authority waste

[2] The latest available data are taken from the December 2010 Energy Trends, http://www.decc.gov.uk/en/content/cms/statistics/publications/trends/trends.aspx

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 been used to present a time-series of air quality pollution emissions.

The inventories for England, Scotland, Wales and Northern Ireland aim to use the best available data. For most sources, more data are available in recent years than for 1990. For example, installation-specific fuel use data from major industrial plant under EUETS are available from 2005 onwards and data for sites regulated under IPC/IPPC are available from 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. As such 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 2009 are estimated at 2.3 Mt, representing a 75% reduction on the emissions in 1990 (9.0 Mt). Emissions of CO are dominated by those from road transport (1A3b) (47% of UK emissions in 2009). The change in emissions between 1990 and 2009 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 72%, 64% and 82% respectively, primarily to a decrease in the use of solid fuels. The overall CO inventory trend between 2008 and 2009 is an average decrease of 21%, ranging from 22% in England to 16% in Wales and Northern Ireland. Across all of the DAs, a decrease in emissions from passenger cars was the main driver for this reduction, with a significant decline in emissions from iron and steel also contributing in Wales, and reductions in residential emissions evident in Northern Ireland. The decline in emissions from passenger cars is due to improvements in the catalyst repair rates for petrol vehicles, coupled with a decline in vehicle km travelled, most likely driven by the recession. Iron and steel production has fallen in Wales, also as a result of the recession.

Non-methane volatile organic compounds (NMVOCs)

UK emissions of NMVOC are estimated as 2.7 Mt for 1990 and 0.83 Mt for 2009, a decrease of 69%. 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 71% reduction in England since 1990, 70% in Northern Ireland, 68% reduction in Scotland, to a 66% reduction in Wales. Each country has its own mix of high-emitting sectors in 2009. In England, road transport (1A3b) accounts for 13% of the inventory and oil & gas sector (NFR 1B2) is 16% of the total. In Scotland the oil and gas sector accounts for 15% in 2009, whilst the food and drink sector (mainly whisky maturation) accounts for 42% of 2009 emissions. In Wales the road transport sector (1A3b) accounts for 9% of 2009 emissions and the oil and gas sector a further 26%. In Northern Ireland the residential sector accounts for 15% of the 2009 total due to the higher incidence of solid fuel use compared to GB, whilst road transport (1A3b) accounts for 10% and the food and drink industry also a further 10%.

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 60% to 1.1 Mt in 2009. This is primarily a consequence of tighter European vehicle emission standards 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 50% of UK emissions in 2009. Emissions from all of the DAs have declined since 1990, ranging from a 63% reduction in Northern Ireland, 61% reduction in England, 60% reduction in Scotland and a 51% reduction in Wales.

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 in determining more recent trends; since 2007 a programme of installation of over-fire air NO_X abatement at the majority of UK coal-fired power stations has contributed to a reduction of 30% in NO_X emissions from power generation in 2 years. In England, power sector NO_X emissions are down 69% since 1990; overall power generation has declined by 2.5% between 2008 and 2009, coal-fired generation declining by 17.5%, gas-fired generation declining by 4.1% and overall NO_X emissions reduced by 13%, 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 68%, with 2008-9 trends down 13%, following a slight increase of 1.7% in coal-fired generation but a 20.6% decrease in gas generation. Power sector NO_X emissions in Northern Ireland have declined by 84% 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. 2008 to 2009 emissions show a 15% reduction, with 33.2% decrease in generation from coal-fired plant and a 13.6% reduction in gas-fired generation. In Wales, power sector NO_X emissions have declined by 51% 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 2007, 2008 and 2009 in Wales has varied from 5121 GWh and then increasing by over 80% to 9364 GWh in 2008 as Aberthaw was back online. In 2009 it decreased 30.1% to 6547 GWh.

Road transport (1A3b) is another very significant source of NO_X emissions across all DAs, and between 2008 and 2009 all DAs show a reduction in emissions of around 15-19%. This was driven by a number of factors including cleaner vehicles penetrating in the fleet, reductions in traffic activity (in particular heavy-duty vehicles) due to the economic downturn, and improvement in catalyst repair rates for petrol vehicles. The latter was due to an introduction of the regulations controlling sale and installation of replacement catalytic converters and particle filters for light vehicles for Euro 3 (or above) LDVs after June 2009 and this trend is evident for all DAs. In England in 2009, road transport accounts for 36% of total emissions, down 66% since 1990. The sector in Scotland is 30% of the total NO_X inventory in 2009, down 66% since 1990. In Wales emissions are down 67% since 1990 and represent a lower share of the overall NO_X inventory at 22%, 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 37% of the total NO_X emissions, down 58% on 1990.

Sulphur dioxide (SO_2)

UK emissions of sulphur dioxide have fallen from 3.7 Mt in 1990 to 0.4 Mt in 2009, representing a decrease of 89%. Between 2008 and 2009, an overall reduction of 20% 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 and a further 21% between 2008 and 2009, which underpinned the overall 2007 to 2009 reduction of 42% in Wales.

The contribution of emissions from industrial combustion sources (NFR 1A2) ranges from 6% of the SO_2 inventory total in 2009 for Scotland, 16% in Wales, to 18% in Northern Ireland and 23% 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 (44% of the 2009 total, compared to a UK average of 9%) 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 more than 98% reduction in emissions from road transport between 1990 and 2009. Recent trends from the impacts from the EU Fuel Quality Directive are illustrated by SO_2 reductions from road transport declining by between 33% and 39% in all constituent countries of the UK between 2008 and 2009. 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 74% between 2008 and 2009 when amendments to the Fuel Quality Directive came into effect, whilst the average content of sulphur in diesel has gone up slightly by 6% between the same years (but remained approx 50% lower than in 2007 and well within the EU Fuel Quality Directive limit of 10ppm S already reached by 2008). There are small changes for gas oil (for non-transport markets), medium and heavy fuel oil, whilst kerosene, aviation fuels have also shown a reduction in sulphur content of around 13% between 2008 and 2009.

Ammonia (NH_3)

The total UK emission of ammonia for 2009 is estimated at 0.29 Mt, compared to the 1990 estimate of 0.37 Mt, representing a 22% reduction. The agricultural sector dominates ammonia emissions, with over 89% of UK emissions coming from agricultural sources. Agricultural emissions have declined by 26% 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 2009, contributing 87% of the total in England, 91% in Scotland, 92% in Wales, and 96% in Northern Ireland. Agricultural emission reductions since 1990 have been greatest in Wales (down 47%), then Scotland (down 30%) and England (down 23%), 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 lead to lower emissions of ammonia. 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% and 2% of total ammonia emissions in 2009 respectively. In Northern Ireland where diesel vehicles are a larger fraction of the vehicle fleet, the emissions from cars are only 1% of the 2009 ammonia emissions, whilst in England the share is 5%.

Ammonia emissions from sewage sludge decomposition and composting are around 2% for England and 1% each from all the other DAs, whilst in England there is also 1% of 2009 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 58% from 0.28 Mt in 1990 to 0.12 Mt in 2009. 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 2009) and particulate from road transport (1A3b) sources (23% of UK emissions in 2009).

Across the constituent countries of the UK, emissions from England show proportionally higher emissions from the road transport sector (1A3b) (25% of the total in 2009) with both Scotland and Northern Ireland around the UK average at 19%, whereas in Wales only 16% of the total is from road transport due to higher emissions from industry (2) sites such as iron and steelworks. Northern Ireland, Wales and Scotland have proportionally higher emissions from the domestic sector (1A4b) (27%, 26% and 24% respectively compared to 14% UK-wide in 2009) 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. In England only 11% comes from domestic sources.

Other sources of note include mobile agricultural machinery which contributes from 7% in Northern Ireland, 4% in Wales, 5% in Scotland and 2% in England in 2009. Quarrying emissions range from 3% in Northern Ireland and 5% in Wales to 6% in England and 7% in Scotland in 2009. Iron and steel works contribute 4% of England PM_{10} emissions and 11% of Wales emissions in 2009 (very low or no emissions in Scotland or Northern Ireland). Industrial coating accounts for 3% 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 12%, whereas in Wales the figure is 3%, Scotland 4% and England 5% of the 2009 total. Small-scale waste burning estimates are highly uncertain at both UK and DA level, but the current estimates for 2009 PM_{10} emissions indicate that they contribute 2% of emissions in Northern Ireland and Wales, 3% in Scotland and 4% in England.

Lead (Pb)

UK lead emissions are estimated at 60 tonnes in 2009, 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 2009 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 59% reduction from iron and steel sources between 1990 and 2009. Emissions from steelworks account for 72% of lead emissions in Wales in 2009, whilst in England the sector accounts for 38% of total emissions. Wales iron and steel emissions account for 13% of the total UK inventory, and the England iron and steel emissions another 28% of the UK total. As a result, England accounts for almost 74% of total UK emissions, whilst Wales accounts for approximately 19% of total UK lead emissions, and in contrast Scotland emits only 5% and Northern Ireland approximately 2% of UK lead releases in 2009.

In Scotland and Northern Ireland, the 2009 inventories indicate that the domestic sector (1A4b) combustion of solid fuels is the largest emission source. In total, the domestic sector (1A4b) accounts for 23% of the Scottish lead inventory and just under 37% 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 2009 include non-ferrous metal processes such as: the alkyl lead industry (8% of the England inventory), copper alloy industry (ranging from 0.2% of the Wales inventory to around 1% of the lead emissions, in England and 0.4% in Scotland and Northern Ireland), secondary lead processes (negligible in Wales, 0.4% in Northern Ireland and 2% of lead emissions in Scotland and 3% in England) .Power sector emissions account for 1% of the Wales inventory, 4% of emissions in England, 2% of emissions in Northern Ireland and 14% of Scottish lead emissions in 2009. Refinery emissions in Scotland account for 6% of the total, with 3% and 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.

Per capita emissions

Emissions per capita have been calculated for each of the DAs, and are summarised for each pollutant within the report. Key features (e.g. where per capita emissions in one DA are much higher than the UK average) are described within the pollutant specific sections of the report, and a brief summary of the findings is described below:

- Across all DAs, for all pollutants, per capita emissions have fallen between 1990 and 2009;
- The most notable decrease (in percentage terms) is for lead, with a decrease of more than 90% across all of the DAs;
- The smallest decline is seen for ammonia emissions in Northern Ireland, falling by 18% per capita between 1990 and 2009;
- In England, per capita emissions are lower than the UK average for all pollutants in 2009;
- In Northern Ireland, ammonia emissions per capita are almost four times the UK average in 2009. This is due to the very high contribution of emissions from agriculture, relative to the rest of the UK; Northern Ireland accounts for 12% of UK agriculture emissions, compared with just 3% of the UK population;
- Sulphur dioxide emissions per capita in Scotland are almost double the UK average, due to the high contribution of Scottish emissions from residential combustion and power stations to the UK totals for these sectors (21% and 27%, respectively, compared with only 8% of the UK population);
- Scottish VOC emissions per capita are 80% higher than the UK average, mostly due to the high contribution of Scottish emissions from food and drink manufacture to both the UK total for this sector, and the Scottish total VOC emission;
- Welsh emissions are much higher than the UK average for NO_x, PM_{10}, SO_2, and most notably for Pb and CO. This is due predominantly to the contribution of iron and steel industry emissions to the Welsh total.

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. Rothamsted Research provides the estimates of agricultural emissions.

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A copy of this report and related data may be found on the Defra NAEI website:

http://naei.defra.gov.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 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 Convention on Long-Range Transboundary Air Pollution.

Under the Second Sulphur Protocol, the UK committed to reducing 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 2009, 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 2009” (Murrells *et al.*, 2011a), 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 2009 report, in 2011 an additional report, the Informative Inventory Report (Passant *et al.,* 2011b), 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:

- 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 five times previously and 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 (1A2) & Commercial (1A4a)
- Agriculture (combustion source) (1A4c)
- 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 2005 to 2008, with gas and electricity data also being available up to 2009.

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

[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.

[4] The latest available data are taken from the December 2010 Energy Trends, http://www.decc.gov.uk/en/content/cms/statistics/publications/trends/trends.aspx

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, and are the best data available to inform the patterns of fuel use across the Devolved Administrations. They 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 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 (in England, Wales and Northern Ireland) and early 2000s (in Scotland);

- 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 1990-2009 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 System (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 1990-2009 dataset, data have been revised for a range of industrial sites where the Phase II EUETS data (from 2009) 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 2009, and the results of this study are available on the NAEI website at:

http://naei.defra.gov.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 (2009 in this case). The mapped emissions data are available on the NAEI web site at:

http://naei.defra.gov.uk/mapping/mapping_2009.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 2009* (Tsagatakis et al., 2011). 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, gas production and industrial employment, 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 1990-2008 DA Air Quality Inventory Report, published in October 2010.

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 disaggregated using a mapping grid for all years in the time series.

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:

- Sub-national 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 2009. 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 developed by TRL on behalf of DfT and 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 2009. 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}, 1990-2009 in NFR format.

Appendix D: Devolved Administration Emission Inventories for CO, 1990-2009 in NFR format.

Appendix E: Devolved Administration Emission Inventories for NO_X, 1990-2009 in NFR format.

Appendix F: Devolved Administration Emission Inventories for SO_2, 1990-2009 in NFR format.

Appendix G: Devolved Administration Emission Inventories for NMVOC, 1990-2009 in NFR format.

Appendix H: Devolved Administration Emission Inventories for NH_3, 1990-2009 in NFR format.

Appendix I: Devolved Administration Emission Inventories for Pb, 1990-2009 in NFR format.

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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).

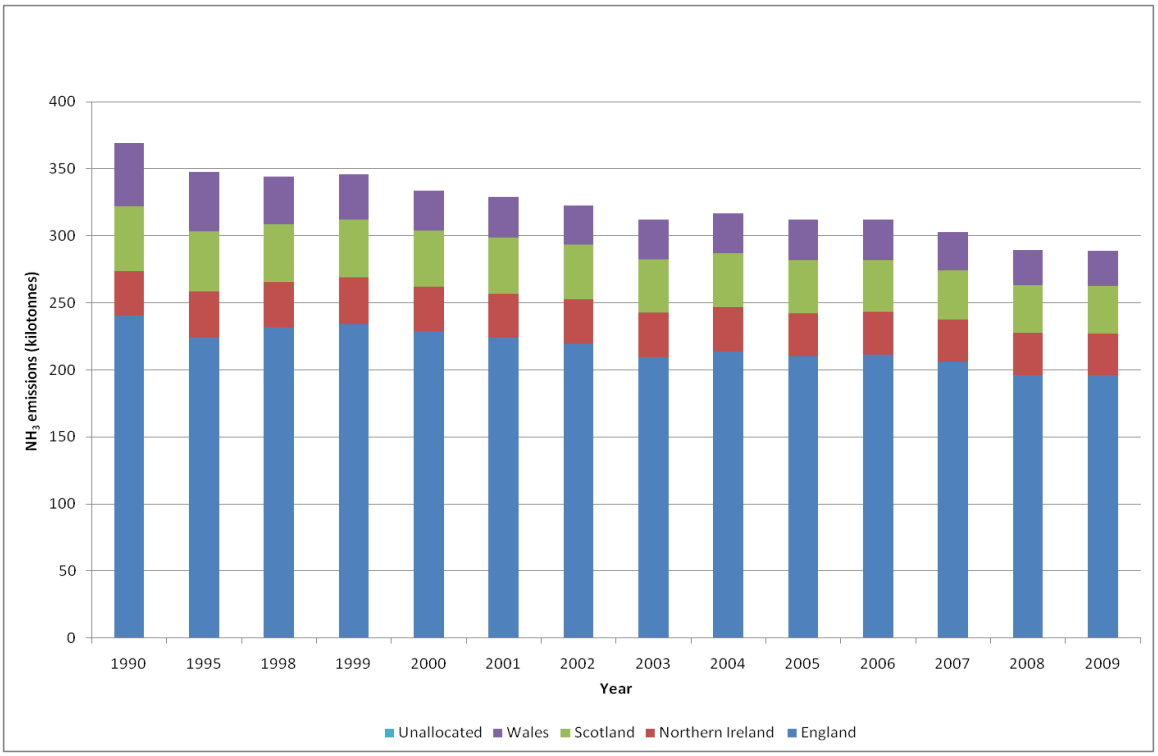
For information on the main sources & emission trends of Air Quality Pollutants in the UK National Atmospheric Emissions Inventory (NAEI) as well as supplementary information on particulate size & composition, monitoring and epidemiological evidence regarding effects on human health, please see Chapter 2 of *"UK Emissions of Air Pollutants 1970 to 2009"* (Murrells *et al*., 2011a).]

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 2009 represent a decrease of 22% on the 1990 emissions (**Figure 2-1**).

Figure 2-1 UK Ammonia Emissions by Constituent Country, 1990-2009



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 lead to lower NH_3 emissions 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, and **Table 2-2** show emissions of ammonia per capita, with a comparison against the average for the UK (excluding unallocated emissions).

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

Year	England	Scotland	Wales	N Ireland	Unallocated
1990	69%	12%	9%	9%	0%
2009	68%	12%	9%	11%	0%

Table 2-2 Emissions of Ammonia per capita by Constituent Country (kg/head)

	England	Scotland	Wales	N Ireland	UK
1990	5.0	9.5	16.4	21.0	6.4
2009	3.8	6.8	8.8	17.2	4.7
DA/UK (2009)	81%	146%	188%	370%	-

2.1.1 England Ammonia Inventory by NFR Sector, 1990-2009

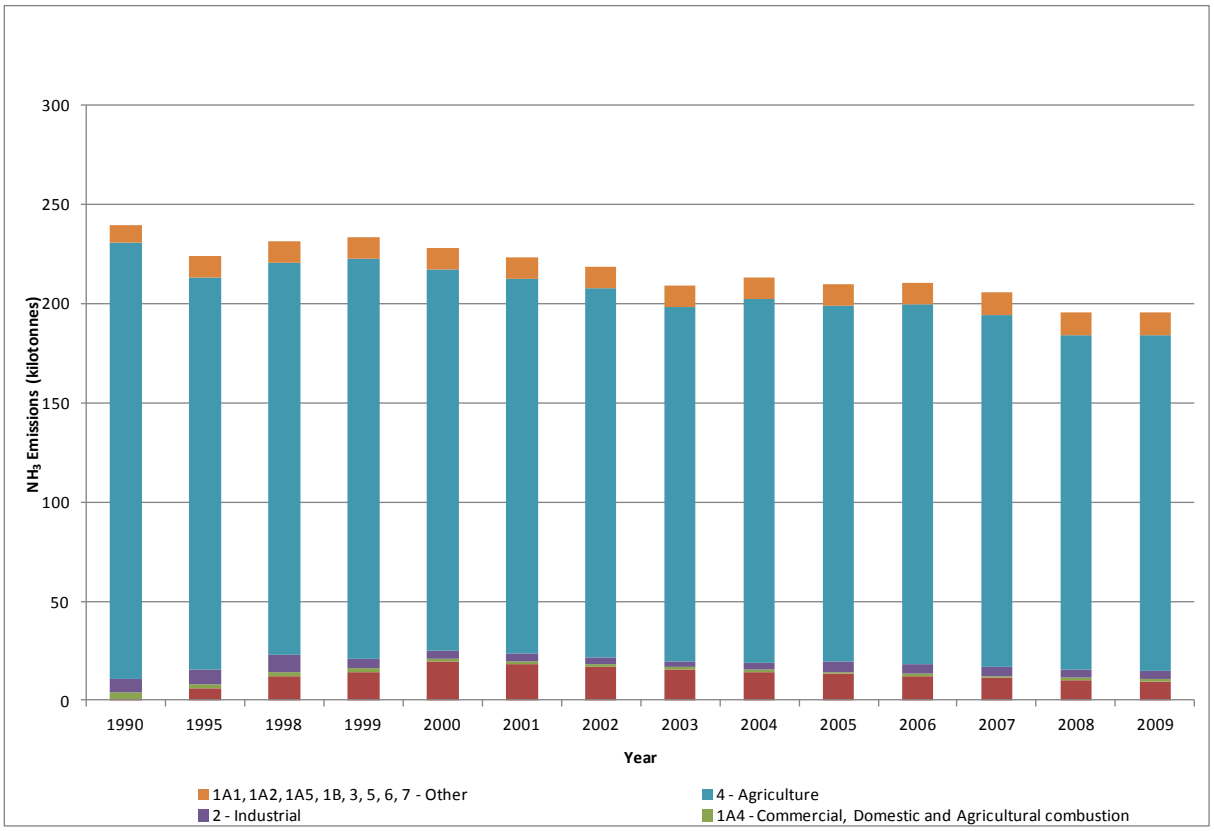
The table and graph below give a summary of the ammonia emissions in England by broad NFR sector categories. The detailed data are available in Appendix H.

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

NFR Code	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2009%
1A3 - Transport Sources	0.7	5.9	12.0	13.9	19.5	18.2	17.0	15.4	14.4	13.2	12.3	11.3	10.2	9.5	4.8%
1A4 - Commercial, Domestic and Agricultural	3.1	2.2	2.0	2.1	1.7	1.7	1.3	1.2	1.1	1.0	0.9	1.0	1.1	1.1	0.6%
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	4.0	2%
4 - Agriculture	219	198	198	202	192	189	186	178	184	179	181	177	169	169	87%
1A1,1A2,1B,3, 6,7 - Other	9.1	10.4	10.4	10.7	10.8	10.9	10.9	10.8	10.6	10.8	10.8	10.9	11.3	11.6	6%
Total	**239**	**224**	**231**	**233**	**228**	**223**	**219**	**209**	**213**	**210**	**210**	**205**	**196**	**196**	**100%**

Units: kilotonnes

Figure 2-2 England Ammonia Emissions by Source, 1990-2009

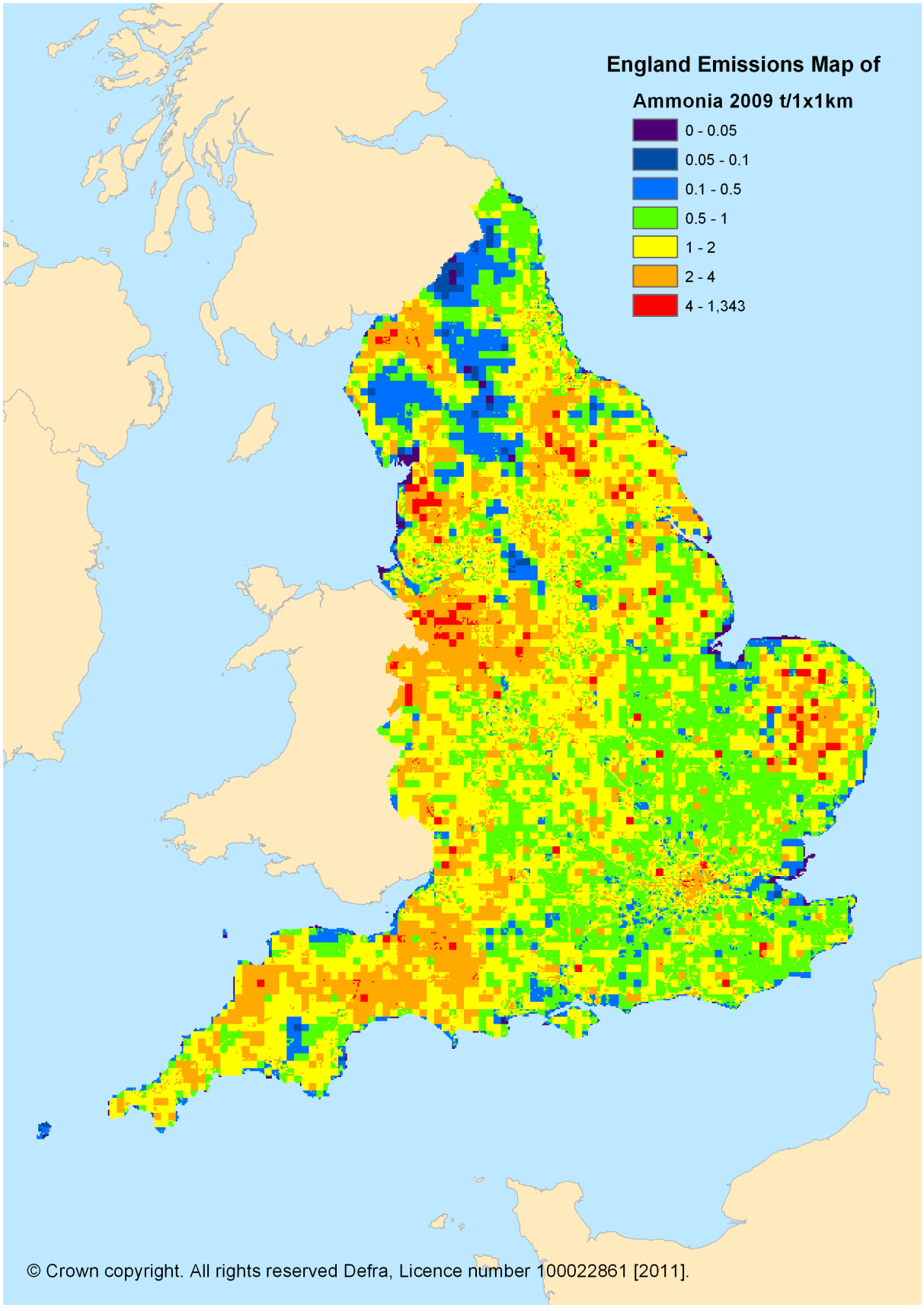


England's ammonia emissions have declined by 18% since 1990 and currently account for 68% of the UK total. The inventory is dominated by emissions from agricultural sources with 63% of the total in 2009 coming from manure management (4B: down 21% since 1990). 34% of the English total is from cattle manure management alone (4B1: down 1% since 1990). Other sources of note include transport emissions (1A3: 5% of the England total in 2009) and waste treatment and disposal (6: 5% of the England total in 2009).

English ammonia emissions per capita are much lower than the UK average. This is mostly due to the smaller contribution of emissions from agriculture in England; English emissions from this sector

account for 66% of UK emissions for the sector, which is much lower than England's contribution to the population (84%).

Figure 2-3 Map of Ammonia Emissions in England, 2009



2.1.2 Scotland Ammonia Inventory by NFR Sector, 1990-2009

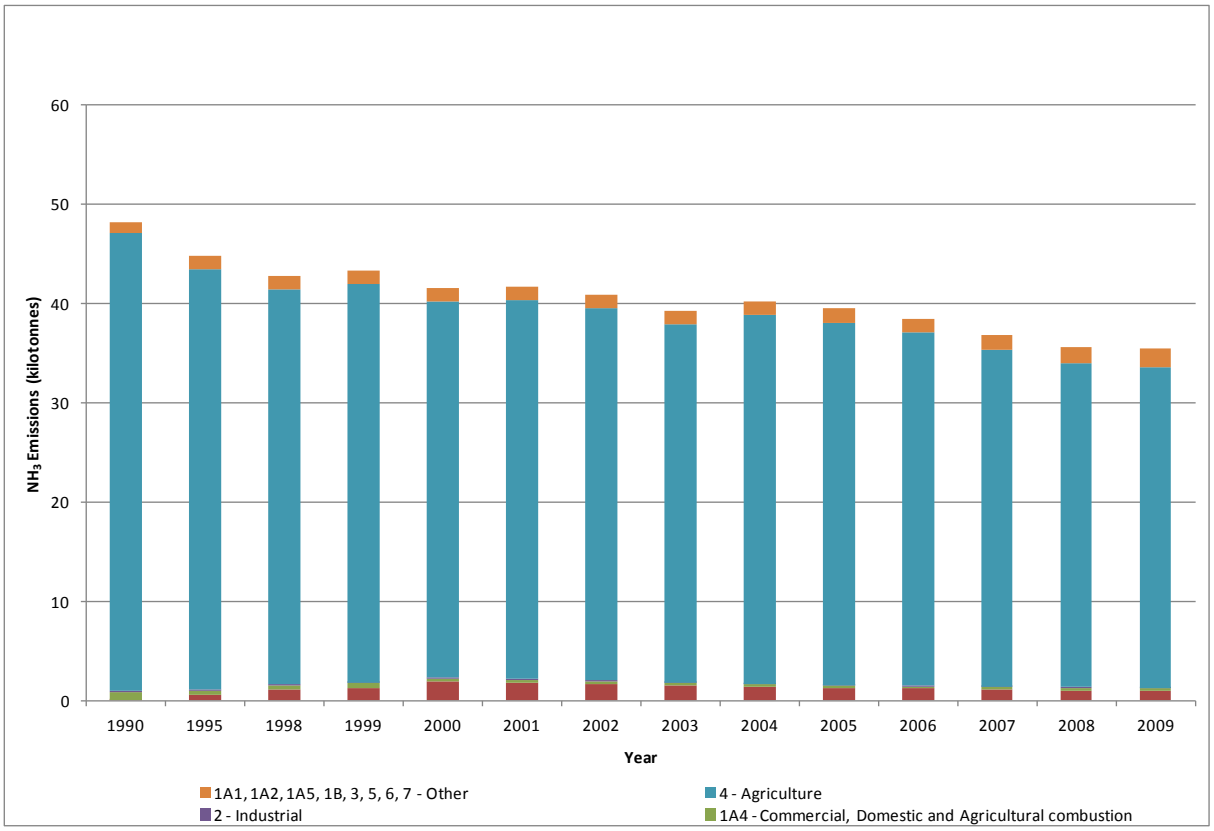
The table and graph below give a summary of the ammonia emissions in Scotland by broad NFR sector categories. The detailed data are available in Appendix H.

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

NFR Code	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2009 (%)
1A3 - Transport Sources	0.1	0.6	1.1	1.3	1.9	1.8	1.7	1.5	1.4	1.3	1.2	1.1	1.0	0.9	2.6%
1A4 -Commercial, Domestic and Agricultural	0.8	0.4	0.4	0.4	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.9%
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	0.1	0%
4 - Agriculture	46.1	42.4	39.8	40.2	37.9	38.2	37.6	36.1	37.1	36.5	35.5	33.9	32.6	32.4	91%
1A1,1A2,1B,3,6,7 - Other	1.2	1.3	1.3	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.5	1.5	1.6	1.8	5%
Total	**48.3**	**44.8**	**42.7**	**43.3**	**41.6**	**41.8**	**41.0**	**39.3**	**40.2**	**39.5**	**38.5**	**36.9**	**35.6**	**35.4**	**100%**

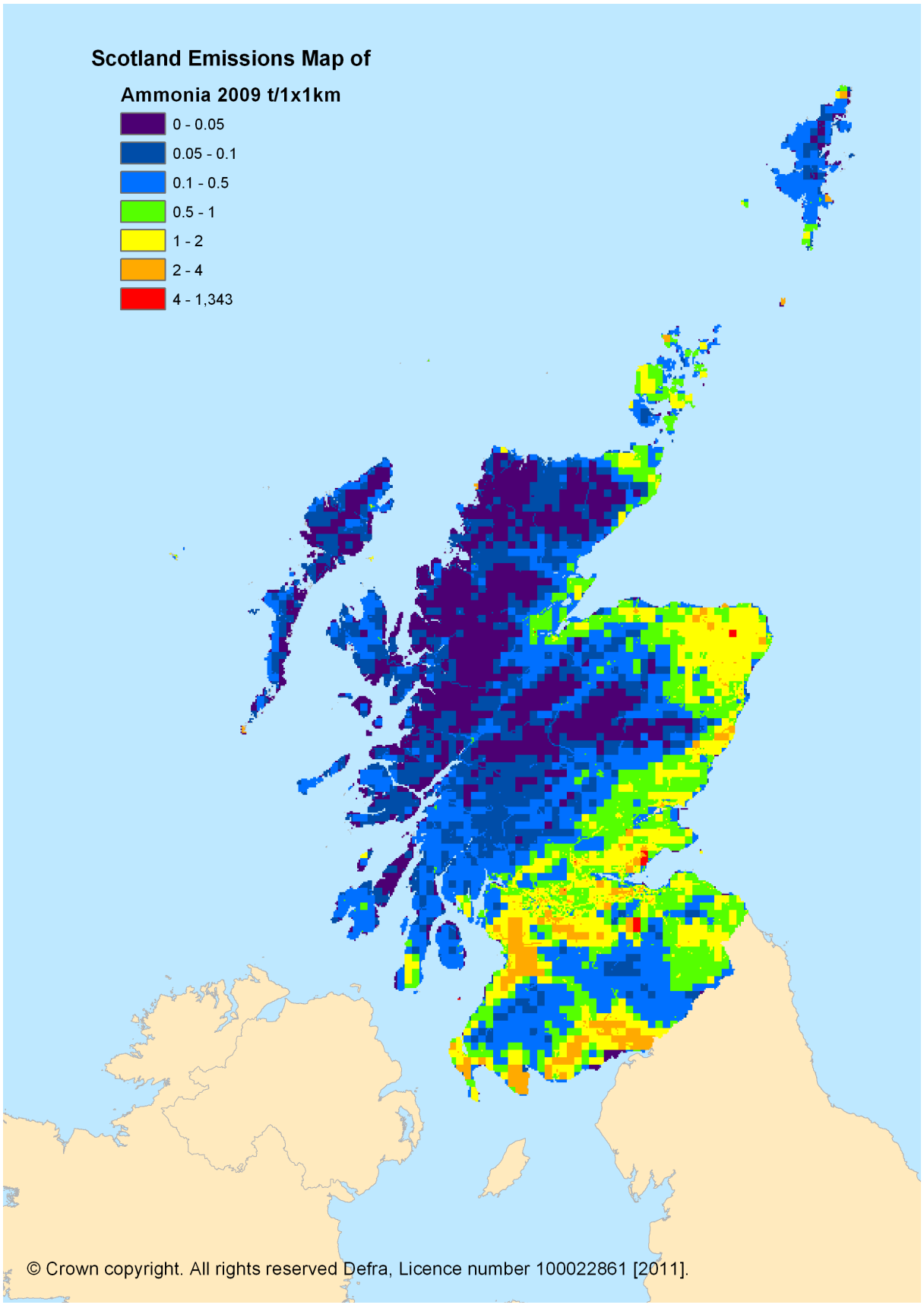
Units: kilotonnes

Figure 2-4 Scotland Ammonia Emissions by Source, 1990-2009



Scotland's ammonia emissions have declined by 27% since 1990 and accounted for 12% of the UK total in 2009. The inventory is dominated by emissions from agricultural sources, with 68% of the total in 2009 estimated to originate from manure management (4B: down 17% since 1990). Other sources of note include transport emissions (1A3: 3% of the Scotland total in 2009) and waste treatment and disposal (6: 4% of the Scotland total in 2009).

Figure 2-5 Map of Ammonia Emissions in Scotland, 2009



2.1.3 Wales Ammonia Inventory by NFR Sector, 1990-2009

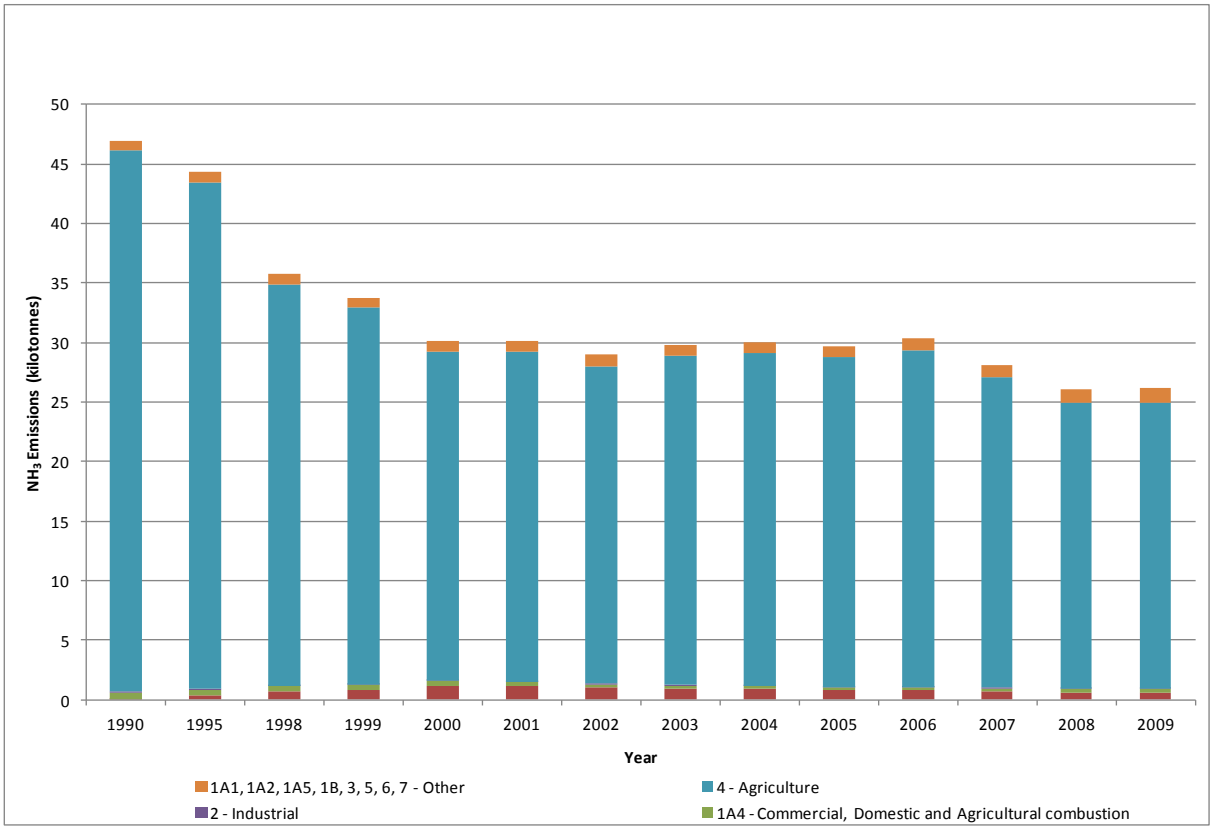
The table and graph below give a summary of the ammonia emissions in Wales by broad NFR sector categories. The detailed data are available in Appendix H.

