Department for Environment, Food & Rural Affairs

Emissions of Air Quality Pollutants

1990 – 2014

The Scottish Government

DOE

Llywodraeth Cymru
Welsh Government

Contents

1 Introduction

This report provides a summary of the 2016 Air Quality Pollution Inventory (AQPI), covering the years 1990 - 2014. Emission inventories are important in assessing the impact of human activity on atmospheric pollution, and provide policy makers and the public with a valuable understanding of the sources and trends (past and future) of key pollutants. This report is updated annually, providing an overview of the key pollutants contributing to air pollution in the UK, along with information on the sources of pollution and trends in emissions – in particular the progress towards achieving international targets on reducing air pollutant emissions.

Information on the full range of air pollutants is available from the pages of the National Atmospheric Emissions Inventory (NAEI) website. **http://naei.defra.gov.uk/index.php**

1.1 Air Quality

When released into the atmosphere air quality pollutants can have a transboundary and/or local impact. Transboundary impacts occur when a pollutant from one area (or country) impacts on another after being transported by weather systems. Examples of transboundary pollutants are acidifying pollutants such as nitrogen oxides (NOx) and sulphur dioxide (SO_2) as well as ozone (O_3) which is not emitted directly into the atmosphere but may be formed over a large distance by reactions of emitted non-methane volatile organic compounds (NMVOC) with NOx in sunlight. Acidifying pollutants can adversely affect buildings, vegetation and aquatic systems, whilst ozone formed in the lower atmosphere (the troposphere) can be damaging to human health, materials, crops and plants. Particulate matter (PM) is formed from chemical reactions in the atmosphere involving NOx, SO_2 and ammonia (NH_3), as well as being directly emitted from human activities, and is damaging to health.

Atmospheric pollution can also impact on local air quality. Where high concentrations occur, there can be a wide range of negative impacts to human health or ecosystems.[1]

Table 1.1 highlights the key pollutant-source combinations in the UK for the five main air quality pollutants as identified in the latest update of the UN/ECE Gothenburg Protocol to Abate Acidification, Eutrophication and Ground-level Ozone[2]. The emissions of NOx, SO_2, and particulate matter ($PM_{2.5}$) are all strongly linked to the burning of fuels which occurs in electricity generation, transport, and industry. These are collectively referred to as fuel combustion sources. NMVOCs are emitted from many sources, including domestic use of products that contain solvents. In comparison, NH_3 emissions are dominated by the agricultural sector. These pollutants are each considered in greater detail in Section 2 of this report.

Table 1.1: Current Key Pollutant-Source Combinations in the UK

	NOx	SO_2	NMVOC	NH_3	$PM_{2.5}$
Electricity generation					
Industrial combustion					
Residential & commercial					
Industrial processes					
Extraction & distribution of fossil fuels					
Solvents					
Road transport					
Other transport & mobile machinery					
Agriculture					
Waste					

Key: key emission source — moderate emission source — minimal /no emissions

[1] For further information on impacts, visit: http://uk-air.defra.gov.uk/air-pollution/effects

[2] http://www.unece.org/env/lrtap/multi_h1.html

1.2

1.2 The UK Inventory

The UK inventory is compiled annually to report emissions totals by pollutant and source sector in a well-defined format. This allows emissions to be easily compared across different countries. National emission estimates for air quality pollutants are submitted to both the European Commission under the National Emissions Ceilings Directive (NECD, 2001/81/EC) and the United Nations Economic Commission for Europe (UN/ECE) under the Convention on Long-Range Transboundary Air Pollution (CLRTAP).

The CLRTAP submissions are available online at: **http://www.ceip.at/overview-of-submissions-under-clrtap/**.

The emissions data are supported by an Informative Inventory Report (IIR), which details the inventory methodology and documents emission factors and other data used in the inventory. All pollutants covered by the UK's air quality pollutant inventory are listed below, and those included in this summary report are underlined. Information and emissions data on all of these pollutants can be found at: **http://naei.defra.gov.uk/**

Air Quality Pollutants

- particulate matter, PM*
- black smoke, BS
- carbon monoxide, CO
- benzene
- 1,3-butadiene
- polycyclic aromatic hydrocarbons, PAH
- nitrogen oxides, NOx
- sulphur dioxide, SO_2
- non-methane volatile organic compounds, NMVOC
- ammonia, NH_3
- hydrogen chloride, HCl
- hydrogen fluoride, HF

* Particulate matter emissions are given as PM_{10}, $PM_{2.5}$, $PM_{1.0}$ and $PM_{0.1}$ and black carbon (BC)

Heavy Metals

- arsenic, As
- beryllium, Be
- cadmium, Cd
- chromium, Cr
- copper, Cu
- lead, Pb
- manganese, Mn
- mercury, Hg
- nickel, Ni
- tin, Sn
- selenium, Se
- vanadium, V
- zinc, Zn

Persistent Organic Compounds (POPs)

- polycyclic aromatic hydrocarbons, PAHs
- dioxins and furans, PCDD/Fs
- polychlorinated biphenyls, PCBs
- pesticides: lindane, hexachlorobenzene (HCB), pentachlorophenol (PCP)
- short-chain chlorinated paraffins, SCCPs
- polychlorinated napthalenes, PCNs
- polybrominated diphenyl ethers, PBDEs

The methodology for calculating air quality pollutant emissions is consistent with the greenhouse gas inventory methodology.

Emission estimates for historic years are typically calculated by combining an emission factor (for example, tonnes of a pollutant per million tonnes of fuel consumed) with an activity statistic (for example, million tonnes of fuel consumed). Commonly, activity data will consist of official national datasets such as fuel use data from the Department of Energy and Climate Change, population, or GDP.

Emission estimates for future years are called emission projections, and are also produced and reported as part of the inventory process. Emission projections are typically estimated by considering how emissions in the most recent year of the historic emissions inventory are likely to change in the future. For example: Are the existing trends expected to continue? Is there new legislation that will be introduced that will affect the emissions? Will the use of new technology help to reduce emissions? This assessment is done at a detailed level, although there can still be substantial uncertainty associated with estimating data that relate to future years.

1.3

1.3 Current Issues and Legislation

Air quality in the UK has improved in recent decades and the UK continues to comply with EU and international emission ceilings. However air quality is still an important issue at a political level whilst the potential for harm to human health and environmental systems remains. Recently, political and legislative focus has surrounded emissions of PM and its precursors in the atmosphere and the formation of tropospheric ozone (O_3). Both can have severe health impacts to humans, as well as damaging environmental processes e.g. reducing crop yields. In addition, recent evidence suggests that exposure to increased NO_2 concentrations arising from emissions of NOx, may give rise to human health impacts that are comparable to those from PM [3].

In the UK, air quality is managed at both the local and national levels. Part IV of the Environment Act 1995 establishes the system of Local Air Quality Management (LAQM), which requires local authorities to carry out regular 'Review and Assessments' of a number of statutory pollutants such as NO_2 and PM in their area and take action to address exceedances of these objectives. At the national level, the Department for the Environment, Food and Rural Affairs is responsible for the national programme of policies and measures that help to ensure that air quality standards are met. However, the development and implementation of air quality policies is the responsibility of the devolved administrations. Meeting the air quality standards can be achieved in different ways, and controlling emissions is one of several options.

At the international scale, legislation on transboundary pollution requires total annual emissions to meet ceilings under the EU's National Emissions Ceilings Directive (NECD), and to meet emission reduction commitments under the Gothenburg Protocol (UN/ECE legislation).

The 2010 emission ceilings, and new 2020 emission reduction commitments (ERC) for the UK under the Gothenburg Protocol are shown in Table 1.3.

Further information on local air quality legislation and both the Gothenburg Protocol and the NECD can be found by exploring the links at the end of this report.

Table 1.3: UK annual emissions[4] and targets 2010 – 2020 (ktonnes)

	NOx	SO_2	NH_3	NMVOC	$PM_{2.5}$
2014 emissions	949	308	281	819	105
2010 Gothenburg Protocol ceiling	1181	625	297	1200	n/a
2020 Gothenburg Protocol ERC[5]	728	292	282	773	76

UK Government has implemented measures to decrease emissions across the key air quality pollutants. Section 2 of this report reviews trends in these pollutants, highlighting the impact of UK Government policies / actions in meeting the necessary agreements and targets. The new 2020 Gothenburg Protocol emission reduction commitments are placed within the context of the historical emissions so that the scale of emission reductions required can be appreciated.

[3] Faustini A, Rapp R, Forastiere F. Nitrogen dioxide and mortality: review and meta-analysis of long-term studies. Eur Respir J 2014;44:744-753

[4] As required by the Gothenburg Protocol, UK emissions include those from Gibraltar.

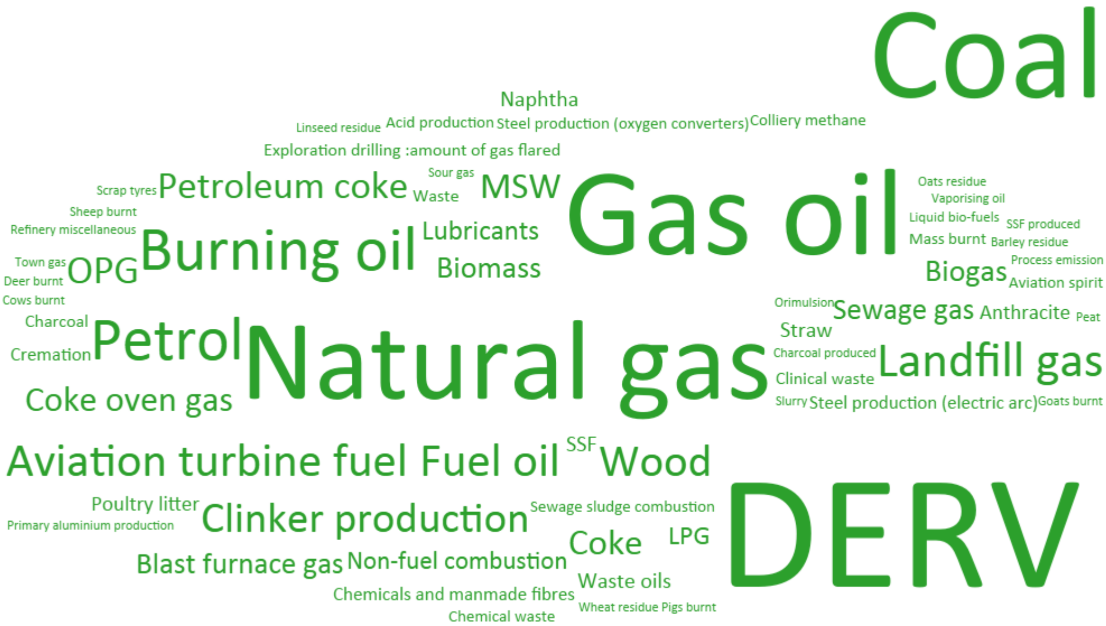
[5] Emission reduction commitments for 2020 under the Gothenburg Protocol are declared as a percentage reduction. The figures given in this table have been calculated for illustrative purposes and may change if the 2005 base year emissions change due to future inventory revisions.

