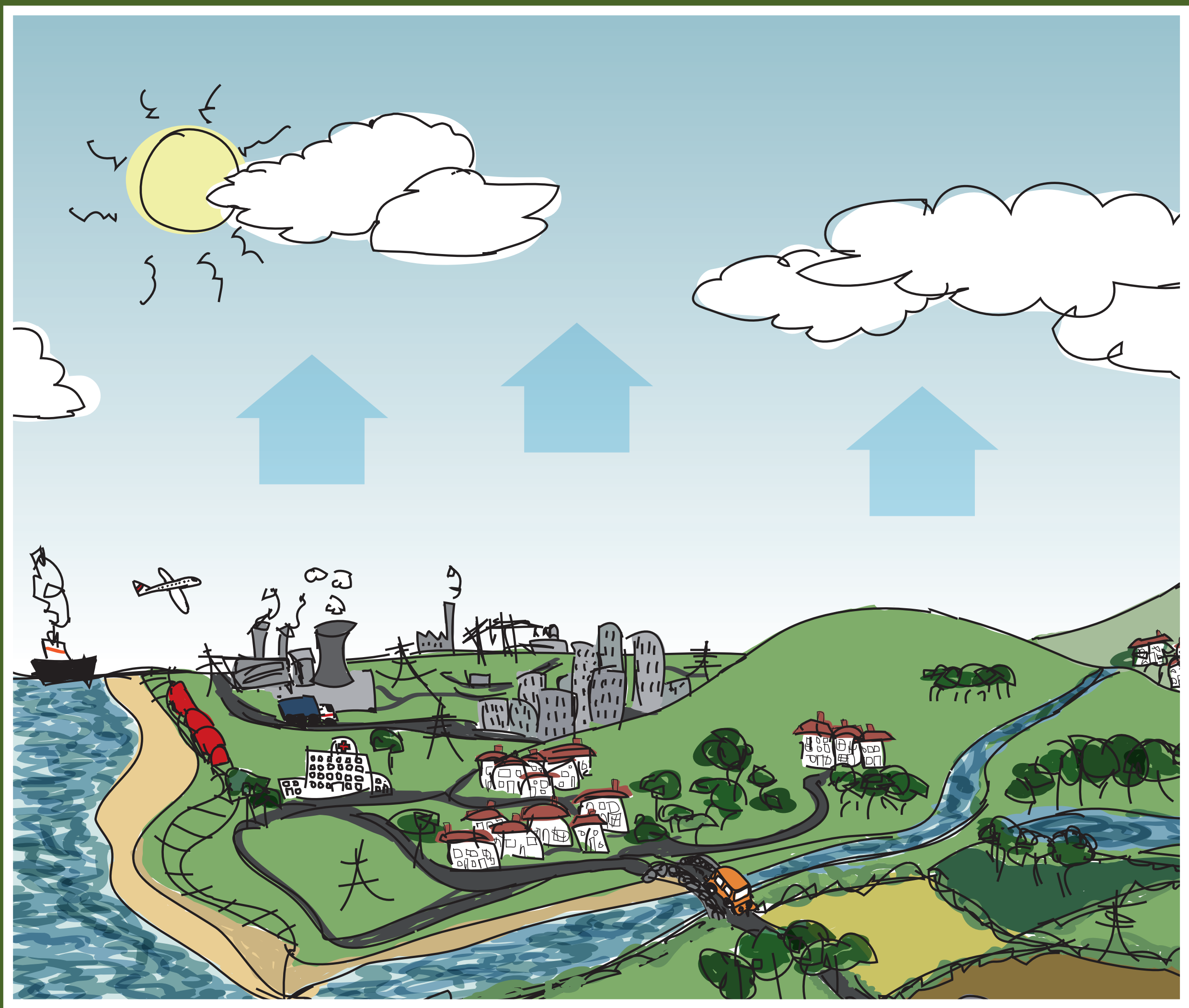
Department for Environment, Food & Rural Affairs

Emissions of Air Quality Pollutants

1970 – 2011



The Scottish Government

DOE

Llywodraeth Cymru
Welsh Government

Contents

1 Introduction

This report provides a summary of the 2011 Air Quality Pollution Inventory (AQPI) and has been prepared for the Department for Environment, Food and Rural Affairs, Welsh Government, the Scottish Government and the Department of the Environment for Northern Ireland. Emission inventories are important as they provide policy makers and the public with a valuable understanding of the sources and trends of pollutants. This report provides an overview of the key air pollutants and their sources, trends, and spatial distribution. Details on pollutants not covered in this report are available from the National Atmospheric Emissions Inventory (NAEI) website. The report also gives a brief summary of air pollution legislation and the UK's performance towards achieving international targets on reducing air quality pollutant emissions.

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 impacts on another after being transported by weather systems. Examples of transboundary pollutants are acidifying pollutants such as nitrogen oxides and sulphur dioxide, and ozone precursors such as non-methane volatile organic compounds. Acidifying pollutants can adversely affect buildings, vegetation and aquatic systems, whilst tropospheric ozone can be damaging to human health, crops and plants.

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 for the five main air quality pollutants as identified in the latest update of the Gothenburg Protocol. The emissions of nitrogen oxides (NOx), sulphur dioxide (SO_2), and fine particulate matter ($PM_{2.5}$) are all strongly linked to the burning of fuels (combustion processes), which occurs in electricity generation, transport, and industrial combustion. Non-methane volatile organic compounds (NMVOCs) are emitted from many sources, though small scale activities such as domestic solvent use are a major contributor. In comparison, ammonia (NH_3) emissions are dominated by the agricultural sector. These pollutants will be discussed in greater detail in Section two of this report.

Table 1.1: Key Pollutant-Source Combinations, 2011 (ktonnes)

	NOx	SO_2	NH_3	NMVOC	$PM_{2.5}$
Electricity generation	313	233	1	5	5
Industrial combustion	168	62	0	22	9
Residential & commercial	85	38	2	36	17
Industrial processes	8	20	5	106	8
Extraction & distribution of fossil fuels	2	8	0	144	1
Solvents	0	0	1	349	1
Road transport	339	1	9	44	17
Other transport & mobile machinery	117	16	0	13	4
Agriculture	0	0	250	0	2
Waste	1	1	21	32	2

Key: key emission source (red) — moderate emission source (orange) — minimal /no emissions (yellow)

[1] For further information on impacts, visit: http://www.defra.gov.uk/environment/quality/air/air-quality/impacts/

1.2 The UK inventory

The UK inventory is compiled annually to report emissions totals by pollutant and source sector in internationally comparable categories. These are submitted to both the European Commission (EC) 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/status-of-reporting/**. The emissions data are supported by an Informative Inventory Report (IIR), which details the inventory methodology and data used in the inventory. All pollutants covered by the AQPI are listed below and those included in this report are underlined.