Table 2-5 Wales Emissions of Ammonia by NFR Source Sector

NFR Code	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2009 (%)
1A3 - Transport Sources	0.0	0.4	0.7	0.8	1.2	1.1	1.1	1.0	0.9	0.8	0.8	0.7	0.6	0.6	2.2%
1A4 - Commercial, Domestic and Agricultural	0.6	0.5	0.4	0.4	0.4	0.4	0.3	0.2	0.2	0.2	0.2	0.3	0.3	0.3	1.1%
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	0.0	0%
4 – Agriculture	45.4	42.6	33.7	31.6	27.7	27.7	26.6	27.6	27.9	27.7	28.3	26.0	24.0	24.1	92%
1A1,1A2,1B,3,6, 7 - Other	0.8	0.9	0.9	0.9	0.9	0.9	1.0	1.0	0.9	0.9	1.0	1.0	1.1	1.2	5%
Total	**46.9**	**44.4**	**35.8**	**33.8**	**30.1**	**30.1**	**29.0**	**29.8**	**30.0**	**29.7**	**30.3**	**28.1**	**26.1**	**26.2**	**100%**

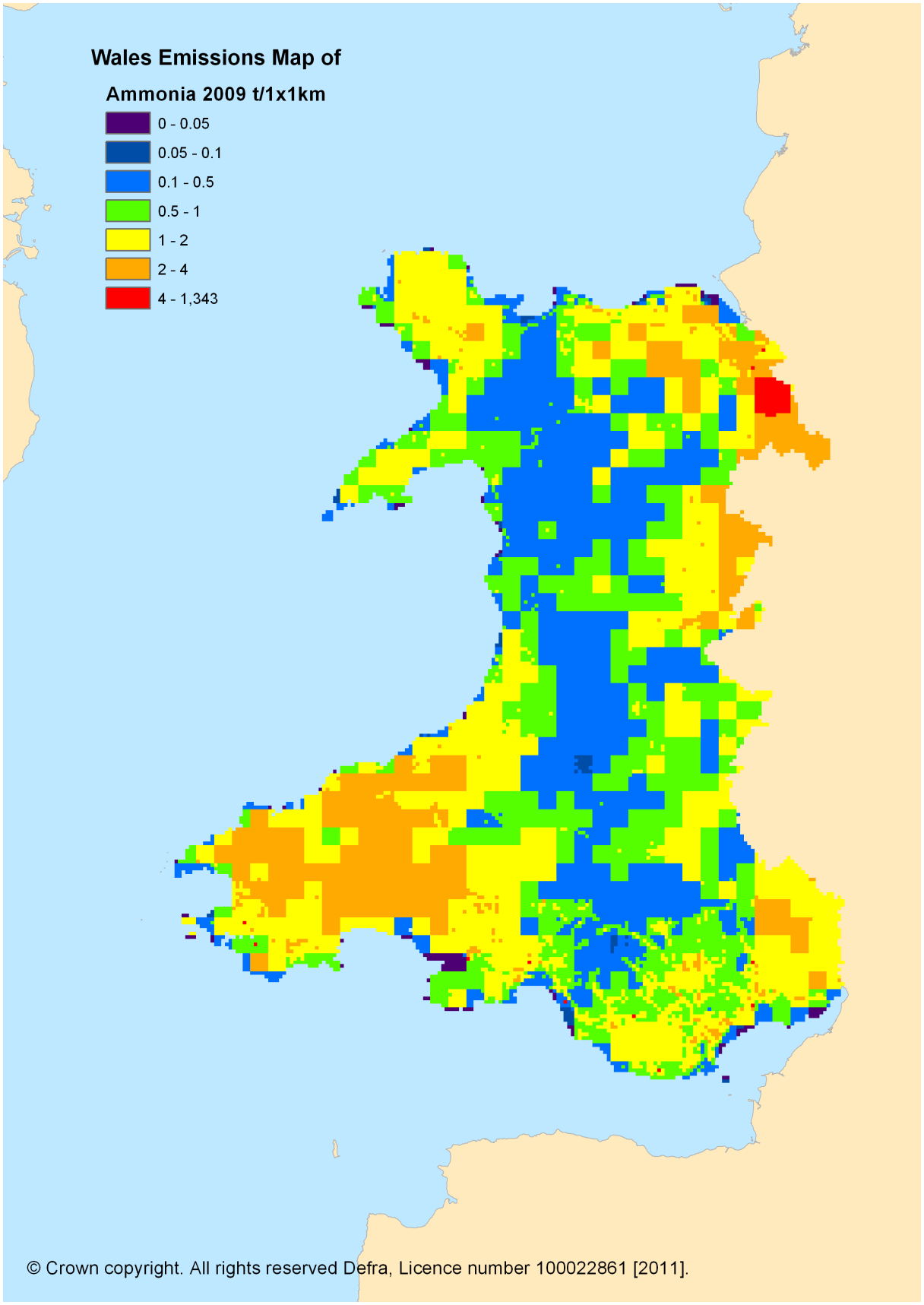
Units: kilotonnes

Figure 2-6 Wales Ammonia Emissions by Source, 1990-2009



Ammonia emissions in Wales have declined by 44% since 1990 and accounted for 9% of the UK total in 2009. The inventory is dominated by emissions from agricultural sources with 66% of the total in 2009 coming from manure management (4B: down 47% since 1990). In 2009, 51% of emissions from Wales is estimated to originate from cattle manure management alone (4B1: down 52% since 1990). Other sources of note include transport emissions (1A3: 2% of the Wales total in 2009) and waste treatment and disposal (6: 4% of the Wales total in 2009).

Figure 2-7 Map of Ammonia Emissions in Wales, 2009



2.1.4 Northern Ireland Ammonia Inventory by NFR Sector, 1990-2009

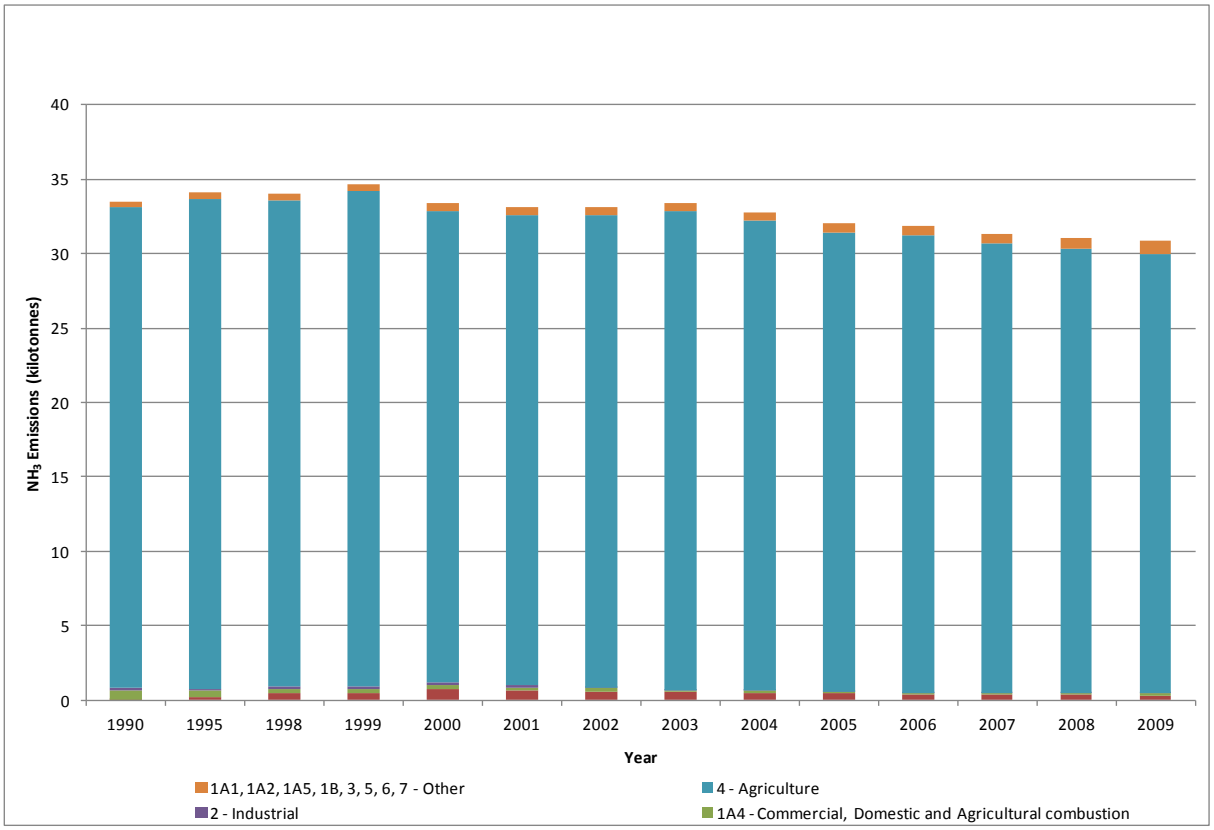
The table and graph below give a summary of the ammonia emissions in Northern Ireland by broad NFR sector categories. The detailed data are available in Appendix H.

Table 2-6 Northern Ireland Emissions of Ammonia by NFR Source Sector

NFR Code	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2009 (%)
1A3 - Transport Sources	0.0	0.2	0.4	0.5	0.8	0.7	0.6	0.5	0.5	0.5	0.4	0.4	0.4	0.3	1.1%
1A4 - Commercial, Domestic and Agricultural	0.6	0.4	0.3	0.3	0.3	0.2	0.2	0.2	0.1	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	0.0	0%
4 - Agriculture	32.3	32.9	32.7	33.2	31.7	31.5	31.7	32.2	31.6	30.9	30.7	30.2	29.8	29.5	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	0.6	0.6	0.7	0.7	0.8	3%
Total	**33.5**	**34.1**	**34.0**	**34.7**	**33.4**	**33.1**	**33.1**	**33.4**	**32.8**	**32.0**	**31.8**	**31.3**	**31.0**	**30.8**	**100%**

Units: kilotonnes

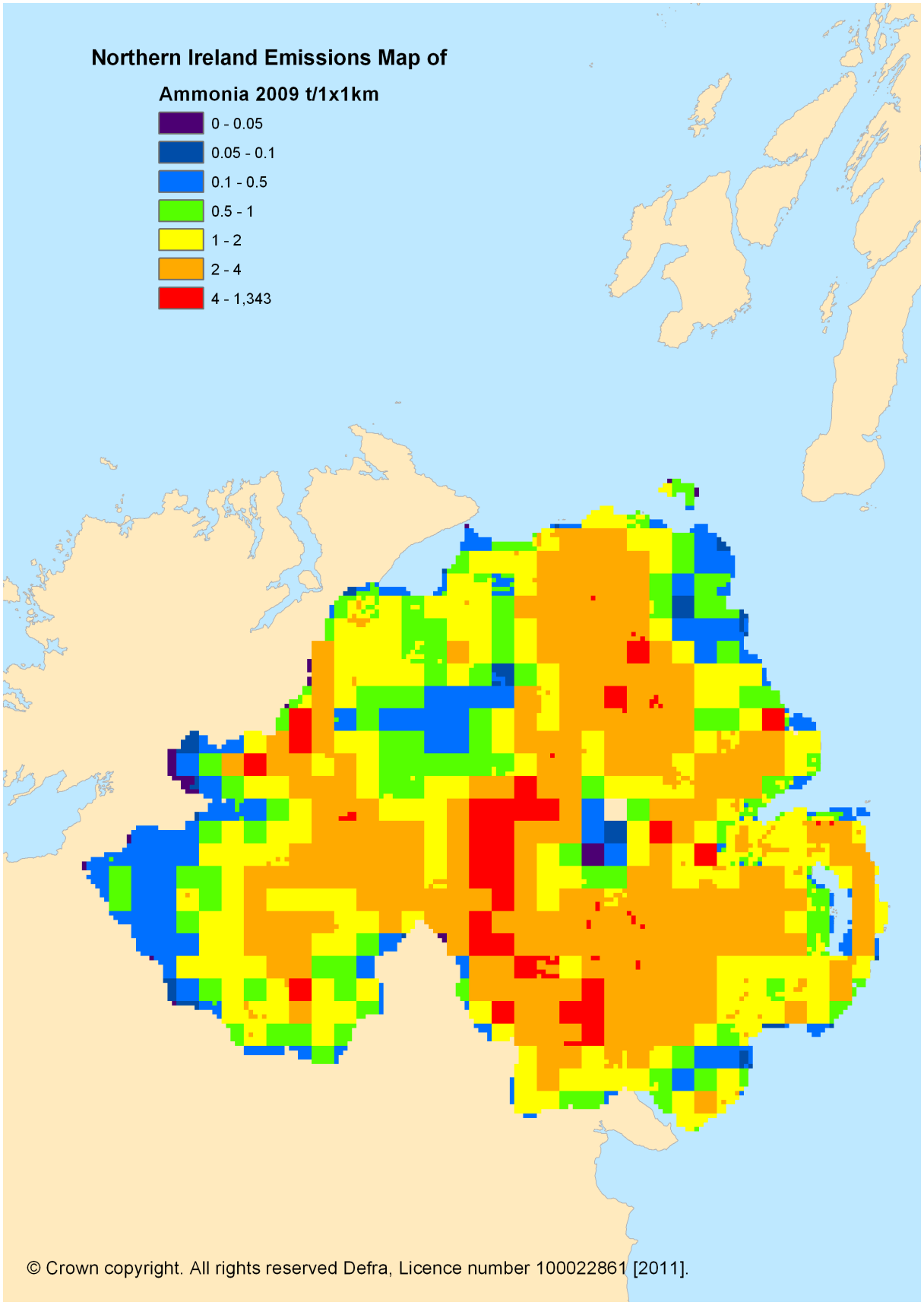
Figure 2-8 Northern Ireland Ammonia Emissions by Source, 1990-2009



Northern Ireland's ammonia emissions have declined by 8% since 1990 and currently account for 11% of the UK total. The inventory is dominated by emissions from agricultural sources (4) with 79% of the total in 2009 coming from manure management (4B: down 3% since 1990). In 2009, 60% of the Northern Ireland total is from cattle manure management alone (4B1: up 10% since 1990). Other sources of note include transport emissions (1A3: 1% of the Northern Ireland total in 2009), and waste treatment and disposal (6: 2% of the Northern Ireland total in 2009).

Per capita emissions for Northern Ireland are almost four times the UK average in 2009. This is mostly due to the high emissions from agricultural sources, where Northern Ireland contributes 12% to the total UK emission for this sector, compared with only 3% of the UK population.

Figure 2-9 Map of Ammonia Emissions in Northern Ireland, 2009

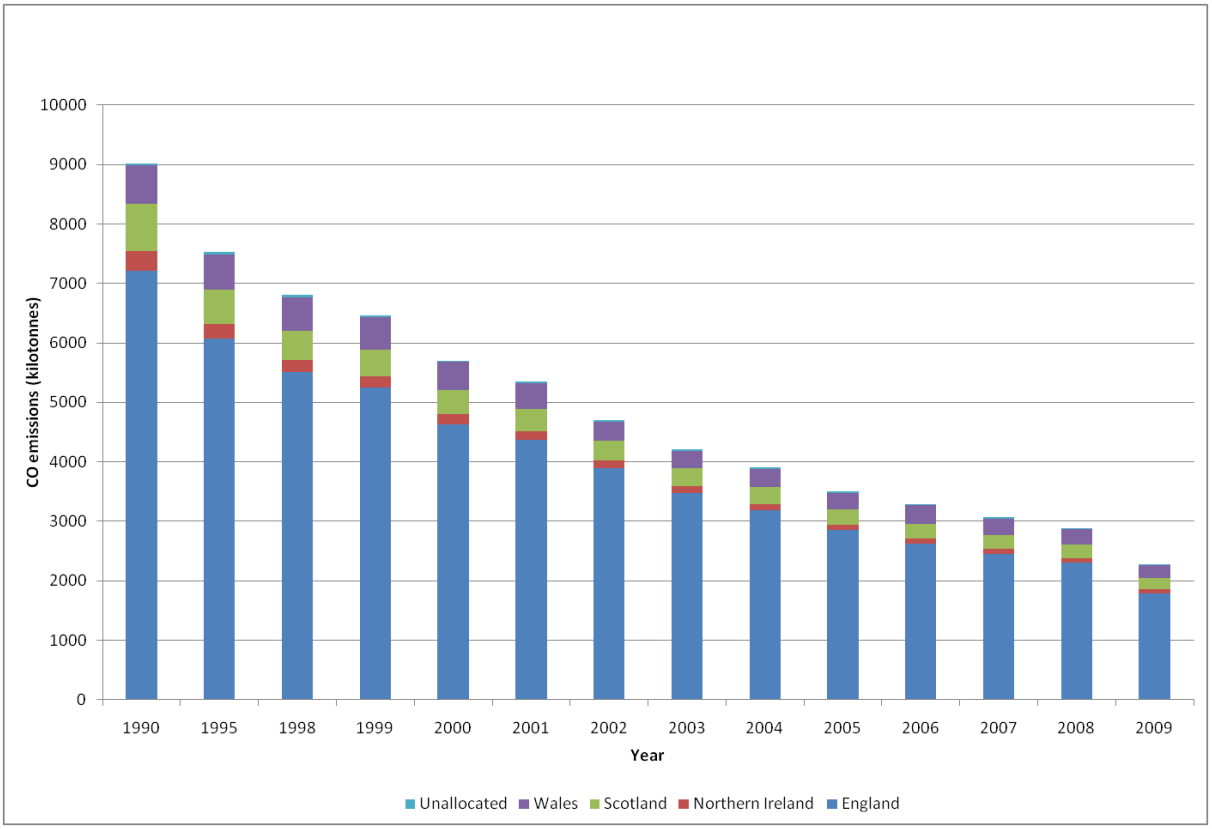


2.2 CARBON MONOXIDE

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, emissions decreased by 75% between 1990 and 2009. This decline has been driven by significant reductions in emissions from road transport (1A3b), agricultural field burning (4F) and the domestic sector (1A4b). The change in emissions between 1990 and 2009 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, 1990-2009



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 83% due to the development of more efficient engine combustion technology, the increased use of catalytic converters and the growth in diesel engine use. Between 2008 and 2009, emissions from passenger cars decreased by 33% due to an improvement in catalyst replacement rates, coupled with a downturn in vehicle km travelled.

- **Non road mobile machinery (1A2fii, 1A4bii, 1A4cii).** In the UK, around 13% of CO emissions arise from off-road mobile industrial, residential and agricultural machinery such as portable generators, forklift trucks, lawnmowers and tractors. Emissions are calculated using a complex model which takes into account the population of machinery in the UK, annual usage, the engine size, replacement rates, and the implementation of legislation aimed at reducing emissions. The population of machinery within the model is based on an in depth survey for a single year, with the time series generated using proxy statistics. As such, these

estimates are relatively uncertain, however a recent comparison the UK's NRMM emissions with those of other EU Member States indicated that the emissions are within the expected range for the UK.

- **Stationary domestic combustion (1A4bi)**. Around 13% of CO emissions in 2009 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 71% 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 28% since 1990, 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 2009.

Most emission sources have decreased significantly between 2008 and 2009, with notable decreases for iron and steel production (-18%) and power generation (-13%), most likely due to the economic downturn.

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 2-7** shows how total UK CO emissions are split between the 4 constituent countries, and **Table 2-8** shows per capita emissions for 1990 and 2009.

Table 2-7 Proportion of UK Carbon Monoxide Emissions by Constituent Country

Year	England	Scotland	Wales	N Ireland	Unallocated
1990	79%	9%	7%	4%	0%
2009	78%	8%	9%	3%	1%

Table 2-8 Emissions of Carbon Monoxide per capita by Constituent Country (kg/head)

	England	Scotland	Wales	N Ireland	UK
1990	151	155	223	214	157
2009	34.5	35.6	71.3	39.1	36.8
DA/UK (2009)	94%	97%	194%	106%	-

2.2.1 England Carbon Monoxide Inventory by NFR Sector, 1990-2009

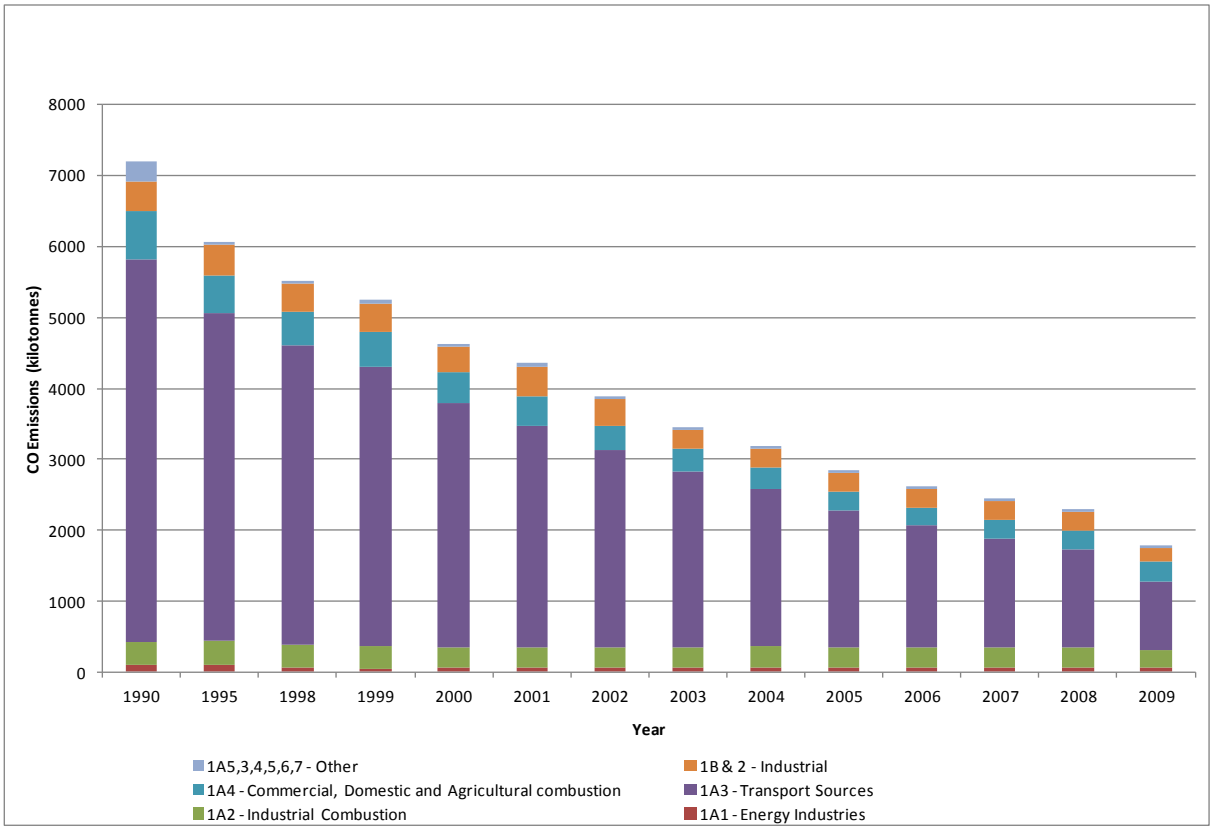
The table and graph below give a summary of the CO emissions in England by broad NFR sector categories. The detailed data are available in Appendix D.

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

NFR Code	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2009 (%)
1A1 - Energy Industries	99	92	56	50	60	58	57	64	62	67	67	69	65	57	3%
1A2 - Industrial Combustion	328	346	330	316	294	289	288	289	298	272	277	282	280	246	14%
1A3 - Transport Sources	5396	4627	4213	3930	3444	3115	2776	2473	2213	1937	1720	1529	1377	968	54%
1A4 - Commercial, Domestic and Agricultural	681	534	482	496	425	429	355	320	307	265	254	261	281	281	16%
1B & 2 - Industrial	412	426	392	410	365	412	365	275	264	266	268	263	255	197	11%
1A5,4,5,6,7 - Other	288	39	38	38	38	54	38	39	38	37	37	37	36	35	2%
Total	**7203**	**6066**	**5510**	**5241**	**4626**	**4357**	**3880**	**3460**	**3184**	**2844**	**2623**	**2441**	**2294**	**1785**	**100%**

Units: kilotonnes

Figure 2-11 England Carbon Monoxide Emissions by Source, 1990-2009

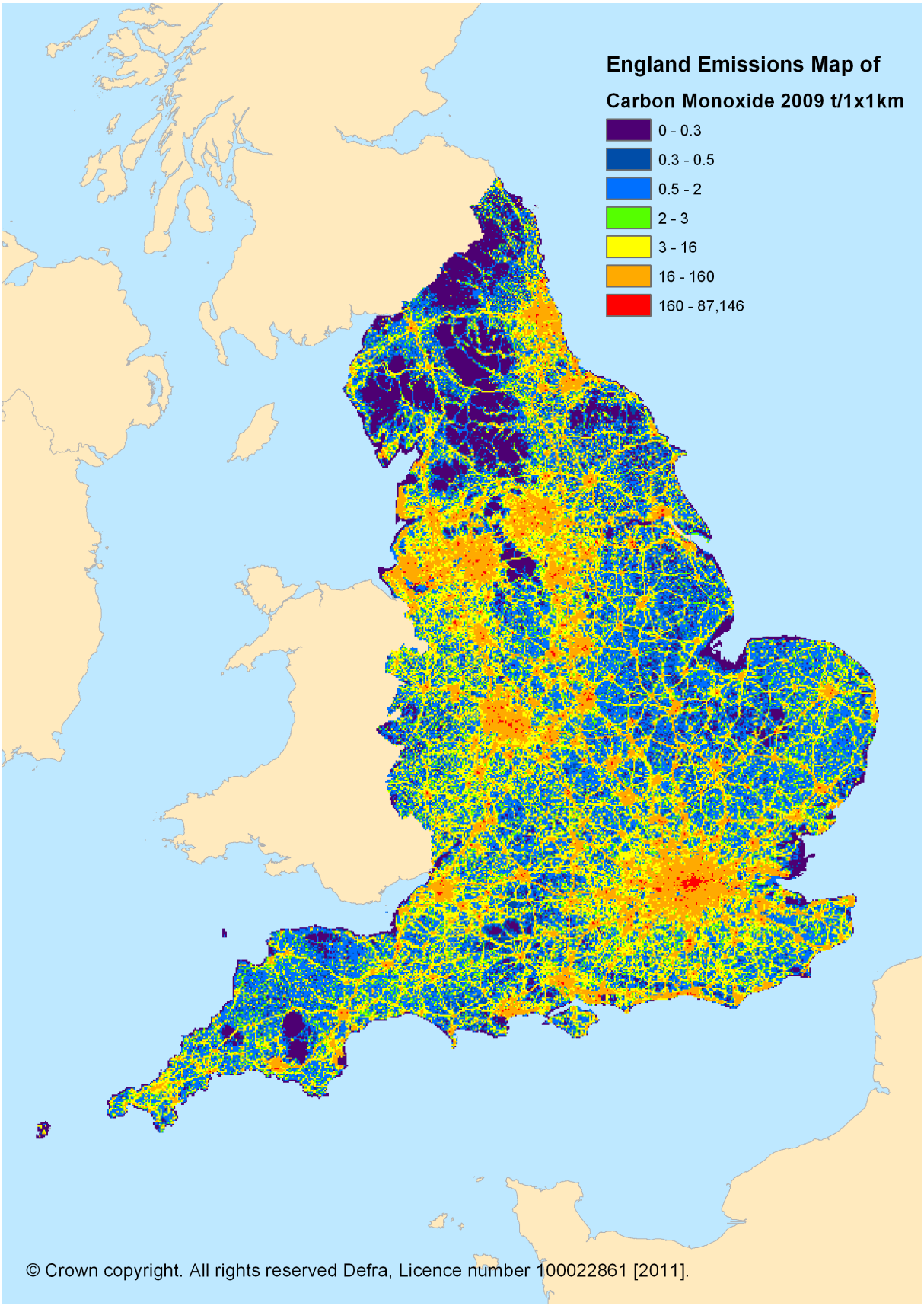


England's CO emissions have declined by 75% since 1990 and account for 78% of the UK total. In 2009, 52% of CO emissions in England stem from road transport combustion sources (1A3bi-iv: down by 83% since 1990), whilst 14% stem from industrial combustion (1A2: down 25% since 1990) and 16% from commercial and residential combustion (1A4: down 59% since 1990). Notable increasing trends in emissions arise from the non-road transport sources, such as railways (1A3c: up by 29% since 1990). However, the levels of emissions from these sources are small relative to emissions that arise from road transport (1A3b) sources.

Between 2008 and 2009, emissions of CO in England have declined by 22%. Much of this change (75%) is driven by the decline in emissions from passenger cars (due to improved catalyst

replacement rates), whilst declining emissions from industrial off road machinery and iron and steel have also made a contribution, due to the economic downturn.

Figure 2-12 Map of Carbon Monoxide Emissions in England, 2009



2.2.2 Scotland Carbon Monoxide Inventory by NFR Sector, 1990-2009

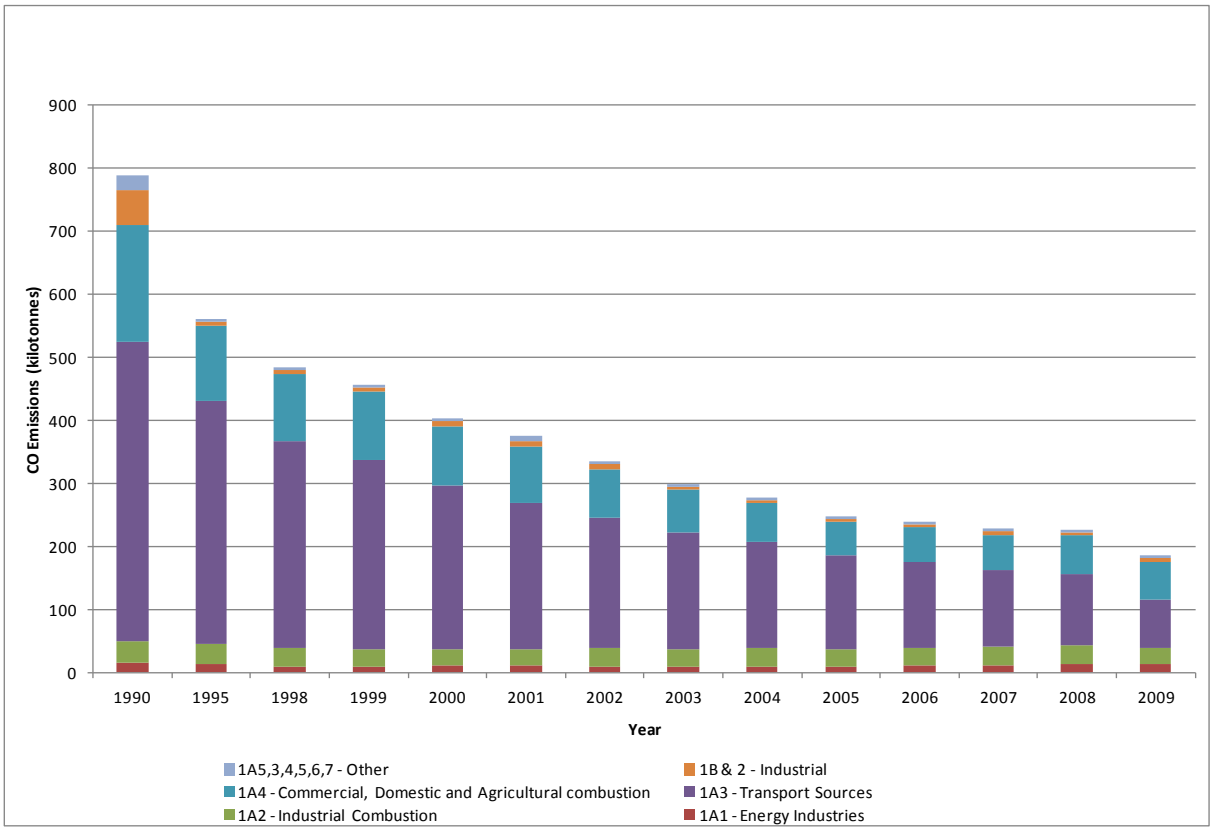
The table and graph below give a summary of the CO emissions in Scotland by broad NFR sector categories. The detailed data are available in Appendix D.

Table 2-10 Scotland Emissions of Carbon Monoxide by NFR Source Sector

NFR Code	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2009 (%)
1A1 - Energy Industries	14.7	14.6	10.0	9.2	11.0	10.6	10.4	9.7	10.1	9.9	11.9	11.4	14.5	13.7	7%
1A2 - Industrial Combustion	34.8	31.5	29.7	28.5	26.7	26.4	28.5	28.2	29.9	27.9	27.8	28.9	29.6	24.9	13%
1A3 - Transport Sources	474	385	327	300	260	231	206	185	168	149	136	122	113	77	42%
1A4 - Commercial, Domestic and Agricultural	186	120	107	108	93.4	90.6	76.9	68.1	62.2	52.6	54.4	55.8	60.8	60.0	32%
1B & 2 - Industrial	55.3	6.3	6.4	7.7	7.8	8.6	8.2	4.4	4.4	4.4	5.0	5.3	5.3	5.3	3%
1A5,4,5,6,7 - Other	23.0	4.3	4.1	4.1	4.0	8.2	4.1	4.1	4.0	3.9	4.0	3.9	3.8	3.7	2%
Total	788	562	484	457	403	376	334	299	278	248	240	228	227	185	100%

Units: kilotonnes

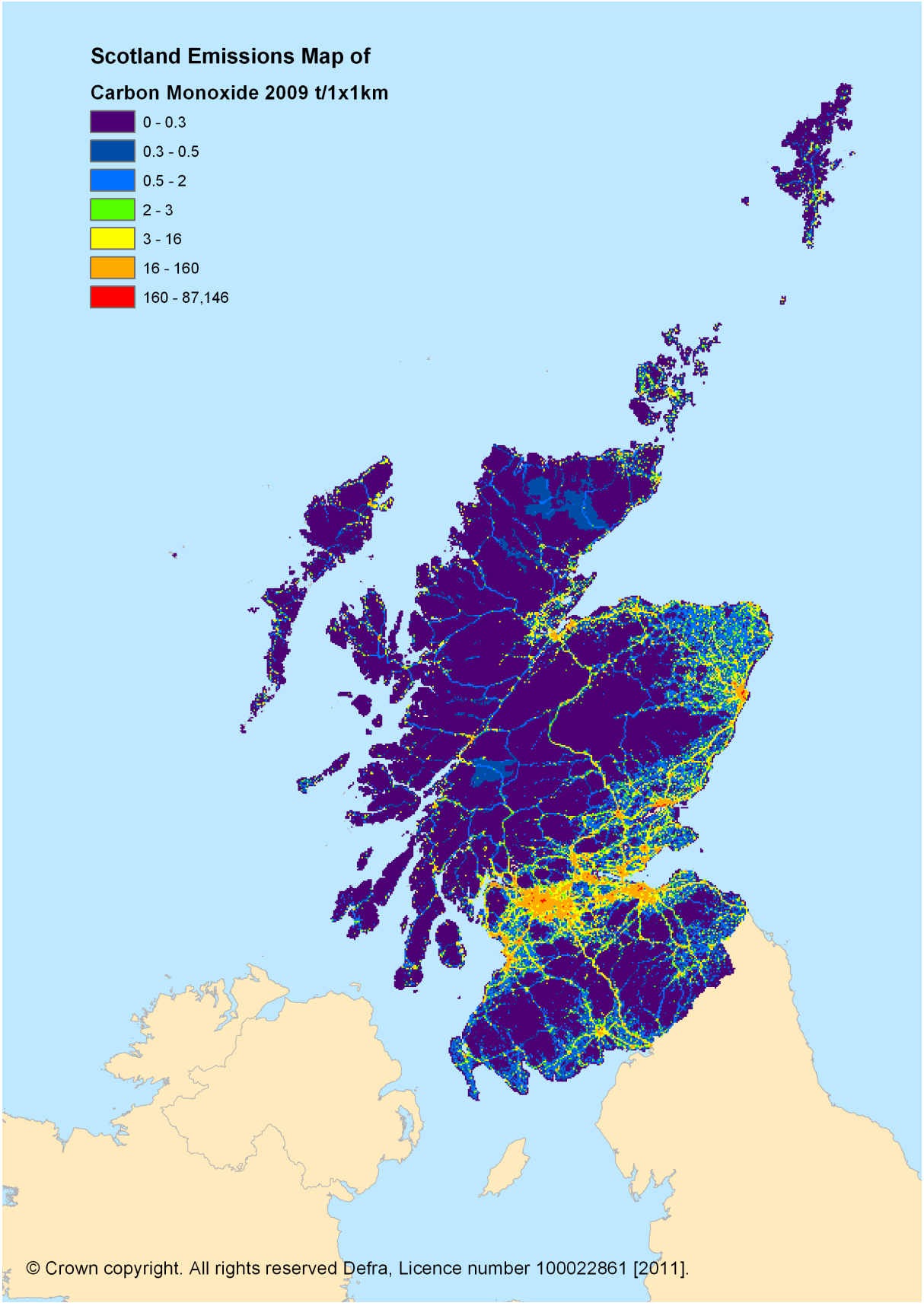
Figure 2-13 Scotland Carbon Monoxide Emissions by Source, 1990-2009



Scotland's CO emissions have declined by 77% since 1990 and account for 8% of the UK total. In 2009, 39% of CO emissions in Scotland stem from road transport combustion sources (1A3bi-iv: down by 84% since 1990), whilst 13% stem from industrial combustion (1A2: down 28% since 1990) and 32% from commercial and residential combustion (1A4: down 68% since 1990).