2 Air Quality Pollutants

2.1 Nitrogen Oxides (NOx)

NOx emissions consist of both nitric oxide (NO) and nitrogen dioxide (NO_2). Short-term exposure to high NOx concentrations is damaging to human health, causing airway inflammation and respiratory symptoms. In the presence of sunlight, NOx can react to produce photochemical smog. NOx is also an acidifying pollutant, and can cause damage to buildings and ecosystems by altering the chemical make-up of minerals, soils and aquatic systems. The main sources of NOx are from the combustion of fossil fuels (Figure 2.1.1). In the UK, the sectors which contribute most to the emissions total are power stations and road transport (see Figure 2.1.2). Road transport has accounted for approximately a third of UK emissions in recent years.

Figure 2.1.1: Fuels and activities responsible for emissions (2014)
The size of the text indicates the size of the corresponding emission. DERV is diesel for road vehicles.



As well as being a pollutant regulated under the Gothenburg Protocol and NECD, there is a great deal of legislation specific to key sources of NOx emissions such as electricity generation (e.g. the Industrial Emissions Directive, IED) and transport (e.g. EURO Standards in vehicle regulation).

The time series (Figure 2.1.2) shows how emissions from the transport sector have decreased significantly since 1990, with vehicle regulations coming into force in the form of Euro Standards, and important technological improvements such as the three-way catalytic converter. The impact on reducing emissions from petrol fuelled vehicles has been dramatic, as highlighted in Figure 2.1.2, although this decrease has been slowed down in recent years with the increased number of higher NOx emitting diesel vehicles in the fleet.

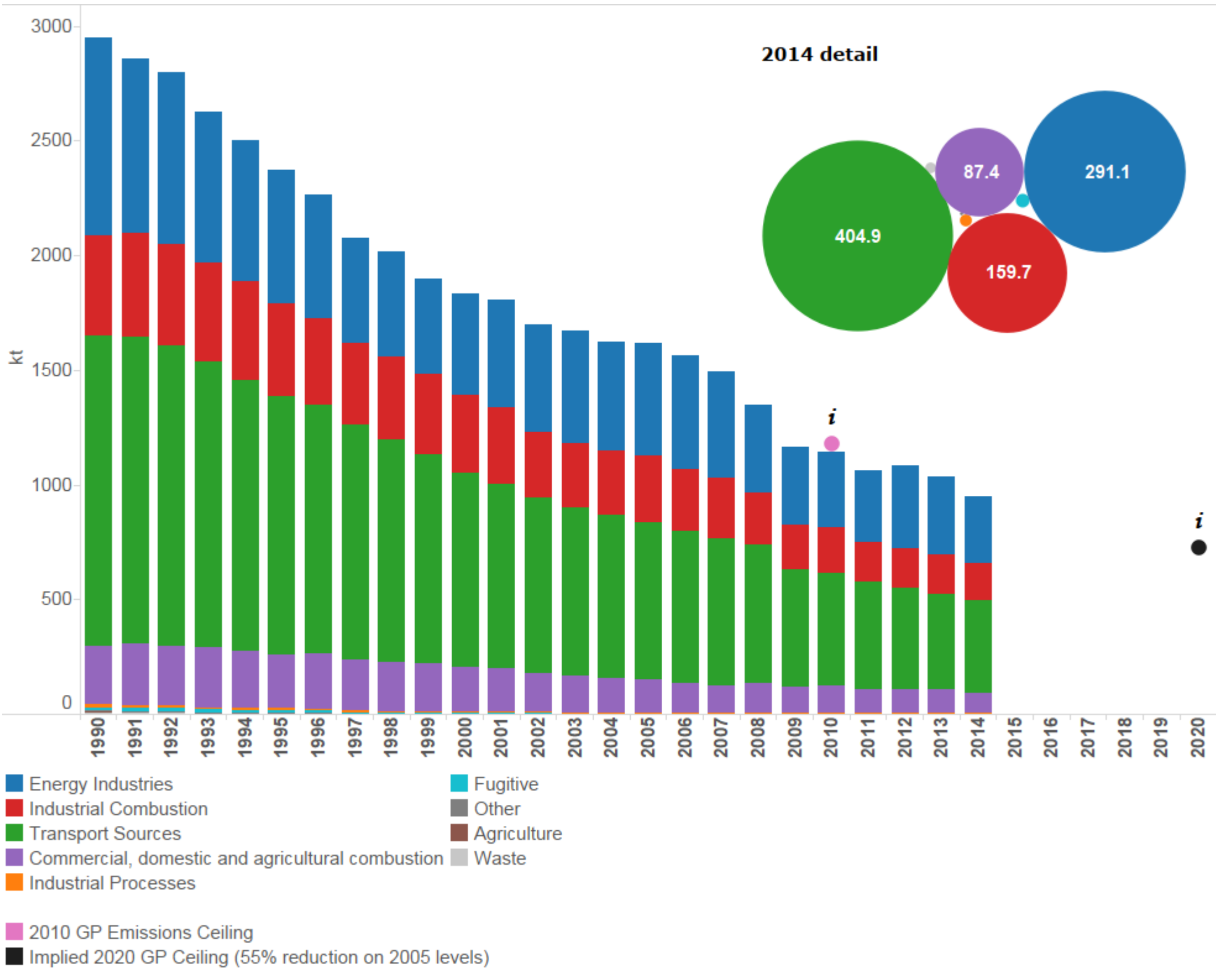
Historically, emissions from power stations were fairly consistent during the 1970s, with a small decrease through the 1980s mainly attributable to increased efficiency of power plants and the increased use of nuclear power. This period also incorporated the miners' strike in 1984 which had a large short-term impact on emissions from the energy generation sector, due to the reduced mining (and therefore availability) of coal and related emissions.

2.1

A greater decrease since 1988 has been due to factors such as the fitting of low NOx burners and other NOx reduction technology to power stations along with a general decline in coal consumption in favour of natural gas. This trend reversed in 2012, with coal consumption in power stations rising above that of natural gas for the first time since 2007, contributing to an increase in emissions from the sector as a whole.

Click here for interactive data viewer

Figure 2.1.2: UK NOx emissions, 1990-2014 with Gothenburg Protocol Ceilings (2010 and 2020)

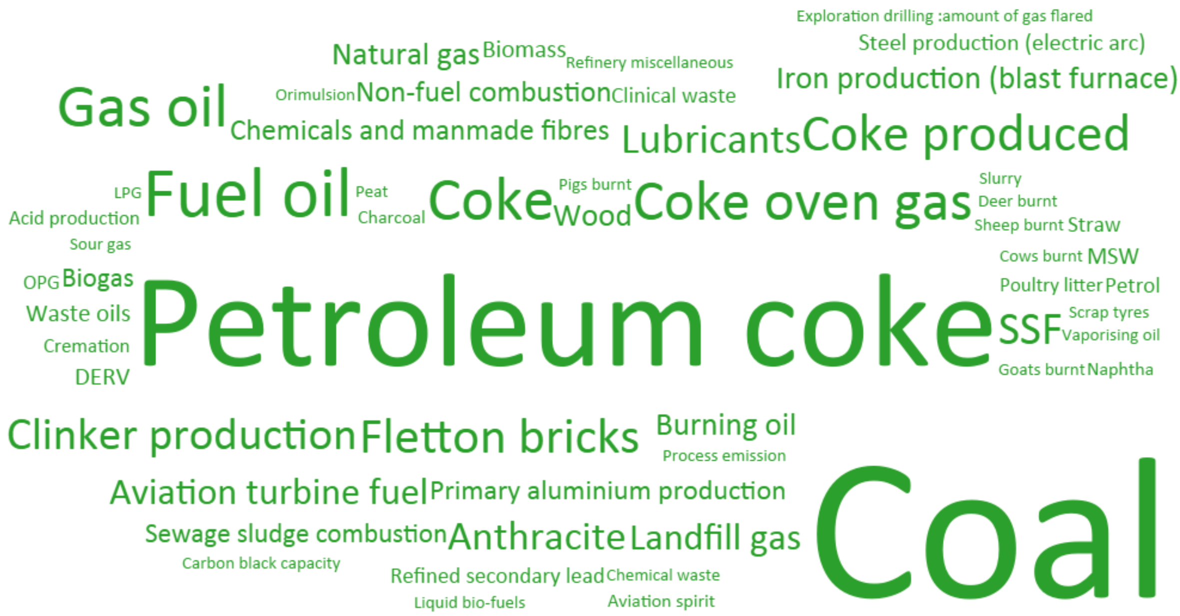


2.2 Sulphur Dioxide (SO_2)

SO_2 emissions are formed by the oxidation of sulphur contained in fuels during combustion processes. Combustion from energy and industry are the most significant sources for SO_2 emissions, contributing approximately three quarters of the 2014 total. Combustion in commercial, residential and agricultural sectors are also important sources, summing to a contribution of more than 10%. Figure 2.2.1 highlights the significance for the UK inventory of the combustion of sulphur-containing fuels, most notably coal and petroleum coke, and to a lesser extent fuel oil and gas oil. Natural gas contains little or no sulphur.