Air Quality Pollutants

- particulate matter, PM*
- black smoke, BS
- black carbon, BC
- 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 $PM_{0.1}$

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

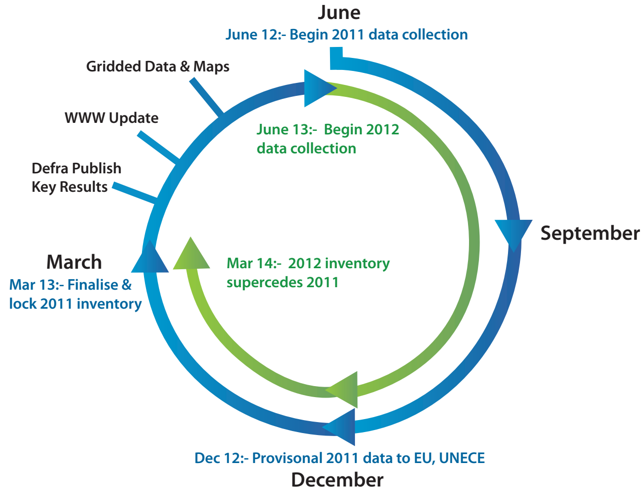
Persistent Organic Compounds (POPs)

- 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. At the simplest level, historical emissions are 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 data sets such as population, GDP and energy statistics. Projections of future emissions are also produced and reported separately as part of the inventory process.

The NAEI is compiled on an annual basis; each year the latest set of data are added to the inventory and the full time series is updated to take account of improved data and any advances in the methodology used to estimate the emissions. Updating the full time series is an important process as it ensures that the entire dataset is consistent and uses the methodology that is the most current, and hence considered to give the most accurate results and the most accurate indication of temporal trends. The new data are then reported to the EC and UN/ECE. This annual cycle of activity is represented schematically in Figure 1.2.

Figure 1.2: The Annual NAEI Cycle



1.3 Current issues and legislation

Generally, air quality in the UK has greatly improved over the last couple of decades, yet it is still an important issue due to the damage caused to human health and the environment. Tackling air pollution requires international, national and local action. The Air Quality Strategy for England, Scotland, Wales and Northern Ireland contains policies for the assessment and management of UK air quality and implementation of European Union (EU) and International agreements. These include the NEC Directive and the Gothenburg Protocol, which require the UK to reduce emissions of key air pollutants by imposing specified emission limits or reduction targets and the Ambient Air Quality Directive which sets legally binding limits for concentrations of major air pollutants in outdoor air.

An increasingly significant challenge facing policy makers is the importance of aligning air quality and climate change agendas. Often, the greatest societal benefits can come from policies which are targeted at both areas. Adversely, implementing schemes to improve one agenda can be damaging to the other. For example, the burning of biomass in place of fossil fuels for power generation can be beneficial in climate change terms due to reduced emissions of carbon dioxide (CO_2), yet at the same time, PM emissions may increase and thereby have a negative impact on air quality.

The 2010 NECD ceilings and new 2020 emission reduction commitments under the Gothenburg Protocol are shown in Table 1.3. Further information on local, national and international air quality legislation can be found by exploring the links at the end of this report.

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

	NOx	SO_2	NH_3	NMVOC	$PM_{2.5}$
2010 emissions	1107	407	286	771	70
2010 NECD target	1167	585	297	1200	n/a
2020 Gothenburg Protocol ERC[2]	707	287	279	714	59

[2] Emission reduction commitments 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

2 Air Quality pollutants

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 the scale of emission reductions required can be appreciated.

2.1 Nitrogen Oxides (NOx)

NOx emissions consist of both nitrogen oxide (NO) and nitrogen dioxide (NO_2). The main sources of NOx are power stations and road transport, the latter accounting for approximately a third of UK emissions in recent years (see Table 2.1). In the presence of sunlight, NOx can react to produce photochemical smog. NOx is also an acidifying pollutant, causing damage to buildings and ecosystems by altering the chemical make-up of minerals, soils and aquatic systems.

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 Large Combustion Plant Directive, LCPD) and transport (e.g. EURO Standards in vehicle regulation).

Table 2.1: UK emissions of NOx by source category (ktonnes)

Source category	1970	1980	1990	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2011 %
Electricity Generation	898	947	862	449	471	472	495	476	491	493	460	380	350	330	313	29.8
Other Stationary Combustion	864	676	597	466	447	416	404	388	383	351	338	315	269	277	250	25.0
Passenger Cars	374	532	852	395	368	339	308	287	268	254	232	225	176	161	150	14.5
Heavy Duty Vehicles	212	242	277	235	231	226	223	219	212	208	208	186	153	144	127	13.0
Other Transport	239	196	225	210	201	198	198	200	200	198	200	194	185	183	180	16.6
Other	64	54	56	23	23	16	16	16	16	15	15	14	12	11	12	1.0
TOTAL	**2651**	**2648**	**2868**	**1777**	**1741**	**1667**	**1643**	**1586**	**1570**	**1518**	**1453**	**1315**	**1145**	**1107**	**1033**	**100**

The time series (Figure 2.1.1) shows fairly constant NOx emissions up to the mid-1980s, at which point increasing traffic levels contributed to a rapid increase in road transport emissions. Since 1990 however, emissions from that sector have decreased significantly, with vehicle regulations coming into force in the form of Euro Standards, and important technological improvements such as the three-way catalytic converter. The impacts of these are discussed in greater detail in Section 4.

Emissions from power stations were fairly consistent during the 1970s, though there were two peaks caused by particularly cold winters in 1973 and 1979. The small decrease through the 1980s is mainly attributable to increased efficiency of power plants and the increased use of nuclear power. This period also incorporates 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. 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 and a decline in coal consumption in favour of natural gas. The noticeable drop from 2008 coincides with the economic downturn.

Figure 2.1.1: Time series of NOx emissions from 1970 to 2011 with the associated 2010 NECD ceiling, and 2020 Gothenburg Protocol emission reduction commitment