Between 2008 and 2009, emissions fell sharply by 18%, driven predominantly by the reduction in emissions from road transport, with further reductions in emissions from industrial combustion emissions (1A2fi and 1A2fii), driven by the economic downturn.

Figure 2-14 Map of Carbon Monoxide Emissions in Scotland, 2009



2.2.3 Wales Carbon Monoxide Inventory by NFR Sector, 1990-2009

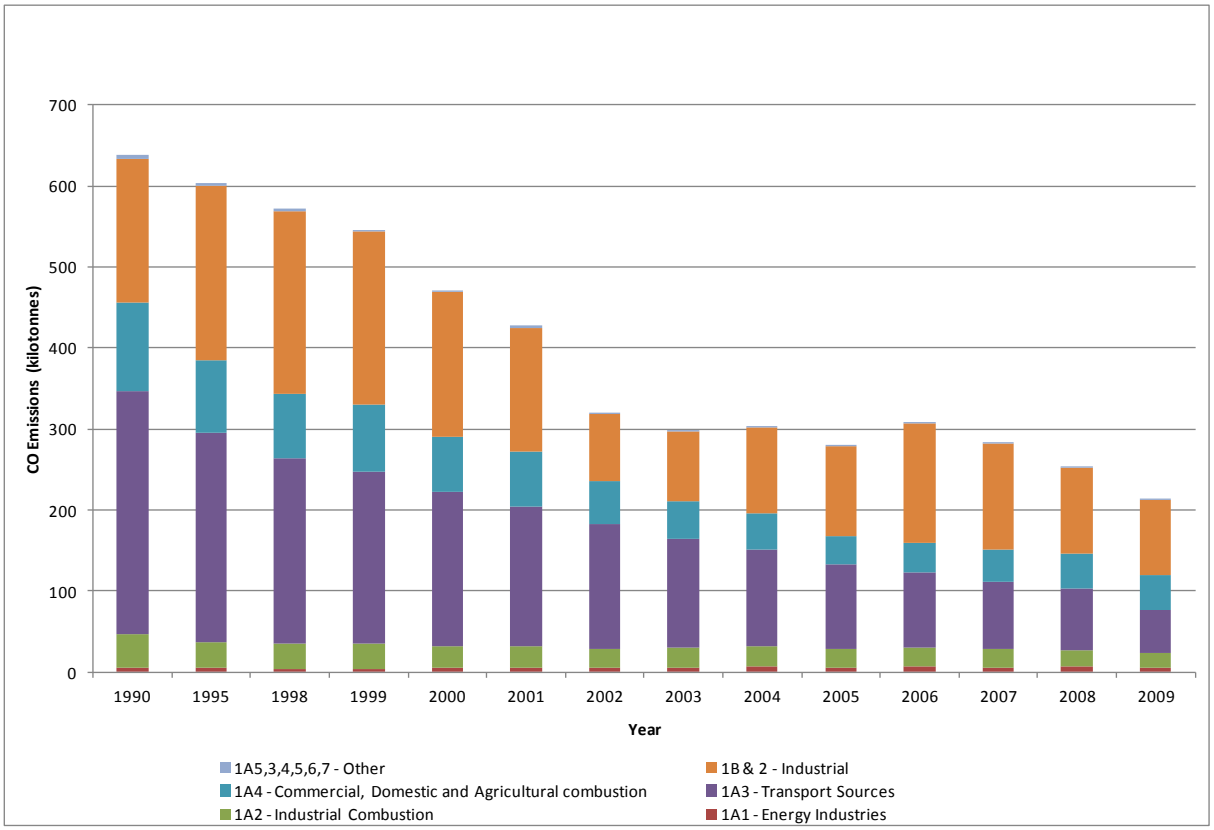
The table and graph below give a summary of the CO emissions in Wales by broad NFR sector categories. The detailed data are available in Appendix D.

Table 2-11 Wales Emissions of Carbon Monoxide by NFR Source Sector

NFR Code	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2009 (%)
1A1 - Energy Industries	6.2	6.2	4.4	3.9	5.2	5.9	4.9	5.2	6.9	6.2	6.8	5.4	6.5	5.7	3%
1A2 - Industrial Combustion	41.4	30.2	31.2	30.8	26.7	26.6	24.7	24.8	24.9	22.5	23.7	23.0	21.3	18.4	9%
1A3 - Transport Sources	300	258	229	213	190	171	153	135	120	104	93	83	76	52	24%
1A4 -Commercial, Domestic and Agricultural	108	89.5	79.1	82.7	68.0	69.1	53.6	46.6	44.5	35.8	36.2	39.4	42.3	43.0	20%
1B & 2 - Industrial	178	217	226	213	180	152	82	86	107	110	147	131	106	93	43%
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	1.8	1.8	1%
Total	**638**	**603**	**571**	**546**	**472**	**428**	**320**	**300**	**304**	**281**	**308**	**284**	**254**	**214**	**100%**

Units: kilotonnes

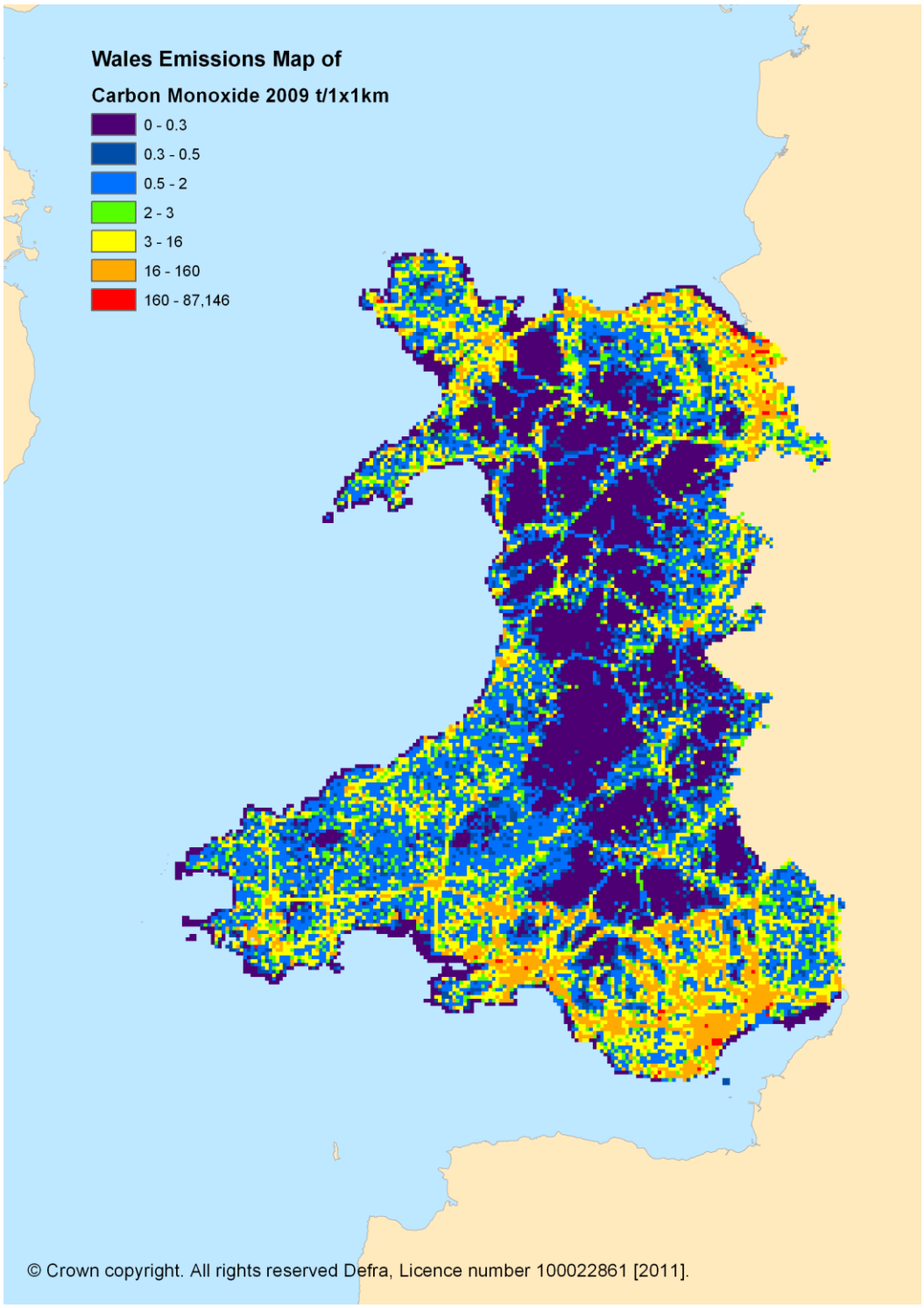
Figure 2-15 Wales Carbon Monoxide Emissions by Source, 1990-2009



Wales CO emissions have declined by 66% since 1990 and account for 9% of the UK total. The iron & steel industry (2C1 and 1A2a) contributes a very significant emission to the Welsh total, with a total of 37%. Emissions from iron and steel production have decreased by 56% since 1990, including a 14% reduction between 2008 and 2009 In 2009, 23% of CO emissions in Wales stem from road transport combustion sources (1A3bi-iv: down by 83% since 1990), whilst 20% stem from commercial and residential combustion (1A4: down 60% 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.

On a per capita basis, Welsh emissions are higher than the UK average, owing to the large contribution of emissions from iron and steel production. The continuing contribution of emissions from this source has also meant that the percentage decline in emissions per capita in Wales is lower than the other DAs (-68%, compared with a decline of 77-82%).

Figure 2-16 Map of Carbon Monoxide Emissions in Wales, 2009



2.2.4 Northern Ireland Carbon Monoxide Inventory by NFR Sector, 1990-2009

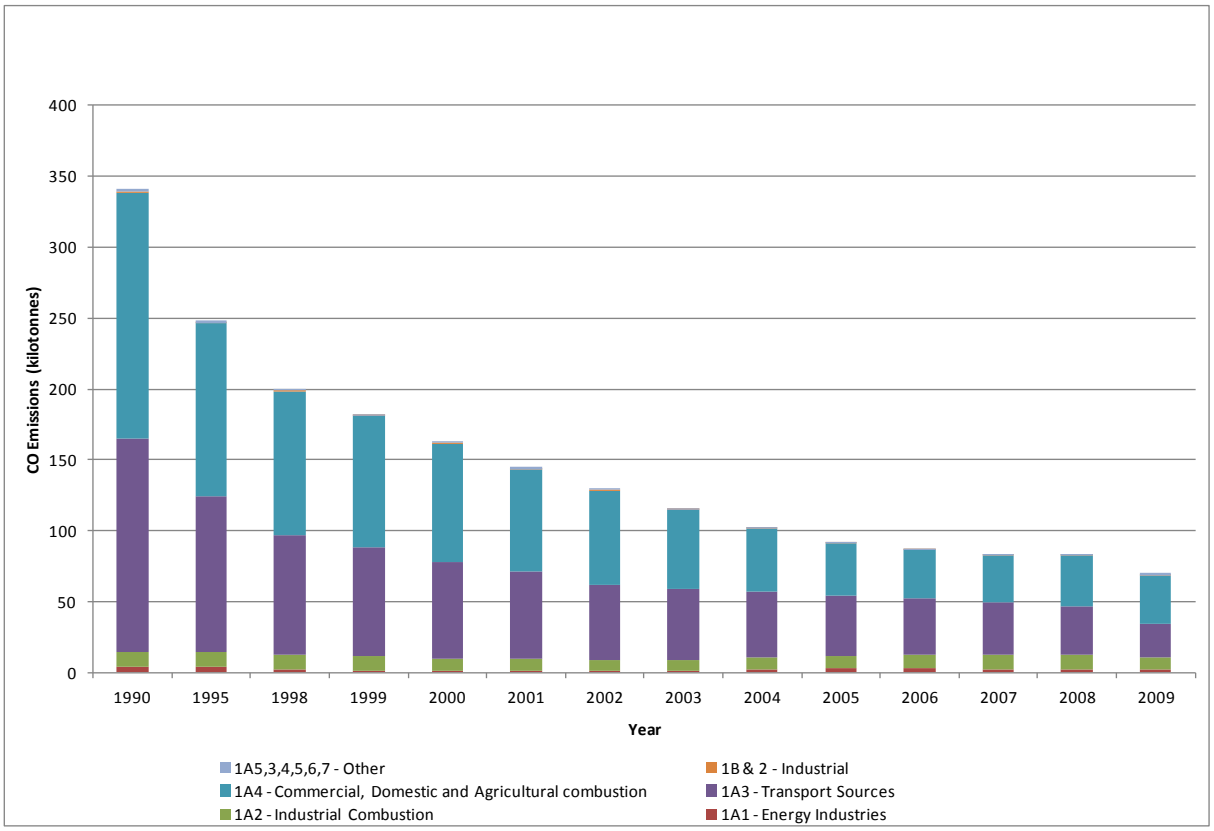
The table and graph below give a summary of the CO emissions in Northern Ireland by broad NFR sector categories. The detailed data are available in Appendix D.

Table 2-12 Northern Ireland Carbon Monoxide Emissions by NFR Source Sector

NFR Code	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2009 (%)
1A1 - Energy Industries	4.1	3.8	2.2	1.4	1.3	1.5	1.2	1.1	2.1	3.4	2.9	2.7	2.6	2.4	3%
1A2 - Industrial Combustion	10.1	11.2	10.6	10.3	8.8	8.2	8.1	8.1	8.5	8.4	9.6	10.1	9.9	8.0	11%
1A3 - Transport Sources	151	110	84	76.6	67.7	61.5	52.7	49.7	46.7	42.7	39.6	37.2	34.7	24.2	35%
1A4 -Commercial, Domestic and Agricultural	173	122	102	92.6	83.8	72.1	66.3	55.5	44.4	36.8	34.2	32.4	35.4	34.3	49%
1B & 2 - Industrial	0.2	0.2	0.2	0.4	0.4	0.4	0.4	0.1	0.0	0.0	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	1.1	1.1	2%
Total	**341**	**248**	**200**	**183**	**163**	**145**	**130**	**116**	**103**	**92.5**	**87.4**	**83.7**	**83.7**	**70.0**	**100%**

Units: kilotonnes

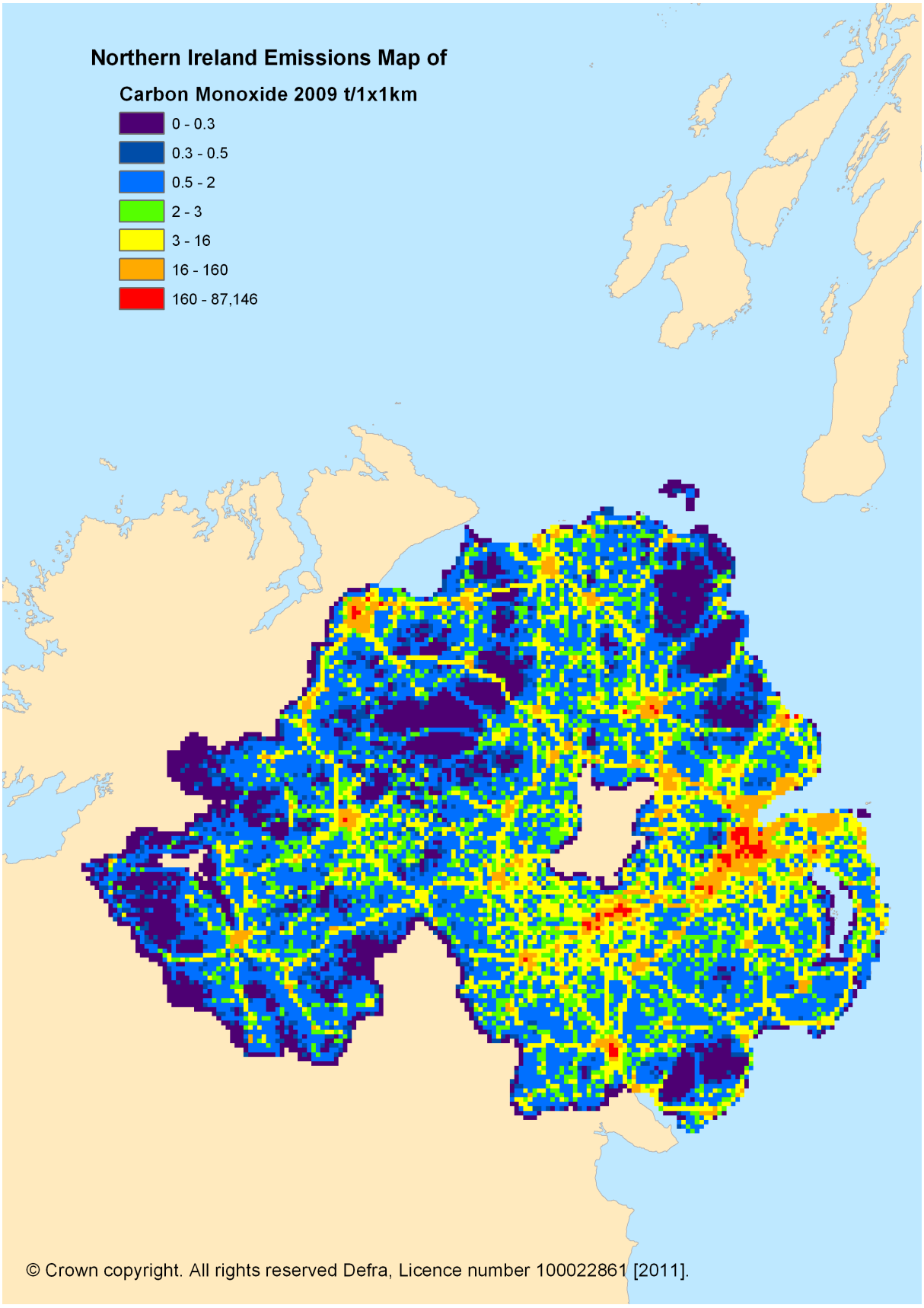
Figure 2-17 Northern Ireland Carbon Monoxide Emissions by Source, 1990-2009



Northern Ireland's CO emissions have declined by 79% since 1990 and accounted for 3% of the UK total in 2009. 33% of CO emissions in Northern Ireland stem from road transport combustion sources (1A3bi-iv: down by 85% since 1990). In 2009, 49% of the Northern Ireland total emission comes from commercial and residential combustion (1A4: down 80% since 1990), which is a much higher contribution than in other DAs (commercial and residential emissions contribute 16%, 32% and 20% within England, Scotland and Wales respectively) due to the greater use of solid fuels as a result of the less well developed gas network in Northern Ireland.

Between 2008 and 2009, emissions fell by 16%, mostly down to the reduction in emissions from passenger cars, but with further significant reductions from industrial (1A2f) and residential combustion (1A4b).

Figure 2-18 Map of Carbon Monoxide Emissions in Northern Ireland, 2009



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 2009 road vehicles contributed 33% 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. Between 2008 and 2009, there was about a 30% reduction in the emissions from passenger cars which was mainly driven by improvement in catalyst repair rates[5]. This was due to the introduction of the Regulations Controlling Sale and Installation of Replacement Catalytic Converters and Particle Filters for Light Vehicles for Euro 3 (or above) LDVs after June 2009. However, roadside measurements of ambient NO_x concentrations and a recent study undertaken by King's College London and AEA (Carslaw *et al.*, 2011) have indicated that the trend of ambient NO_x concentration has been fairly flat since 2002, and there is also some evidence from roadside remote sensing of exhaust plumes from a large number of vehicles indicating that NO_x emissions are significantly higher than indicated by the current emissions factors. Consideration is therefore currently underway by Defra and the inventory team to update the NO_x emission factors for the next inventory cycle so that they are more representative of the real world observations and the latest evidence on vehicle 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.

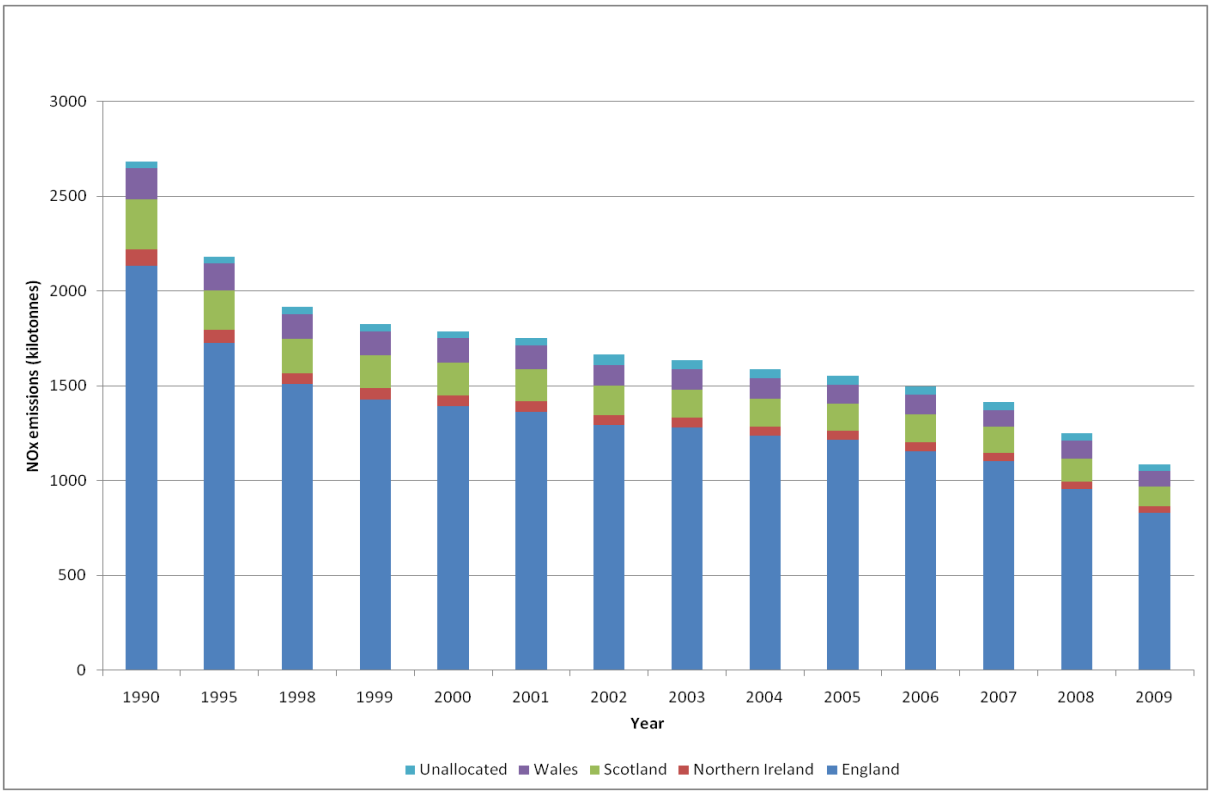
- **Power Generation (1A1a).** Since 1988 the electricity generators have adopted a programme of progressively fitting low-NO_x burners to their 500 MWe (megawatt electric) or larger coal fired units. More recently the increased use of nuclear generation and the introduction of CCGT (Combined Cycle Gas 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 2008 and 2009, there was an 18% decrease in the emissions from coal burning power stations due to the use of BOFA, as well as the decreased consumption of coal.

- **Industrial Combustion (1A2).** The emissions from industrial combustion have declined by 63% since 1970 and they currently contribute 18% 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 60% since 1990.

[5] A sensitive parameter in the emission calculations for petrol cars is the assumption made about the proportion of the fleet with catalyst systems that have failed, for example due to mechanical damage or failure of the lambda sensor. Following discussions with DfT, it is assumed that the failure rate is 5% per annum for all Euro standards and that up to 2008, only 20% of failed catalysts were rectified properly, but those that were rectified were done so within a year of failing. The revisions are based on evidence on fitting of replacement catalysts. According to DfT there is evidence that a high proportion of replacement catalysts were not Type Approved and do not restore the emission performance of the vehicle to its original level (DfT 2009). This is being addressed through the Regulations Controlling Sale and Installation of Replacement Catalytic Converters and Particle Filters for Light Vehicles for Euro 3 (or above) LDVs after June 2009. Therefore a change in the repair rate is taken into account for Euro 3 and above petrol LDVs from mid-2009, assuming all failed vehicles are rectified properly.

Figure 2-19 UK Nitrogen Oxides Emissions by Constituent Country, 1990-2009



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 2-13** shows how total UK NO_x emissions are split between the 4 constituent countries and **Table 2-14** shows per capita emissions.

Table 2-13 Proportion of UK Nitrogen Oxides Emissions by Constituent Country

Year	England	Scotland	Wales	N Ireland	Unallocated
1990	79%	10%	6%	3%	1%
2009	77%	10%	7%	3%	3%

Table 2-14 Emissions of NO_x per capita by Constituent Country (kg/head)

	England	Scotland	Wales	N Ireland	UK
1990	45	52	57	56	47
2009	16	20	27	18	18
DA/UK (2009)	91%	115%	153%	104%	-

2.3.1 England Nitrogen Oxides Inventory by NFR Sector, 1990-2009

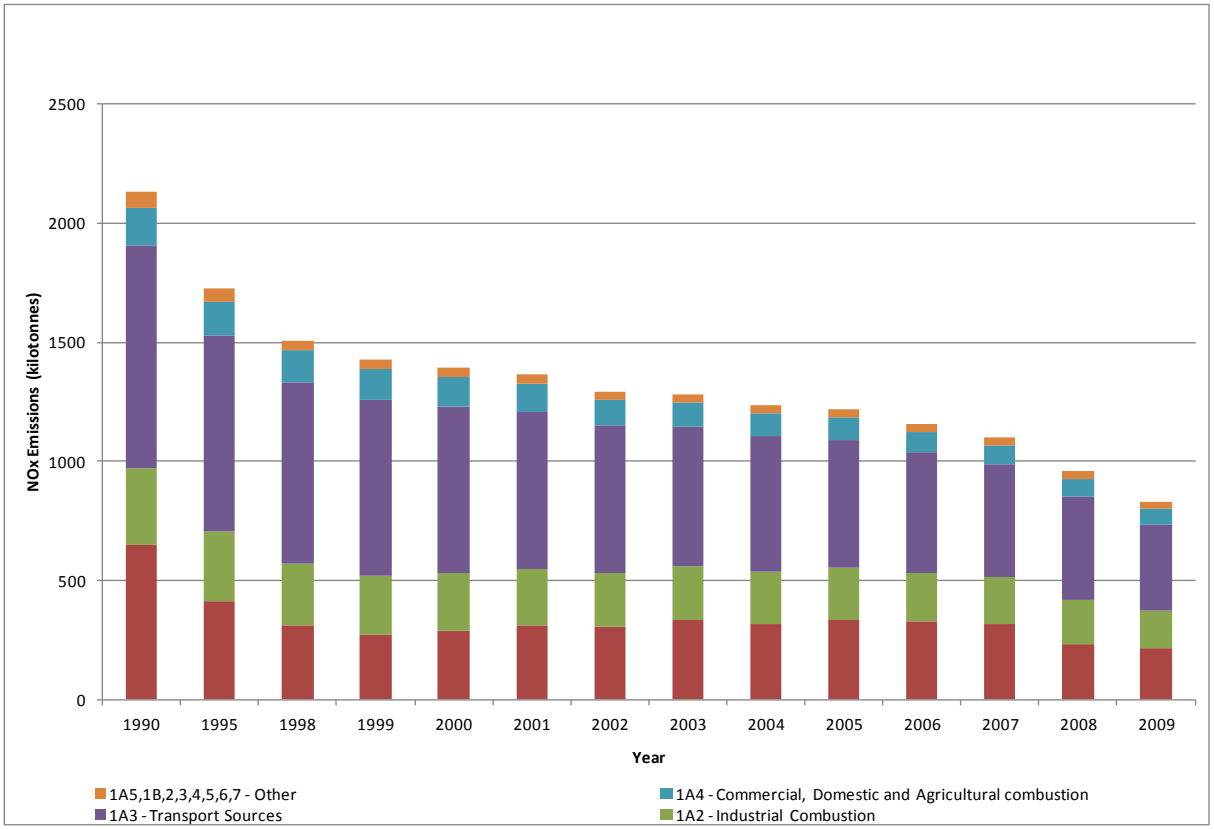
The table and graph below give a summary of the NO_x emissions in England by broad NFR sector categories. The detailed data are available in Appendix E.

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

NFR Code	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2009 (%)
1A1 - Energy Industries	650	414	311	274	292	314	304	336	317	336	327	316	231	214	26%
1A2 - Industrial Combustion	320	294	263	249	242	232	226	221	223	217	207	201	189	162	19%
1A3 - Transport Sources	939	820	761	735	698	661	623	587	566	538	506	473	431	359	43%
1A4 - Commercial, Domestic and Agricultural	155	143	135	130	122	119	107	102	95.8	90.6	82.5	76.7	74.0	67.0	8%
1A5,1B,2,4,5, 6 - Other	68.9	57.0	39.5	41.4	37.9	37.8	33.4	35.5	36.5	33.8	33.1	35.4	32.4	28.9	3%
Total	**2132**	**1728**	**1509**	**1430**	**1392**	**1364**	**1293**	**1281**	**1239**	**1217**	**1156**	**1102**	**958**	**831**	**100%**

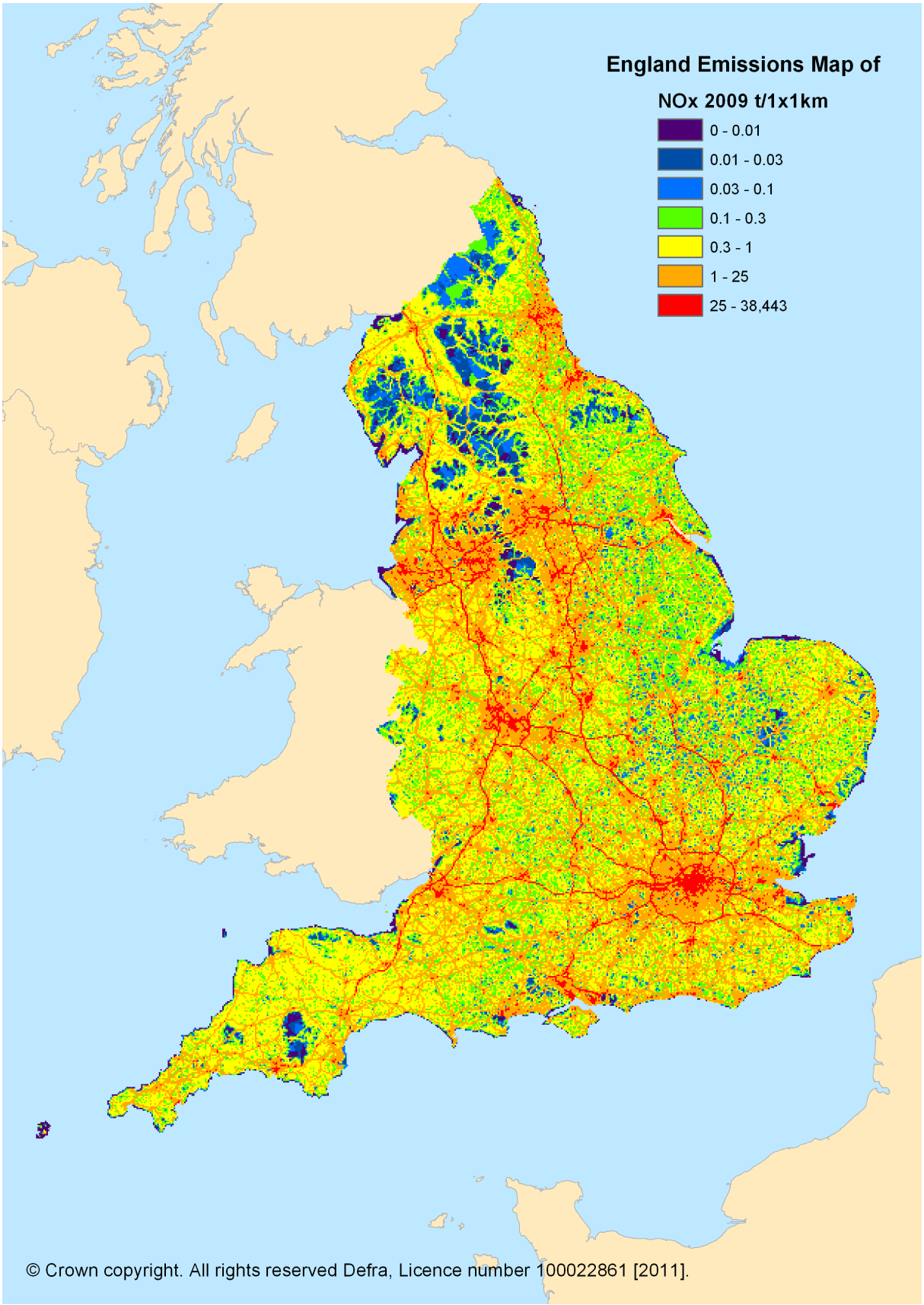
Units: kilotonnes

Figure 2-20 England Nitrogen Oxides Emissions by Source, 1990-2009



England's NO_x emissions have declined by 61% since 1990 and account for 77% of the UK total. Power generation (1A1a) is a very significant source, accounting for 23% of the England total in 2009, although emissions from this source have reduced by 69% since 1990. In 2009, 36% of NO_X emissions in England stem from road transport combustion sources (1A3bi-iv: down by 66% since 1990), whilst 19% stem from industrial combustion (1A2: down 49% since 1990). Notable increases in emissions arise from railways (1A3c: up by 73% since 1990 accounting for 3% of the 2009 England's total emission) and from international aviation landing and take off (LTO) (1A3ai(i): up by 106% since 1990 and 1A3aii(i): up by 30% since 1990 in 2009). Aviation emissions account for only 1% of the emissions in England in 2009.

Figure 2-21 Map of Nitrogen Oxides Emissions in England, 2009



2.3.2 Scotland Nitrogen Oxides Inventory by NFR Sector, 1990-2009

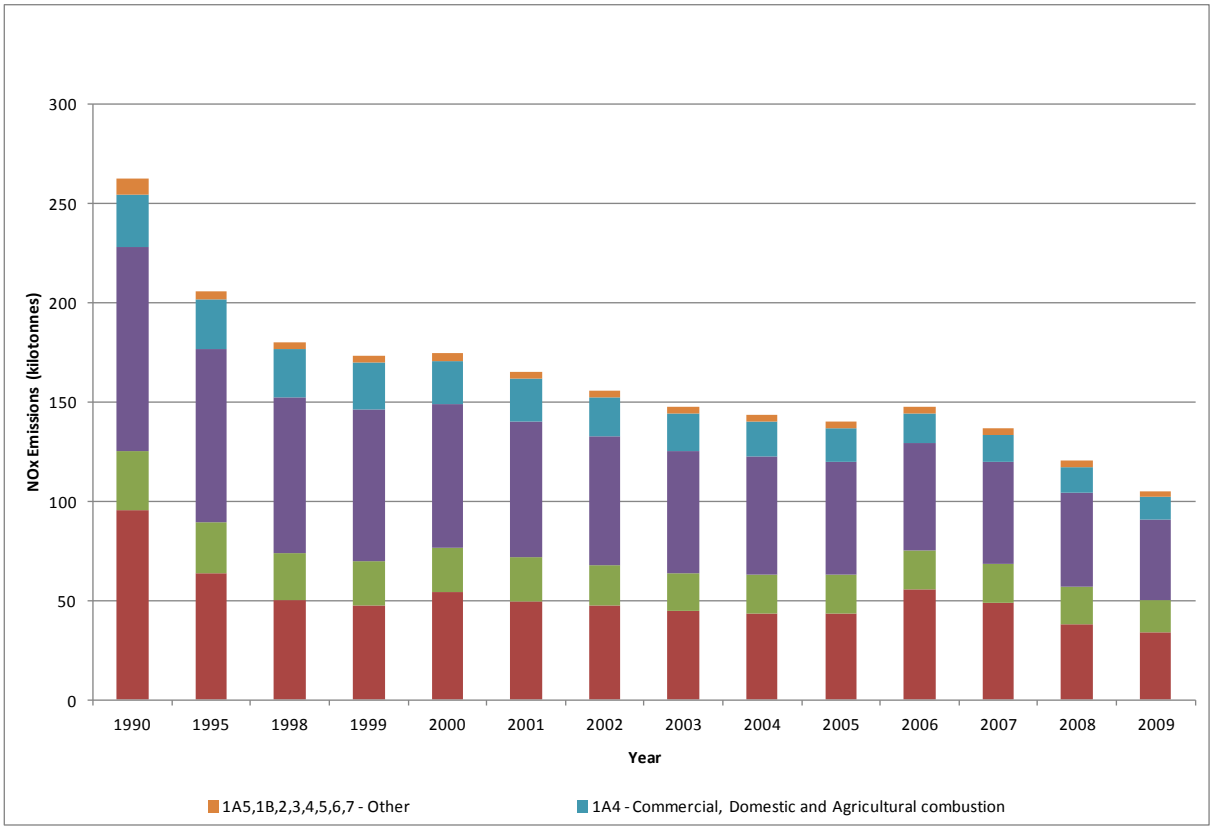
The table and graph below give a summary of the NO_x emissions in Scotland by broad NFR sector categories. The detailed data are available in Appendix E.