The adverse impacts of SO_2 have long been realised due to its contribution to low level winter smogs, in particular the severe impacts of the London smogs in the 1950s. As with NOx, major impacts to buildings and ecosystems are associated with its acidifying properties, SO_2 can damage lung functionality in humans and also contributes to secondary particulate matter as a result of reactions with other pollutants in the air.

Figure 2.2.1: Fuels and activities responsible for emissions (2014)
The size of the text indicates the size of the corresponding emission.



Of all of the air quality pollutants that are governed under the NECD and Gothenburg Protocol, the UK emissions of SO_2 show the most marked decrease over time; since 1990 emissions have declined by more than 90% and this is directly linked to an economy-wide shift away from sulphur-containing fuels, as natural gas has largely replaced coal as the main fuel across energy, industry and in residential heating. Where coal use is still prevalent, such as in electricity generation, the introduction of emissions abatement (such as flue gas desulphurisation) has reduced emissions further.

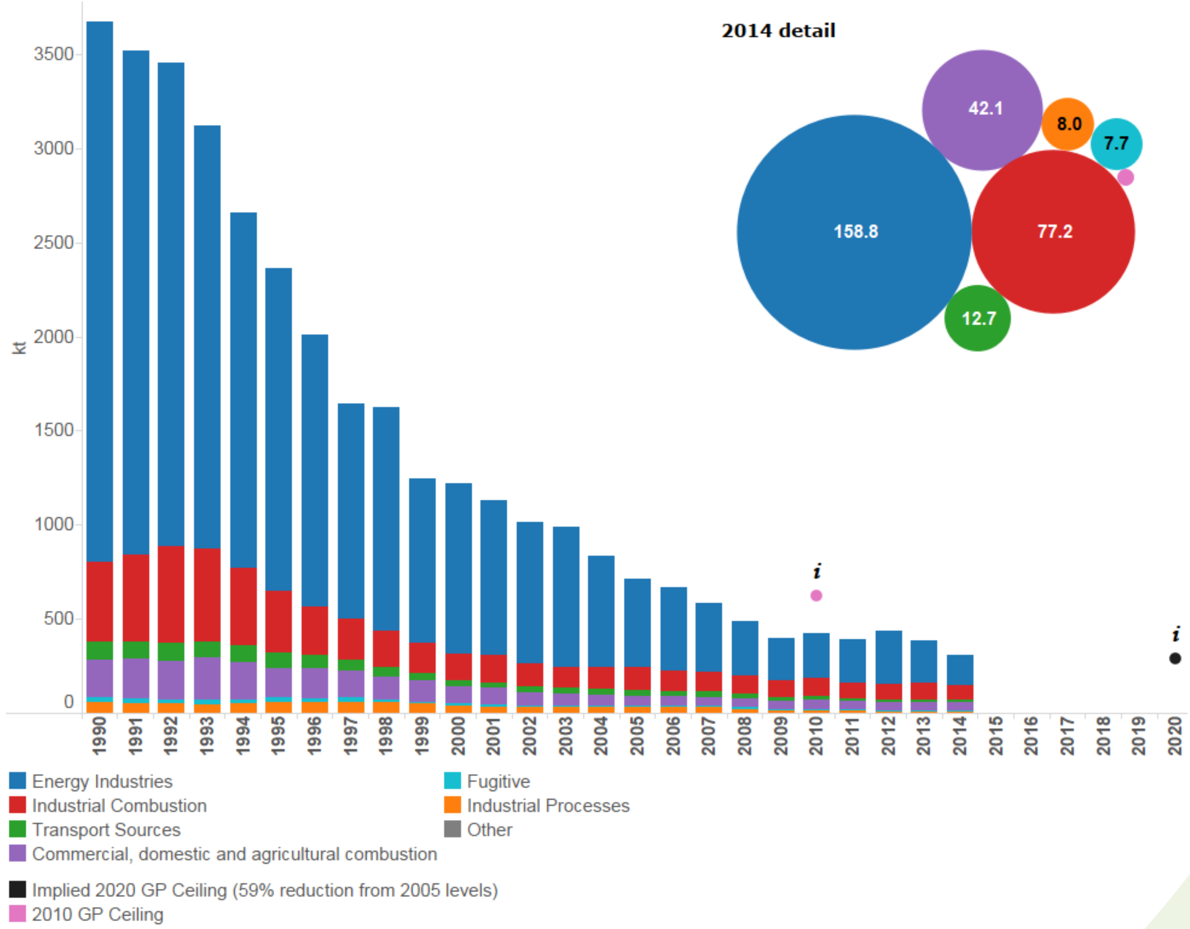
In addition, several high-emitting industry sectors (such as iron and steel, oil refining) have been in decline in the UK as production has increasingly moved overseas during the 1990s and 2000s.

2.2

Figure 2.2.2 shows trends in SO_2 emissions by source sector since 1990. Until this point emissions from electricity generation were fairly static at around 3,000 ktonnes per year. Improved abatement at power plants and legislation such as the Environmental Protection Act (1990), the Large Combustion Plant Directive (2001) and the Industrial Emissions Directive (2010) have all contributed to the regulation and mitigation of SO_2 emissions across energy and industrial sources. Road transport emissions have declined due to tightening of fuel standards during the 1990s and more recently due to the EU Fuel Quality Directive and its amendments leading to a reduction in the sulphur content of diesel.

Click here for interactive data viewer

Figure 2.2.2: UK SO_2 emissions, 1990-2014 with Gothenburg Protocol Ceilings (2010 and 2020)



2.3 Ammonia (NH_3)

NH_3 emissions can cause damage to terrestrial and aquatic ecosystems through acidification and eutrophication. As with SO_2 and NOx, it is also a precursor to secondary particulate matter. The chemistry of NH_3 means that it contributes to both localised and transboundary pollution.

Figure 2.3.1: Fuels and activities responsible for emissions (2014)
The size of the text indicates the size of the corresponding emission. Agricultural sources dominate the total.

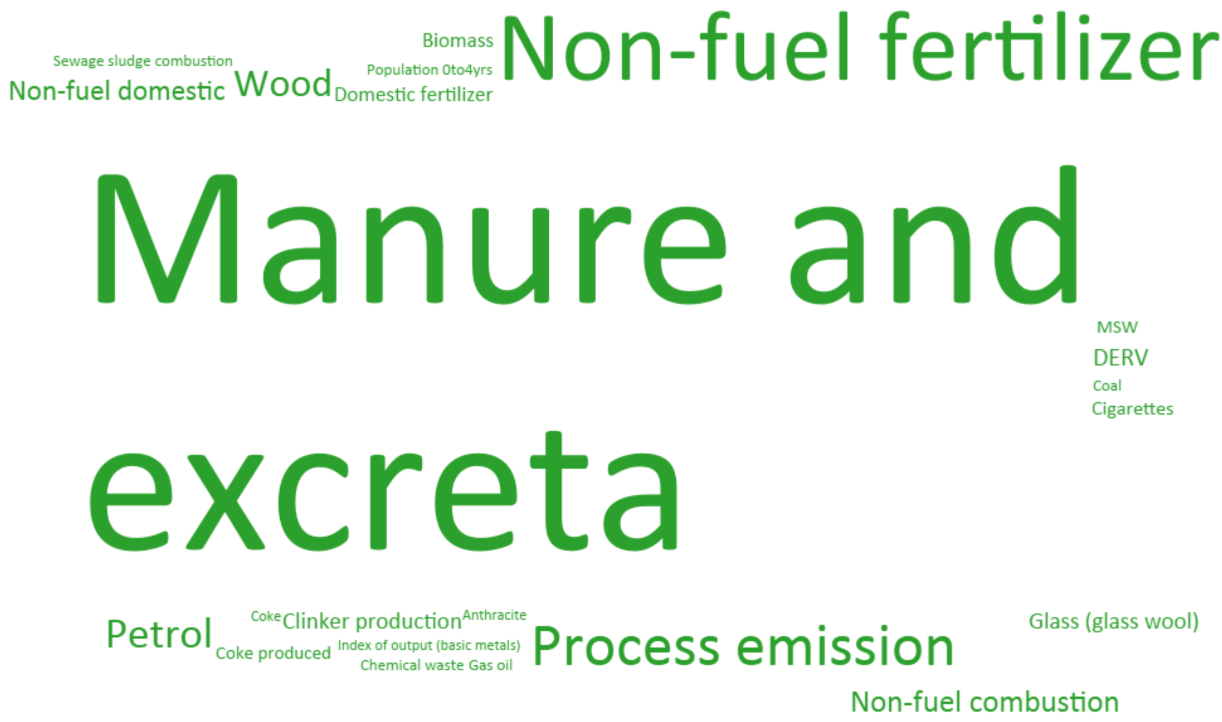


Figure 2.3.1 shows that the sources within the Agriculture sector are the dominant sources for emissions of NH_3, the largest component being emissions from livestock, specifically the decomposition of urea in animal wastes (and uric acid in poultry wastes). Of the livestock classes, cattle are the largest emitters of NH_3, accounting for more than half of all emissions from livestock. The application of synthetic fertiliser to soils is also a major source of NH_3 emissions at approximately 15% in 2014.