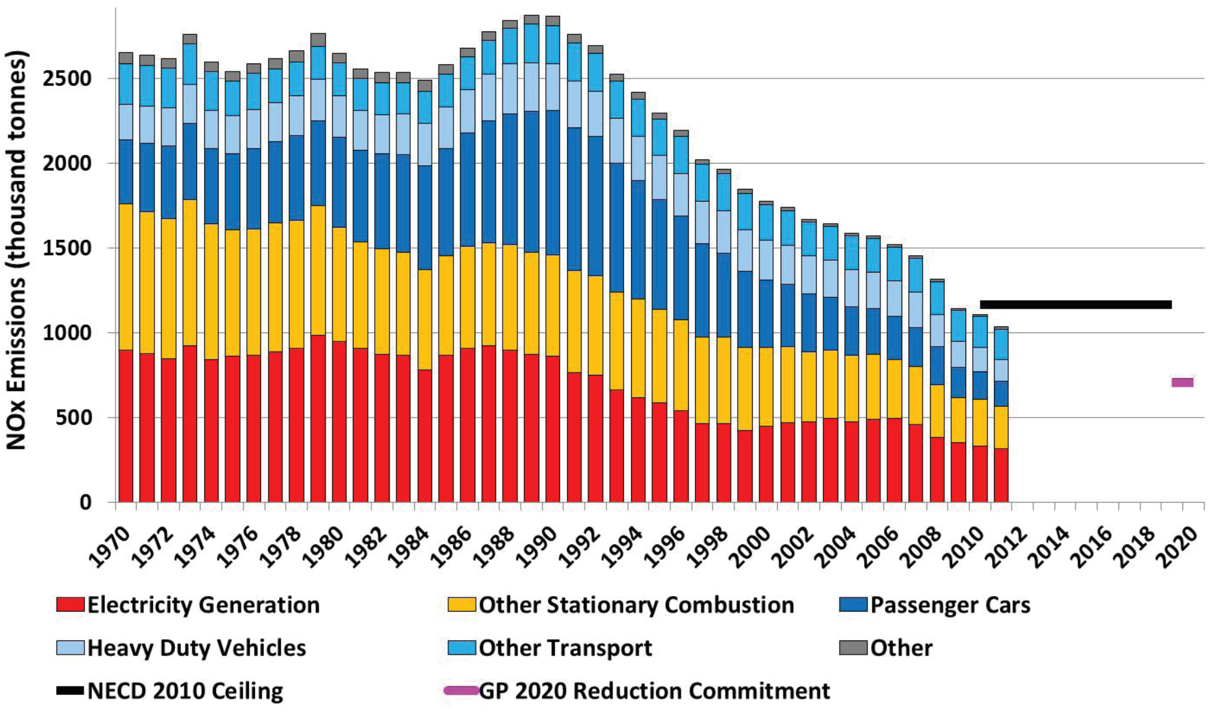


Figure 2.1.2: Spatially disaggregated UK emissions of NOx

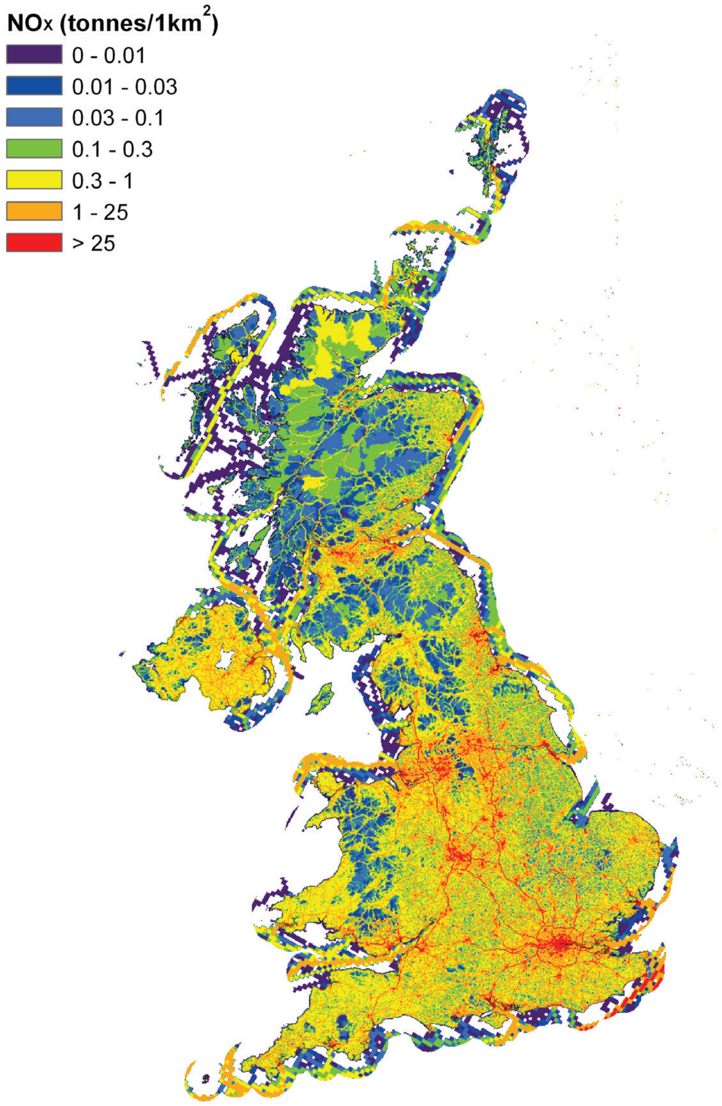


Figure 2.1.2 shows the spatial disaggregation of NOx emissions in the UK. A large proportion of NOx emissions are attributable to point sources such as power stations, which have an important local impact, but are not easily visible on the map. However, larger conurbations and cities are clearly visible due to the emissions from urban traffic and residential and commercial combustion associated with their high population densities.

Motorways and primary roads are also clearly defined where a high volume of high speed road transport contributes significantly to NOx emissions. A large amount of national shipping activity is concentrated within a few major ports, leading to clearly visible localised emissions close to locations such as Dover and Southampton.

2.2 Sulphur Dioxide (SO_2)

SO_2 emissions are formed by the oxidation of sulphur contained in fuels during combustion processes. Table 2.2 highlights that energy production and the manufacturing industries are the most significant sources for SO_2 emissions, with electricity generation alone contributing to 58% of the 2011 total. Residential and commercial combustion is another important source, contributing just over 10%, with the transport sector a smaller contributor. The main sulphur-containing fuels are coal and heavy fuel oil, while lighter petroleum products such as gas oil and petrol have lower sulphur contents. Natural gas contains little or no sulphur.

The impact of SO_2 has 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.

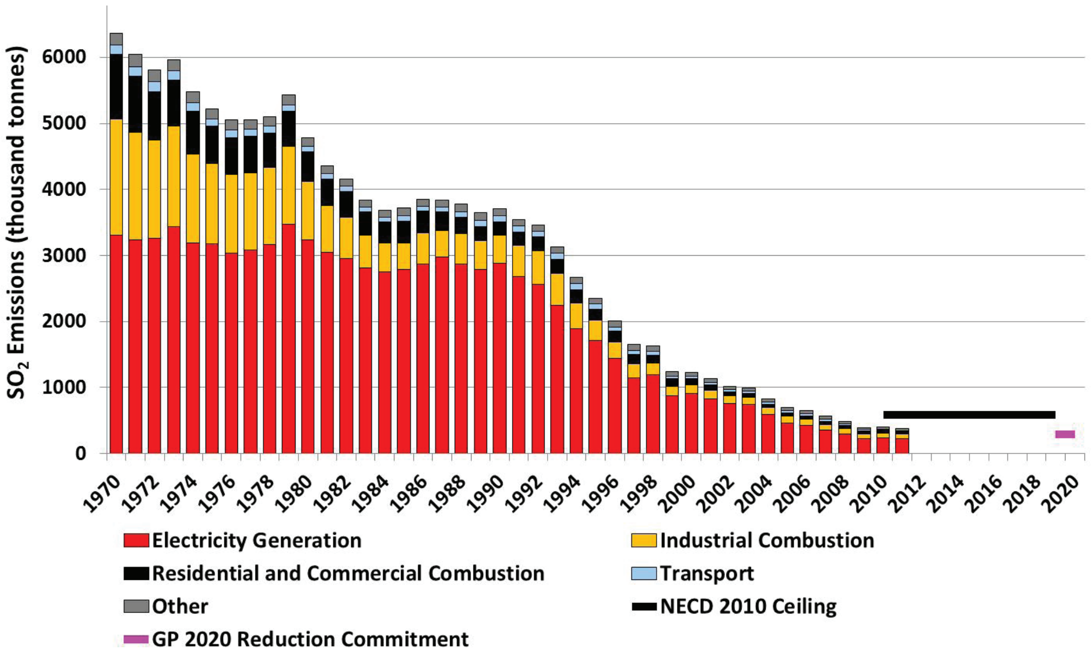
Table 2.2: UK emissions of SO_2 by source category (ktonnes)