Table 2-16 Scotland Emissions of Nitrogen Oxides by NFR source sector

NFR Code	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2009 (%)
1A1 - Energy Industries	95.6	63.7	50.1	47.5	54.3	49.4	47.8	45.1	43.6	43.3	55.7	48.9	37.8	34.3	33%
1A2 - Industrial Combustion	29.7	25.5	23.5	22.4	22.3	22.5	19.8	18.8	19.6	19.5	19.4	19.4	19.1	16.0	15%
1A3 - Transport Sources	103	87.5	79.1	76.7	72.1	68.0	64.9	61.5	59.4	57.3	54.5	51.7	47.7	40.5	39%
1A4 -Commercial, Domestic and Agricultural	26.5	25.1	24.1	23.5	22.1	21.8	20.0	18.9	17.5	16.7	15.0	13.6	12.9	11.8	11%
1A5,1B,2,4,5,6 - Other	8.0	3.8	3.1	3.7	3.6	3.8	3.5	3.5	3.5	3.4	3.2	3.0	2.9	2.5	2%
Total	**262**	**206**	**180**	**174**	**174**	**166**	**156**	**148**	**144**	**140**	**148**	**137**	**120**	**105**	**100%**

Units: kilotonnes

Figure 2-22 Scotland Nitrogen Oxides Emissions by Source, 1990-2009

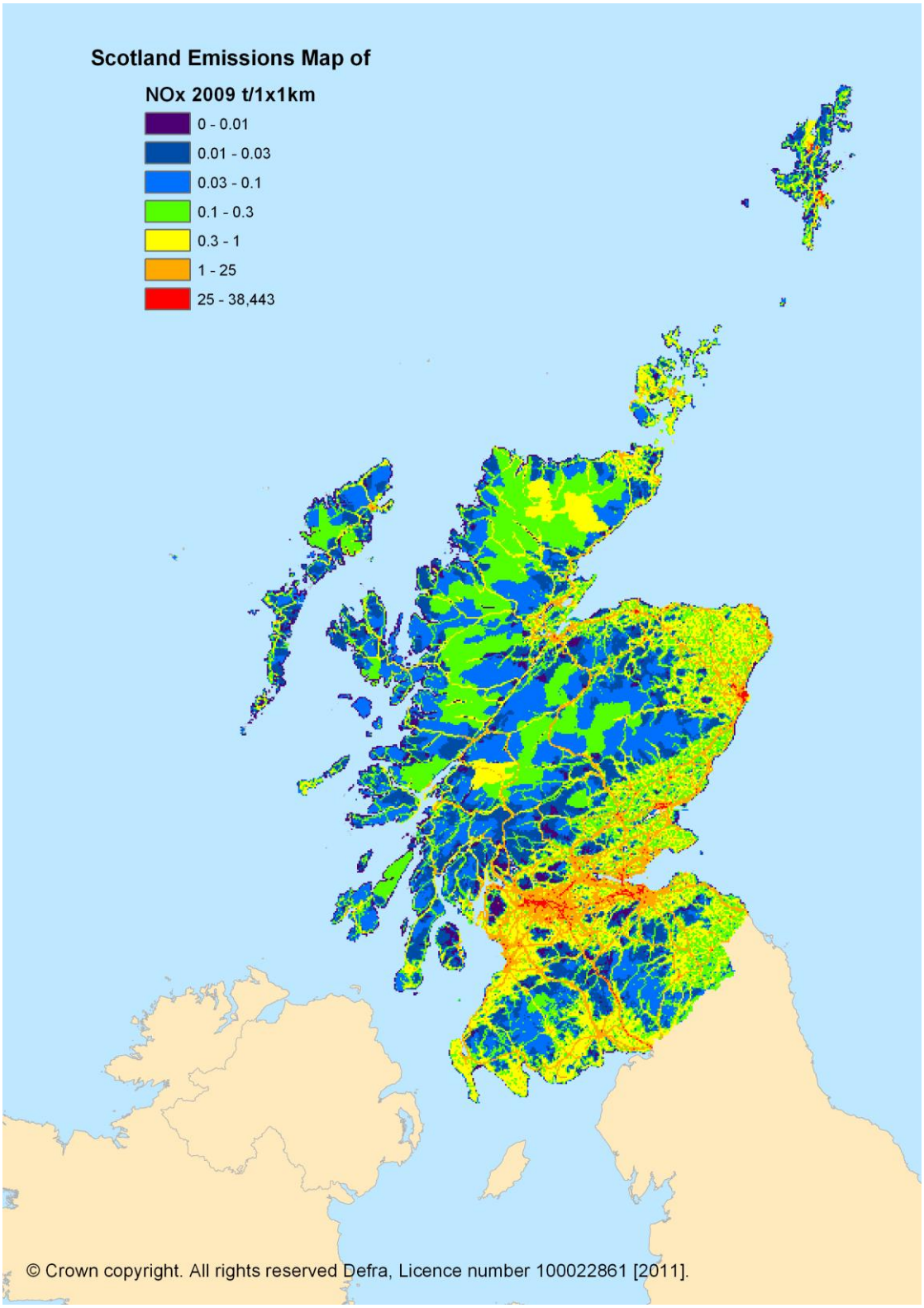


Scotland's NO_x emissions have declined by 60% since 1990 (Figure 2-22) and currently account for 10% of the UK total. Power generation (1A1a) is a very significant source of NO_x emissions, accounting for 27% of the Scotland total in 2009; although emissions from this source have reduced by 68% since 1990. *(Note that in the table and 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 32% between 2006 and 2009 (to 11,896 GWh). Between 2008 and 2009, coal-fired generation has increase slightly by 1.7%, whilst gas-fired generation has decreased by 20.6% to 7,615 GWh. A further 30% of NO_x emissions in Scotland arise from road transport sources (1A3bi-iv: down by 66% since 1990), 15% stem from industrial combustion (1A2: down 46% since 1990) and 6% is from

agricultural mobile machinery (1A4cii, down 57% since 1990). Increases in emissions are apparent mostly in relatively minor source sectors such as domestic and international aviation landing and takeoff (LTO) (1A3ai(i): up by 151% since 1990 and 1A3aii(i): up by 16% since 1990 in 2009). Emissions from rail have also increased by 74% since 1990, now contributing 3% to the total emissions in Scotland. This is due to increases in fuel oil consumption by the rail sector from 1990 due to rise in passenger train km and freight train km during this time.

Figure 2-23 Map of Nitrogen Oxides Emissions in Scotland, 2009



2.3.3 Wales Nitrogen Oxides Inventory by NFR Sector, 1990-2009

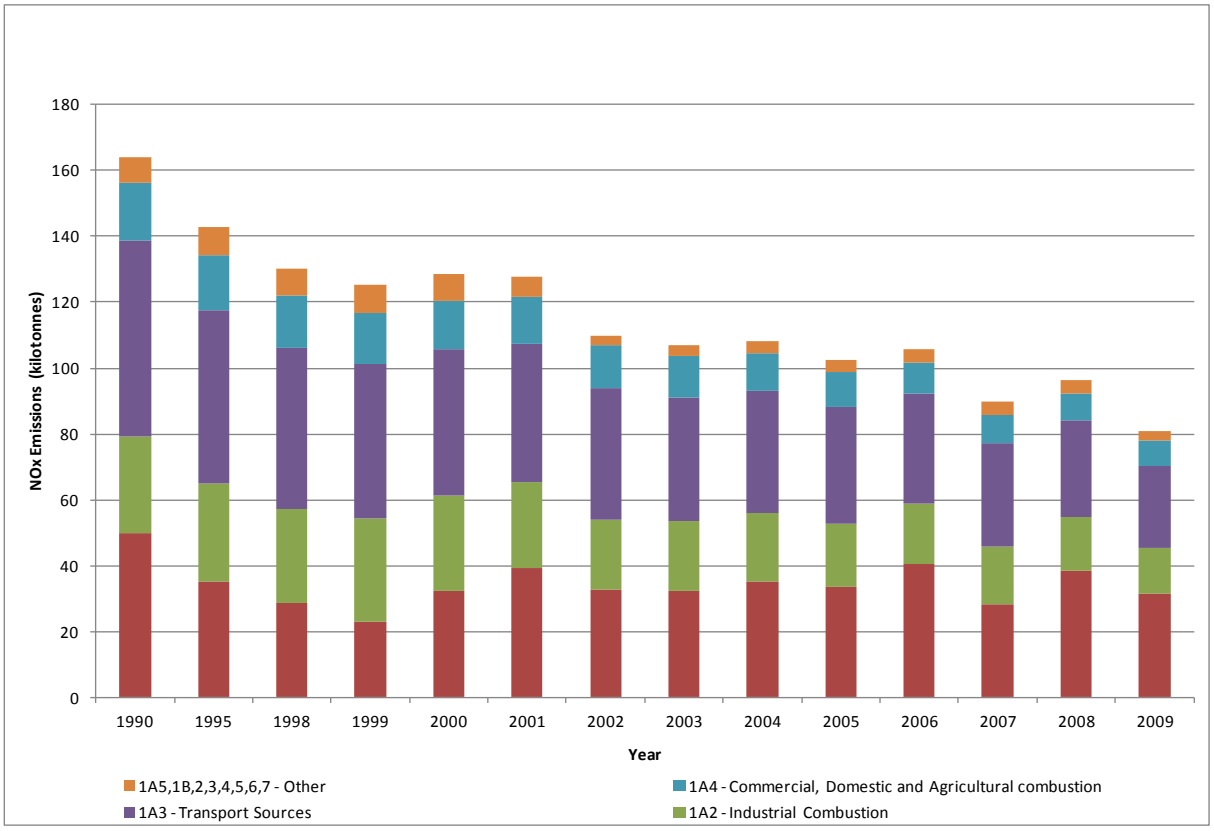
The table and graph below give a summary of the NO_X emissions in Wales by broad NFR sector categories. The detailed data are available in Appendix E.

Table 2-17 Wales Emissions of Nitrogen Oxides by NFR source sector

NFR Code	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2009 (%)
1A1 - Energy Industries	49.9	35.2	28.5	23.2	32.5	39.2	32.6	32.2	35.1	33.4	40.7	28.3	38.4	31.5	39%
1A2 - Industrial Combustion	29.3	29.8	28.8	31.2	28.8	26.0	21.3	21.2	21.0	19.5	18.4	17.4	16.5	14.0	17%
1A3 - Transport Sources	59.7	52.6	48.8	46.9	44.6	42.0	40.0	37.7	36.9	35.2	33.1	31.4	29.3	24.9	31%
1A4 - Commercial, Domestic and Agricultural	17.2	16.6	15.8	15.4	14.5	14.2	13.1	12.4	11.5	10.8	9.7	8.7	8.2	7.6	9%
1A5,1B,2,4,5,6 - Other	7.7	8.7	8.3	8.5	8.2	6.3	2.9	3.3	3.7	3.4	3.9	4.0	3.9	2.8	3%
Total	**164**	**143**	**130**	**125**	**129**	**128**	**110**	**107**	**108**	**102**	**106**	**90**	**96**	**81**	**100%**

Units: kilotonnes

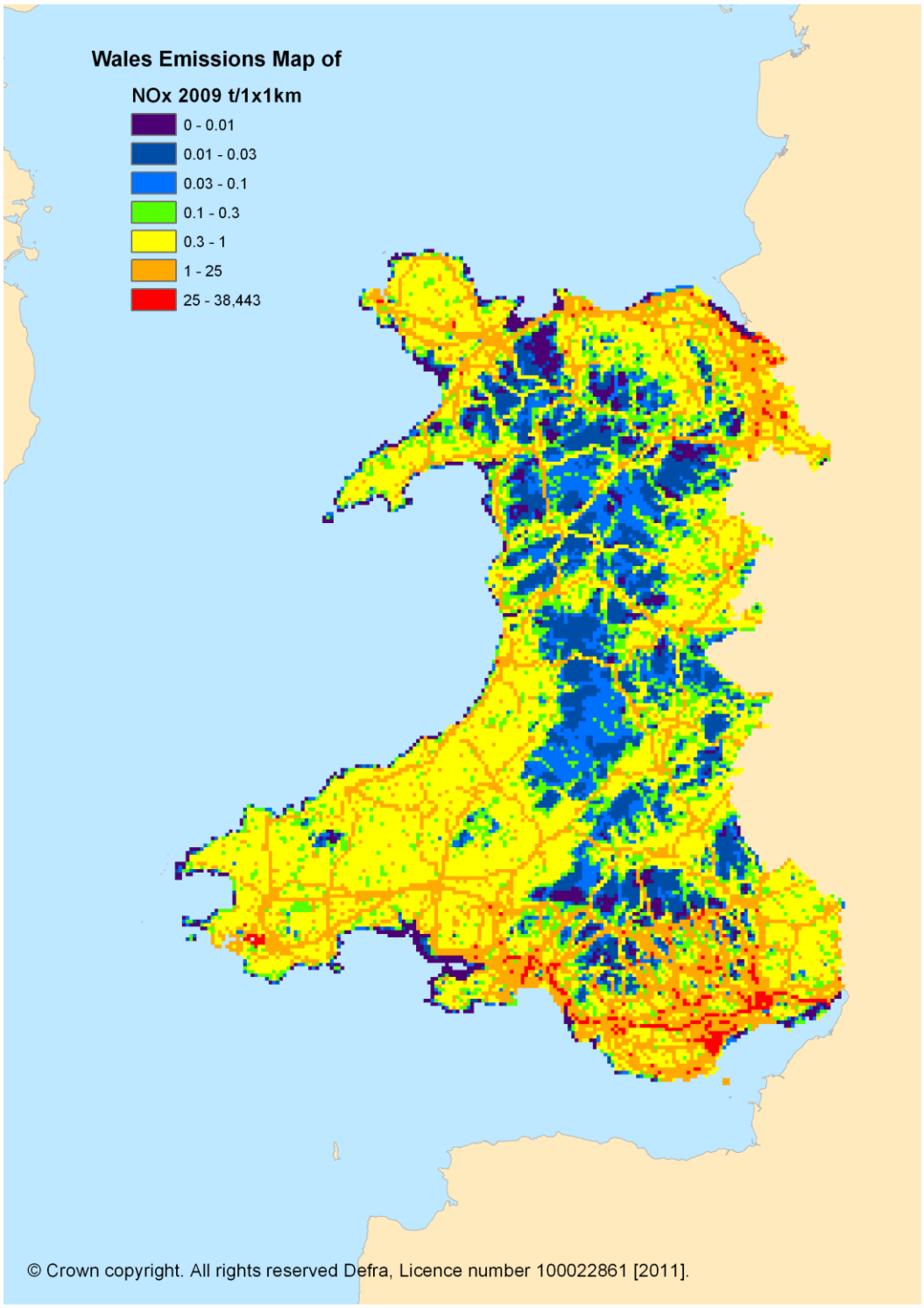
Figure 2-24 Wales Nitrogen Oxides Emissions by Source, 1990-2009



Wales NO_x emissions have declined by 51% since 1990 and accounted for 7% of the UK total in 2009. Power generation (1A1a) accounts for 30% of the Wales NO_x inventory total in 2009; emissions from this source have reduced by 41% 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). Between 2007 and 2008, coal-fired generation increased by nearly 83% (up to 9,364 GWh) once Aberthaw came back on-line, then decreasing between 2008 and 2009 by 30.1% (down to 6,547 GWh). Gas-fired generation has fallen by 10.5% between 2008 and 2009 to 14,376 GWh. As a result, the overall NO_X emissions from the sector decreased by 34% between 2008 and 2009 (Figure 2-24). A further 22% of NO_x emissions in Wales stem from road transport combustion sources (1A3bi-iv: down by 67% since 1990), 17% stem from industrial

combustion (1A2: down 52% since 1990) and 6% of emissions are from petroleum refining (1A1b: down 23% since 1990). Notable increases in emissions arise from railways (1A3c: up by 174% since 1990 to 5% of the 2009 Wales total) and from aviation landing and takeoff (LTO) (1A3ai(i): up by 114% since 1990 and 1A3aii(i): up by 117% since 1990 in 2009; combined, these sources account for less than 1% of the emissions in Wales in 2009).

Figure 2-25 Map of Nitrogen Oxides Emissions in Wales, 2009



2.3.4 Northern Ireland Nitrogen Oxides Inventory by NFR Sector, 1990-2009

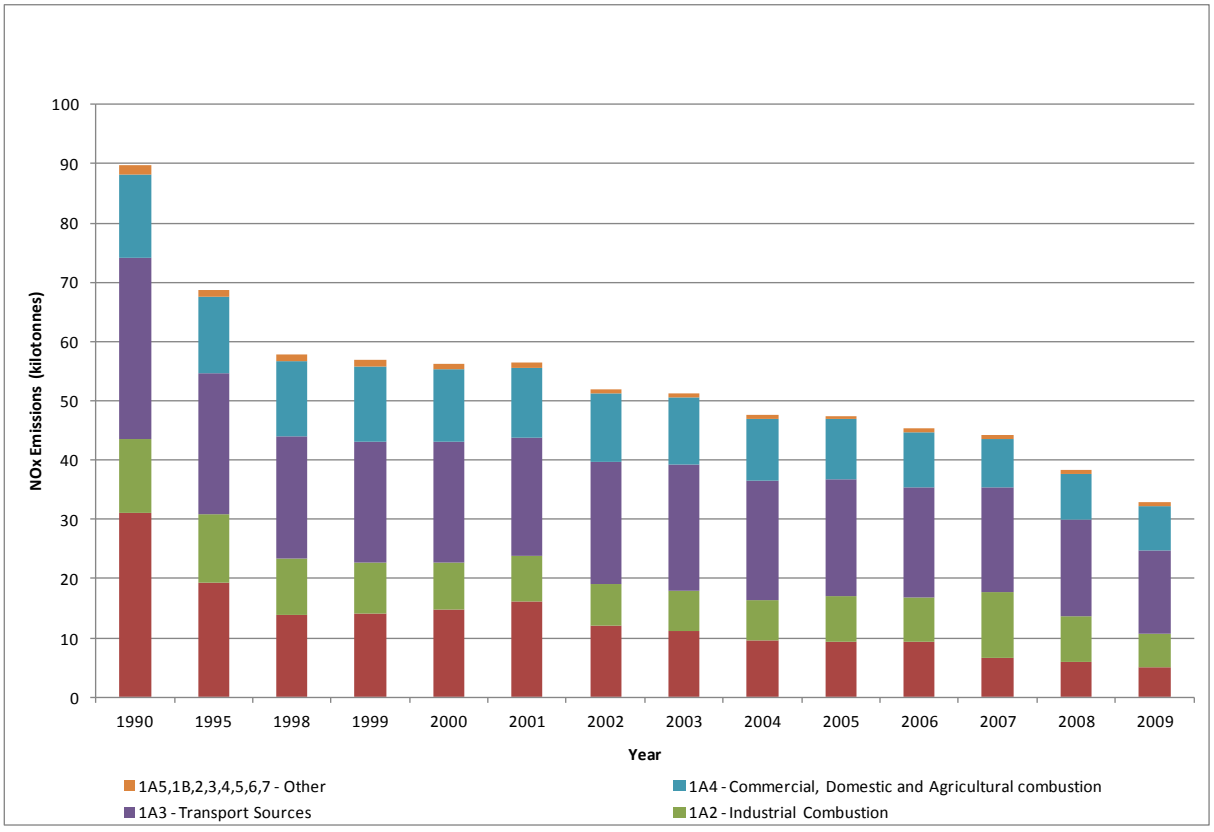
The table and graph below give a summary of the NO_x emissions in Northern Ireland by broad NFR sector categories. The detailed data are available in Appendix E.

Table 2-18 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	2009	2009(%)
1A1 - Energy Industries	31.0	19.2	13.8	14.1	14.8	16.2	12.1	11.3	9.5	9.3	9.3	6.6	6.1	5.1	16%
1A2 - Industrial Combustion	12.7	11.6	9.6	8.6	7.9	7.7	7.0	6.7	6.8	7.8	7.6	11.1	7.5	5.6	17%
1A3 - Transport Sources	30.5	23.8	20.6	20.6	20.3	19.8	20.5	21.3	20.2	19.7	18.5	17.6	16.3	14.0	43%
1A4 - Commercial, Domestic and Agricultural	13.9	13.0	12.8	12.7	12.2	11.9	11.6	11.2	10.4	10.0	9.2	8.2	7.8	7.5	23%
1A5,1B,2,4,5, 6 - Other	1.7	1.1	0.9	1.0	0.9	0.8	0.6	0.7	0.7	0.7	0.7	0.7	0.7	0.6	2%
Total	**89.8**	**68.7**	**57.7**	**56.9**	**56.2**	**56.5**	**51.9**	**51.2**	**47.6**	**47.5**	**45.4**	**44.2**	**38.4**	**32.8**	**100%**

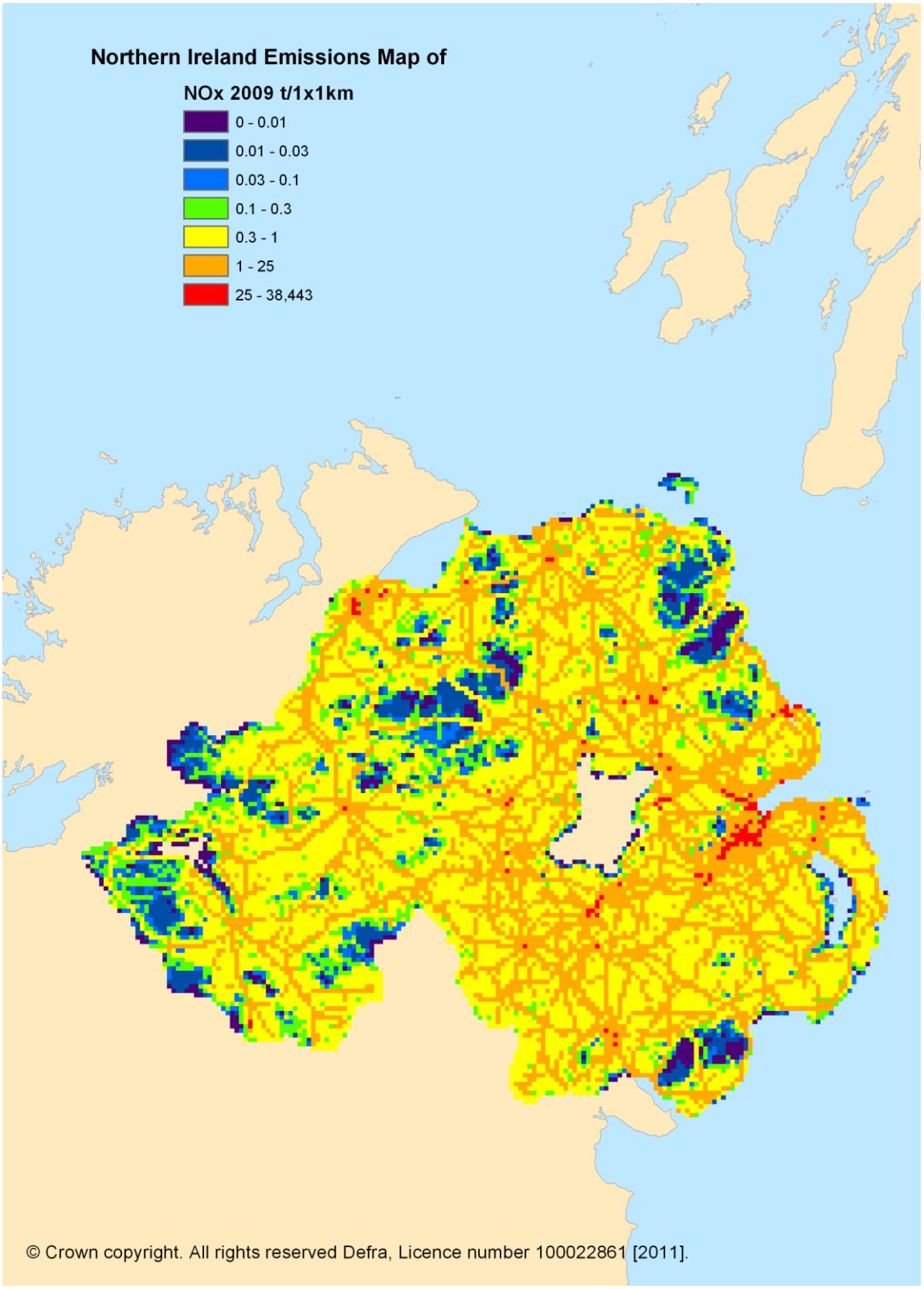
Units: kilotonnes

Figure 2-26 Northern Ireland Nitrogen Oxides Emissions by Source, 1990-2009



Northern Ireland's NO_x emissions have declined by 63% since 1990 and account for only 3% of the UK total. Power generation (1A1a) accounts for 16% of the Northern Irish total in 2009; emissions from this source have reduced by 84% since 1990. 37% of NO_X emissions in Northern Ireland stem from road transport combustion sources (1A3bi-iv: down by 58% since 1990), whilst 17% stem from industrial combustion (1A2: down 56% since 1990) and 11% are from agricultural off road machinery (1A4cii: down 56% since 1990). Notable increases in emissions arise from very minor sources sector such as international and domestic aviation LTO (1A3ai(i): up by 310% since 1990 and 1A3aii(i): up by 85% since 1990). However, combined these two sources account for less than 1% of the Northern Ireland total emission in 2009.

Figure 2-27 Map of Nitrogen Oxides Emissions in Northern Ireland, 2009



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 21% 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 44% of the UK total NMVOC emission in 2009. 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 2009.

- **Processes in wood, paper pulp and food & drink.** Emissions from the food and drink industry comprised approximately 10% of the total NMVOC emission in 2009. 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 11% of NMVOC emissions, with road transport (1A3b) accounting for most of this. During the 1990s, these emissions have declined significantly due to the increased use of catalytic converters and fuel switching from petrol to diesel cars. Between 2008 and 2009, emissions from passenger cars fell by 43% due to the assumed improvements in catalyst repair rates.

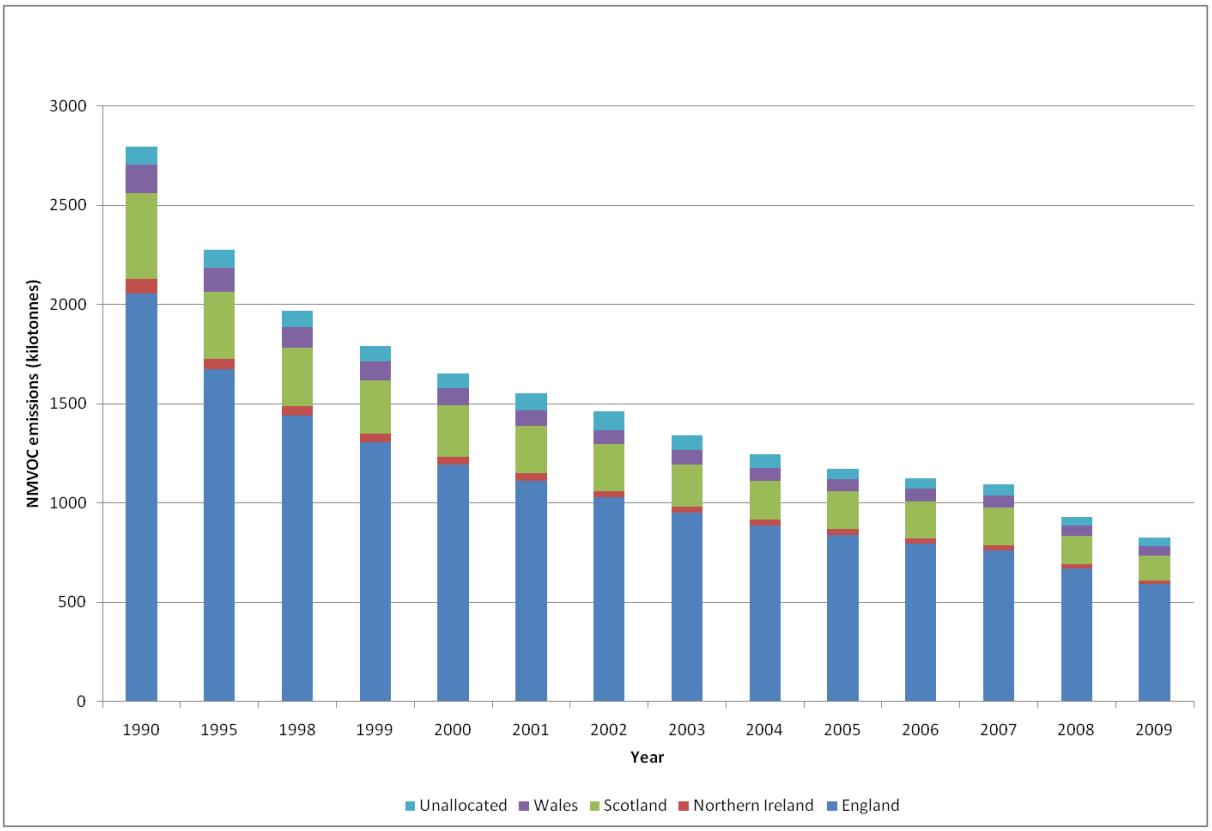
- **Offshore oil and gas.** Emissions from this sector have increased substantially with the growth of the UK's offshore activities, and stem primarily from tanker loading / unloading.

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 69% between 1990 and 2009, 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, 1990-2009



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 2-19** shows how total UK NMVOC emissions are split between the 4 constituent countries and **Table 2-20** shows per capita emissions.

Table 2-19 Proportion of UK NMVOC Emissions by Constituent Country

Year	England	Scotland	Wales	N Ireland	Unallocated
1990	74%	15%	5%	3%	4%
2009	72%	15%	6%	2%	5%

Table 2-20 Emissions of NMVOC per capita by Constituent Country (kg/head)

	England	Scotland	Wales	N Ireland	UK
1990	42	78	47	43	47
2009	11	24	15	11	13
DA/UK (2009)	85%	180%	115%	86%	-

2.4.1 England NMVOC Inventory by NFR Sector, 1990-2009

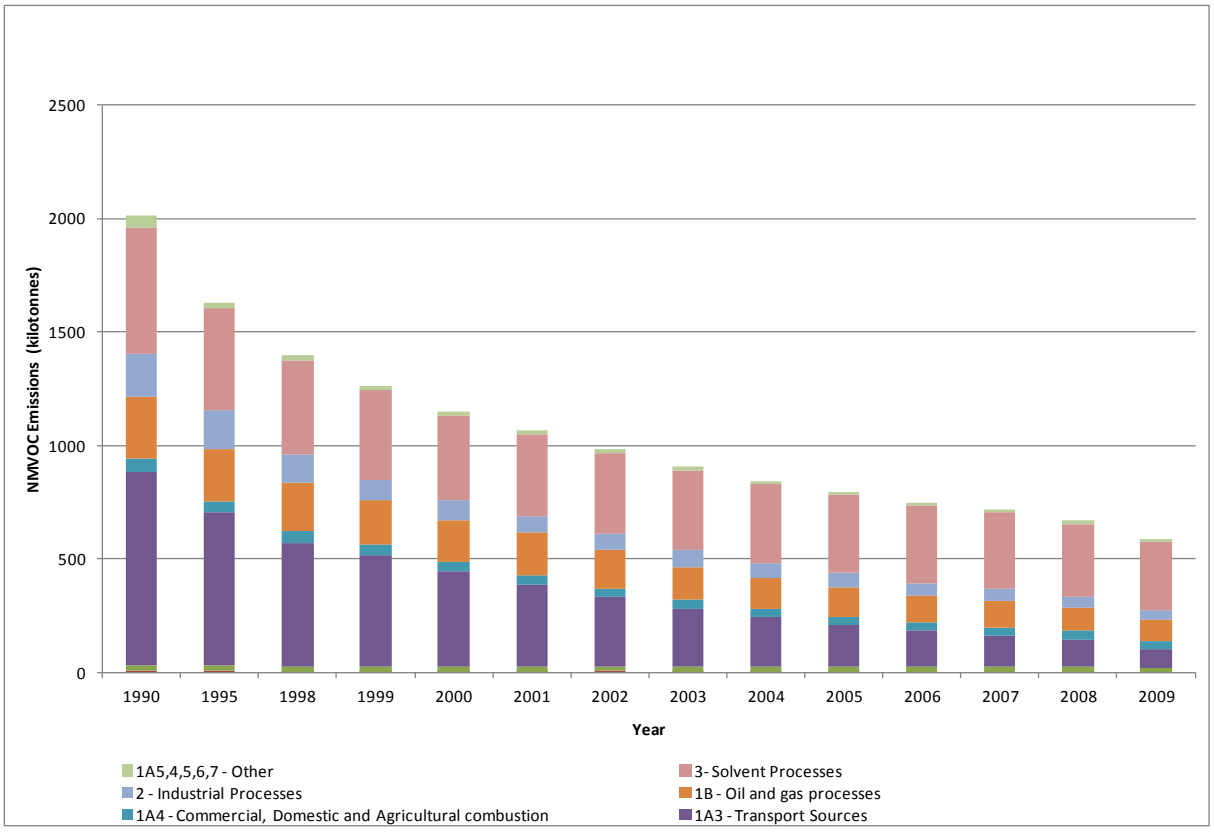
The table and graph below give a summary of the NMVOC emissions in England by broad NFR sector categories. The detailed data are available in Appendix G.

Table 2-21 England Emissions of NMVOC by NFR Source Sector

NFR Code	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2009 (%)
1A1 - Energy Industries	5.8	6.1	3.6	3.3	4.7	4.0	5.7	4.2	4.1	3.8	4.0	3.0	3.1	2.8	0%
1A2 - Industrial Combustion	23.1	23.8	24.0	23.6	23.2	23.3	22.7	22.4	23.1	22.5	22.2	22.5	21.5	18.6	3%
1A3 - Transport Sources	853	674	543	487	417	358	303	255	216	183	158	139	122	79.5	13%
1A4 - Commercial, Domestic and Agricultural	63.7	49.2	49.8	51.5	44.8	42.7	39.3	38.3	37.9	37.1	35.8	36.3	37.8	36.5	6%
1B - Oil and gas processes	271	231	217	194	183	187	167	141	134	130	118	113	103	95.1	16%
2 - Industrial Processes	186	169	122	90.6	87.3	76.3	75.2	80.4	64.0	60.8	54.3	53.0	48.1	41.2	7%
3- Solvent Processes	556	450	416	393	372	360	354	349	349	343	343	337	319	303	51%
1A5,4,5,6,7 - Other	54.8	25.7	21.9	20.8	19.8	18.3	17.5	16.6	15.6	15.1	15.0	14.9	14.3	14.0	2%
Total	**2013**	**1629**	**1398**	**1264**	**1151**	**1070**	**984**	**907**	**844**	**796**	**750**	**718**	**669**	**591**	**100%**

Units: kilotonnes

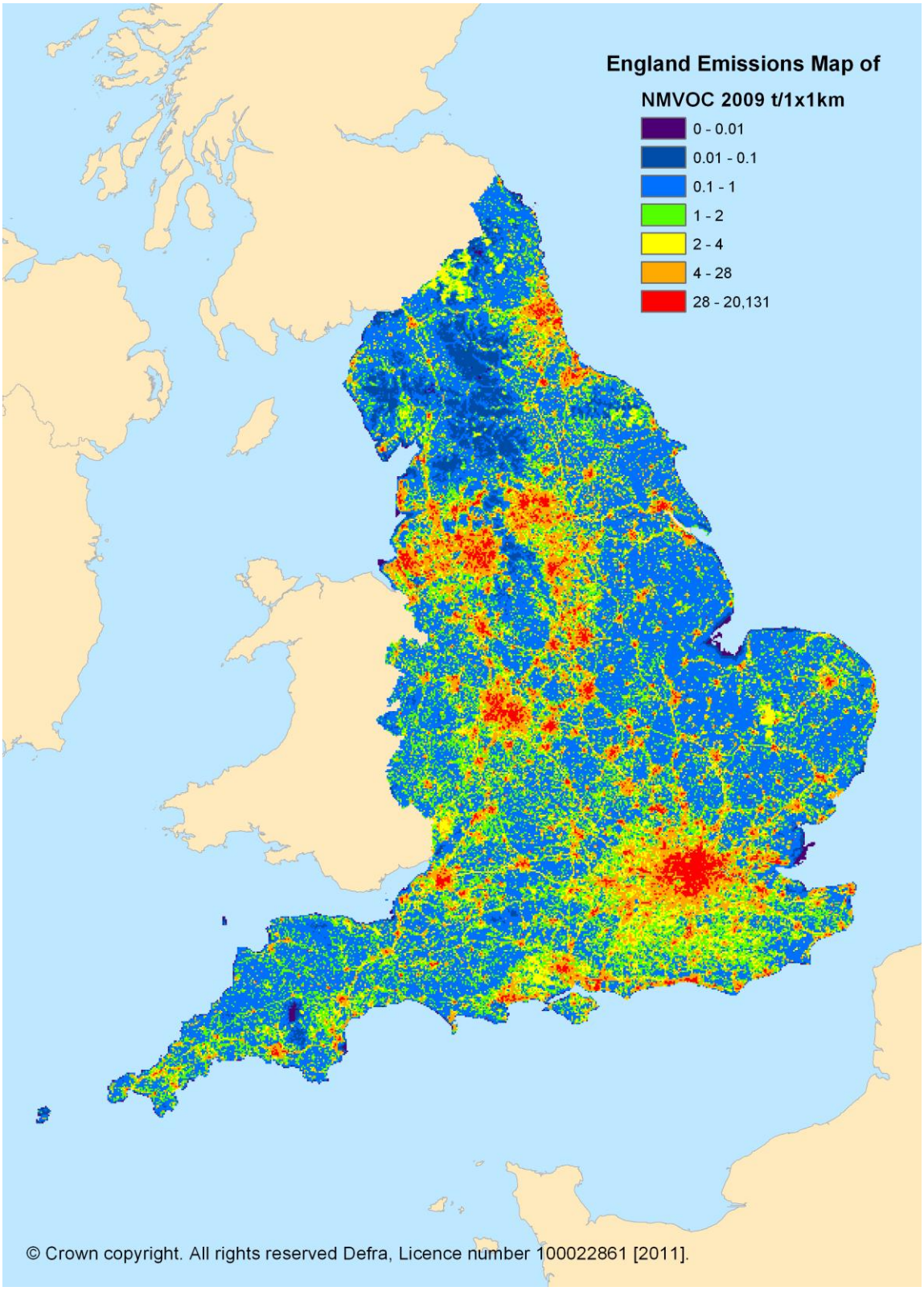
Figure 2-29 England NMVOC Emissions by Source, 1990-2009



England's NMVOC emissions have declined by 71% since 1990 and account for 72% of the UK total. Solvent processes (3) are a very significant source, accounting for 51% of the total in 2009. Emissions from this source have reduced by 46% since 1990. Fugitive emissions from fuels (1B) account for 16% of the total in 2009 with emissions down 65% since 1990. Further signification source are road transport, including evaporative losses (1A3bi-v), these are 13% of the total in 2009,

emissions from this source have reduced 91% since 1990. Industrial processes (2) accounts for 7% of the total in 2009, with emissions down 78% since 1990.