NH_3 emissions are difficult to measure because they are dominated by "diffuse" sources (e.g. livestock), rather than point sources (e.g. power stations and industrial installations). Uncertainty in the UK inventory estimates are greater for NH_3 than for many other air quality pollutants (such as SO_2, NOx) due to:

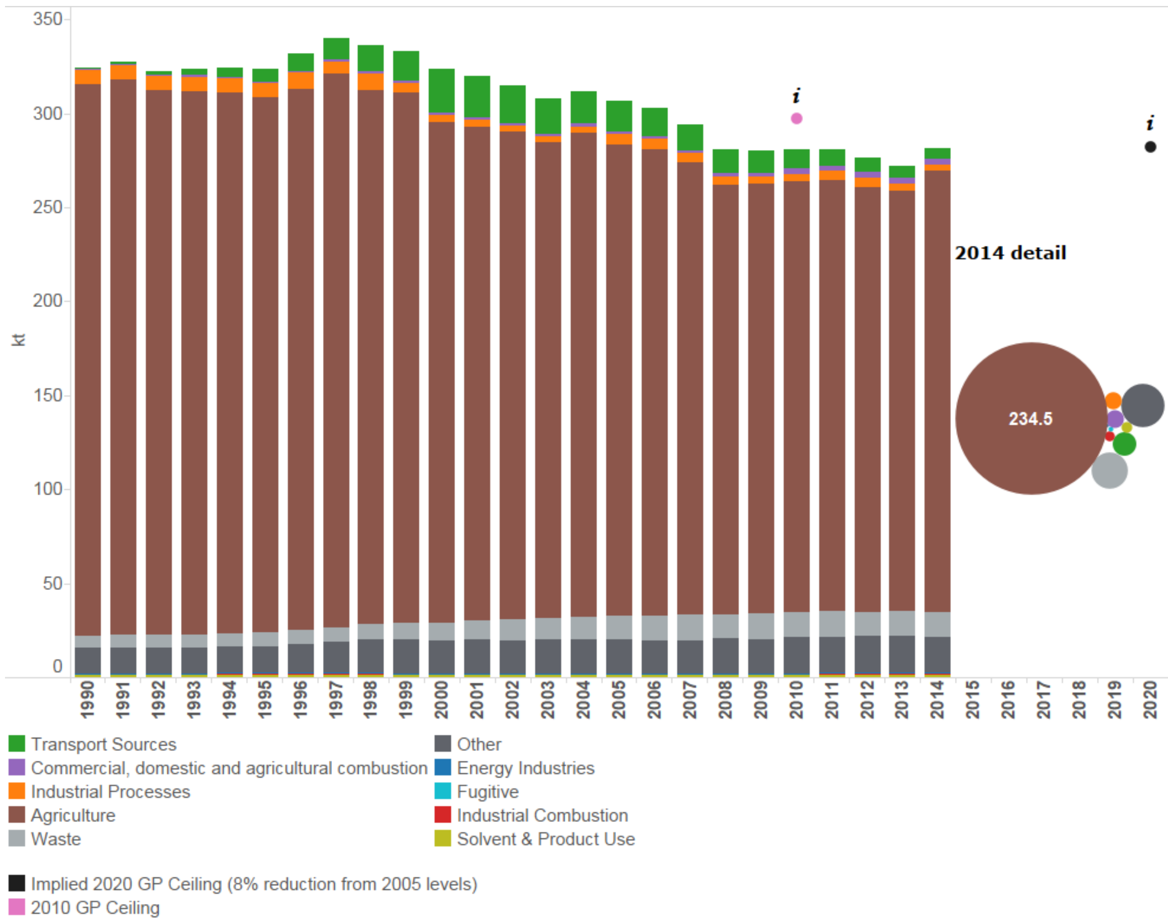
- The dependency on highly variable factors such as the species, age and diet of animals in determining livestock emission levels.
- The complexities of the behaviour of nitrogen compounds in the natural environment. For example, after the application of fertiliser to crops, the chemical processes that result in the release of NH_3 to air depend on a range of factors such as soil type, climatic conditions, crop species and the type of fertiliser applied.

Reliable source data for NH_3 are only available since 1980. Compared to other air quality pollutants, there has been relatively little reduction in total emissions over the time series (Figure 2.3.2). The reduction of NH_3 emissions that has been achieved in the UK is largely due to a decrease in UK cattle numbers, where better farming practices have improved efficiencies (generating the same amount of products with fewer animals, for example increasing milk yields). The implementation of regulations such as the Nitrate Sensitive Areas Order (1990), and subsequent designation of Nitrate Vulnerable Zones where use of manufactured nitrogen fertilisers and organic manures is controlled, have led to a reduction in fertiliser use and resultant NH_3 emissions since the late 1990s.

Since 2008, a rise in the use of anaerobic digestion and composting for organic waste treatment has led to increased NH_3 emissions from the waste sector. However the trend in total NH_3 emissions continues to be dominated by trends in livestock numbers.

Click here for interactive data viewer

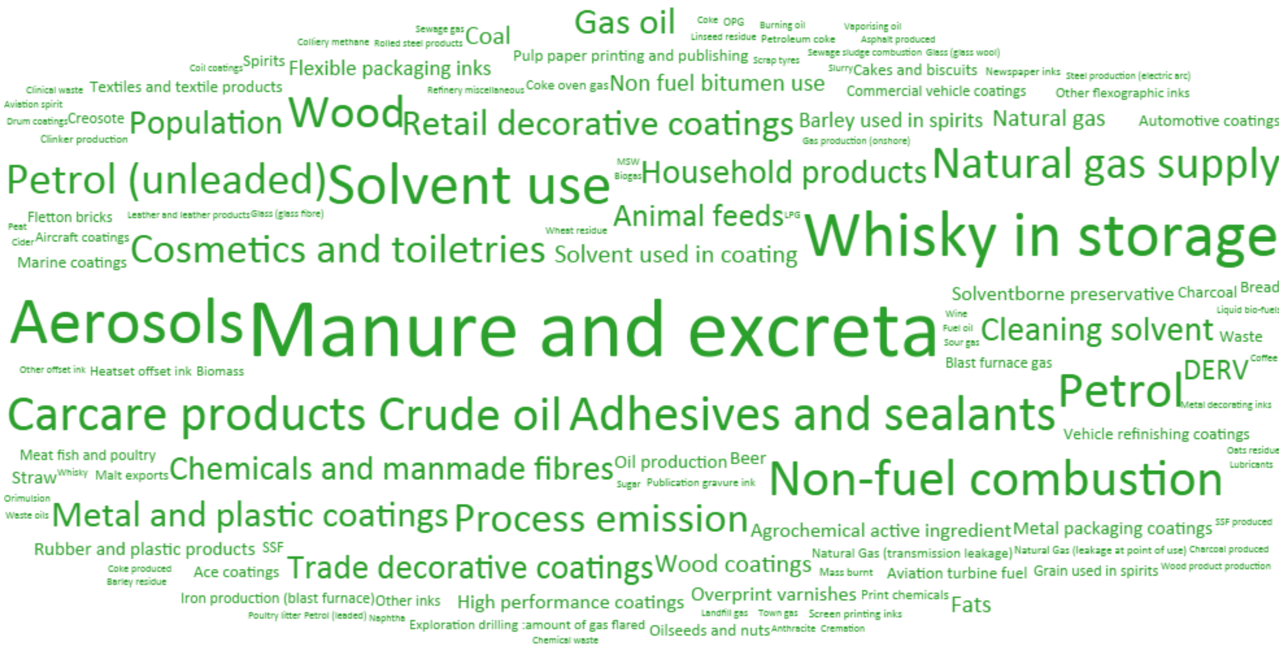
Figure 2.3.2: UK NH_3 emissions, 1990-2014 with Gothenburg Protocol Ceilings (2010 and 2020)



2.4 Non-Methane Volatile Organic Compounds (NMVOCs)

NMVOCs are a group of organic compounds. They are formed either as combustion products, or more commonly as vapour emitted from a wide range of industrial processes, solvent use and fossil fuel extraction and distribution.

Figure 2.4.1: Fuels and activities responsible for emissions (2014)
The size of the text indicates the size of the corresponding emission.



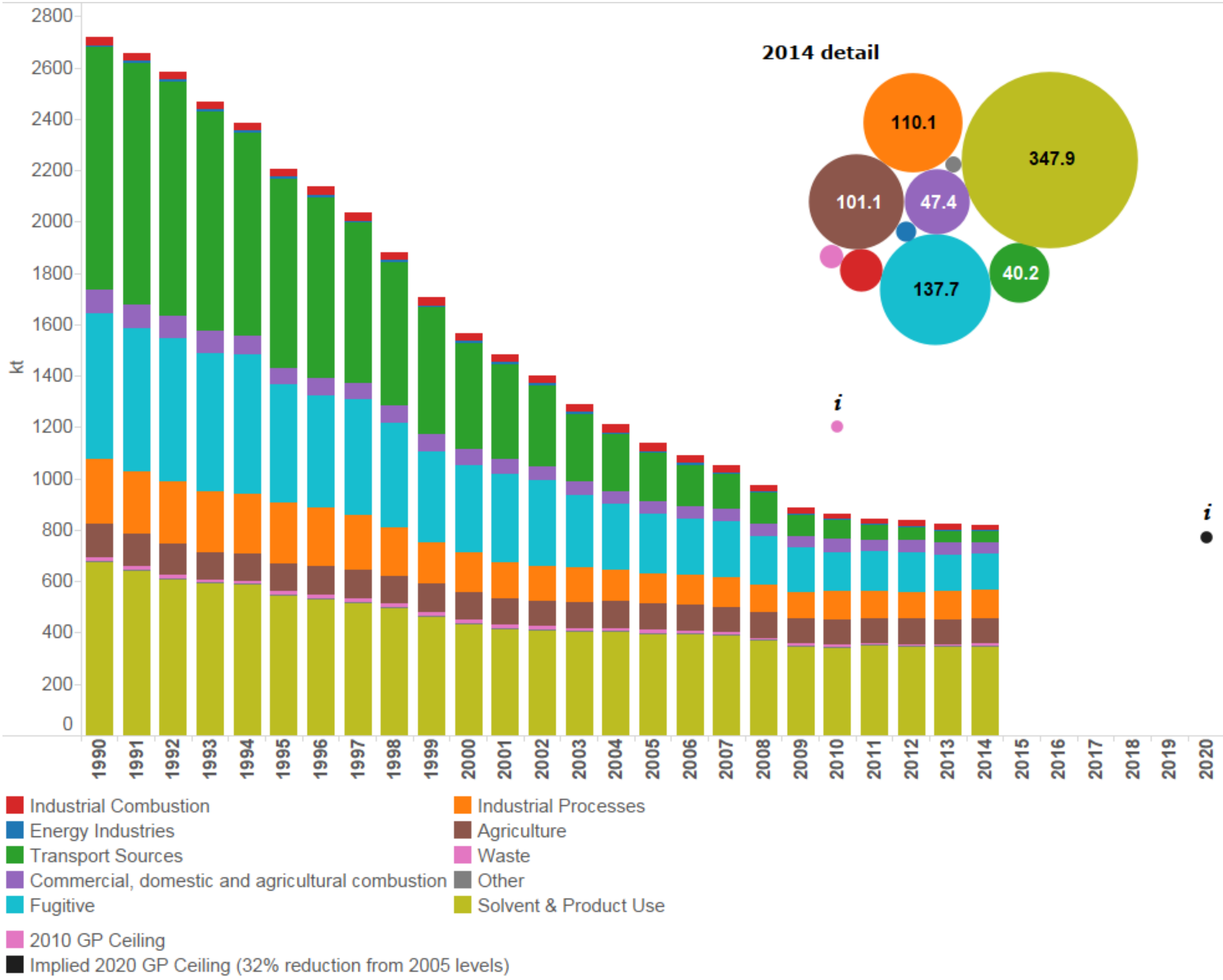
Emissions of NMVOC from some sources are challenging to estimate, and are therefore high in uncertainty. This is particularly the case for fugitive emissions - emissions that are released either accidentally or e.g. through the use of products, rather than emissions arising from sources such as fuel combustion. Emissions due to solvents and other products are an example of a fugitive source that is challenging to estimate, and make up over 40% of NMVOC emissions in 2014.