Source category	1970	1980	1990	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2011 %
Electricity Generation	3309	3234	2877	910	825	753	745	587	460	426	352	292	225	236	233	58.0
Industrial Combustion	1755	892	429	135	136	117	107	108	111	98	92	85	76	74	62	18.1
Residential & Commercial Combustion	980	444	200	91	85	66	60	54	47	44	43	45	41	42	38	10.4
Transport	145	84	98	34	30	31	31	31	31	31	29	23	22	20	17	5.0
Other	1809	130	105	61	57	48	50	52	51	51	51	43	31	34	29	8.4
TOTAL	**6369**	**4784**	**3708**	**1230**	**1134**	**1015**	**993**	**833**	**700**	**650**	**568**	**4891**	**395**	**407**	**379**	**100**

Figure 2.2.1 shows trends in SO_2 emissions by source sector. SO_2 emissions have seen the most dramatic decrease in the UK out of all air quality pollutants regulated under the NECD and Gothenburg Protocol, at over 94% since 1970. Apart from the harsh winters in 1973 and 1979, there has been a steady decline in emissions from both industrial and residential combustion sources, with the most significant decreases during the 1970s and 1980s. The reduction in industrial emissions was mainly a result of significantly decreased activity of 'heavy industries' such as steel and iron production, which are large consumers of sulphur containing fuels. Similarly, a decline in use of solid fuels for domestic heating was the main factor in reducing emissions from residential combustion. Reduced sulphur content of gas oil has also been an important factor.

The trend for the electricity generation sector is less consistent, with fairly static SO_2 emissions of around 3,000kt per year up until the 1990s where annual emissions began to reduce significantly. SO_2 emissions from transport have also decreased significantly over the time series, due mainly to the reduction in sulphur content of petroleum products, specifically DERV (diesel fuel specifically used for road vehicles).

Figure 2.2.1: Time series of SO_2 emissions from 1970 to 2011 with the associated 2010 NECD target, and 2020 Gothenburg Protocol emission reduction commitment



As discussed previously and highlighted in Figure 2.2.1, there has been a steady downward trend for total SO_2 emissions in the UK since 1970, however emissions from the energy sector were fairly static throughout the 1970s and 1980s, with the reduction in industrial emissions driving the overall trend. Since 1990 however, there has been a dramatic decrease in SO_2 emissions from the energy sector, particularly between 1990 and 2000, with emissions decreasing by approximately two thirds in just one decade. This trend has been a major contributor to improved air quality, particularly in urban areas in the past 20 years.

2.2.2

Key Impact: SO_2 emissions from electricity generation

Figure 2.2.2 highlights the huge impact of a changing fuel mix in determining SO_2 emissions from the electricity generation sector. From 1992 there was a sharp increase in natural gas consumption, and a related decrease for coal. This change correlates to the sudden drop in SO_2 emissions (due to a lack of sulphur content in natural gas compared to coal). From the turn of the millennium to the mid-2000s, the fuel mix remained fairly constant, yet emissions continued to decrease. This was largely down to improved SO_2 abatement, particularly the use of flue-gas desulphurisation (FGD). There was another steep decline in coal use between 2006 and 2009, causing further emission reductions, before consumption levelled once again in 2010. Gas consumption fell sharply in 2011, due largely to market conditions that favoured the consumption of coal in power stations. The significant short-term decrease in coal consumption in 1984 was due to the miners' strike.

Figure 2.2.2: Time series of fuel consumption and SO_2 emissions from electricity generation