Figure 2-30 Map of NMVOC Emissions in England, 2009



2.4.2 Scotland NMVOC Inventory by NFR Sector, 1990-2009

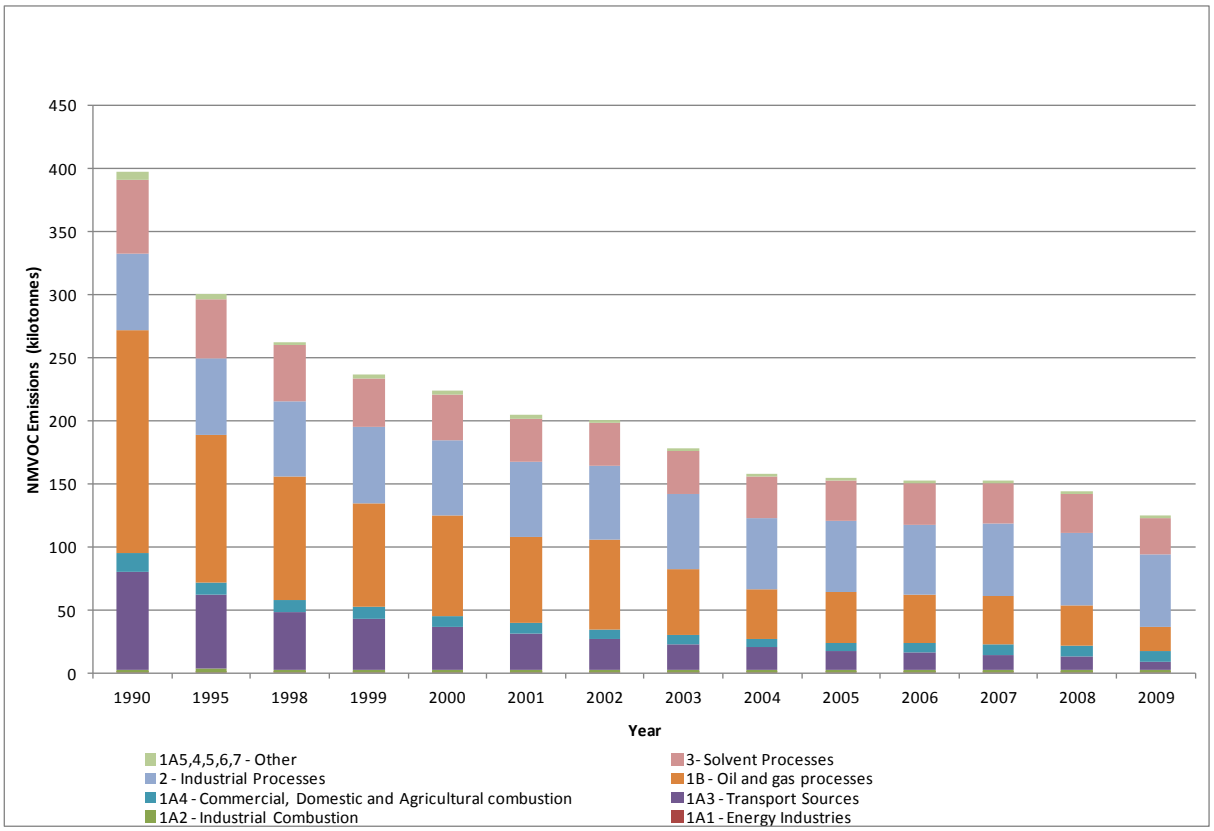
The table and graph below give a summary of the NMVOC emissions in Scotland by broad NFR sector categories. The detailed data are available in Appendix G.

Table 2-22 Scotland Emissions of NMVOC by NFR Source Sector

NFR Code	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2009(%)
1A1 - Energy Industries	0.8	0.9	0.7	0.4	0.6	0.5	0.7	0.5	0.6	0.6	0.7	0.4	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	2.0	2.0	2.1	2.0	1.7	1%
1A3 - Transport Sources	77.6	58.9	45.2	40.1	34.1	28.9	24.5	20.6	17.5	14.9	13.2	11.6	10.4	6.7	5%
1A4 - Commercial, Domestic and Agricultural	14.5	9.8	9.7	10.0	8.6	8.0	7.3	7.2	6.8	6.8	7.9	8.2	8.6	8.5	7%
1B - Oil and gas processes	177	117	97.8	81.6	79.0	68.4	71.5	52.5	39.2	40.2	38.1	38.5	32.2	18.8	15%
2 - Industrial Processes	60.5	60.3	59.7	61.1	60.6	59.4	58.6	59.6	56.6	55.9	56.1	57.8	57.3	57.7	46%
3- Solvent Processes	58.5	47.8	44.5	38.3	36.1	34.8	33.8	33.3	33.3	32.5	32.4	32.0	30.7	29.3	23%
1A5,4,5,6,7 - Other	6.0	3.4	2.9	2.7	2.6	2.3	2.2	2.1	2.0	1.9	2.0	2.0	1.9	1.8	1%
Total	**397**	**300**	**263**	**236**	**224**	**204**	**201**	**178**	**158**	**155**	**152**	**153**	**144**	**125**	**100%**

Units: kilotonnes

Figure 2-31 Scotland NMVOC Emissions by Source, 1990-2009

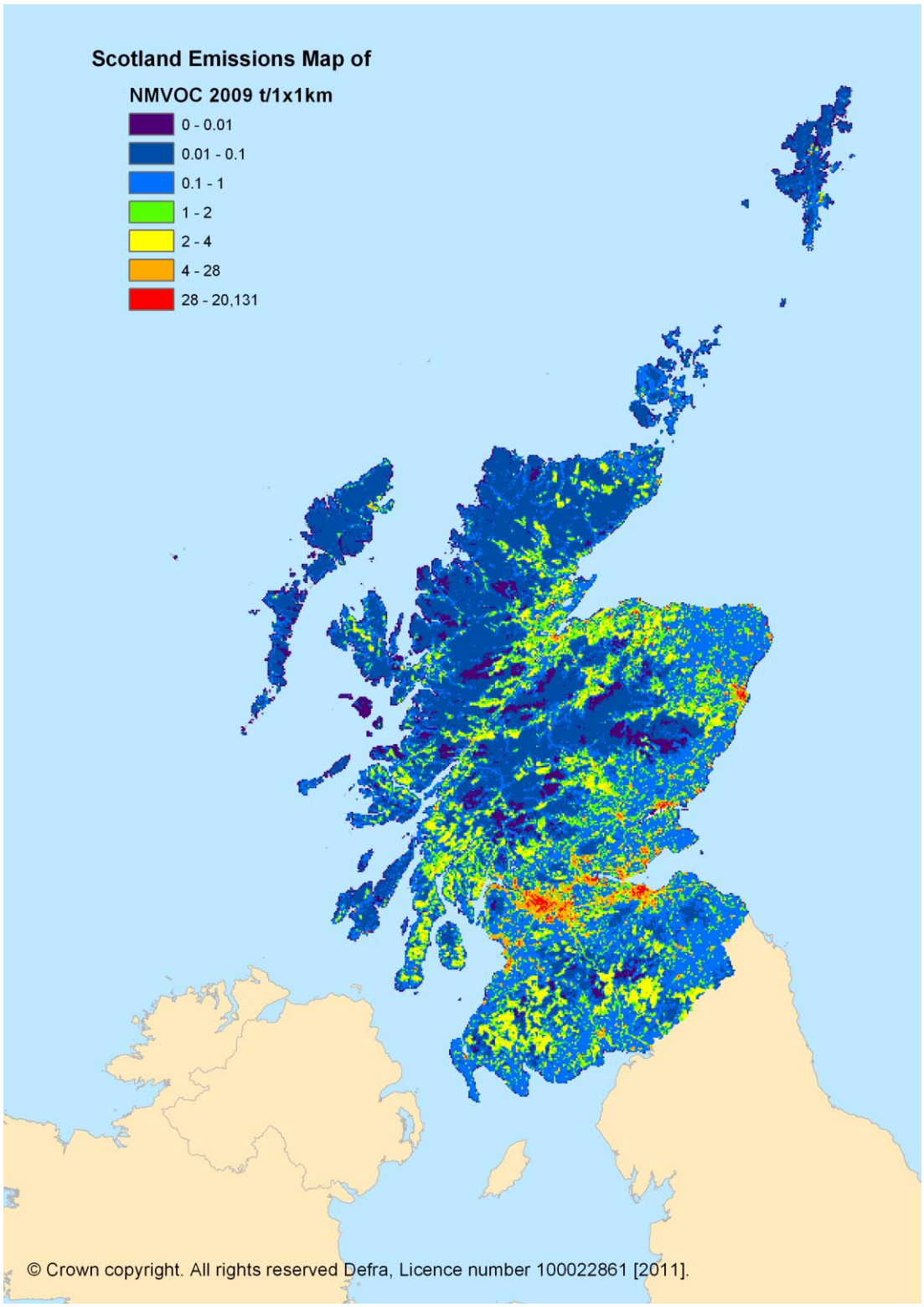


Scotland's NMVOC emissions have declined by 68% since 1990 and account for 15% of the UK total. Industrial processes (2) are a significant source making up 46% of the total in 2009, with emissions down 5% since 1990. Industrial processes include food and drink emissions (2D2) dominated by brewers and distilleries. This is 42% of the Scottish total in 2009, up 23% since 1990. Other significant sources are solvents and other product use (3) which account for 23% of the total in 2009. Emissions from this source are down 50% since 1990. Fugitive emissions from fuels (1B) make up

15% of the total in 2009, these emissions have reduced by 89% since 1990. Road transport is also a significant source, including evaporative losses (1A3bi-v) accounting for 5% of the total in 2009, with emissions down 92% since 1990.

On a per capita basis, Scottish emissions are around 80% higher than the UK average, due to the high contribution of NMVOC emissions from food and drink processes.

Figure 2-32 Map of NMVOC Emissions in Scotland, 2009



2.4.3 Wales NMVOC Inventory by NFR Sector, 1990-2009

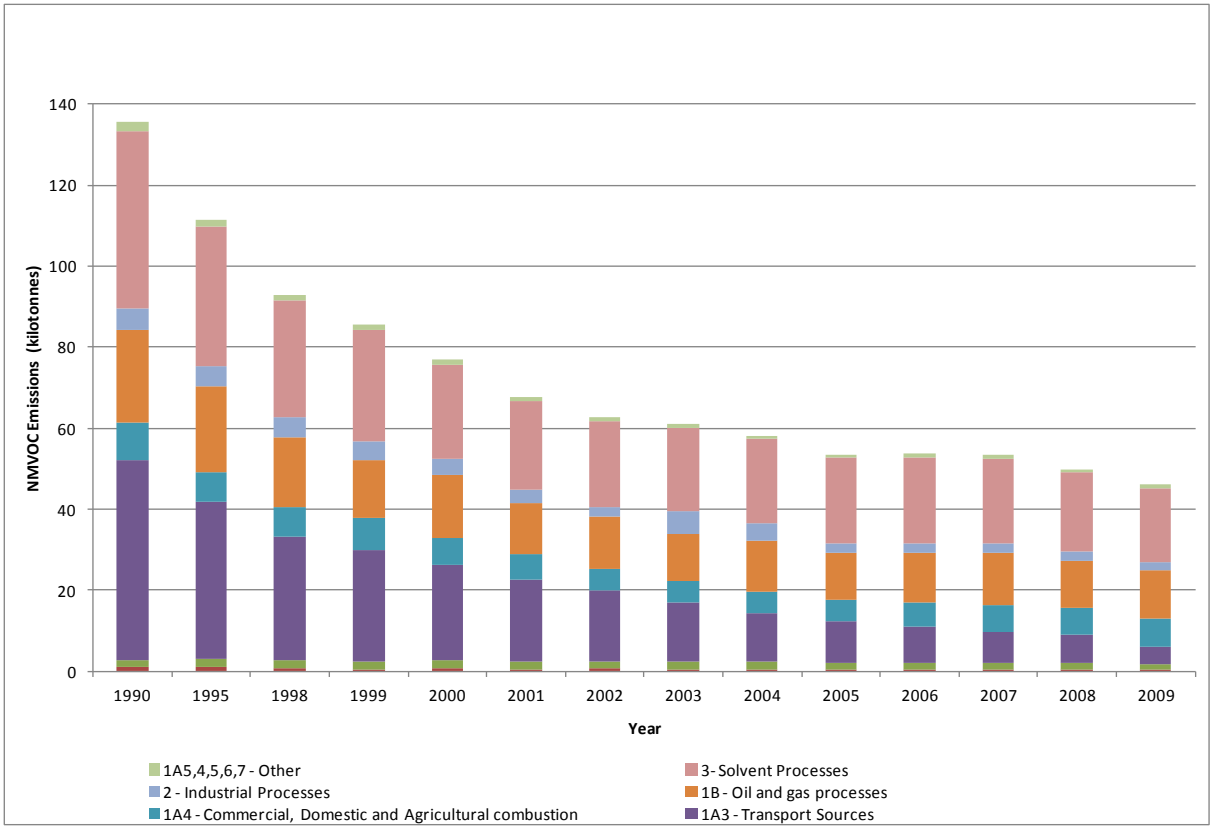
The table and graph below give a summary of the NMVOC emissions in Wales by broad NFR sector categories. The detailed data are available in Appendix G.

Table 2-23 Wales Emissions of NMVOC by NFR Source Sector

NFR Code	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2009 (%)
1A1 - Energy Industries	1.0	1.1	0.7	0.5	0.7	0.5	0.7	0.6	0.4	0.4	0.4	0.3	0.4	0.3	1%
1A2 - Industrial Combustion	1.8	1.9	1.9	2.0	2.1	2.0	1.9	2.0	1.9	1.7	1.7	1.7	1.6	1.4	3%
1A3 - Transport Sources	49.3	39.0	30.5	27.3	23.6	20.2	17.3	14.5	12.2	10.2	8.9	7.8	7.0	4.5	10%
1A4 - Commercial, Domestic and Agricultural	9.3	7.3	7.6	8.0	6.6	6.1	5.5	5.3	5.3	5.3	5.9	6.4	6.7	6.7	15%
1B - Oil and gas processes	22.8	20.9	17.2	14.3	15.4	12.7	12.9	11.7	12.4	11.6	12.2	13.1	11.6	12.0	26%
2 - Industrial Processes	5.5	5.2	5.0	4.6	4.1	3.3	2.2	5.4	4.2	2.3	2.4	2.3	2.2	2.1	4%
3- Solvent Processes	43.7	34.2	28.8	27.5	23.2	21.8	21.2	20.8	20.9	21.2	21.2	20.8	19.6	18.3	40%
1A5,4,5,6,7 - Other	2.2	1.6	1.3	1.2	1.2	1.1	1.0	1.0	0.9	0.9	0.9	0.9	0.8	0.8	2%
Total	**136**	**111**	**93.0**	**85.4**	**76.9**	**67.7**	**62.7**	**61.2**	**58.2**	**53.6**	**53.7**	**53.3**	**49.9**	**46.1**	**100%**

Units: kilotonnes

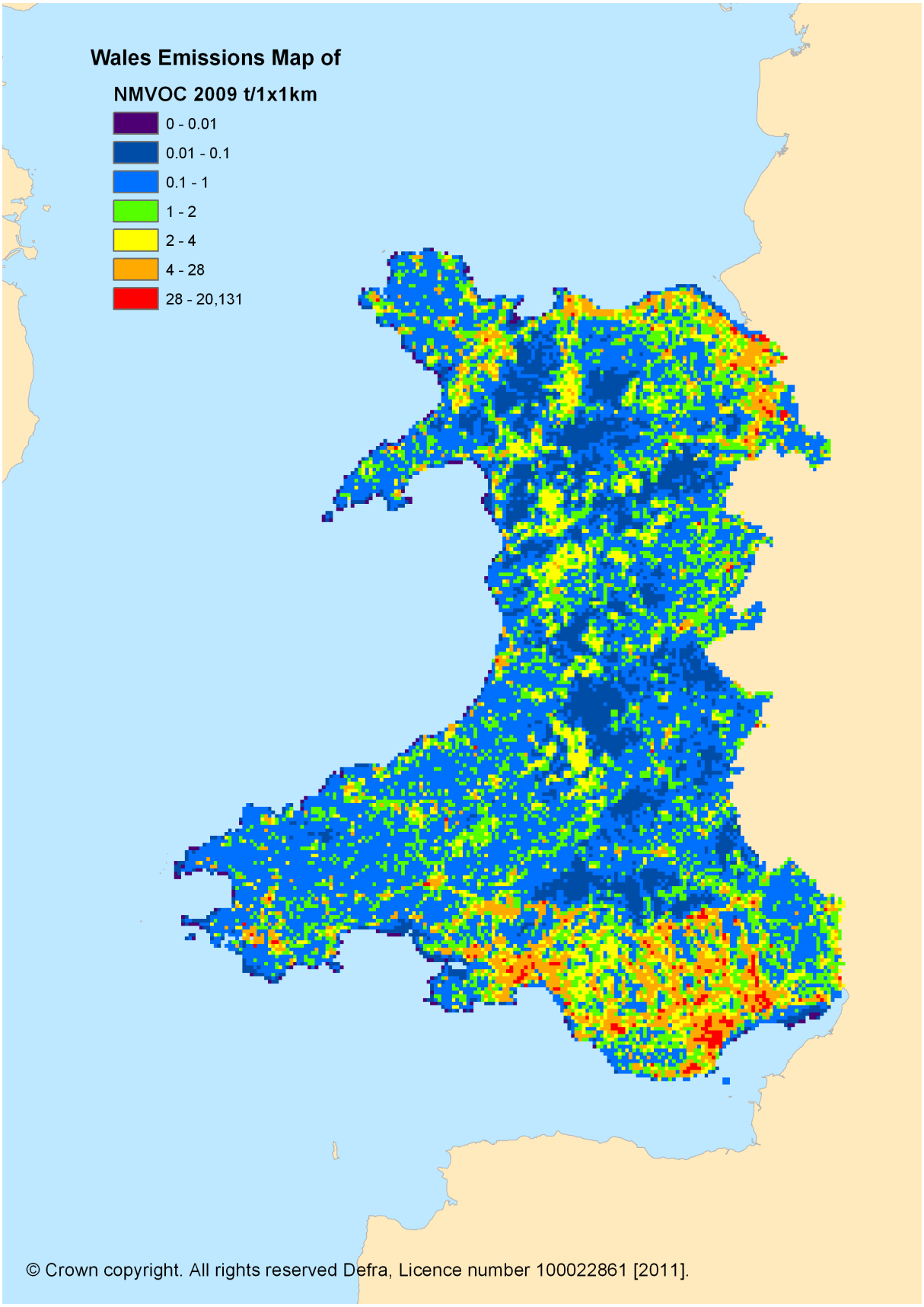
Figure 2-33 Wales NMVOC Emissions by Source, 1990-2009



Wales' NMVOC emissions have declined by 66% since 1990 and account for 6% of the UK total. Solvent processes (3) account for 40% of the Wales NMVOC inventory total in 2009; emissions from this source have reduced by 58% since 1990. Fugitive emissions from fuels (1B) are another significant source of emissions making up 26% of the total in 2009. Emissions from this source have been reduced by down 47% since 1990. Road transport are an important source of emissions, including evaporative losses (1A3bi-v) accounting for 9% of the total in 2009. Emissions from this

source are down 92% since 1990. Industrial processes (2) account for 4% of the total in 2009, with emissions down 63% since 1990.

Figure 2-34 Map of NMVOC Emissions in Wales, 2009



2.4.4 Northern Ireland NMVOC Inventory by NFR Sector, 1990-2009

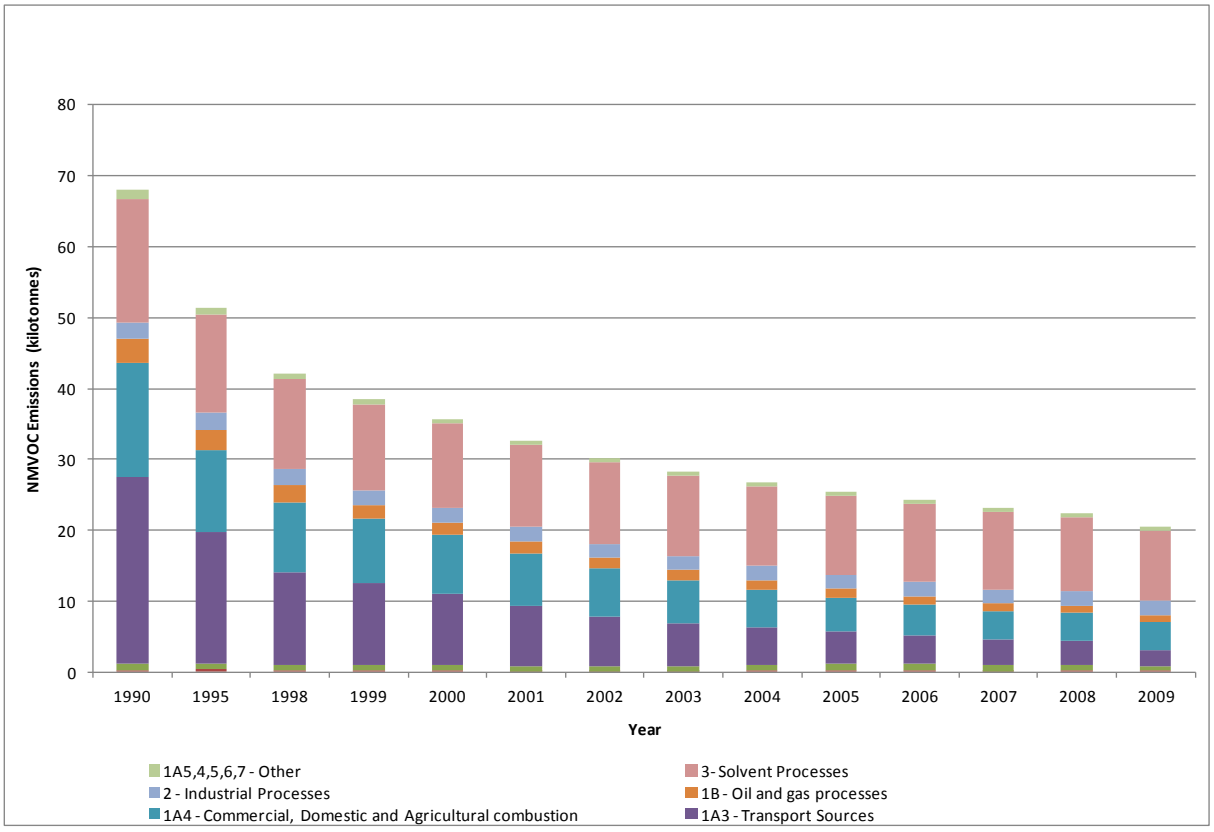
The table and graph below give a summary of the NMVOC emissions in Northern Ireland by broad NFR sector categories. See Appendix G for more detailed data.

Table 2-24 Northern Ireland Emissions of NMVOC by NFR Source Sector

NFR Code	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2009 (%)
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	0.2	1%
1A2 - Industrial Combustion	0.8	0.9	0.9	0.8	0.8	0.8	0.7	0.8	0.8	0.8	0.8	0.8	0.8	0.7	3%
1A3 - Transport Sources	26.3	18.5	13.0	11.6	10.0	8.5	7.0	6.1	5.3	4.6	4.0	3.7	3.4	2.2	11%
1A4 - Commercial, Domestic and Agricultural	16.2	11.5	9.8	9.0	8.3	7.5	6.9	6.1	5.3	4.7	4.3	3.9	4.0	3.9	19%
1B - Oil and gas processes	3.4	3.0	2.6	1.9	1.8	1.7	1.6	1.5	1.4	1.3	1.2	1.1	1.0	0.9	4%
2 - Industrial Processes	2.4	2.4	2.1	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.1	2.1	10%
3- Solvent Processes	17.3	13.8	12.8	12.2	11.9	11.6	11.4	11.2	11.2	11.0	11.1	10.9	10.4	9.9	48%
1A5,4,5,6,7 - Other	1.3	0.9	0.8	0.7	0.7	0.7	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	3%
Total	**68.0**	**51.3**	**42.2**	**38.6**	**35.7**	**32.7**	**30.1**	**28.2**	**26.7**	**25.4**	**24.4**	**23.2**	**22.4**	**20.4**	**100%**

Units: kilotonnes

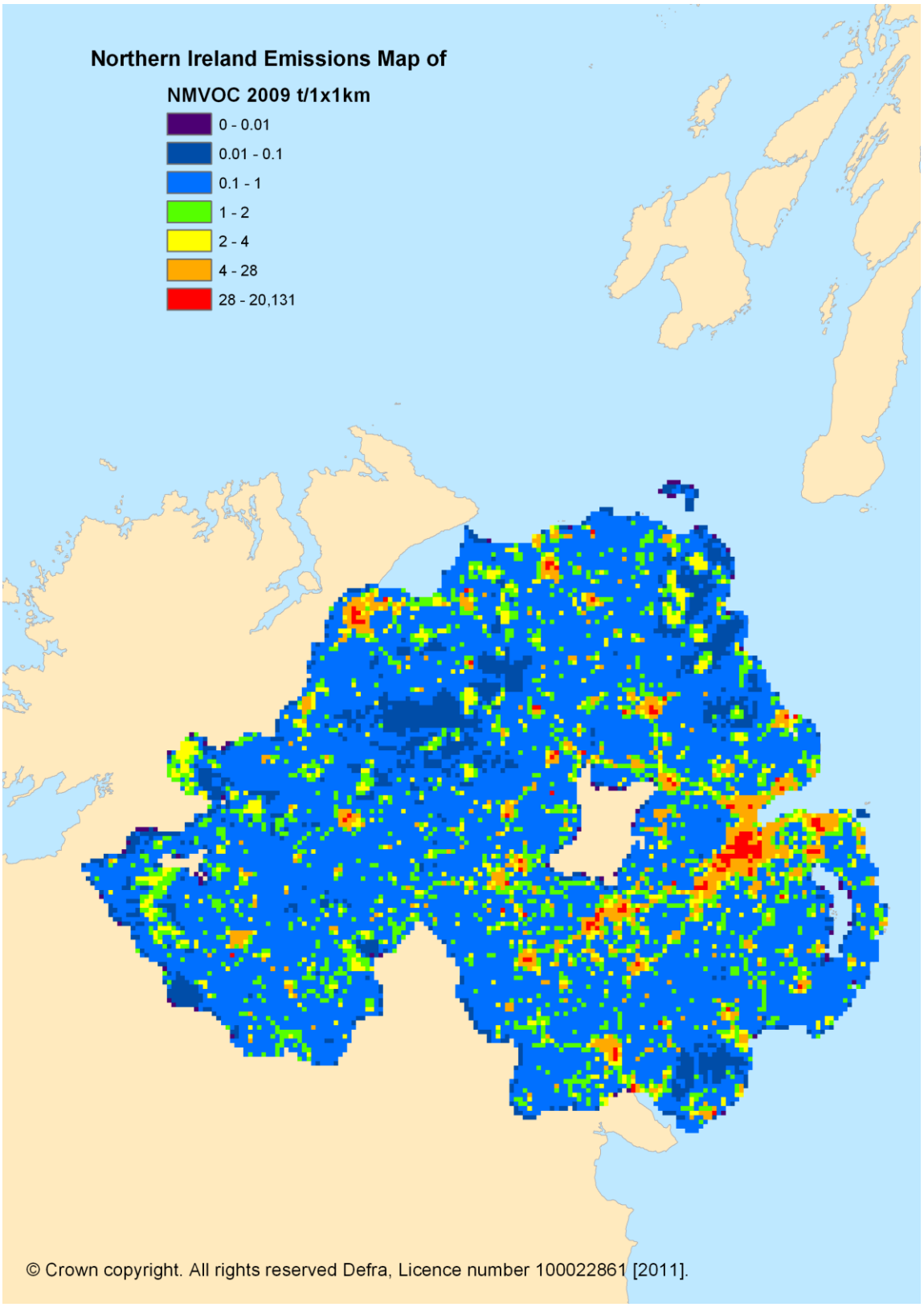
Figure 2-35 Northern Ireland NMVOC Emissions by Source, 1990-2009



Northern Ireland's NMVOC emissions have declined by 70% since 1990 and account for 2% of the UK total. Solvent and other product use (3) are a major source making up 48% of the NMVOC inventory total in Northern Ireland in 2009. Emissions from this source are down 43% since 1990. Another significant source is commercial & domestic combustion (1A4), which accounts for 19% of the NMVOC inventory total in Northern Ireland in 2009. Emissions from this source are down 76% since 1990. The food & drink sector (2D2) accounts for 10% of the total in 2009 and emissions from this source have increased by 11% since 1990 due to increased emissions from whisky production.

Road transport sources, including evaporative losses (1A3bi-v) make up 10% of the total in 2009 with a 92% reduction since 1990. Another important source is fugitive emissions from fuels (1B) accounting for 4% of the total in 2009. This source of emission has reduced by 74% since 1990.

Figure 2-36 Map of NMVOC Emissions in Northern Ireland, 2009



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.

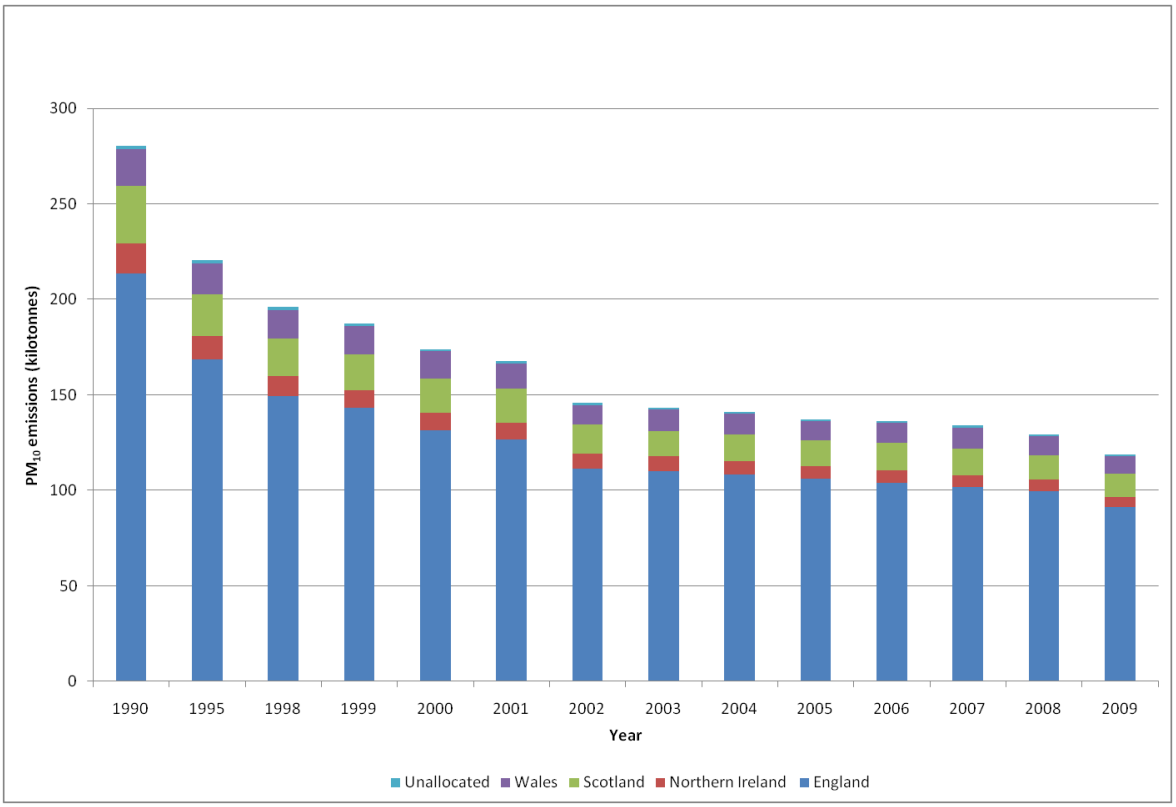
- **Stationary Combustion (1A1, 1A2 and 1A4).** Domestic coal combustion has historically been the main source of particulate emissions in the UK, but restrictions in the use of coal for domestic combustion through the Clean Air Acts has lead to other sources becoming more important nationally. Domestic 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 kt (50% of the total emission) in 1970 to 17 kt (14%) in 2009.

Figure 2-37 UK PM_{10} Emissions by Constituent Country, 1990-2009



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 2-25** shows how total UK PM_{10} emissions are split between the 4 constituent countries, and **Table 2-26** show per capita emissions.

Table 2-25 Proportion of UK PM_{10} Emissions by Constituent Country

Year	England	Scotland	Wales	N Ireland	Unallocated
1990	74%	10%	7%	8%	1%
2009	77%	10%	8%	5%	1%

Table 2-26 Emissions of PM_{10} per capita by Constituent Country (kg/head)

	England	Scotland	Wales	N Ireland	UK
1990	4.5	5.8	6.8	9.9	4.9
2009	1.8	2.3	3.1	3.1	1.9
DA/UK (2009)	91%	119%	161%	161%	-

2.5.2 England PM_{10} Inventory by NFR Sector, 1990-2009

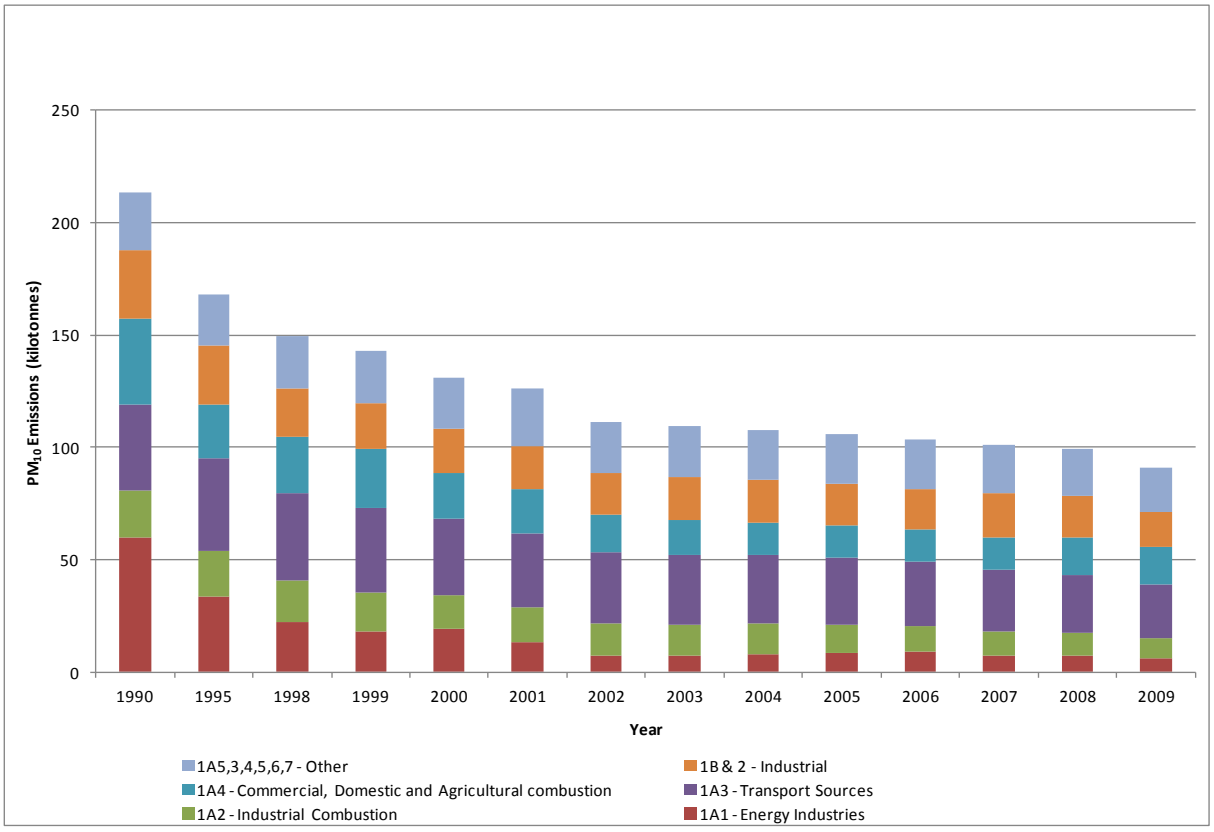
The table and graph below give a summary of the PM_{10} emissions in England by broad NFR sector categories. The detailed data are available in Appendix C.