Interest in NMVOC emissions has grown since its role in photochemical ozone creation was realised during the 1980s. Ozone gas acts as an irritant on the surface tissues of the body, including the eyes, nose and lungs, making it harmful to human health at low levels in the atmosphere. It can also damage materials, and be toxic to crop species, reducing yields and decreasing biodiversity. Some NMVOCs such as benzene are also directly harmful to human health and they are also involved in formation of organic aerosols in the atmosphere, another component of particulate matter.

As a result of increasing road traffic and industrial activity, there was a steady increase in total NMVOC emissions until around 1990. Since then (Figure 2.4.2), emissions have rapidly decreased to well below the Gothenburg Protocol Ceiling in 2010. Decreases in emissions have occurred in all major source sectors, which is generally attributed to the introduction of wide ranging legislative controls. The inventory data indicates that emissions from transport have seen the most dramatic decreases due to the introduction of three-way catalytic converters, and to a lesser degree, fuel switching from petrol to diesel cars. Emissions from the transport sector represented only 5% of UK NMVOC emissions in 2014 compared to 35% in 1990.

Click here for interactive data viewer

Figure 2.4.2: UK NMVOC emissions, 1990-2014 with Gothenburg Protocol Ceilings (2010 and 2020)



2.5 Particulate Matter (PM)

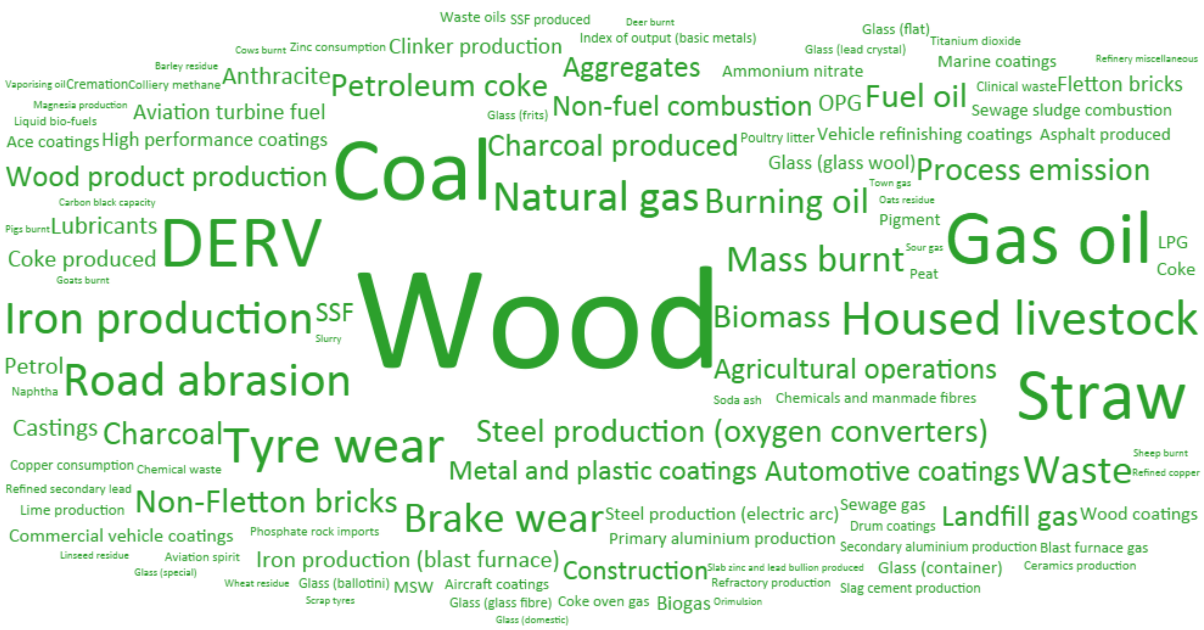
As a result of the extensive use of coal during the 1950s, PM emissions were mostly thought of in terms of smoke due to the very severe impacts that resulted, most notably the heavy smogs in London during this period. Since the Clean Air Act however, and the resultant reduction of coal burning in urban areas, the focus has switched to finer particles – those arising from various other sectors such as combustion of diesel fuels in road transport. As well as road transport, the inventory indicates that main sources of PM are stationary combustion and industrial processes. Road transport becomes an increasingly important source as particle sizes decrease.

In comparison, some industrial processes, particularly quarrying, are more important for emissions of larger particles. PM_{10} refers to particles with a diameter smaller than 10µm and $PM_{2.5}$ to particles with a diameter smaller than 2.5µm. Figure 2.5.2 shows emissions by category.

Stationary combustion sources contribute approximately 65% of 2014 $PM_{2.5}$ emissions. This includes electricity generation, industrial combustion, and commercial and residential combustion sources. Emissions from the transport sector (road transport, rail, domestic aviation and domestic shipping) make a contribution of more than 15% to the total $PM_{2.5}$ emissions. The ban on field burning in the UK causes a small decline in emissions of $PM_{2.5}$ from agriculture between 1992 and 1993.

As well as impacting upon air quality, PM emissions have a cross-cutting effect, as emissions of black carbon (a specific element of fine PM emissions) act as a short-term climate forcer. In terms of health hazards, studies show that PM emissions are more significant than those of other pollutants. The complex mixture of particles gives rise to a range of problems including lung cancer and cardiovascular disease from chronic exposure. A significant proportion of the particulate matter in the atmosphere are inorganic aerosols created through chemical processes involving SO_2, NOx and NH_3, while organic aerosols are formed from processes involving emitted NMVOCs. These aerosols, which directly affect human health are also the main drivers through which these species damage ecosystems through acidification and eutrophication. However, with increasing concern over the damaging nature of PM, the direct emission of $PM_{2.5}$ has now been added to the list of regulated pollutants under the Gothenburg Protocol.

Figure 2.5.1: Fuels and activities responsible for emissions (2014)
The size of the text indicates the size of the corresponding emission.



PM emissions occur from a broad range of sources. The time series (Figure 2.5.2) shows steady reductions in total $PM_{2.5}$ emissions since 1990. However, increases in the total emissions in recent years are driven by increased emissions from the domestic combustion caused by an increase in the amount of wood burning in the domestic sector.

For the domestic sector, Figure 2.5.2 shows decreasing emissions in the earlier part of the time series. This is mostly due to the declining use of solid fuel use (particularly coal) in favour of natural gas. However, in recent years, there has been an increase in emissions, caused by the increased use of wood. Emissions from wood burning are particularly challenging to estimate. This is because the amount of wood used is high in uncertainty, and emissions of most pollutants are heavily dependent on the way in which the wood is used and the specifics of the appliance. Emissions in recent years have become increasingly complex to estimate because wood is now consumed in a much wider array of different domestic appliances. Wood can be used in a traditional "open fire", in a simple "wood burner", or in sophisticated modern equipment. Emission rates vary considerably across the different domestic appliances, depending on how well the conditions of the combustion can be controlled. More sophisticated modern equipment provides more complete combustion, which gives rise to lower emission rates of $PM_{2.5}$. But in general, the use of wood as a domestic fuel gives rise to relatively high levels of $PM_{2.5}$ compared to the use of e.g. natural gas or oil. This explains the dominance of wood in Figure 2.5.1.