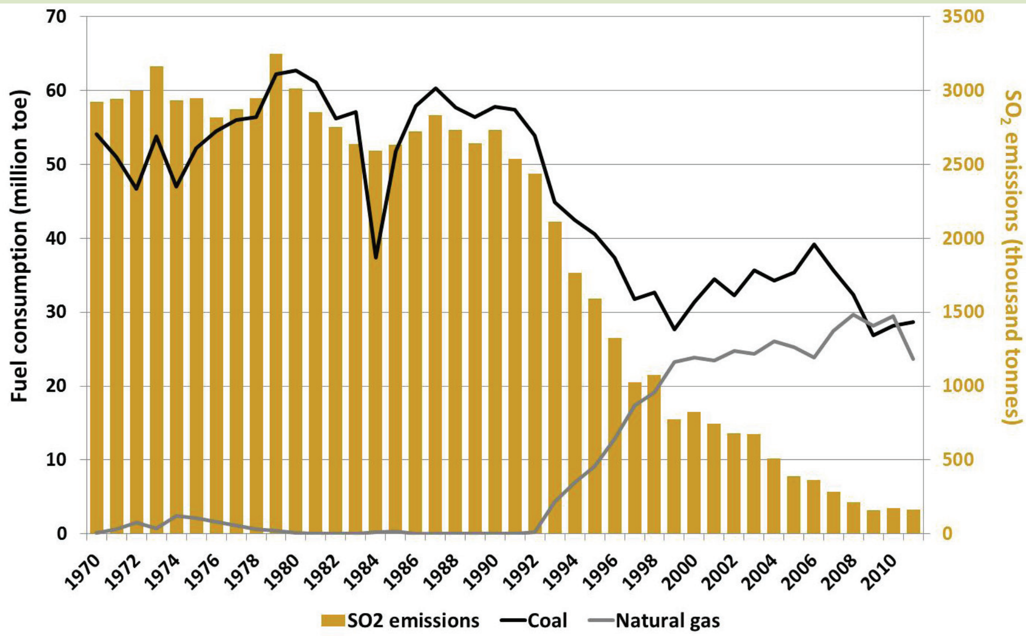


Figure 2.2.3: Spatially disaggregated UK emissions of SO_2

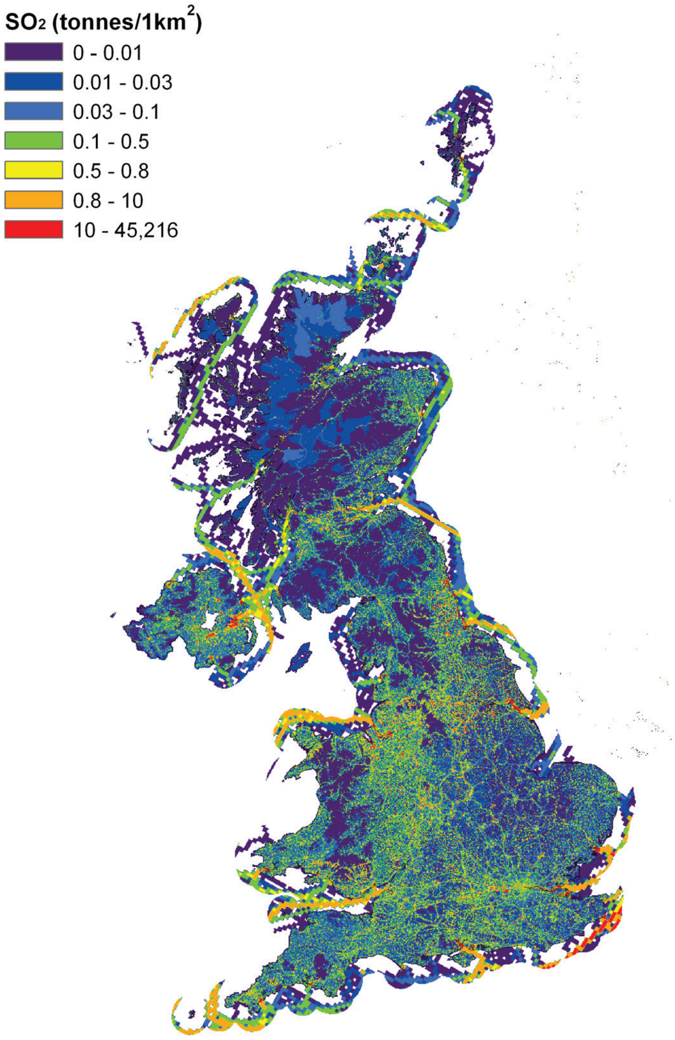


Figure 2.2.3 shows the spatial disaggregation of SO_2 emissions in the UK. Even more so than for NOx emissions, the majority of SO_2 emissions are from point sources which are difficult to see on the emissions map.

The location of SO_2 emissions has changed considerably over the last 40 years due to targeted legislation such as designated Smoke Control Areas where solid fuel consumption is restricted. This leads to visible disparity at the national level between cities where the legislation is in place such as Birmingham and London, compared to others such as Belfast, where there is greater use of solid fuels, particularly for domestic heating.

A clear difference to the map for NOx (figure 2.1.2) is the much reduced visibility of the road network due to the lesser contribution of road transport to SO_2 emissions.

2.3 Ammonia (NH_3)

Table 2.3 shows in detail the key source contributions to ammonia emissions. Agriculture is the dominant source for ammonia with the vast majority coming from livestock, specifically the decomposition of urea in animal wastes (and uric acid in poultry wastes). Cattle alone contribute well over half of all emissions from livestock. The application of fertiliser to soils is also a major source of ammonia emissions at over 22% in 2011. The chemistry of ammonia means that it contributes to both localised and transboundary pollution.

Estimating ammonia emissions is difficult as it is not possible to make direct measurements as it is for other pollutants, where the majority of emissions may be a result of point sources, such as power stations. Estimating ammonia emissions is difficult due to:

- The dependency on highly variable factors such as the species, age and diet of animals in determining livestock emission levels.
- The way fertiliser use impacts on crops and decomposition of nitrates, which is extremely complex and varies by factors such as soil type and crop species.

Ammonia emissions can cause damage to terrestrial and aquatic ecosystems through acidification and eutrophication. As with SO_2, it is also a precursor to secondary particulate matter.

Table 2.3: UK emissions of NH_3 by source category (ktonnes)

Source category	1980	1990	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2011 %
Combustion & Processes	20	15	32	31	29	26	25	25	24	23	21	20	19	19	6.4
Cattle	146	131	122	119	118	120	120	119	119	115	113	112	114	113	39.1
Poultry	40	35	38	42	38	38	38	36	35	32	31	29	29	30	10.3
Other Livestock	61	67	56	52	50	48	48	47	50	45	44	43	42	42	14.4
Soils	84	93	62	64	66	60	66	65	63	65	57	61	63	65	22.3
Other	12	13	13	13	13	12	12	12	13	12	12	15	18	22	7.5
TOTAL	**363**	**354**	**323**	**321**	**314**	**304**	**309**	**304**	**303**	**292**	**279**	**281**	**286**	**290**	**100**

Reliable source data for ammonia is only available since 1980. Compared to other air quality pollutants, there has been relatively little reduction in total emissions over the time series (Figure 2.3.1).

The reduction of ammonia emissions that has been achieved in the UK is largely down to a decrease in UK cattle numbers, where better farming practices have improved efficiencies (generating the same productivity with fewer animals, for example increasing milk yields). Decreases in fertiliser use as a result of stricter regulations on their application, such as the implementation of Nitrate Sensitive Areas, have also led to a reduction in ammonia emissions since the late 1990s. Since 2008, a rise in the practice of anaerobic digestion for organic waste treatment, and to a lesser degree small scale composting, has increased ammonia emissions from the waste sector (categorised as 'other') by approximately 10kt in just three years.

Figure 2.3.1: Time series of ammonia emissions from 1980 to 2011 with associated 2010 NECD target, and 2020 Gothenburg Protocol emission reduction commitment