Table 2-27 England Emissions of PM_{10} by NFR Source Sector

NFR Code	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2009 (%)
1A1 - Energy Industries	59.8	33.8	22.4	18.2	19.1	13.4	7.5	7.7	7.9	8.9	9.0	7.4	7.6	6.0	7%
1A2 - Industrial Combustion	21.0	20.1	18.6	17.1	15.3	15.5	14.4	13.8	13.9	12.5	11.6	11.0	10.1	9.1	10%
1A3 - Transport Sources	38.2	41.0	38.8	37.9	33.8	33.0	31.7	30.8	30.2	29.4	28.5	27.0	25.5	24.1	26%
1A4 - Commercial, Domestic and Agricultural	38.2	24.2	24.8	26.3	20.7	19.3	16.3	15.4	14.8	14.4	14.3	14.9	16.9	16.6	18%
1B & 2 - Industrial	30.5	26.2	21.4	20.0	19.2	19.3	18.9	19.2	18.6	18.6	17.9	19.3	18.2	15.3	17%
1A5,3,4,5,6,7 - Other	25.5	22.5	23.3	23.4	23.0	25.9	22.5	22.9	22.5	22.0	22.3	21.7	21.3	19.8	22%
Total	**213**	**168**	**149**	**143**	**131**	**126**	**111**	**110**	**108**	**106**	**104**	**101**	**99.5**	**90.9**	**100%**

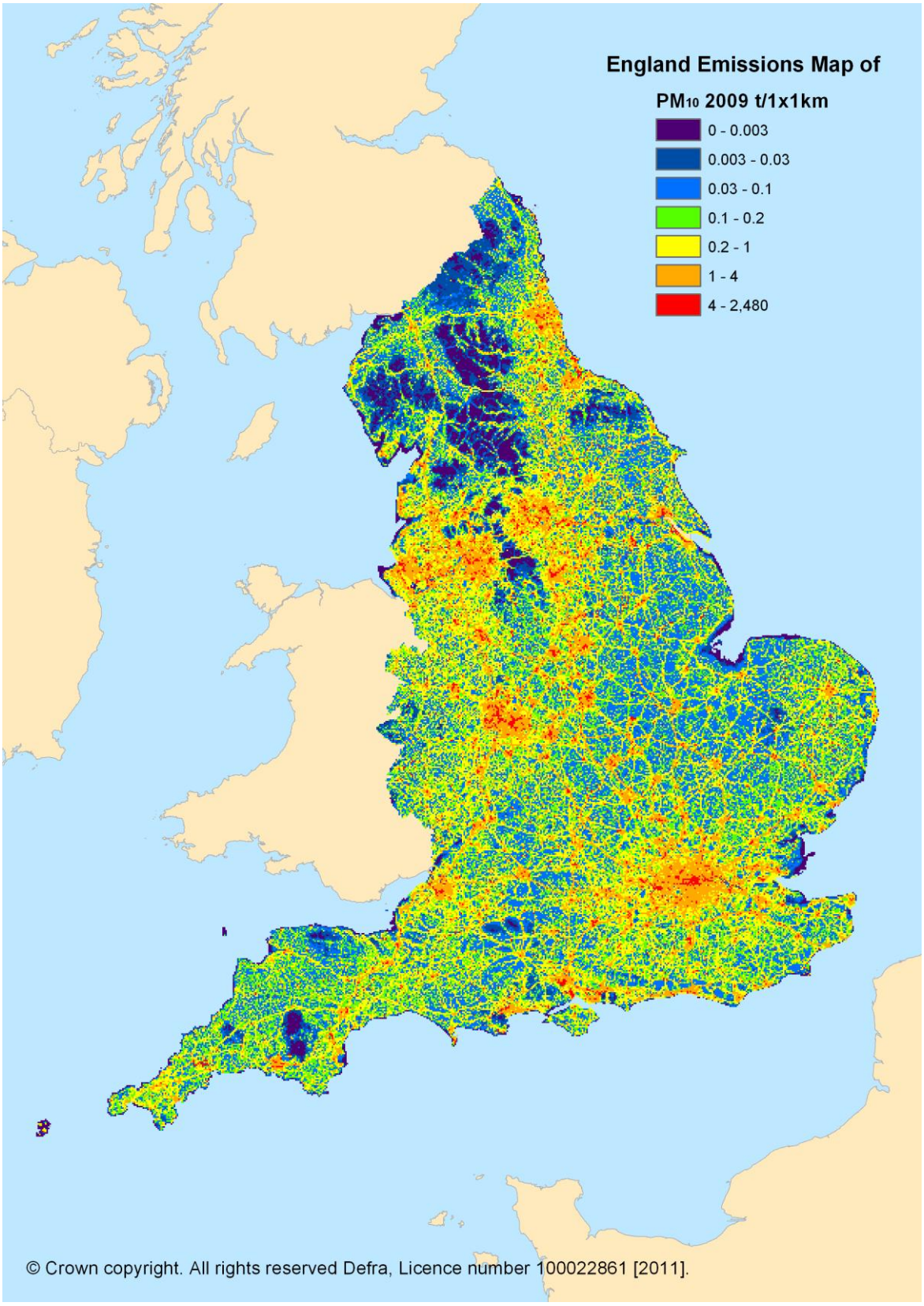
Units: kilotonnes

Figure 2-38 England PM_{10} Emissions by Source, 1990-2009



England's PM_{10} emissions have declined by 57% since 1990 and account for 77% of the UK total. 26% of PM_{10} emissions in England come from transport (1A3) sources (down by 37% since 1990), whilst 18% stem from commercial and residential combustion (mainly of coal and solid fuels, down by 56% since 1990). Emissions from power generation (1A1a) were 28% of the England total emission in 1990, but have been significantly reduced to 5% of the England total in 2009.

Figure 2-39 Map of PM_{10} Emissions in England, 2009



2.5.3 Scotland PM_{10} Inventory by NFR Sector, 1990-2009

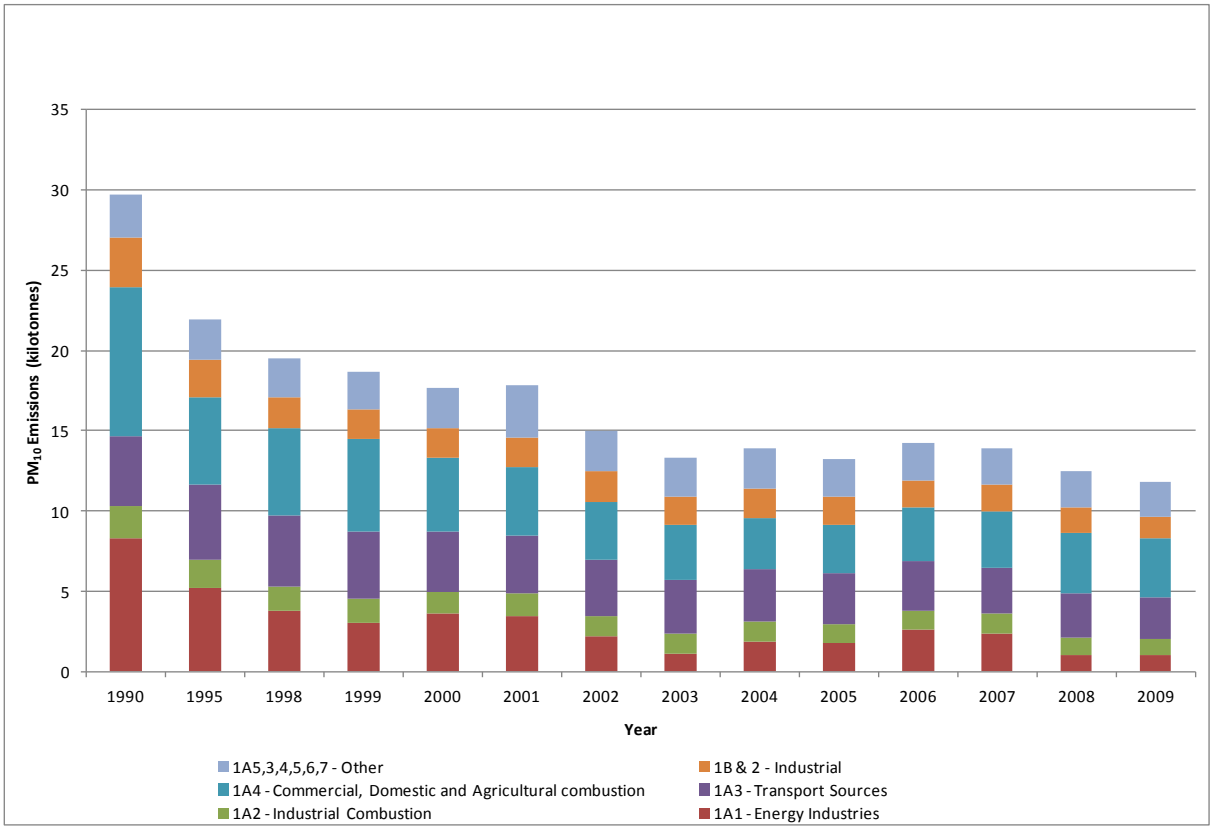
The table and graph below give a summary of the PM_{10} emissions in Scotland by broad NFR sector categories. The detailed data are available in Appendix C.

Table 2-28 Scotland Emissions of PM_{10} by NFR Source Sector

NFR Code	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2009(%)
1A1 - Energy Industries	8.3	5.2	3.8	3.0	3.6	3.5	2.2	1.1	1.9	1.8	2.7	2.4	1.0	1.0	9%
1A2 - Industrial Combustion	2.0	1.8	1.5	1.5	1.4	1.4	1.3	1.2	1.3	1.1	1.1	1.2	1.1	1.0	8%
1A3 - Transport Sources	4.4	4.6	4.4	4.2	3.7	3.6	3.5	3.3	3.3	3.2	3.1	2.9	2.7	2.6	22%
1A4 - Commercial, Domestic and Agricultural	9.3	5.4	5.5	5.7	4.6	4.2	3.6	3.4	3.2	3.0	3.4	3.5	3.8	3.7	31%
1B & 2 - Industrial	3.1	2.4	1.9	1.9	1.9	1.8	1.9	1.8	1.9	1.8	1.7	1.6	1.6	1.4	12%
1A5,3,4,6,7 - Other	2.6	2.5	2.4	2.3	2.5	3.3	2.5	2.4	2.5	2.4	2.3	2.3	2.3	2.2	18%
Total	**29.7**	**21.9**	**19.5**	**18.6**	**17.7**	**17.8**	**15.0**	**13.3**	**13.9**	**13.3**	**14.3**	**13.9**	**12.5**	**11.8**	**100 %**

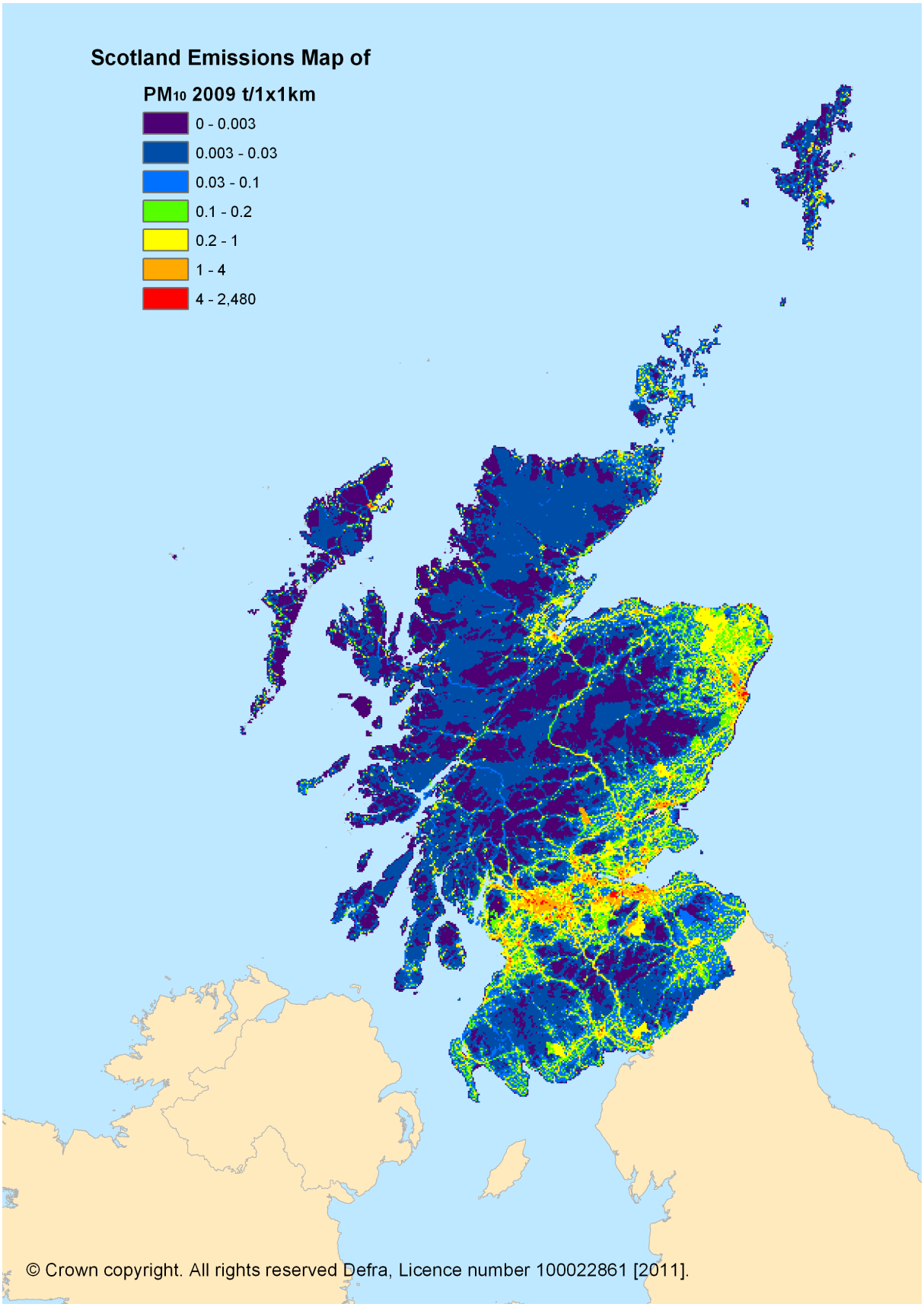
Units: kilotonnes

Figure 2-40 Scotland PM_{10} Emissions by Source, 1990-2009



Scotland's PM_{10} emissions have declined by 60% since 1990 and account for 10% of the UK total. 22% of PM_{10} emissions in Scotland come from transport (1A3) sources (down by 42% since 1990), whilst 31% stem from commercial and residential combustion (mainly of coal and solid fuels, down by 60% since 1990). Emissions from power generation (1A1a) were 25% of the Scotland total emission in 1990, but have been reduced to 8% of the Scotland total in 2009.

Figure 2-41 Map of PM_{10} Emissions in Scotland, 2009



2.5.4 Wales PM_{10} Inventory by NFR Sector, 1990-2009

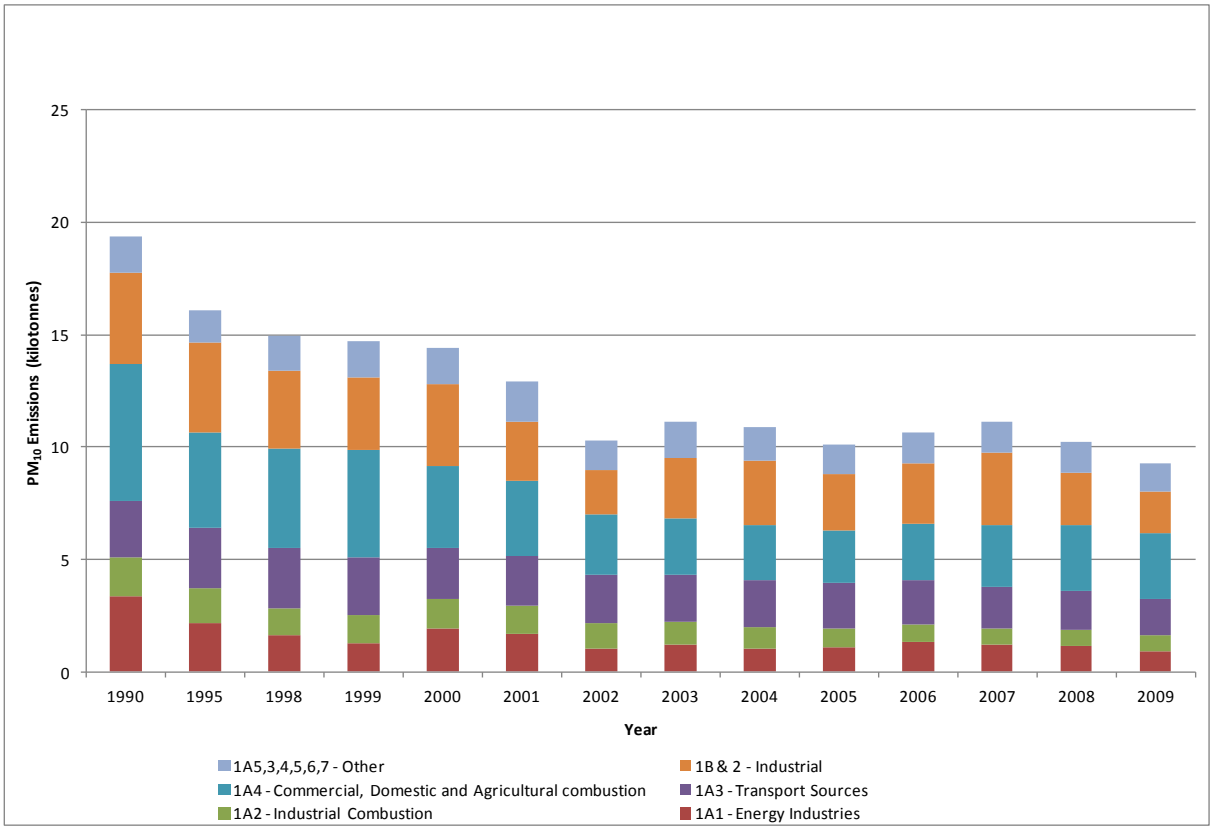
The table and graph below give a summary of the PM_{10} emissions in Wales by broad NFR sector categories. The detailed data are available in Appendix C.

Table 2-29 Wales Emissions of PM_{10} by NFR Source Sector

NFR Code	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2009 (%)
1A1 - Energy Industries	3.3	2.2	1.7	1.3	2.0	1.7	1.0	1.2	1.0	1.1	1.3	1.2	1.1	0.9	10%
1A2 - Industrial Combustion	1.8	1.6	1.2	1.3	1.3	1.3	1.1	1.0	1.0	0.8	0.8	0.8	0.7	0.7	7%
1A3 - Transport Sources	2.5	2.7	2.7	2.6	2.3	2.2	2.1	2.1	2.1	2.0	1.9	1.8	1.7	1.6	18%
1A4 - Commercial, Domestic and Agricultural	6.1	4.2	4.4	4.8	3.6	3.3	2.7	2.6	2.4	2.3	2.5	2.8	3.0	2.9	32%
1B & 2 - Industrial	4.1	4.0	3.5	3.2	3.7	2.7	1.9	2.7	2.8	2.5	2.7	3.2	2.3	1.8	19%
1A5,3,4,6,7 - Other	1.6	1.4	1.5	1.6	1.6	1.7	1.3	1.6	1.5	1.4	1.3	1.4	1.4	1.3	14%
Total	**19.3**	**16.1**	**14.9**	**14.7**	**14.4**	**12.9**	**10.3**	**11.1**	**10.9**	**10.1**	**10.6**	**11.1**	**10.2**	**9.3**	**100 %**

Units: kilotonnes

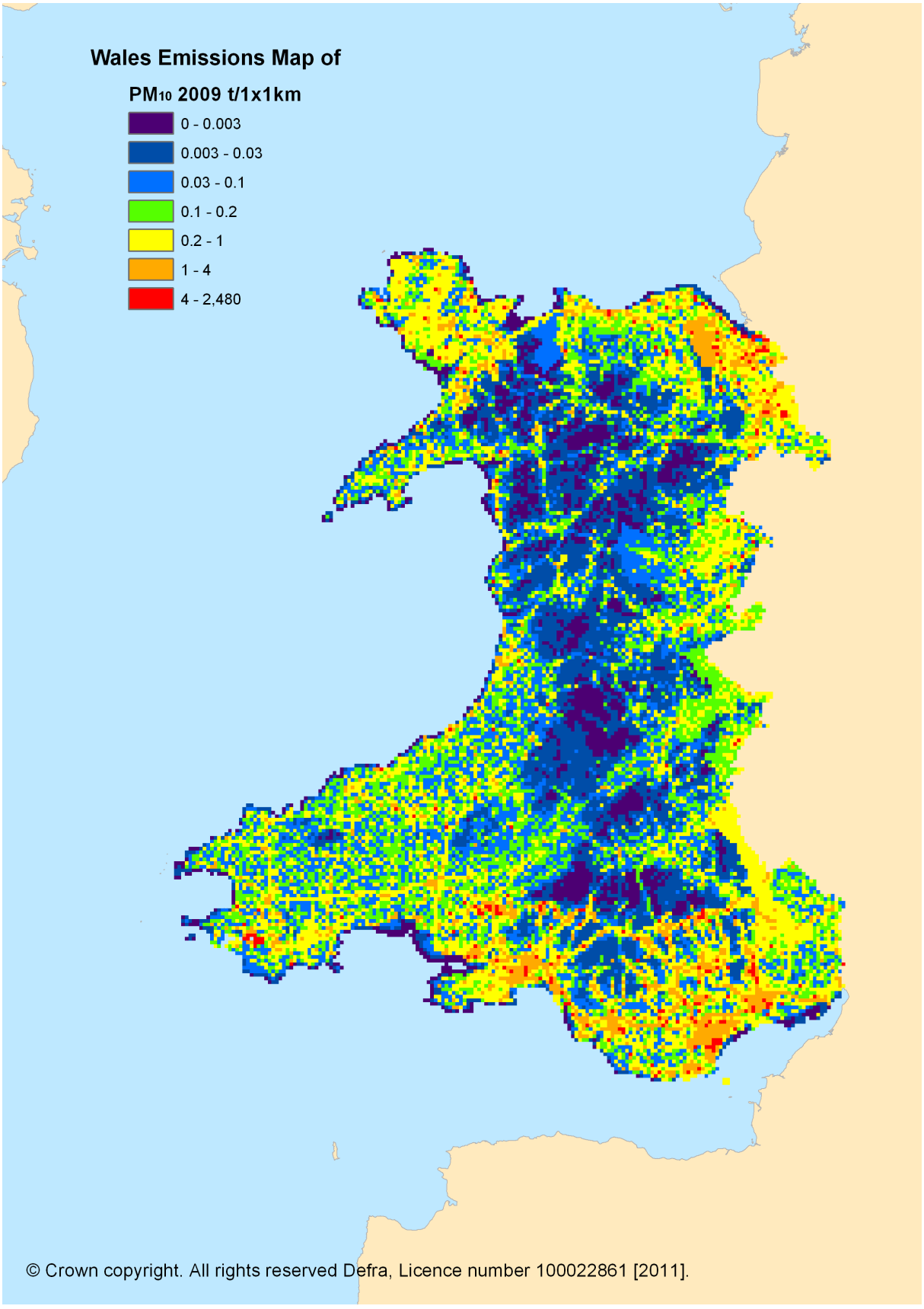
Figure 2-42 Wales PM_{10} Emissions by Source, 1990-2009



Wales PM_{10} emissions have declined by 52% since 1990 and accounted for 8% of the UK total in 2009. Commercial and domestic sources accounted for 32% of Welsh emissions in 2009, mainly from combustion of solid fuels; these emissions have declined by 52% since 1990. In 2009, 18% of PM_{10} emissions in Wales come from transport (1A3) sources (down by 34% since 1990), whilst emissions from power generation (1A1a) accounted for 5% of the Wales total in 2009, down 82% 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 2009 total from quarrying and mining (5%), iron & steel

production (11%), other manufacturing combustion (7%). Welsh per capita emissions of PM_{10} are 61% higher than the UK average, due primarily to emissions from iron and steel manufacture.

Figure 2-43 Map of PM_{10} Emissions in Wales, 2009



2.5.5 Northern Ireland PM_{10} Inventory by NFR Sector, 1990-2009

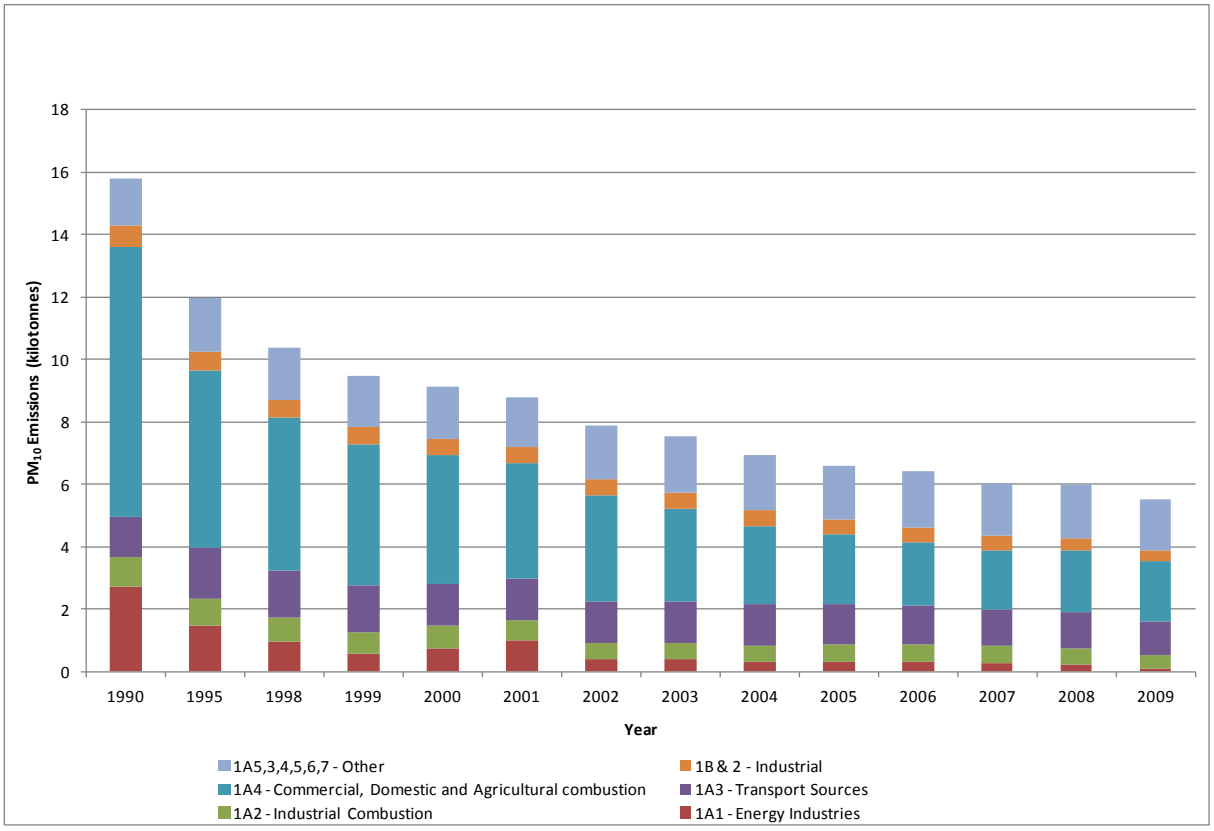
The table and graph below give a summary of the PM_{10} emissions in Northern Ireland by broad NFR sector categories. The detailed data are available in Appendix C.

Table 2-30 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	2009	2009 (%)
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	0.1	2%
1A2 - Industrial Combustion	0.9	0.9	0.8	0.7	0.7	0.6	0.5	0.5	0.5	0.6	0.6	0.6	0.5	0.4	7%
1A3 - Transport Sources	1.3	1.6	1.5	1.5	1.4	1.3	1.3	1.4	1.3	1.3	1.3	1.2	1.1	1.1	20%
1A4 - Commercial, Domestic and Agricultural	8.6	5.7	4.9	4.5	4.1	3.7	3.4	3.0	2.5	2.2	2.0	1.9	2.0	1.9	34%
1B & 2 - Industrial	0.7	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.4	0.4	0.3	6%
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	1.6	30%
Total	**15.8**	**12.0**	**10.4**	**9.5**	**9.1**	**8.8**	**7.9**	**7.5**	**6.9**	**6.6**	**6.4**	**6.1**	**6.0**	**5.5**	**100 %**

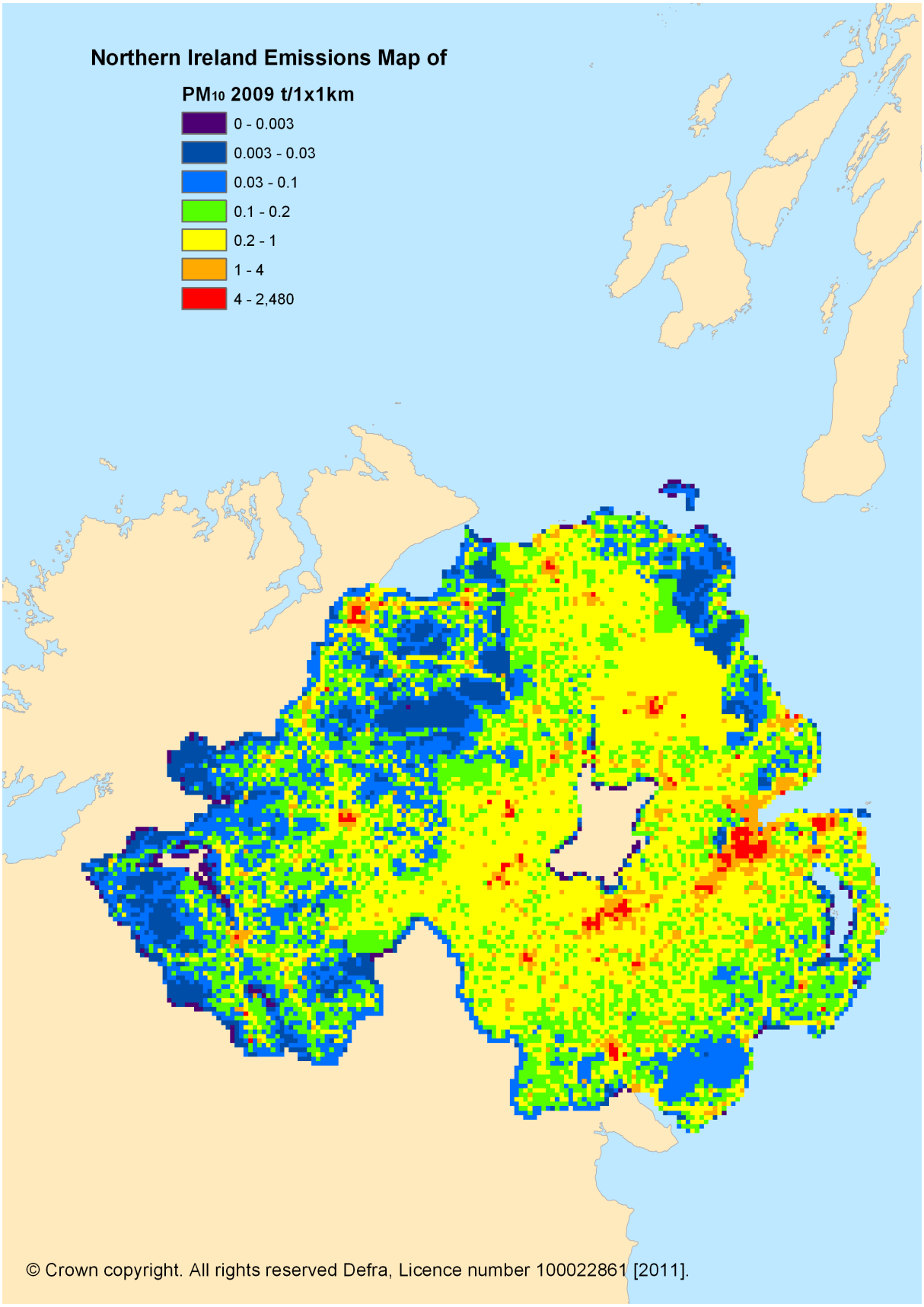
Units: kilotonnes

Figure 2-44 Northern Ireland PM_{10} Emissions by Source, 1990-2009



Northern Ireland's PM_{10} emissions have declined by 65% since 1990 and accounted for 5% of the UK total in 2009. 20% of PM_{10} emissions in Northern Ireland come from transport (1A3) sources (down by 13% since 1990), whilst 34% stem from commercial and residential combustion (mainly of coal and solid fuels), down by 78% since 1990. Emissions from power generation (1A1a) were 13% of the total emissions in 1990, but have been reduced to 2% of the Northern Ireland total in 2009. Per capita emissions of PM_{10} in Northern Ireland are 61% higher than the UK average due to the high contribution of emissions from residential combustion and agricultural mobile machinery.

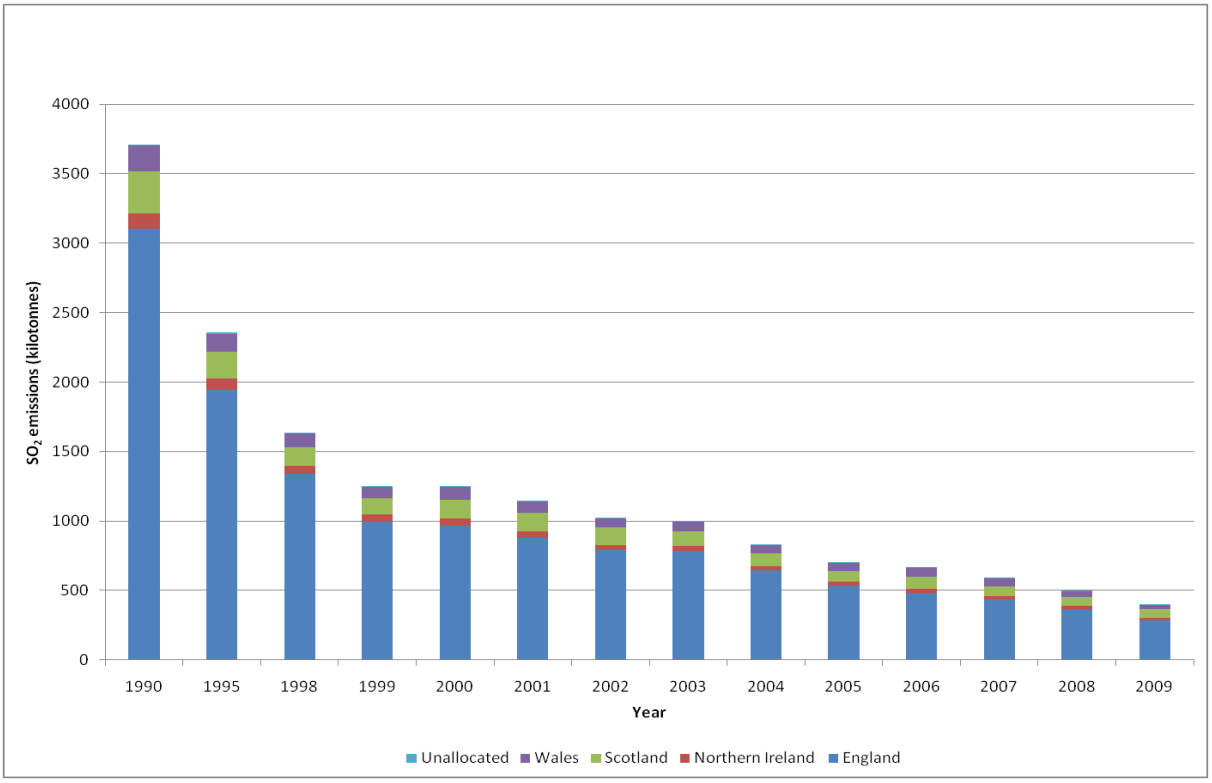
Figure 2-45 Map of PM_{10} Emissions in Northern Ireland, 2009



2.6 SULPHUR DIOXIDE

Since 1970 there has been a substantial overall reduction of more than 94% 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, 1990-2009



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 92% 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, 2010), 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 40% of UK SO_2 emissions in 2009. 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 2009 emissions from combustion sources have fallen by 83%, 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 2009, 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 EU Fuel Quality Directive and its amendments 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 2-31** shows how total UK SO_2 emissions are split between the 4 constituent countries, and **Table 2-32** shows per capita emissions.