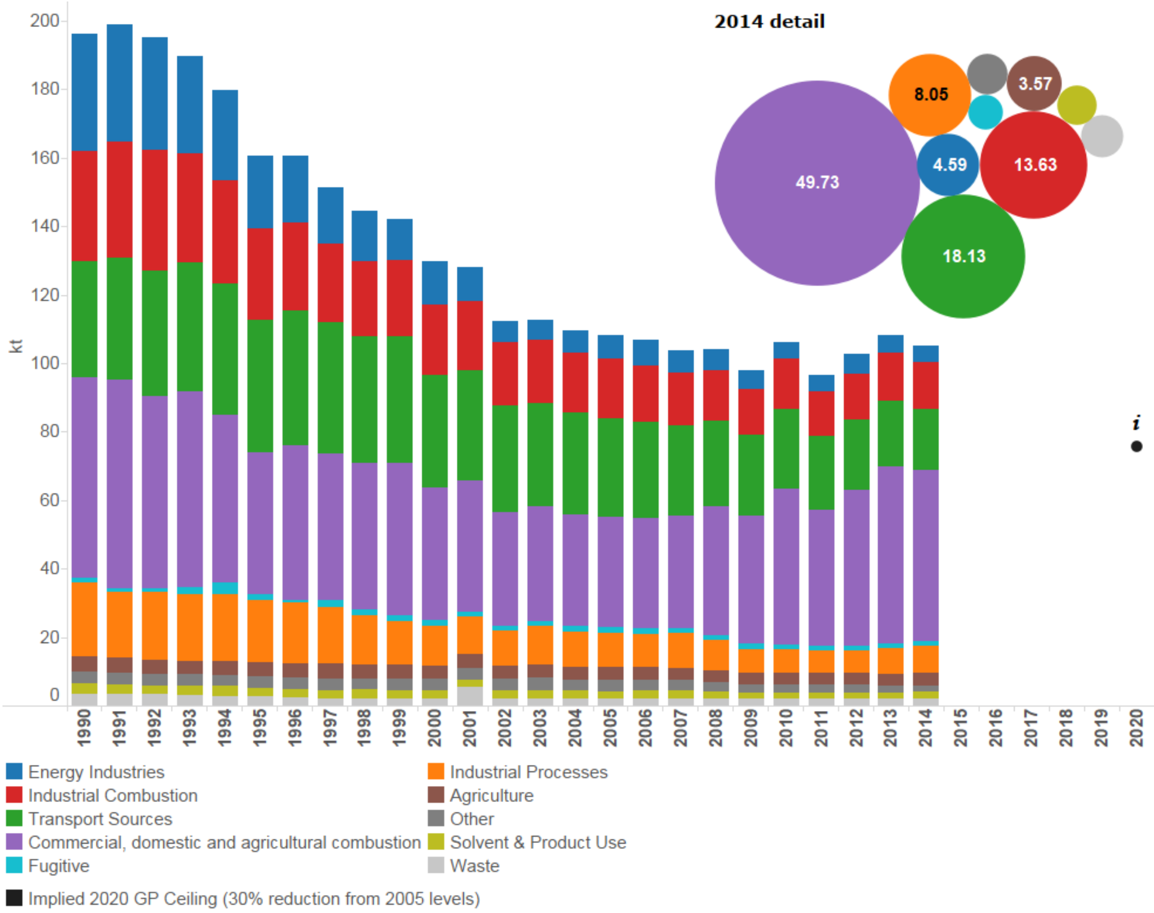
Over time, transport has become an increasingly important source. Whilst emissions from the transport sector have generally been decreasing since the 1980s, other sectors have achieved a much greater emission reduction in comparison, leaving the transport sector with a greater total share. The trend for transport is influenced by several different factors. Better vehicle regulations such as the introduction of EURO Standards have contributed to emissions reductions. However, the benefits have been countered by the fuel switch to diesel engines, which despite contributing to fewer emissions for many other pollutants actually contribute more PM and NOx emissions per vehicle kilometre than petrol vehicles. More stringent emissions legislation now means that modern diesel vehicles are fitted with diesel particulate filters which result in emissions of PM that are comparable to petrol engines.

As vehicle emission regulations have succeeded in reducing exhaust emissions from diesel vehicles, there is now an increasing influence from non-exhaust emissions of PM from mechanical wear of tyre and brake material and road abrasion.

The trend for emissions from electricity generation follows that of SO_2, where reduced coal use has been a major factor in reducing PM emissions, as well as more stringent emissions legislation. A combination of stricter regulations and the decline of heavy industry have also made a substantial contribution to emissions reductions, for both industrial combustion and process emissions.

Click here for interactive data viewer

Figure 2.5.2: UK $PM_{2.5}$ emissions, 1990-2014 with 2020 Gothenburg Protocol Ceiling



3 UK Emission Maps

3.1 Introduction

As well as providing the official UK emissions estimates, the UK emissions inventory programme provides other important outputs. Maps of the emissions from the UK are produced each year, and are a key resource for a number of stakeholders to support their work on assessing and addressing air quality issues. As with the national emissions inventory, the emission maps are subject to a programme of continuous improvement. The following sections outline the need for the emissions maps, the main users, how the maps are compiled and some of the recent improvements that have been made.

Drivers

Maps of emissions at 1km x 1km resolution across the UK are produced as part of the NAEI programme every year based on the latest data available, for 27 pollutants. These high resolution emissions maps are produced for input into air quality modelling and for calculating a disaggregation of the national inventory to lower levels of geography, such as by local authority.

The maps are important in determining local impacts of pollution, both in terms of human health and also ecosystem impacts, to ensure that actions can be targeted in the right places to reduce these impacts. In this context, the UK is required to report to the EC annually to assess compliance with European Directives on Air Quality (the Fourth Daughter Directive (2004/107/EC) and the Air Quality Framework Directive (2008/50/EC).

The maps are also used to compile and report on emissions as part of the UK's commitment to the UNECE Convention on Long-range Transboundary Air Pollution (CLRTAP) every 4 years, for use in European scale air pollution modelling. Under this reporting convention, UK emissions were historically mapped to the 50km x 50km EMEP Grid spatial resolution, and more recently to a 0.1° x 0.1° Longitude/Latitude grid.

Users

There are a range users of the emission maps with different needs. The high resolution dataset provides an excellent resource for government reporting, local analysis and academic research:

- UK modellers use the emission maps to generate pollution concentration maps of key air pollutants such as NO_2, PM_{10} $PM_{2.5}$ and ozone and to apportion concentrations to different sources. For example, for national reporting under the European Directives and input to national scale air quality strategies, the Pollution Climate Mapping model[6] uses the emission maps to calculate maps of annual average and roadside pollutant concentrations. These concentration maps are used by Defra and local authorities for policy formation and the review of existing policies.
- Academics in the UK use the maps for a wide range of research applications. For example in the UK, the Centre of Ecology and Hydrology[7] use the maps in modelling air pollution transport and ecosystem impacts. Similar work is undertaken at the European level by MSC-West[8], where they also study transport of air pollution across national boundaries.
- The maps are also used as a starting point in the compilation of local emission inventories in the UK, which may then be used to assess the status of current and future air quality;
- Emission estimates for point sources and emissions arising from the surrounding area are used in modelling studies that contribute to Environmental Impact Assessments in the UK.

[6] https://uk-air.defra.gov.uk/research/air-quality-modelling?view=modelling

[7] http://www.pollutantdeposition.ceh.ac.uk/frame

[8] http://emep.int/mscw/index_mscw.html

- Data derived from the mapping calculations are used as input to the DECC local authority CO_2 statistics[9]. High resolution energy consumption maps used in the NAEI emission map production are used for sectors where energy data are not published at local authority level.
- Members of the public are also able to access the maps to identify sources of emissions, via the interactive mapping portal, at **http://naei.defra.gov.uk/data/gis-mapping**
- Consultants use emission maps to predict future pollutant concentrations and run scenarios for different development or planning applications, e.g. airports, highways, or when they need to assess the local impacts of different mitigation measures.

3.2 Calculating Emission Maps

Overview

The distribution of emissions across the UK is built up from many component distributions, or "layers", for each NAEI emission sector or sub-sector. These individual sectoral distributions are developed using a variety of statistics appropriate to each sector. For large industrial 'point' sources, emissions are compiled from site specific data sources. These enable both the geographic location and the magnitude of the emissions to be well characterised. For smaller and more widely distributed sources, such as domestic combustion, less detailed information on the location and magnitude of emissions is available, so it is often necessary to use surrogate statistics. The method used for each sector varies according to the data available. A technical description of the methods used to compile the maps is available on the NAEI website[10].

Approaches to calculating the maps

Three different approaches are taken to calculating the emission maps depending on the nature of the data available for the sources: "points" for large single sources of emissions, "lines" for transport routes (where data permit) and "areas" for distributed sources with many sites of activity that cannot be represented individually because data are not available.

Point sources: Point sources are typically large industrial installations such as power stations and plant in heavy industry sectors. These are installations that are regulated processes which are required to report emissions data on a regular basis. The data are obtained each year from the following sources:

- Environment Agency's Pollution Inventory, the Scottish Environment Protection Agency's Scottish Pollutant Release Inventory, the Northern Ireland Pollution Inventory;
- EU-Emissions Trading System; and
- Industry trade associations or companies.

The data available for these sites is typically good quality and can be mapped accurately because the locations are known. Point sources often represent a significant portion of combustion emissions; emission maps for pollutants dominated by point sources are typically of better quality.

Line sources: For major roads, railways and shipping lanes, activity data are available at a detailed geographical level to enable link-by-link representation of the emissions in calculation of the maps. Geographical activity data and emission factors (in some cases using geographically specific emission factors) are combined within the mapping process to produce estimates for emissions per km of each link. These data are then overlaid with the 1km x 1km resolution grid across the UK to allow aggregation of the linear data to the 1km x 1km grid so that it can be combined into integrated maps.

[9] https://www.gov.uk/government/statistics/uk-local-authority-and-regional-carbon-dioxide-emissions-national-statistics-2005-2014

[10] UK Emission Mapping Methodology http://naei.defra.gov.uk/reports/reports?report_id=855

Area Sources: Many of the emission sectors refer to a collection of many individual sources such as small commercial or residential buildings, and agricultural holdings. Data on activity or emissions are not available for individual sources, therefore surrogate geographical data are required to estimate and model the pattern of emissions across the UK. Assumptions are made about the relationships between surrogate data and actual emissions and therefore the results are less certain than those for the point sources.

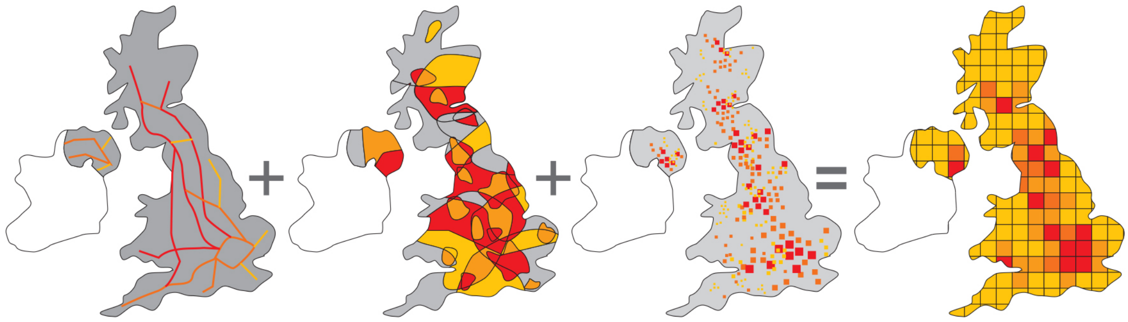
Some examples of area source mapping approaches are shown in the table below:

Source	Brief summary of approach and data used
Small commercial and industry installations	Business level employment data at actual locations combined with energy consumption rates per employee for the relevant business sector (derived from DECC data). Account is taken of fuel available at the location (DECC gas consumption; off gas grid locations; smoke control zones) to develop maps of consumption of different fuel types for various industrial and commercial sub-sectors. These are aggregated to a 1km x 1km grid.
Minor roads	A small number of minor roads are mapped as line sources where data are available but the majority are mapped using lengths of minor roads within each 1km x 1km grid square combined with estimates of vehicle kilometres on minor roads at local authority level from the Department for Transport.
Agriculture livestock	Data on the numbers of animals at farm locations are aggregated to 5km x 5km grid squares to anonymise confidential data for very large farms. The numbers of animals are combined with emission factors for different types of animals.
Agriculture soils and chemicals	Land cover data from the Centre of Ecology and Hydrology is used to identify locations of crop production. Emissions are distributed in proportion to the occurrence of relevant land cover.