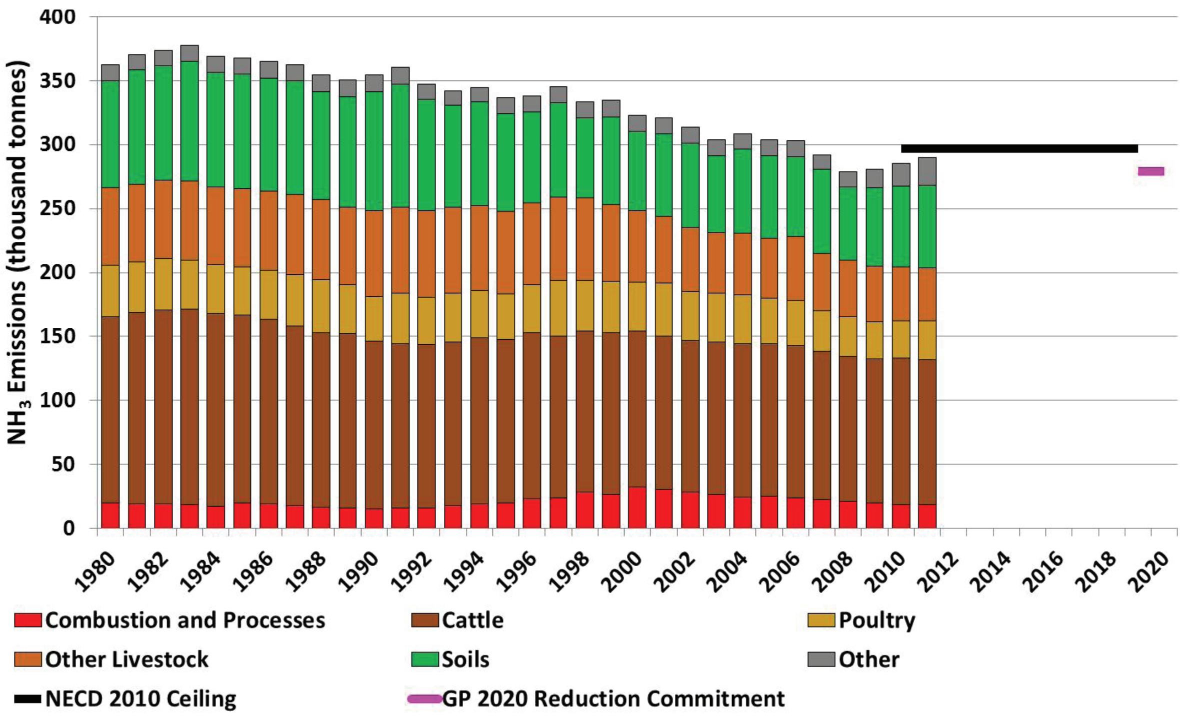


Figure 2.3.2: Spatially disaggregated UK emissions of NH_3

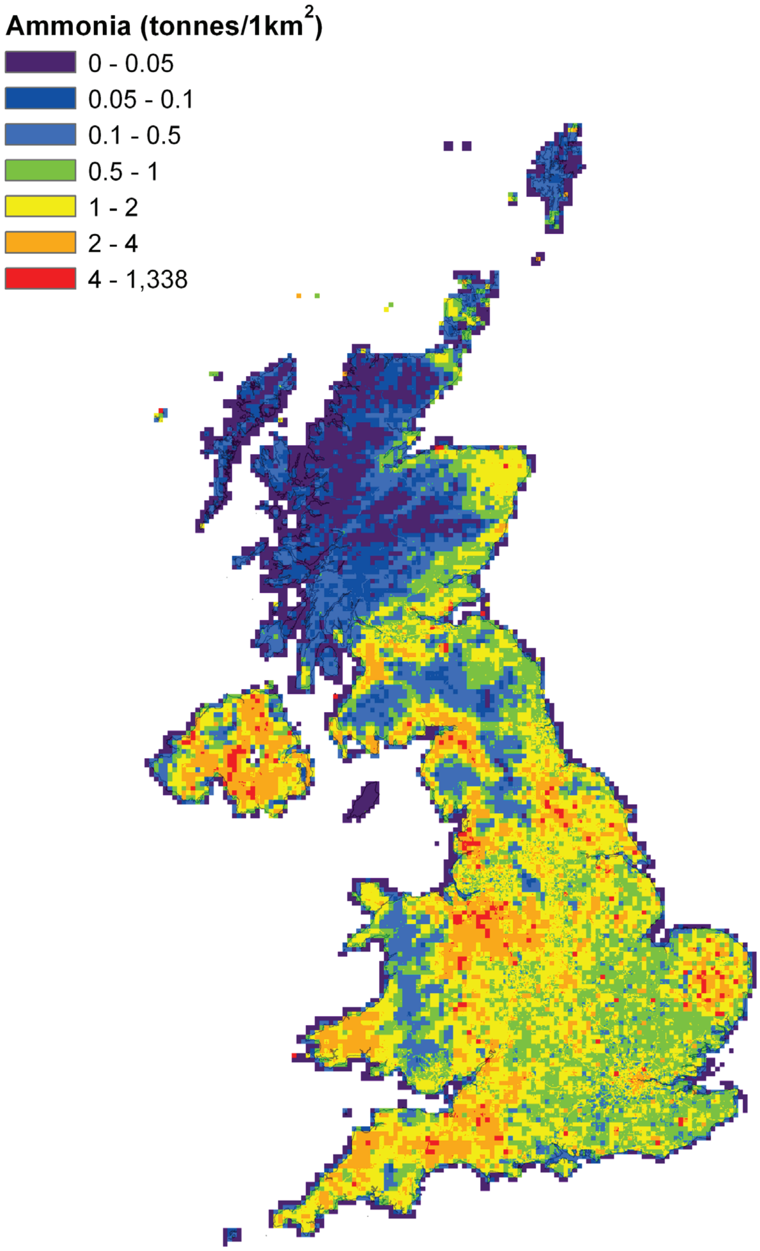


Figure 2.3.2 shows the spatial disaggregation of ammonia emissions in the UK. The emissions map is constructed at a lower resolution to other pollutants due to a high level of associated uncertainties.

In comparison to the other main air quality pollutants, it is areas dominated by agriculture – such as East Anglia, the South West, the North of England and Northern Ireland – that are the most visible emission locations. Non-agricultural emissions are also visible to a far lesser extent in cities and major conurbations.

2.4 Non-Methane Volatile Organic Compounds (NMVOCs)

NMVOCs are a group of organic compounds. Despite having varying chemical make-ups, they are grouped together based on how they behave and react in the atmosphere. 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. Emissions due to solvents and other products make up nearly half of NMVOC emissions in 2011 (Table 2.4).

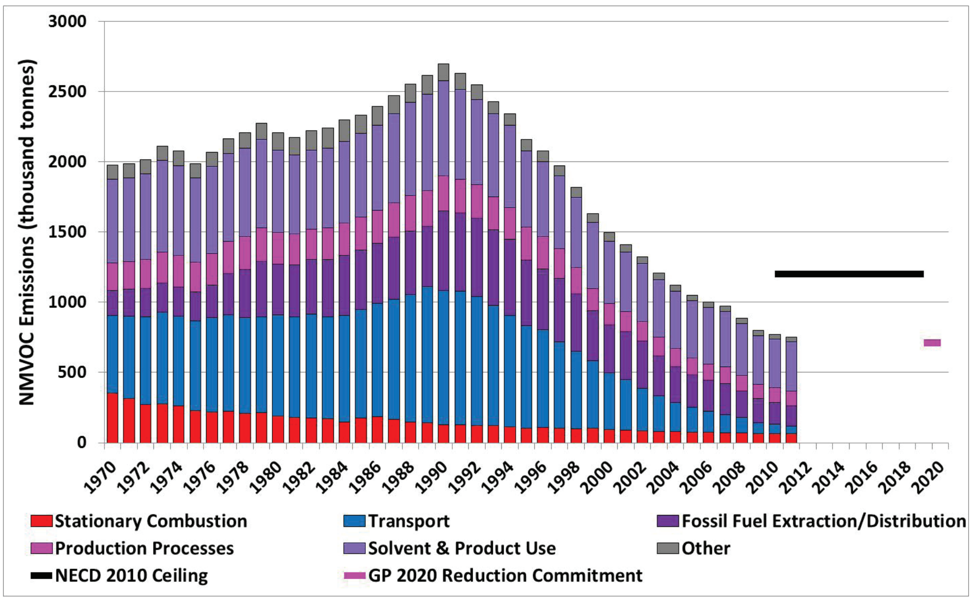
Interest in NMVOC emissions has grown since its role in photochemical ozone creation was realised during the 1980s. Ozone gas acts as an irritant on the surface tissues of the body, including the eyes, nose and lungs – making it harmful to human health at low levels in the atmosphere. It can also be toxic to crop species, reducing yields and decreasing biodiversity.