Table 2-31 Proportion of UK Sulphur Dioxide Emissions by Constituent Country

Year	England	Scotland	Wales	N Ireland	Unallocated
1990	83%	8%	5%	3%	0%
2009	71%	17%	8%	4%	0%

Table 2-32 Emissions of Sulphur Dioxide per capita by Constituent Country (kg/head)

	England	Scotland	Wales	N Ireland	UK
1990	65.1	58.8	65.4	70.9	64.8
2009	5.5	12.6	10.5	8.7	6.4
DA/UK (2009)	85%	196%	164%	135%	-

2.6.1 England Sulphur Dioxide Inventory by NFR Sector, 1990-2009

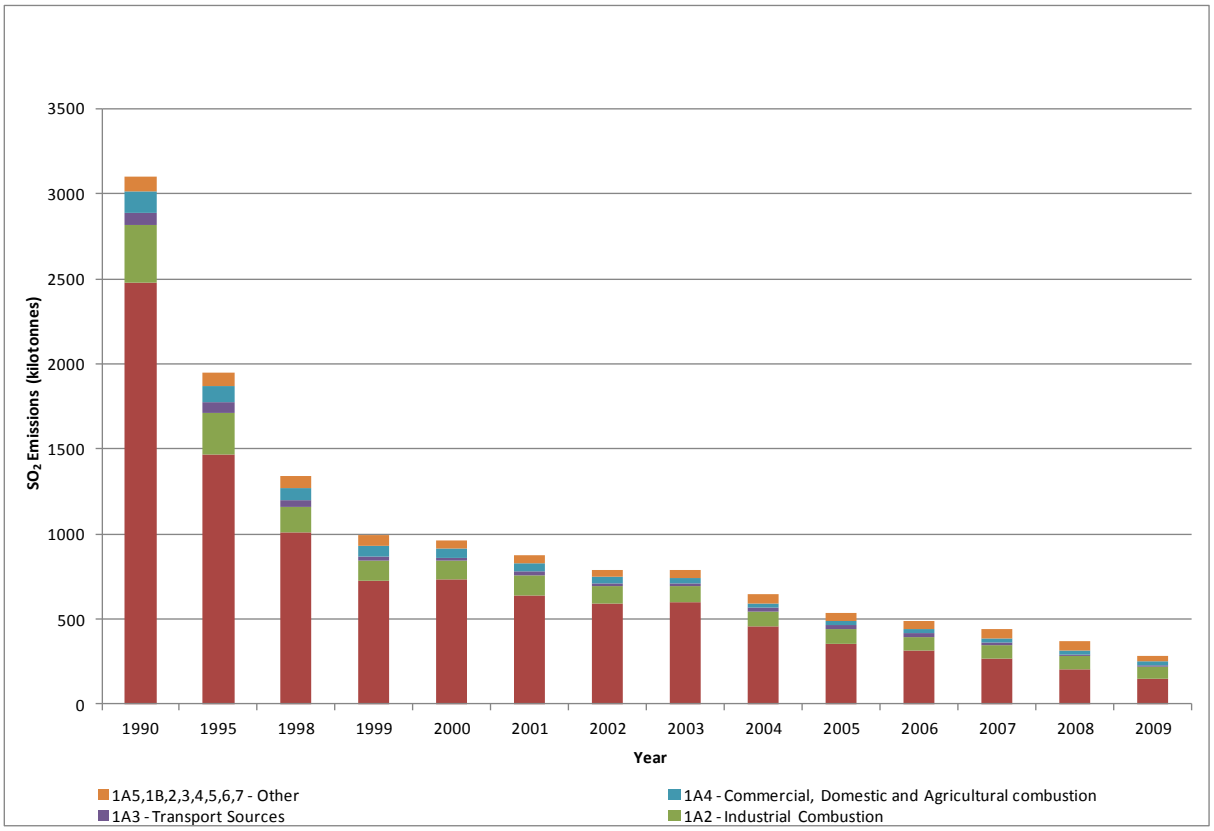
The table and graph below give a summary of the SO_2 emissions in England by broad NFR sector categories. The detailed data are available in Appendix F.

Table 2-33 England Emissions of Sulphur Dioxide by NFR Source Sector

NFR Code	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2009 (%)
1A1 - Energy Industries	2480	1470	1011	723	733	643	594	597	456	355	314	271	208	151	53%
1A2 - Industrial Combustion	335	243	150	119	109	118	101	93.4	91.2	89.8	82.7	79.2	72.4	65.4	23%
1A3 - Transport Sources	70.9	59.0	35.6	27.6	20.1	17.8	18.2	18.5	18.4	18.7	18.1	13.6	12.0	10.9	4%
1A4 - Commercial, Domestic and Agricultural	132	95.9	69.4	64.1	50.8	48.6	35.6	31.6	29.2	24.5	24.0	24.2	25.5	23.4	8%
1A5,1B,2,3,4,5,6,7 - Other	85.6	78.5	74.4	63.5	52.5	49.4	43.5	45.9	47.8	46.3	45.7	50.6	49.4	32.5	11%
Total	**3103**	**1947**	**1341**	**996**	**966**	**876**	**792**	**787**	**643**	**535**	**485**	**438**	**367**	**284**	**100 %**

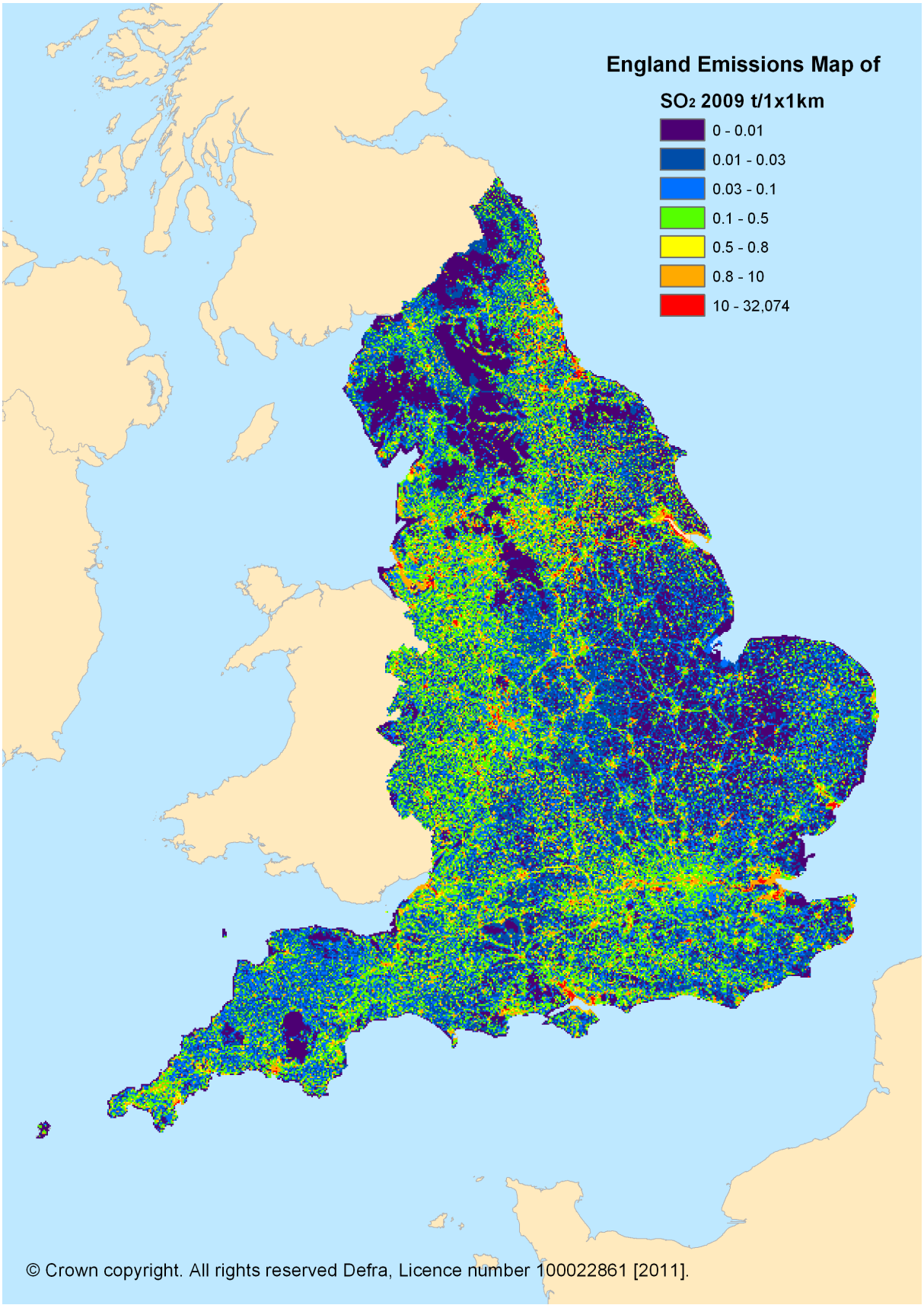
Units: kilotonnes

Figure 2-47 England Sulphur Dioxide Emissions by Source, 1990-2009



England's SO_2 emissions have declined by 91% since 1990 and accounted for 71% of the UK total in 2009. Power generation (1A1a) is by far the most significant source, accounting for 38% of the England total in 2009 (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 95% since 1990. 23% of SO_2 emissions in England are from industrial combustion (1A2: down by 80% since 1990), 14% from refineries (1A1b: down 58% since 1990) whilst residential combustion and national navigation contribute 6 and 3% 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, 2009



2.6.2 Scotland Sulphur Dioxide Inventory by NFR Sector, 1990-2009

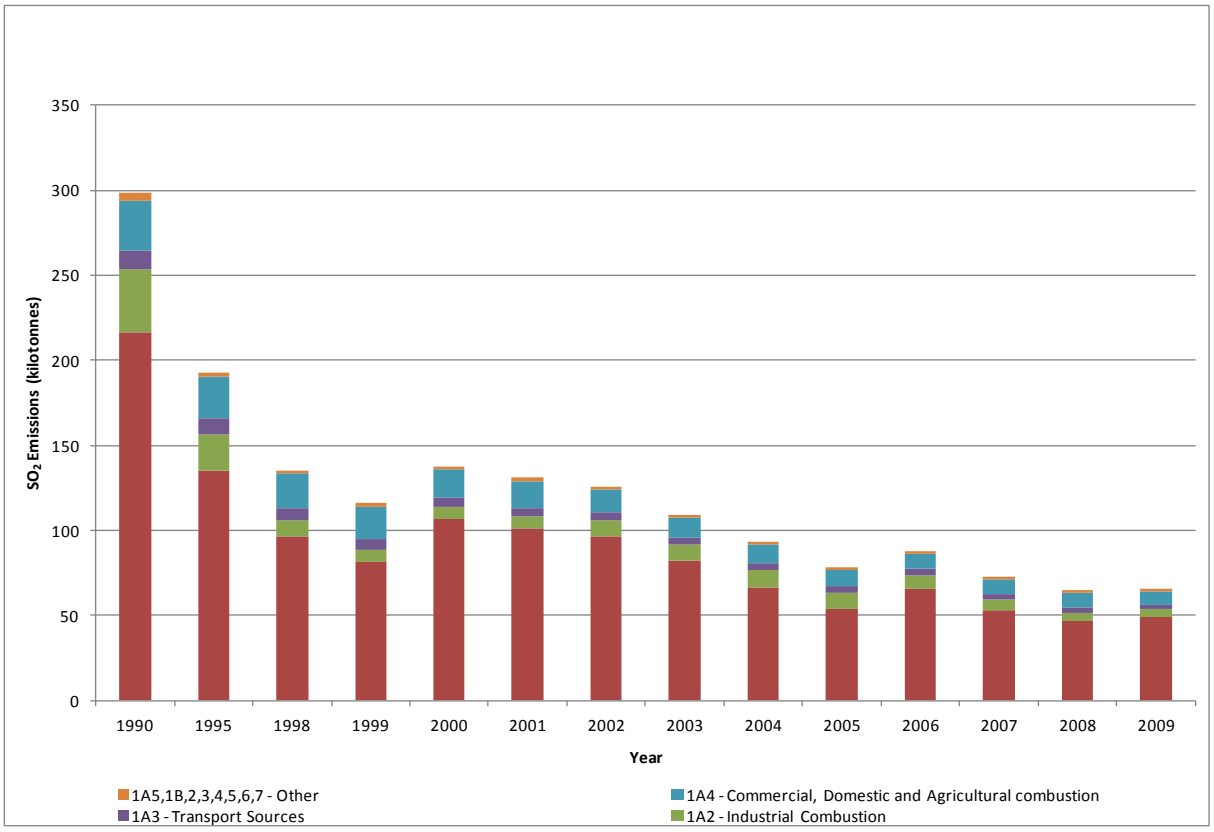
The table and graph below give a summary of the SO_2 emissions in Scotland by broad NFR sector categories. The detailed data are available in Appendix F.

Table 2-34 Scotland Emissions of Sulphur Dioxide by NFR Source Sector

NFR Code	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2009 (%)
1A1 - Energy Industries	217	135	96.3	81.2	107	101	96.2	82.3	66.8	53.6	65.9	52.8	46.6	49.4	75%
1A2 - Industrial Combustion	36.6	21.4	9.7	7.1	6.6	6.8	9.6	9.3	9.8	9.5	7.8	6.8	5.4	4.2	6%
1A3 - Transport Sources	11.5	9.9	7.0	6.4	5.3	4.8	5.0	4.5	4.4	4.4	3.9	2.9	2.6	2.4	4%
1A4 - Commercial, Domestic and Agricultural	28.9	24.6	20.8	19.4	16.6	15.4	13.0	11.7	10.5	9.1	8.9	8.6	9.1	8.2	13%
1A5,1B,2,3,4,5, 6,7 - Other	4.6	1.7	1.6	1.9	1.6	2.7	2.0	1.8	1.7	1.6	1.4	1.6	1.5	1.3	2%
Total	**299**	**192**	**136**	**116**	**137**	**131**	**126**	**110**	**93.3**	**78.1**	**87.8**	**72.7**	**65.2**	**65.5**	**100%**

Units: kilotonnes

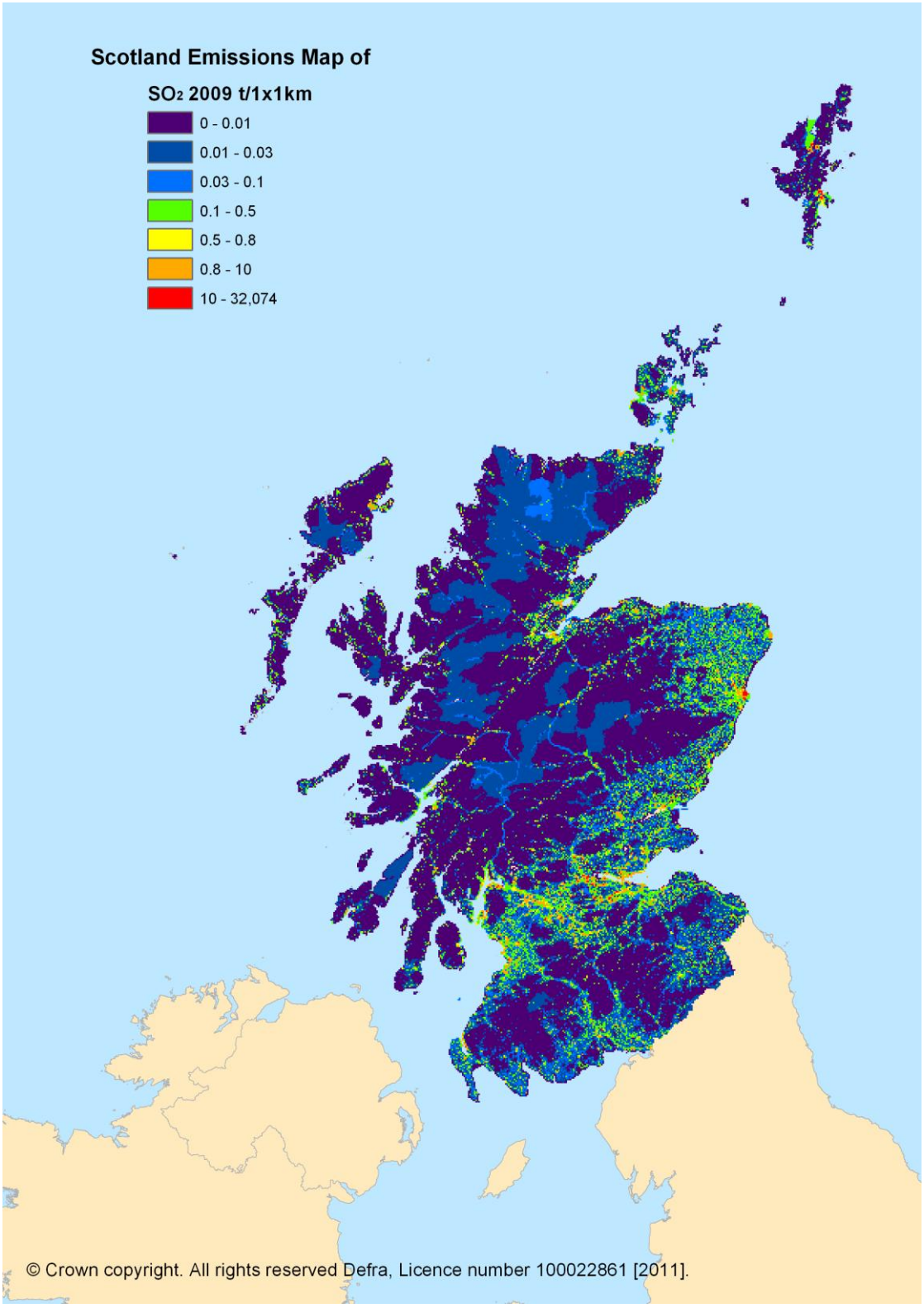
Figure 2-49 Scotland Sulphur Dioxide Emissions by Source, 1990-2009



Scotland's SO_2 emissions have declined by 78% since 1990 and account for 17% of the UK total. Power generation (1A1a) is by far the most significant source, accounting for 66% of the Scotland total in 2009 (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 78% 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 reached it peak, producing 17,488 GWh since then it has declined by 32% in 2009 (down to 11,896 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.)* The contribution of emissions from power stations to the UK total leads to Scotland having higher than average per capita

emissions of SO_2. In 2009, 6% of SO_2 emissions in Scotland are from industrial combustion (1A2: down by 88% since 1990), 9% from refineries (1A1b: down 71% since 1990) whilst residential combustion and national navigation contribute 11% and 3% 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, 2009



2.6.3 Wales Sulphur Dioxide Inventory by NFR Sector, 1990-2009

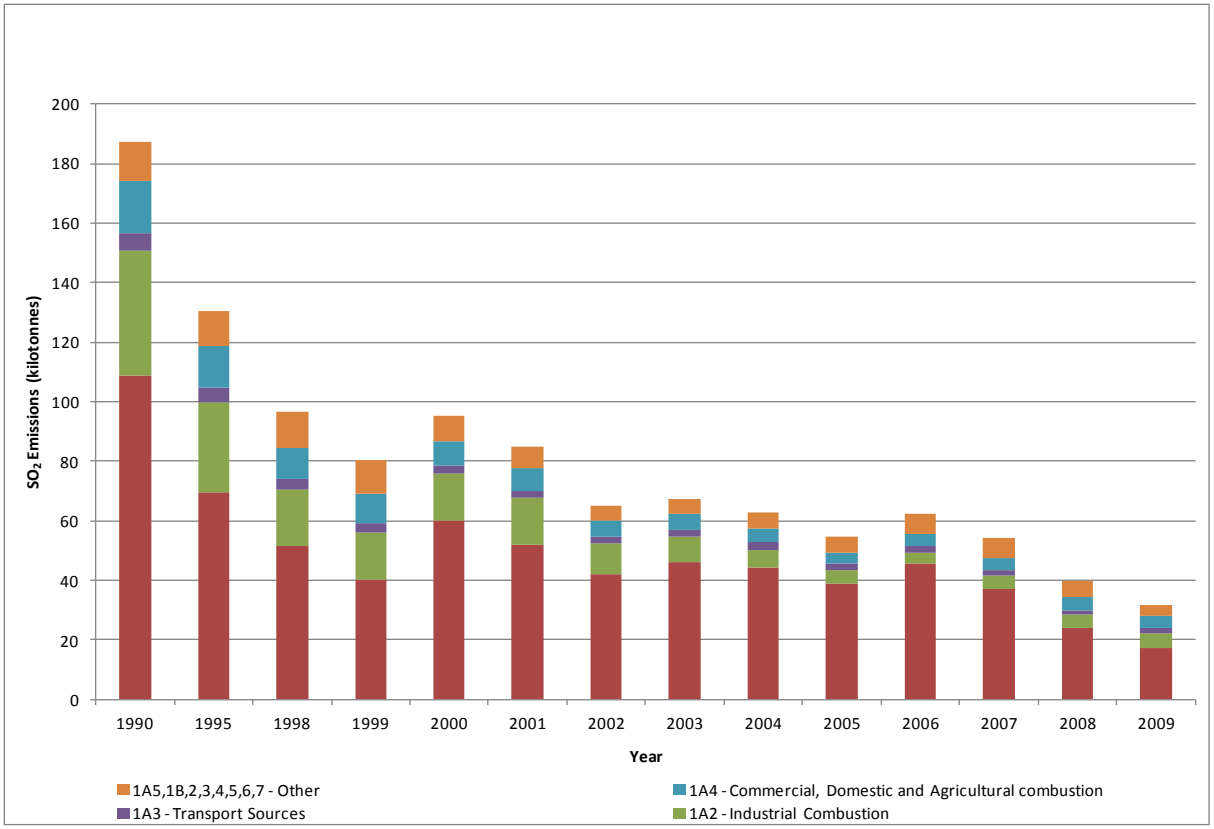
The table and graph below give a summary of the SO_2 emissions in Wales by broad NFR sector categories. The detailed data are available in Appendix F.

Table 2-35 Wales Emissions of Sulphur Dioxide by NFR Source Sector

NFR Code	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2009 (%)
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	24.2	17.3	55%
1A2 - Industrial Combustion	41.7	30.1	18.7	15.9	15.9	15.9	10.2	8.6	6.1	4.1	3.8	4.6	4.3	5.1	16%
1A3 - Transport Sources	5.9	5.1	3.5	3.0	2.5	2.2	2.2	2.2	2.4	2.4	2.2	1.6	1.5	1.5	5%
1A4 -Commercial, Domestic and Agricultural	17.5	13.7	10.5	10.0	8.0	7.6	5.6	5.0	4.7	3.7	3.8	4.2	4.4	4.1	13%
1A5,1B,2,3,4,5,6, 7 - Other	13.1	11.9	12.0	11.1	8.9	7.4	4.8	5.0	5.3	5.5	6.7	6.6	5.5	3.6	11%
Total	**187**	**130**	**96.5**	**80.2**	**95.5**	**85.1**	**65.0**	**67.2**	**62.7**	**54.9**	**62.2**	**54.0**	**39.9**	**31.5**	**100%**

Units: kilotonnes

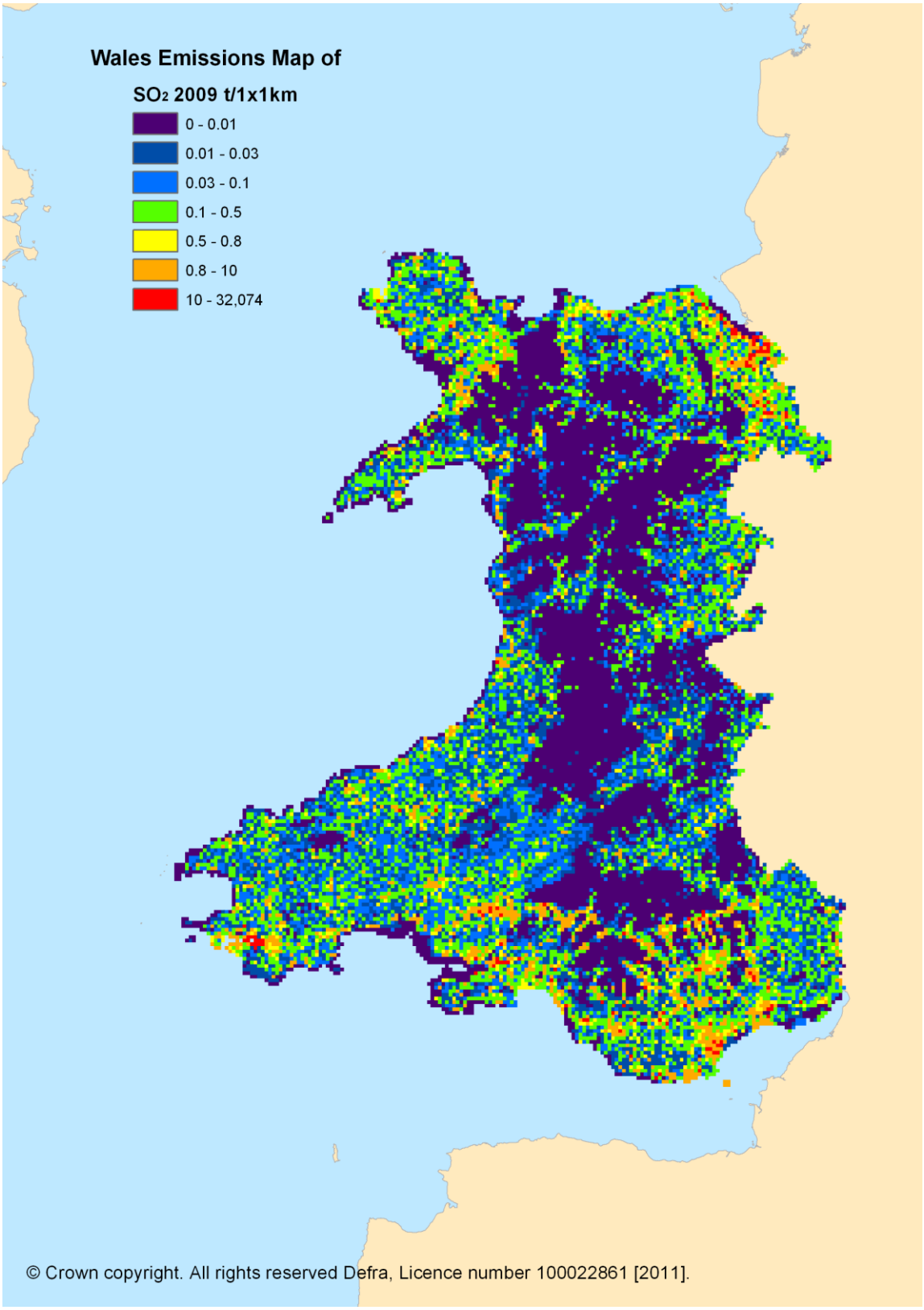
Figure 2-51 Wales Sulphur Dioxide Emissions by Source, 1990-2009



Wales SO_2 emissions have declined by 83% since 1990 and accounted for 8% of the UK total in 2009. In 2009, emissions from petroleum refineries are the most significant source in Wales, accounting for 42% of all SO_2 emissions (1A1b: down 41% 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 11% of the Wales total in 2009 (a reduction in emissions of 84% between 2007 and 2009).

In 2009, 16% of SO_2 emissions in Wales are from industrial combustion (1A2: down by 88% since 1990), 11% from residential combustion and 8% from iron and steel production (2C1: down by 55% 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, 2009



2.6.4 Northern Ireland Sulphur Dioxide Inventory by NFR Sector, 1990-2009

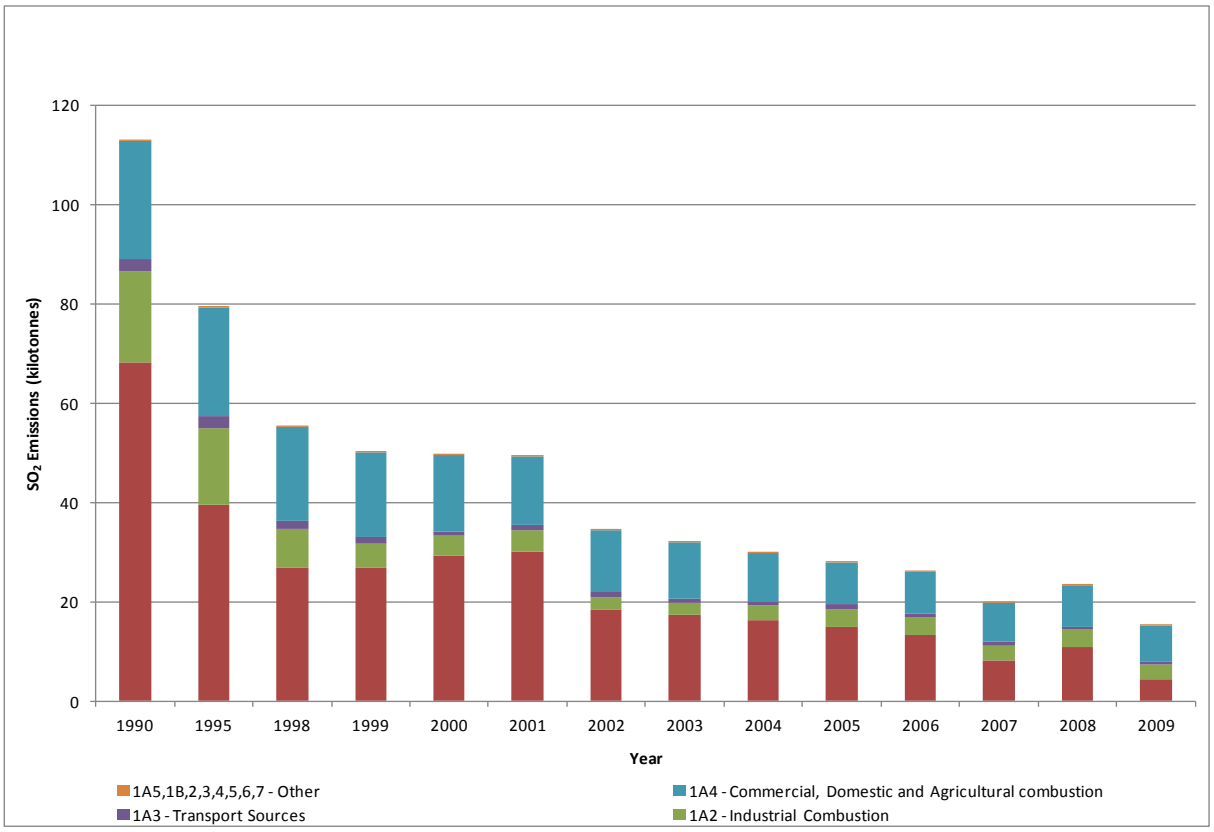
The table and graph below give a summary of the SO_2 emissions in Northern Ireland by broad NFR sector categories. The detailed data are available in Appendix F.

Table 2-36 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	2009	2009 (%)
1A1 - Energy Industries	68.2	39.7	26.8	26.8	29.2	30.1	18.3	17.4	16.4	14.9	13.4	8.3	11.0	4.5	29%
1A2 - Industrial Combustion	18.4	15.4	8.0	5.0	4.1	4.4	2.6	2.3	2.8	3.6	3.3	3.0	3.4	2.9	18%
1A3 - Transport Sources	2.6	2.4	1.5	1.3	1.0	0.9	0.9	1.0	1.0	1.0	1.0	0.7	0.6	0.6	4%
1A4 - Commercial, Domestic and Agricultural	23.6	21.7	19.0	17.1	15.4	13.8	12.5	11.2	9.7	8.6	8.3	7.8	8.2	7.4	47%
1A5,1B,2,3,4,5, 6,7 - Other	0.3	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	1%
Total	**113**	**79.5**	**55.5**	**50.3**	**49.8**	**49.3**	**34.5**	**32.0**	**30.0**	**28.2**	**26.1**	**20.0**	**23.4**	**15.5**	**100%**

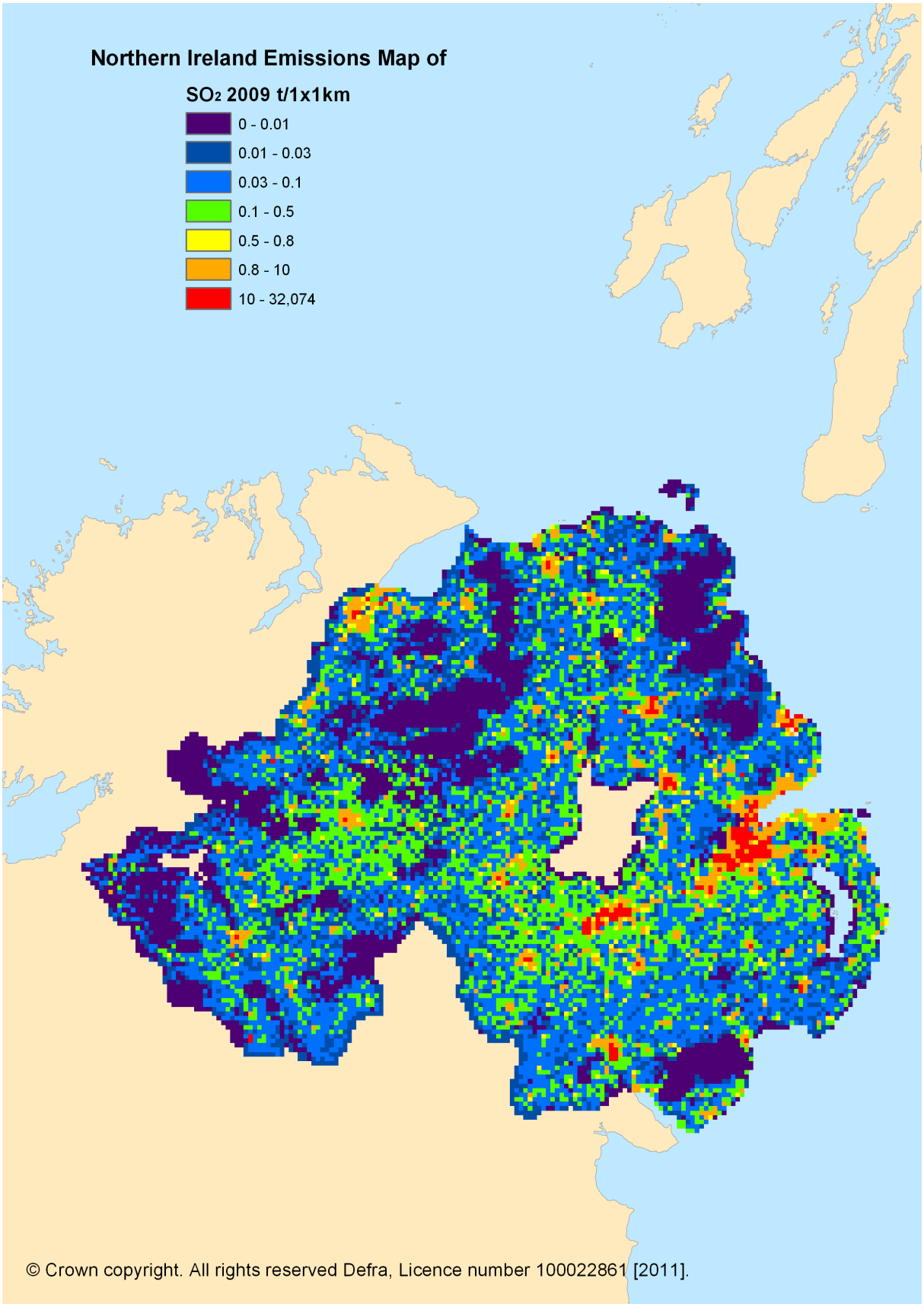
Units: kilotonnes

Figure 2-53 Northern Ireland Sulphur Dioxide Emissions by Source, 1990-2009



Northern Ireland's SO_2 emissions have declined by 86% since 1990 and they accounted for 4% of the UK total in 2009. Residential combustion is by far the most significant source accounting for 44% of the Northern Irish total in 2009 (1A4bi: down 60% 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. Power generation accounted for 29% (1A1a) (mainly from the sulphur in coal and fuel oil), but due to the growth in gas use, emissions from this source have reduced by 93% since 1990. 18% of SO_2 emissions in Northern Ireland are from industrial combustion (1A2: down by 85% since 1990). 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.

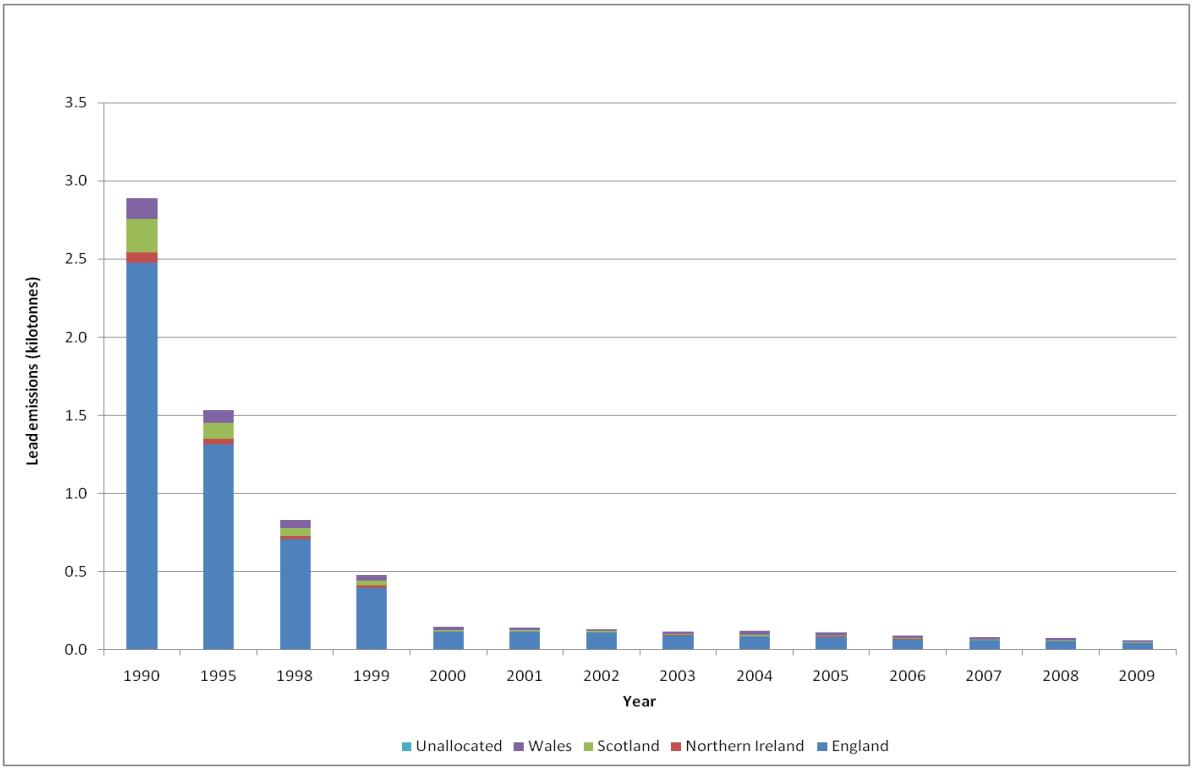
Figure 2-54 Map of Sulphur Dioxide Emissions in Northern Ireland, 2009



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, 1990-2009



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 41% of the lead emissions in the UK in 2009, of which sinter production accounts for over 75%. Emissions from sinter production have reduced by around 63% 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 2009 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 2009, transport (1A3) emissions accounted for 3% 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 2-37** shows how total UK lead emissions are split between the 4 constituent countries and **Table 2-38** shows per capita emissions.