Some sources in the UK emissions inventory may be represented by a combination of two approaches. For example some industrial sectors include large sites which can be represented as point sources and some smaller sites for which the residual emissions of the sector are distributed as an area source after the point emissions are taken into account. A second example is road transport where the major roads are represented as line sources but the minor roads are calculated as an area source, based on distributing the residual fuel consumption from road transport after taking account of fuel used on major roads.

The illustrative figure below shows how line, area and point sources are summed to give a map of total emissions, which is presented on a square grid.

Figure 3.2.1: An illustration of summing emission sources to generate a total emission map



Examples of Specific Challenges for mapping methodology

The following two examples highlight the value of being able to use detailed input data in generating emission maps. The domestic fuel consumption and road transport sectors are particularly important to map accurately because they are significant contributors to air pollution hot spots in city centres. Good data can help to support local authorities in planning interventions. Fortunately the UK has a lot of data to support this work, and a mature inventory for these sectors and associated mapping.

Domestic Sector

There are very good data to enable accurate mapping of gas consumption, but emissions of solid and liquid fuels are significantly more uncertain.

Gas consumption is well represented by datasets available from DECC and aggregated from the bottom-up gas meter point level to 1km x 1km resolution.

However there is no sub-national data on the use or sale of oil and solid fuels. DECC's National Household Model provides average household energy consumption estimates across the 13 regions of England, Wales and Scotland. These data are combined with census data on types of fuel used in households, with factors varying depending on the type of dwelling. Further assumptions are made about fuel types with regard to location:

- Coal and wood is burnt exclusively outside Smoke Control Areas;
- Smokeless solid fuels (SSF, coke, anthracite) are burnt exclusively within smoke control areas;
- Liquid petroleum gas is burnt in off gas grid locations where the census indicates gas central heating.

Road Transport

Emissions from major roads are calculated by combining many factors based on road types, average speeds, road-type and regional variations in fleet composition and numbers of vehicles. These good quality datasets result in high resolution emissions maps with lower uncertainty compared to other sources.

Ordnance Survey data are combined with a database of traffic count locations to produce a detailed map of annual average daily traffic flows by vehicle type on all major roads. DfT's Automatic Number Plate Recognition data are used in conjunction with vehicle licensing data from the DVLA to indicate the composition of the vehicle fleet on different types of roads. Combined with variations in speeds on different road types, this allows different emission factors to be applied in different places to best represent emissions.

3.3 The Emission Maps

The NAEI emission maps are produced at a 1km x 1km resolution. The images presented in this report show total emissions for each pollutant but these are published at sector level based on the SNAP classification (Selected Nomenclature for reporting of Air Pollutants) which divides emissions into 11 sectors. The sectors available are shown in the table below. This provides a sufficient level of disaggregation for most purposes but more detailed maps are made available for some specific purposes, such as the Pollution Climate Mapping modelling used for national air quality assessments.

UNECE Sector Code	Description
1	Combustion in energy production and transfer
2	Combustion in commercial, institutions, residential and agricultural sectors
3	Combustion in industry
4	Production processes
5	Extraction / Distribution of fossil fuels
6	Solvent use
7	Road transport
8	Other transport and machinery
9	Waste Treatment and disposal
10	Agricultural, forests and land use change
11	Other sources and sinks
Points	Large point sources are presented in a separate map

A full set of maps are available at: **http://naei.defra.gov.uk/data/map-uk-das** and through an online interactive GIS tool at: **http://naei.defra.gov.uk/data/gis-mapping**

NMVOC and NOx comparison

A comparison of the NOx and NMVOC emission maps is included below because it provides a useful illustration of the different spatial patterns and features that arise from the emission maps of different pollutants.

The map below, on the right, shows total NOx emissions. The map clearly shows the road network and urban areas, but large point sources are not readily visible because of the size of the individual grid cells and because of the choice of distribution chosen for the map legend to show the variation in emissions in most of the map.

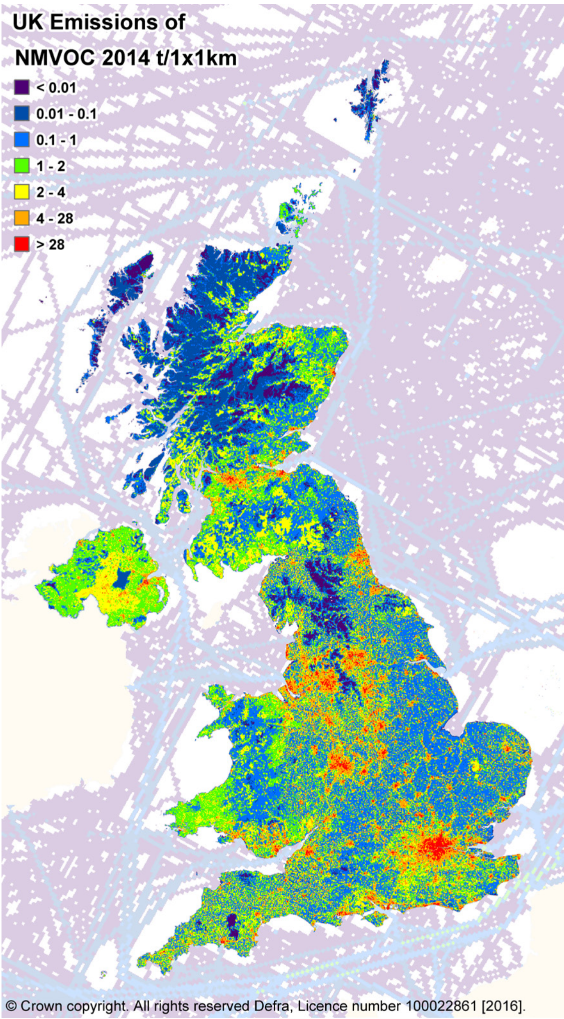
Emissions in urban areas dominate because the NOx inventory is dominated by combustion in industry, for heating (commercial and residential) and from engines used in transport and other machinery (see Figure 2.1.2 above).

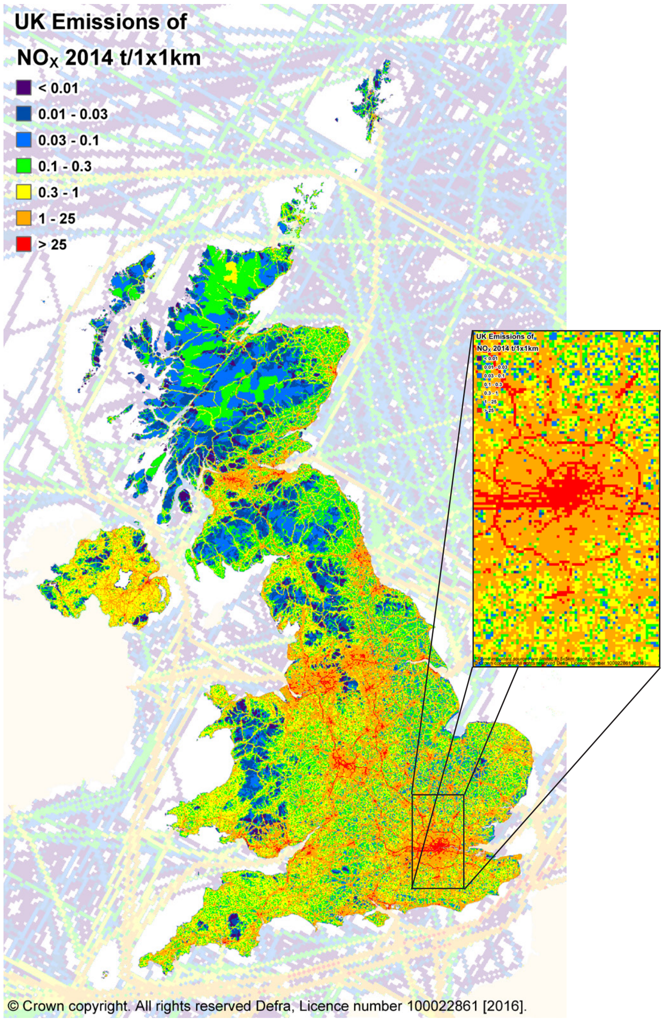
Some other specific features are visible, such as the large airports around London.

Shipping emissions are shown in ports and in UK waters areas, with emissions following the main shipping lanes based on a 5km x 5km EMEP grid rather than 1km x 1km grid squares.

In contrast, the map of Non-methane Volatile Organic Compounds (NMVOCs) on the left, shows a distribution that is dominated by urban areas, but less by roads. The major road network is not a significant element of the map because vehicle emissions of NMVOCs are not so dominant on these roads compared with urban areas where there is a greater dominance of higher emitting petrol vehicles. In addition, a significant proportion of the NMVOC emissions arises from sources in areas of population - such as use of solvents in industry and in the domestic sector.