Table 2.4: UK emissions of NMVOC by source category (ktonnes)

Source category	1970	1980	1990	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2011 %
Stationary Combustion	354	188	128	94	89	85	81	78	76	73	72	71	65	67	63	8.7
Transport	554	720	954	404	359	303	252	211	176	150	126	108	79	67	57	8.7
Fossil Fuel Extraction/ Distribution	178	363	566	343	343	334	283	255	233	222	223	189	170	153	143	19.8
Production Processes	196	223	253	154	141	138	137	127	121	115	118	109	104	107	106	13.9
Solvent & Product Use	597	590	675	441	425	416	410	410	404	403	395	371	345	343	349	44.5
Other	96	122	119	60	54	49	44	41	40	39	38	37	36	35	34	4.54
TOTAL	**1975**	**2206**	**2696**	**1496**	**1411**	**1326**	**1207**	**1121**	**1049**	**1002**	**973**	**886**	**799**	**771**	**752**	**100**

Figure 2.4.1 shows a steady increase in total NMVOC emissions until 1990 as a result of increasing road traffic and industrial activity. Emissions since then have rapidly decreased to well below the NECD ceiling in 2010 as a result of the introduction of wide-ranging legislative controls. Decreases have occurred in all major source sectors, showing how legislation and pollution limits have been widely applied. 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 less than 9% of UK NMVOC emissions in 2011 compared to 35% in 1990.

Figure 2.4.1: Time series of NMVOC emissions from 1970 to 2011 with associated 2010 NECD target, and 2020 Gothenburg Protocol emission reduction commitment



Key Impact: UK and EU legislation

Since the 1990s, NMVOC emissions from paints and solvents have decreased rapidly, as shown in Figure 2.4.2. The UK Environmental Protection Act (1990) introduced a number of measures regarding the decrease of emissions from solvent-using processes. Implementation of Emission Limit Values (ELVs) for paints and solvents caused a drive in abatement technology development and installation, with vast reductions in emissions during the following decade a direct result. Since 2000, emission reductions have decreased further, with EU legislation in the form of the Solvents Directive (1999) and the Paints Directive (2004).