Table 2-37 Proportion of UK Lead Emissions by Constituent Country

Year	England	Scotland	Wales	N Ireland	Unallocated
1990	86%	7%	5%	2%	0%
2009	74%	5%	19%	2%	0%

Table 2-38 Emissions of Lead per capita by Constituent Country (g/head)

	England	Scotland	Wales	N Ireland	UK
1990	51.9	41.2	47.5	44.2	50.5
2009	0.9	0.6	3.7	0.8	1.0
DA/UK (2009)	89%	60%	382%	77%	-

2.7.1 England Lead Inventory by NFR Sector, 1990-2009

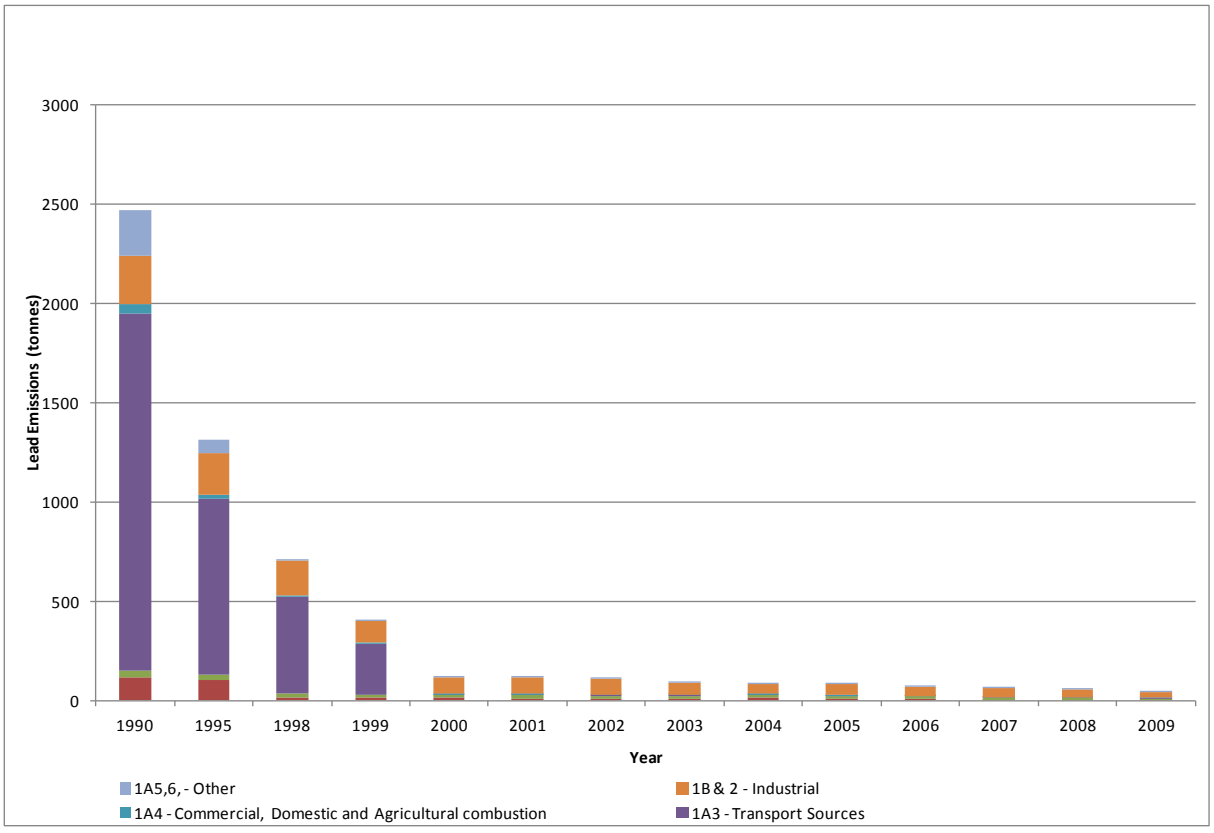
The table and graph below give a summary of the lead emissions in England by broad NFR sector categories. The detailed data are available in Appendix I.

Table 2-39 England Emissions of Lead by NFR Source Sector (tonnes)

NFR Code	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2009 (%)
1A1 - Energy Industries	116	106	18	14	14	11	11	11	12	11	10	3	3	2	5%
1A2 - Industrial Combustion	32	25	20	17	14	15	14	14	15	12	10	10	10	9	21%
1A3 - Transport Sources	1804	883	485	255	2	2	2	2	2	2	2	2	2	2	4%
1A4 - Commercial, Domestic and Agricultural	44	24	10	9	6	6	5	4	4	3	3	3	3	3	8%
1B & 2 - Industrial	248	209	175	103	79	81	76	61	53	53	43	42	38	27	61%
1A5,6, - Other	230	69	0.5	0.7	0.7	0.3	1.5	1.4	1.2	0.7	0.7	0.7	0.7	0.7	2%
Total	**2474**	**1316**	**708**	**398**	**116**	**115**	**109**	**93**	**86**	**82**	**68**	**61**	**56**	**45**	**100%**

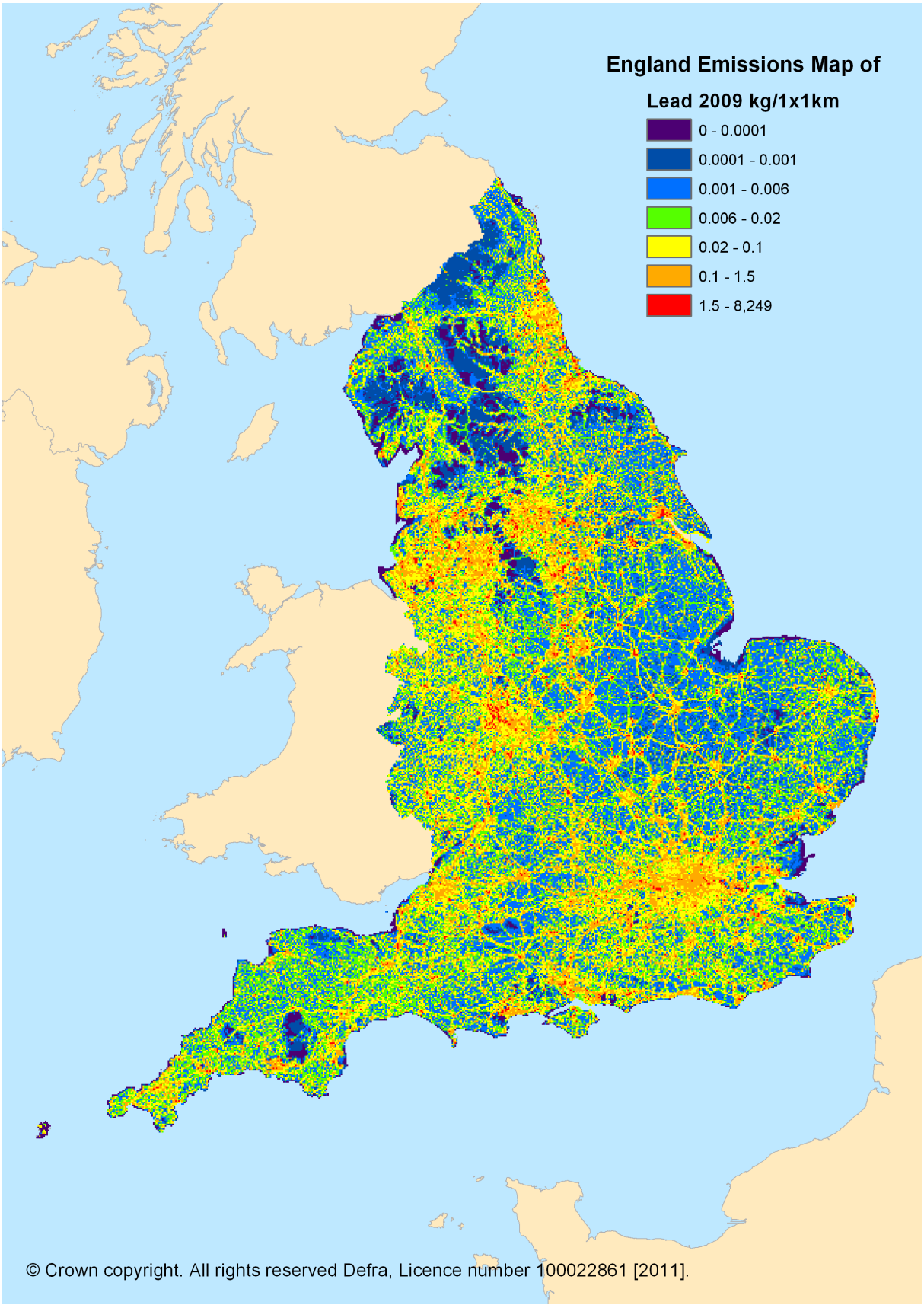
Units: tonnes

Figure 2-56 England Lead Emissions by Source, 1990-2009



England's lead emissions have declined by 98% since 1990 and accounted for 74% of the UK total in 2009. The emissions that arise due to the production in the iron and steel industries represent the most significant source, accounting for 38% of the England total in 2009. As a result, 57% of the overall emissions are from industrial processes (2C3: aluminium production up 316% 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, 2009



2.7.2 Scotland Lead Inventory by NFR Sector, 1990-2009

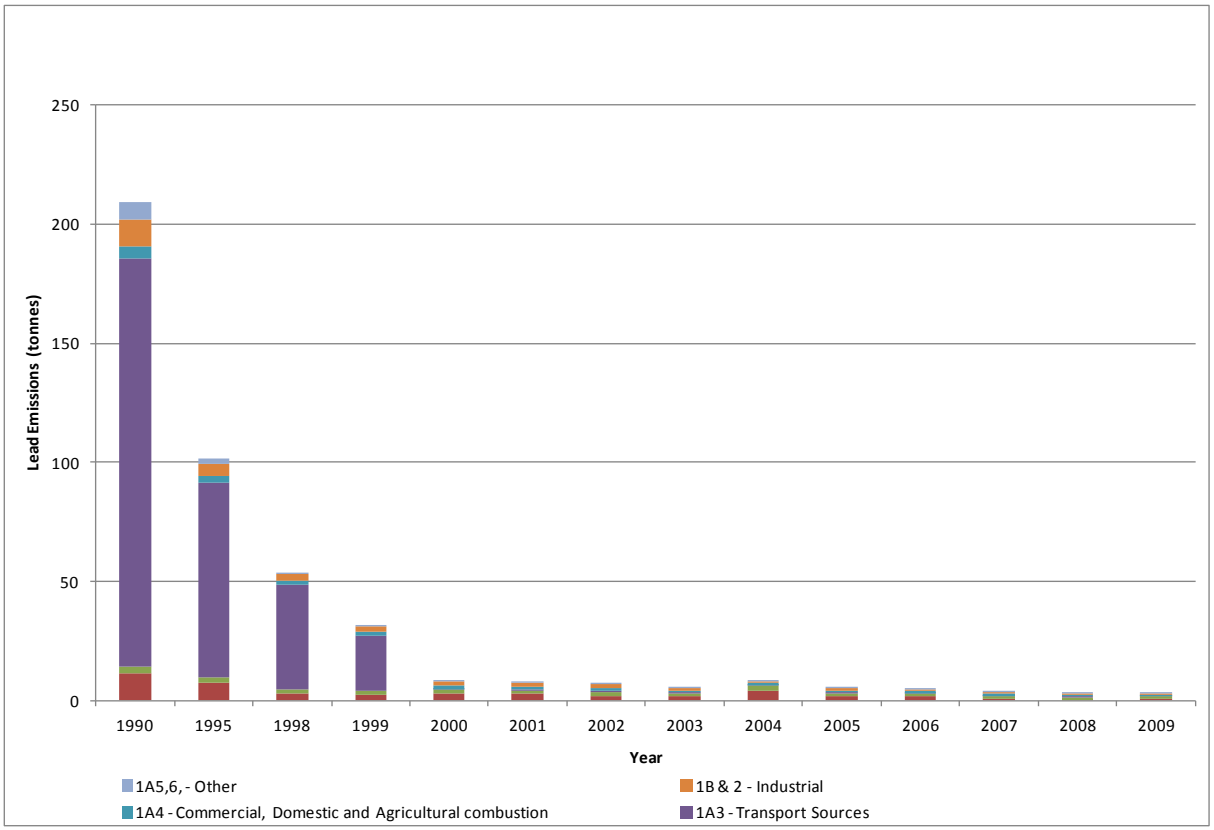
The table and graph below give a summary of the lead emissions in Scotland by broad NFR sector categories. The detailed data are available in Appendix I.

Table 2-40 Scotland Emissions of Lead by NFR Source Sector (tonnes)

NFR Code	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2009 (%)
1A1 - Energy Industries	11.2	7.2	2.7	2.2	3.0	2.8	2.0	1.6	4.1	1.9	1.8	0.7	0.4	0.6	21%
1A2 - Industrial Combustion	3.3	2.6	2.0	1.7	1.5	1.5	1.7	1.6	2.1	1.4	1.1	1.1	1.0	1.0	33%
1A3 - Transport Sources	171	81.6	43.8	23.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	6%
1A4 - Commercial, Domestic and Agricultural	5.1	2.8	2.0	1.9	1.5	1.4	1.2	1.0	0.9	0.7	0.8	0.8	0.9	0.9	28%
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	0.5	0.3	9%
1A5,6, - Other	7.4	2.6	0.04	0.06	0.06	0.03	0.15	0.14	0.12	0.07	0.07	0.07	0.07	0.07	2%
Total	**210**	**102**	**53.4**	**31.2**	**8.1**	**7.7**	**7.2**	**5.7**	**8.3**	**5.1**	**4.5**	**3.5**	**3.0**	**3.0**	**100%**

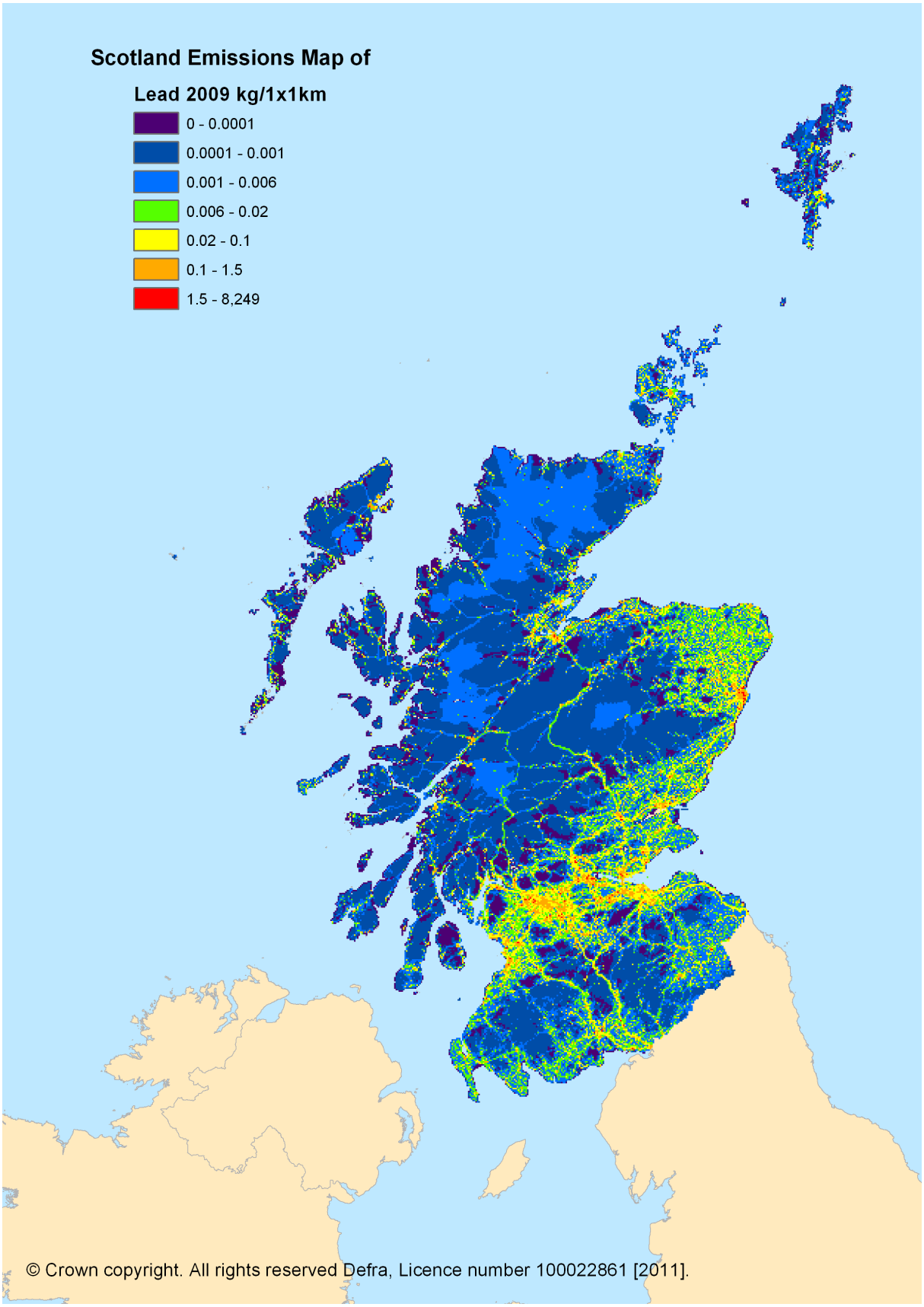
Units: tonnes

Figure 2-58 Scotland Lead Emissions by Source, 1990-2009



Scotland's lead emissions have declined by 99% since 1990 and accounted for 5% of the UK total in 2009. In Scotland, emission from domestic combustion is the most significant source, accounting for 23% of the Scotland total in 2009 (1A4bi: down 77% since 1990). 21% of lead emissions in Scotland come from energy industries (1A1: down 94% since 1990). Emissions from power generation (1A1a) accounted for 14% of the Scotland total emissions in 2009, 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, 2009



2.7.3 Wales Lead Inventory by NFR Sector, 1990-2009

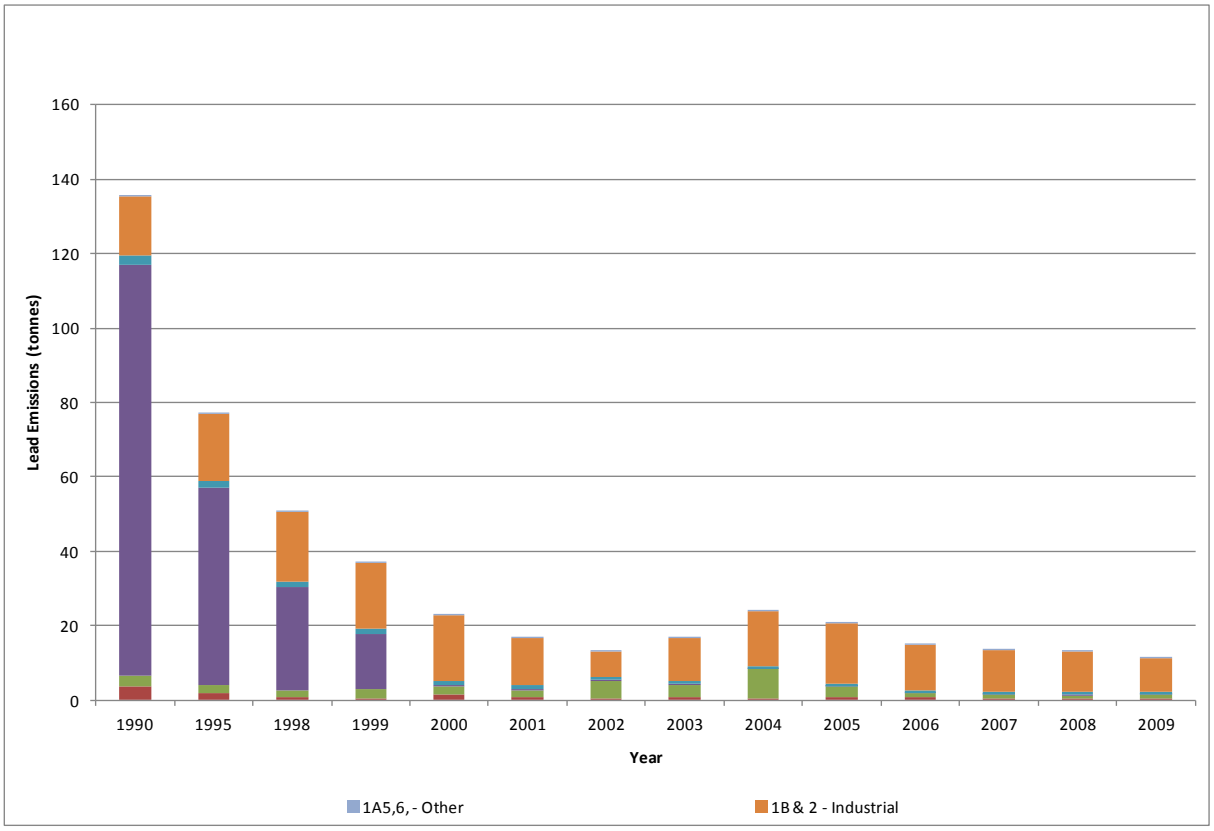
The table and graph below give a summary of the lead emissions in Wales by broad NFR sector categories. The detailed data are available in Appendix I.

Table 2-41 Wales Emissions of Lead by NFR Source Sector (tonnes)

NFR Code	1990	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2009(%)
1A1 - Energy Industries	3.7	1.8	0.8	0.6	1.5	1.0	0.5	0.9	0.4	0.8	0.8	0.4	0.5	0.5	4%
1A2 - Industrial Combustion	3.0	2.4	1.9	2.5	2.4	1.7	4.8	3.4	7.8	2.9	0.9	1.0	0.9	1.0	9%
1A3 - Transport Sources	110	52.8	27.7	14.5	0.14	0.13	0.13	0.13	0.14	0.14	0.14	0.12	0.12	0.11	1%
1A4 - Commercial, Domestic and Agricultural	2.7	1.8	1.5	1.5	1.1	1.1	0.8	0.7	0.7	0.5	0.5	0.6	0.7	0.7	6%
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	10.9	8.9	80%
1A5,6, - Other	0.4	0.4	0.02	0.03	0.03	0.01	0.09	0.08	0.07	0.04	0.04	0.04	0.04	0.04	0%
Total	**136**	**77.5**	**50.6**	**36.8**	**22.9**	**16.8**	**13.1**	**16.9**	**24.1**	**20.9**	**15.0**	**13.6**	**13.1**	**11.2**	**100 %**

Units: tonnes

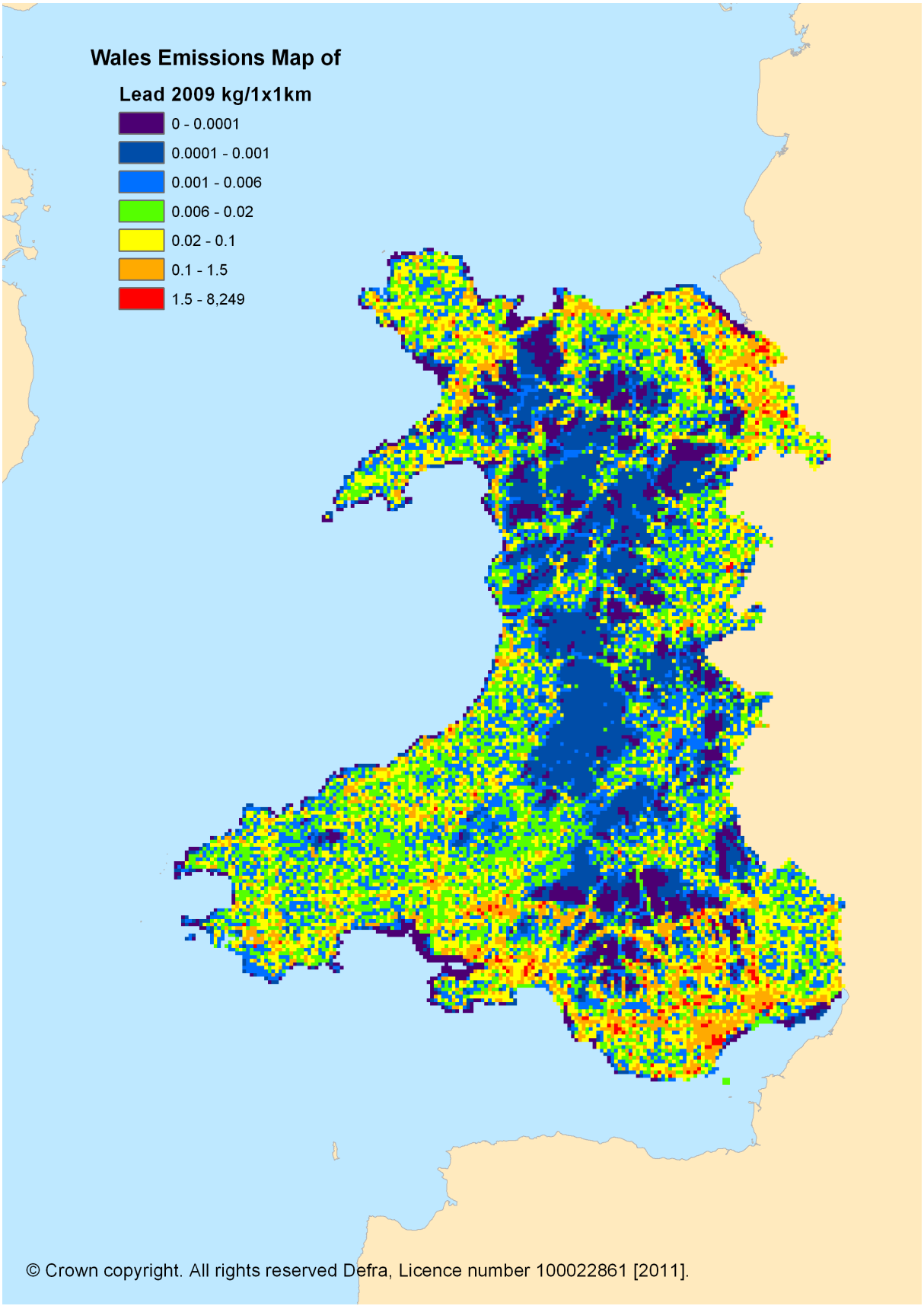
Figure 2-60 Wales Lead Emissions by Source, 1990-2009



Wales lead emissions have declined by 92% since 1990 and accounted for 19% of the UK total in 2009. The emissions that arise due to the production in the iron and steel industries are by far the most significant source, accounting for 72% of the Wales total in 2009. 76% of lead emissions in Wales are from industrial production (2C3: aluminium up 316% since 1990 and lead production 2C5b: down 87% since 1990), 12% from industrial processes and fugitive emissions from fuels (1A2 & 1B: down 70% 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, and is also the reason per capita emissions are much higher in Wales than the other constituent countries in 2009.

Figure 2-61 Map of Lead Emissions in Wales, 2009



2.7.4 Northern Ireland Lead Inventory by NFR Sector, 1990-2009

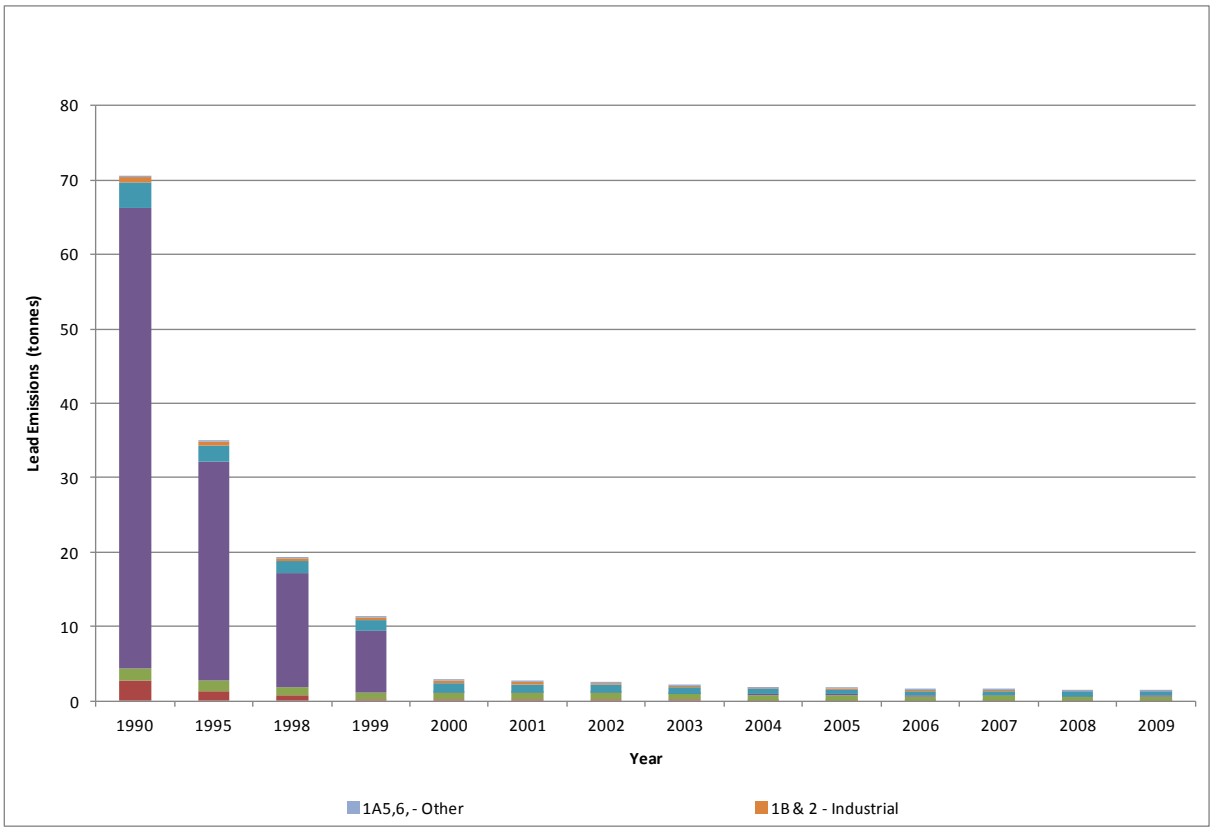
The table and graph below give a summary of the lead emissions in Northern Ireland by broad NFR sector categories. The detailed data are available in Appendix I.

Table 2-42 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	2009	2009 (%)
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	0.03	0.02	2%
1A2 - Industrial Combustion	1.6	1.4	1.1	1.0	0.8	0.8	0.9	0.7	0.8	0.8	0.6	0.7	0.6	0.6	45%
1A3 - Transport Sources	61.9	29.5	15.3	8.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	5%
1A4 - Commercial, Domestic and Agricultural	3.5	2.1	1.7	1.5	1.3	1.1	1.1	0.9	0.7	0.6	0.6	0.6	0.6	0.6	45%
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	0.05	0.03	2%
1A5,6, - Other	0.2	0.2	0.01	0.02	0.02	0.01	0.05	0.05	0.04	0.02	0.02	0.02	0.02	0.02	2%
Total	**70.5**	**35.0**	**19.1**	**11.2**	**2.8**	**2.5**	**2.5**	**2.0**	**1.8**	**1.6**	**1.4**	**1.5**	**1.4**	**1.3**	**100%**

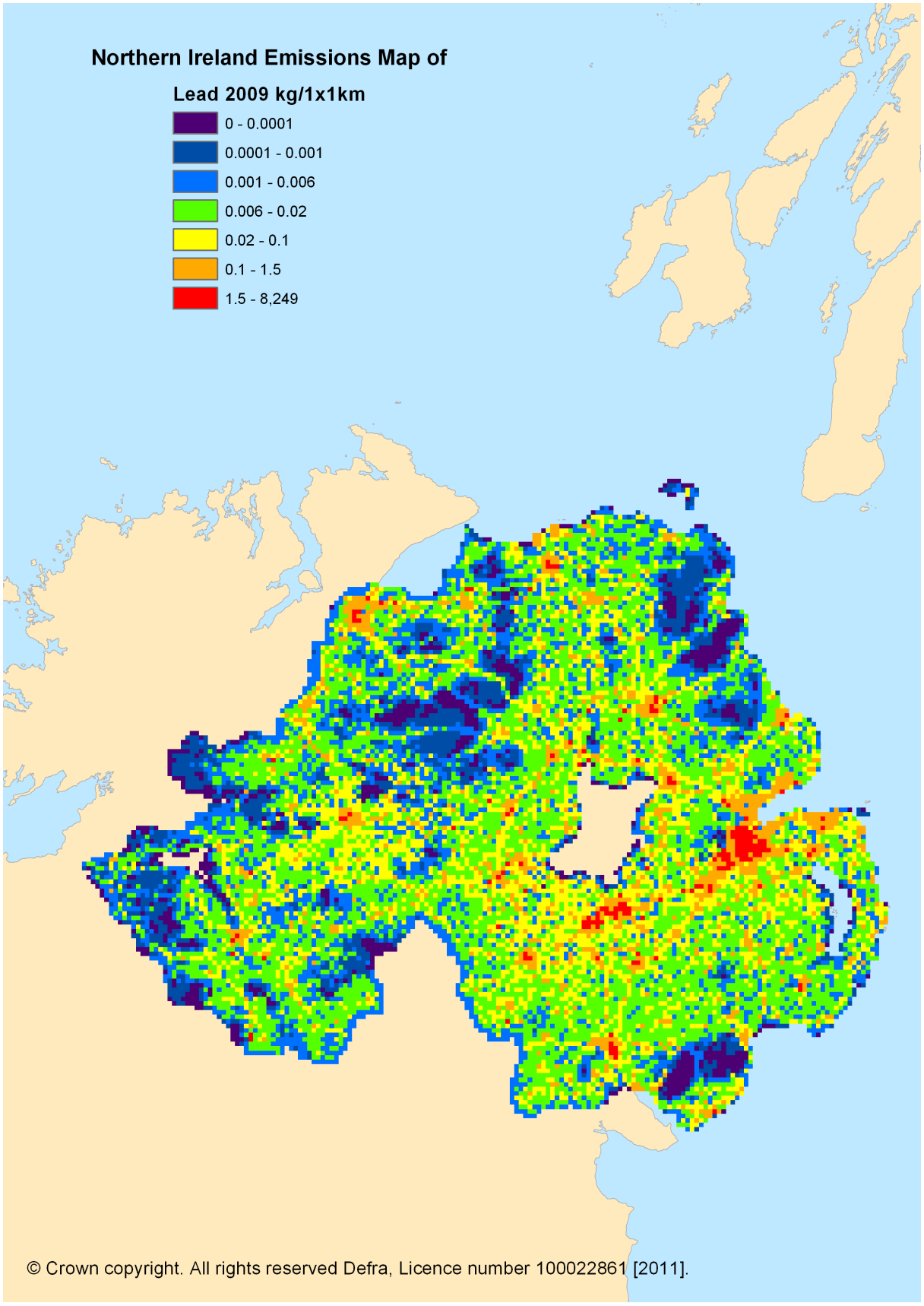
Units: tonnes

Figure 2-62 Northern Ireland Lead Emissions by Source, 1990-2009



Northern Ireland's lead emissions have declined by 98% since 1990 and accounted for 2% of the UK total in 2009. In Northern Ireland, emissions that arise from domestic combustion (1A4b) is the most significant source, accounting for 37% of the Northern Ireland total in 2009 (1A4bi: down 81% since 1990). 45% of lead emissions in Northern Ireland come from industrial combustion (1A2: down 62% since 1990), 5% from transport sources (1A3: down more than 99% since 1990) and 2% arise from energy industries (1A1: down by 99% since 1990).

Figure 2-63 Map of Lead Emissions in Northern Ireland, 2009



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 2009"*, Murrells *et al*., 2011)

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 time series, as these estimates are frequently based on very limited historic data; in more recent years the development of environmental regulation and reporting has increased, for example through the development of annual reporting of emissions by operators of major industrial plant, regulated under Environmental Permitting Regulations (EPR) / Integrated Pollution Prevention and Control (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 2009, 47% of the UK total CO came from road transport sources (1A3b) alone, with 13% of UK carbon monoxide emissions 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; 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 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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