Figures 3.3.1 and 3.3.2: NMVOC and NOx emission maps of the UK



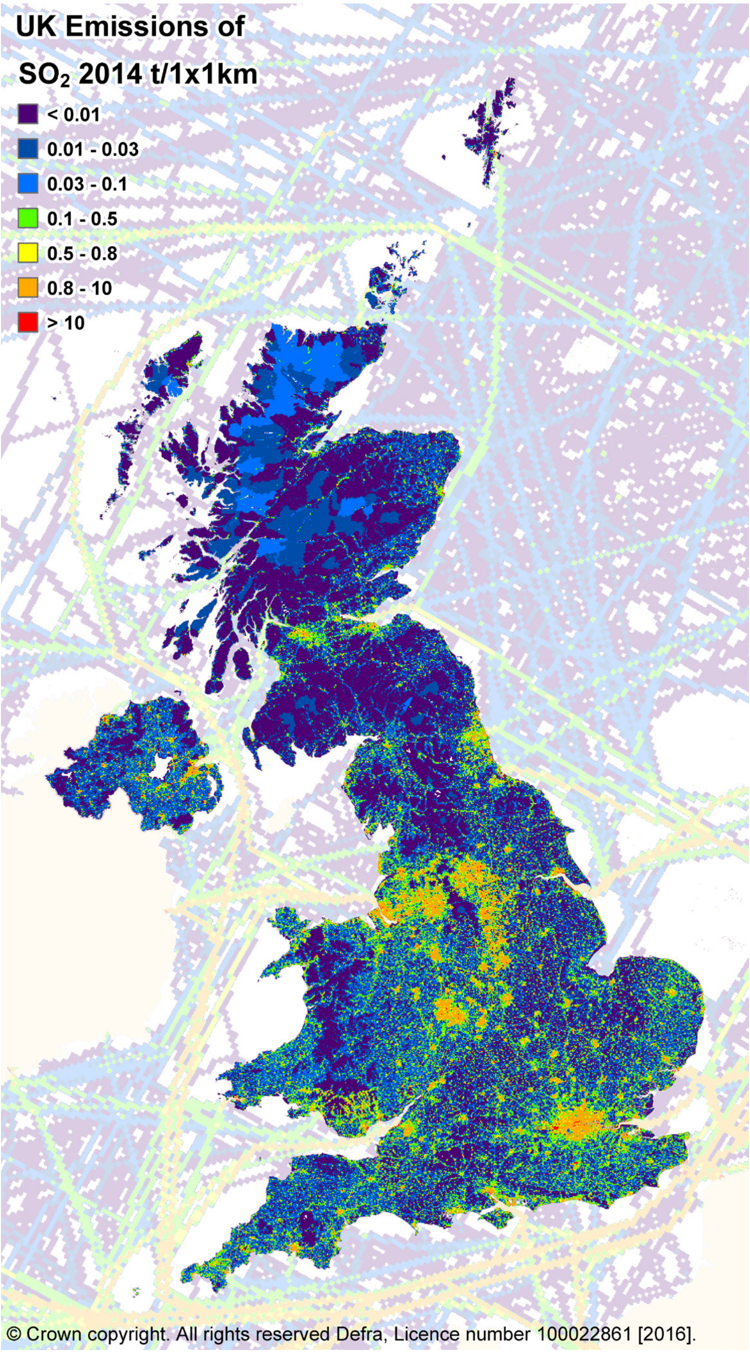


SO_2 Emission Map

SO_2 emissions are dominated by the energy industries and industrial combustion, but when these are mapped the largest emissions are from a relatively small number of point sources.

The map shows low levels of emissions across much of the UK. Emissions from road transport are less than 0.5% of total SO_2 (UK national total and shipping activity outside the UK territory, as shown on the map below). Power stations account for 24% and the remainder of point sources account for 17%. As a result, there are very high emissions in a very low number of grid cells, but it is difficult to see this on a map of the UK. High values generally occur in areas of industrial activity. SO_2 emissions from shipping are also very evident at ports, reflecting the use of fuel with higher sulphur contents than those for diffuse land based activities

Figure 3.3.3: SO_2 emission maps of the UK

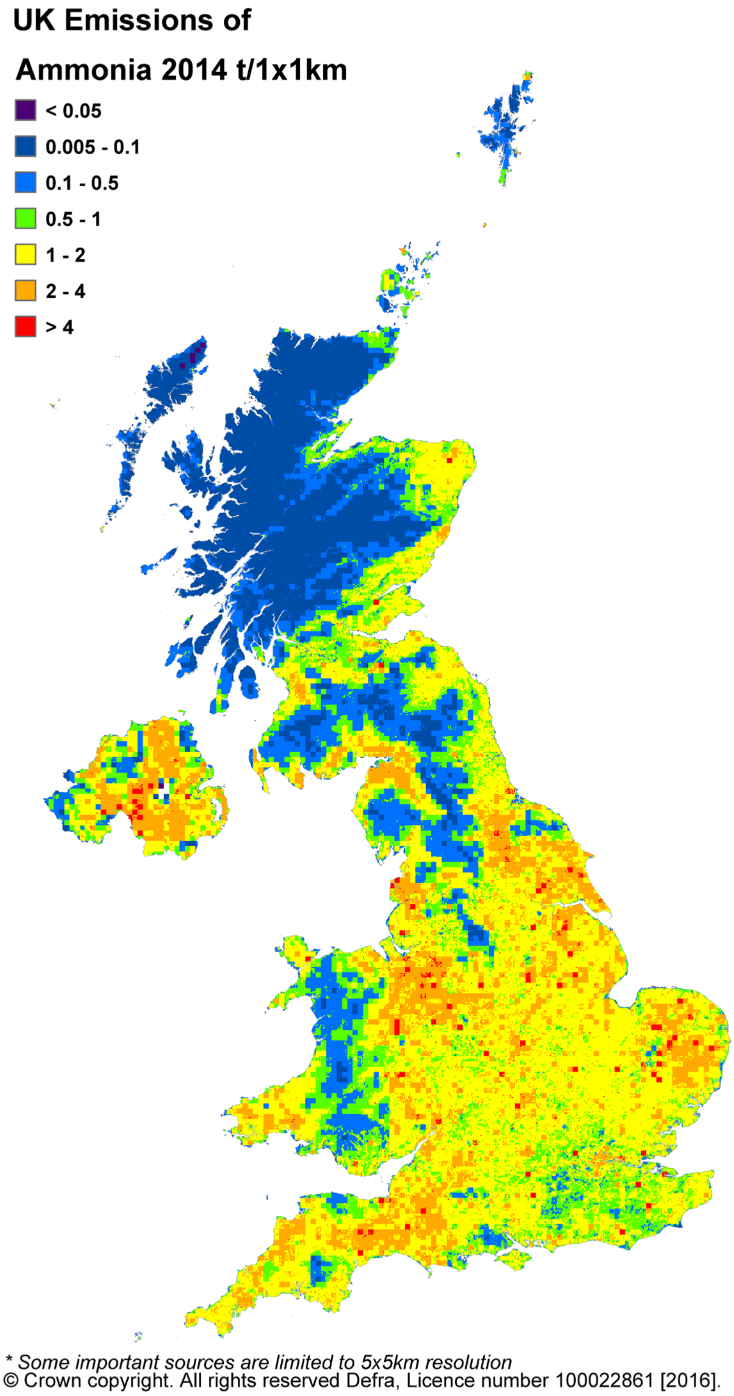


NH_3 Emission Map

Ammonia shows a very different spatial pattern because it is dominated by agricultural sources (80% of total NH_3 when the total includes natural sources), and from livestock manure and excreta in particular (36%). There is also much less certainty regarding spatial patterns because of variations in agricultural practices and detail of the agricultural census data is provided at 5km x 5km resolution to supress commercial confidential information.

Emissions are lowest in areas of higher ground where sheep grazing dominates, and highest in regions dominated by mixed farming and in particular in areas of poultry farming such as East Anglia, pigs in the East in Yorkshire and the Humber and East Anglia and dairy farming in areas such as Cheshire and the South West of England.

Figure 3.3.4: NH_3 emission maps of the UK



3.4 Annual Updates and Continuous Improvements

Each year the mapping methods are reviewed and some components are updated. Not all emission sector distributions are updated each year because there are not significant changes in geographical distribution of most sectors. However the emission maps are re-calculated each year by applying the latest sector total emission estimates to the most up-to-date distribution pattern for the relevant sector.

Point source emissions are updated every year based on reported data. The major roads network is also updated every year based on Department for Transport vehicle counts data and fleet weighted emission factors. The distribution of other sectors are updated on a rolling programme such as the domestic maps, small industry/commercial and minor roads as well as other transport sources such as shipping, aircraft and rail. These updates always make use of any new data, and methods are reviewed to make the best use of these new data.

Improvements made for the 2014 maps involved updates to the maps of solid and liquid fuels in the domestic sector, by incorporating new information on Smoke Control Zones collected from local authorities. Further review of the distribution of domestic solid fuel is expected to happen in next year's emission maps.

In addition, the 2014 maps include an update of aircraft emissions with the use of the latest airport inventories. More detailed information was used to distribute emissions in the Heathrow airport area.

Shipping has become an increasingly important source as land based emissions decrease, and an update to the shipping maps is planned for 2015.

4

Glossary

AQPI	Air Quality Pollutant Inventory
CEIP	Centre on Emission Inventories and Projections
CLRTAP	Convention on Long-Range Transboundary Air Pollution
DECC	Department of Energy and Climate Change
Defra	Department for Environment, Food and Rural Affairs
NAEI	National Air Emissions Inventory
Spatial disaggregation	The process by which information at a coarse spatial scale is translated to finer scales while maintaining consistency with the original dataset
Transboundary pollution	Transboundary pollution is pollution that originates in one country but, by crossing the border through pathways of water or air, is able to cause damage to the environment in another country.
UN/ECE	United Nations Economic Commission for Europe

Finding out more information...

There is a lot of information available on all of the pollutants covered in the UK air quality pollution inventory, along with what is being done to improve air quality in the UK and across Europe. The following web pages provide an excellent starting point for those wanting to explore air quality issues further:

NAEI website, giving information on the UK inventory:
http://naei.defra.gov.uk/index.php

Defra air quality pages, providing background information and details on UK air quality legislation: **http://uk-air.defra.gov.uk/air-pollution/**

European Environment Agency air pollution pages:
http://www.eea.europa.eu/themes/air

Further information on CLRTAP: **http://www.unece.org/env/lrtap/welcome.html**

CEIP website, providing links to international inventories: **http://www.ceip.at/**

The UK inventory for air quality is compiled by the UK inventory team at Ricardo Energy & Environment with contributions from Aether, AMEC and SKM Enviros on behalf of Defra.

Department for Environment Food & Rural Affairs

Aether

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