Figure 2.4.2: Time series of NMVOC emissions from industrial paints and solvents

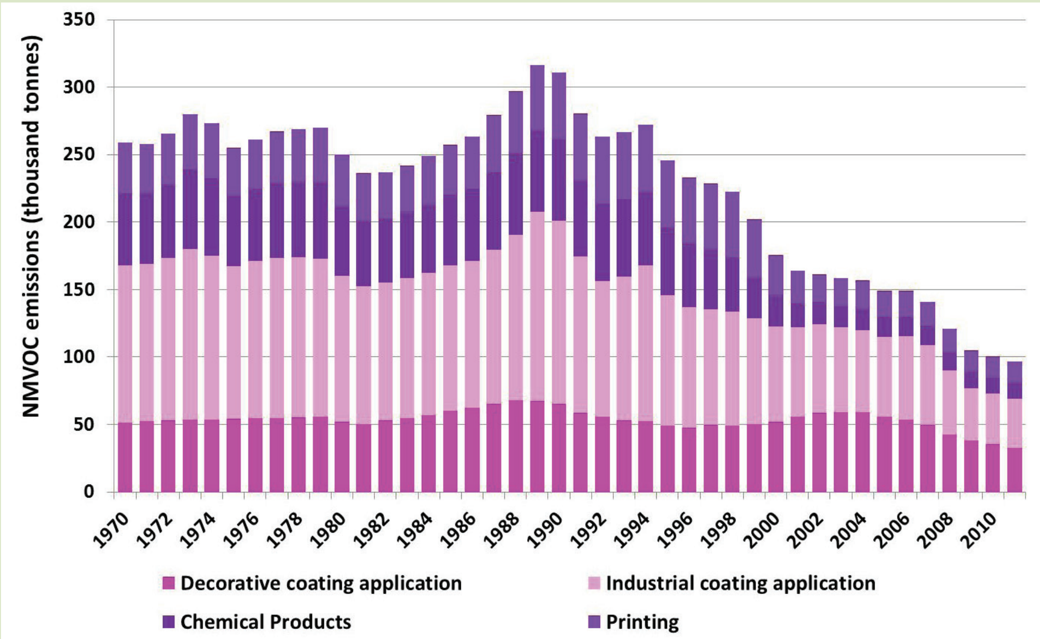


Figure 2.4.3: Spatially disaggregated UK emissions of NMVOC

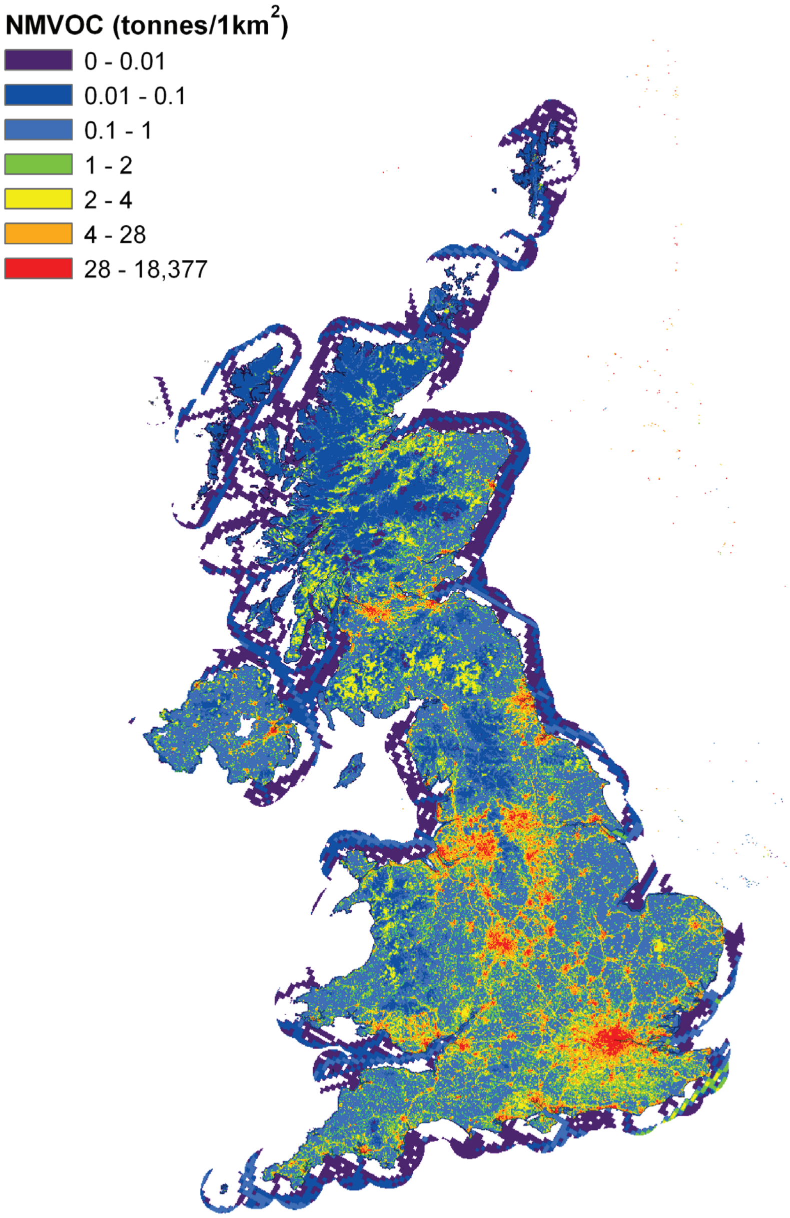


Figure 2.4.3 shows the spatial disaggregation of NMVOC emissions in the UK. The map correlates well to population density, as the major sources of NMVOC are centred on where people live, including domestic combustion and solvent use, along with widespread industrial activity. Because of the importance of industrial emissions, much of the map is determined by the density of point sources around urban centres.

In comparison to NOx emissions, NMVOC emissions from road transport are greatest at low speeds, making emissions more visible in urban areas as opposed to major roads and motorways.

2.5 Particulate Matter (PM)

As a result of intense coal burning 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 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. Table 2.5 shows emissions of $PM_{2.5}$ by source category. Stationary combustion sources such as residential heating contribute a third of 2011 emissions, with another third a result of the transport sector.

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, 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. The particles that make up secondary PM in the atmosphere such as SO_2, NOx and NH_3 are the main drivers for ecosystem damage through acidification and eutrophication. With increasing concern over the damaging nature of PM emissions, $PM_{2.5}$ has now been added to the list of regulated pollutants under the Gothenburg Protocol. $PM_{2.5}$ has been selected as the PM fraction of most importance to transboundary pollution, due to the ability of finer particles to remain airborne for longer periods of time.

Table 2.5: UK emissions of $PM_{2.5}$ by source category (ktonnes)

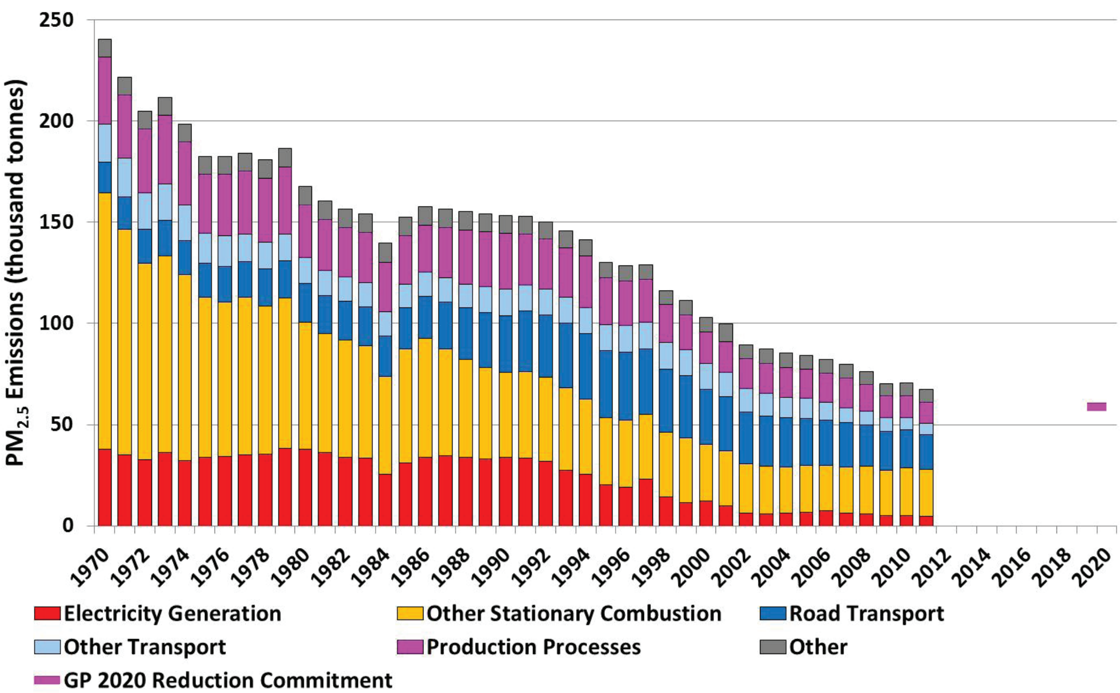
Source category	1970	1980	1990	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2011 %
Electricity Generation	38	38	34	12	10	6	6	6	7	7	6	6	5	5	5	6.9
Other Stationary Combustion	126	63	42	28	27	25	24	23	23	22	23	23	23	24	23	33.9
Road Transport	15	19	28	27	27	25	25	24	23	22	22	20	19	19	17	26.5
Other Transport	19	13	13	13	12	12	11	10	10	9	7	7	6	6	6	8.6
Production Processes	33	26	28	16	15	15	15	15	14	14	15	13	11	11	10	15.0
Other	9	9	9	7	9	7	7	7	7	7	7	7	6	6	6	9.1
TOTAL	**240**	**168**	**153**	**103**	**100**	**90**	**88**	**85**	**84**	**82**	**80**	**76**	**70**	**70**	**67**	**100**

PM emissions occur from a broad range of sources. The time series (Figure 2.5.1) shows steady reductions in total $PM_{2.5}$ emissions, though it is particularly interesting to see the visible impact of the miners' strike in 1984, where a temporary decline in the mining (and therefore availability) of coal decreased emissions of particulates from the electricity generation sector. Over time, transport has become an increasingly important source. Whilst emissions from the transport sector have 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 fairly complex, as better vehicle regulations such as the introduction of Euro Standards have contributed to emissions reductions. However, these 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-engined vehicles.

For production processes, a combination of stricter regulations and the decline of heavy industry have contributed to emissions reductions. The trend for electricity generation follows that of SO_2, where reduced coal use has also decreased PM emissions. Importantly, emissions from other stationary combustion sources have decreased significantly over the series. The majority of these emissions are a result of domestic heating, which was initially accountable for the vast majority of PM emissions. Over the series, the impact of declining solid fuel use (particularly coal) in favour of natural gas has been hugely important in decreasing emissions.

Figure 2.5.1: Time series of $PM_{2.5}$ emissions from 1970 to 2011 and the associated 2020 Gothenburg Protocol emission reduction commitment



2.5.2

Figure 2.5.2: Spatially disaggregated UK emissions of $PM_{2.5}$

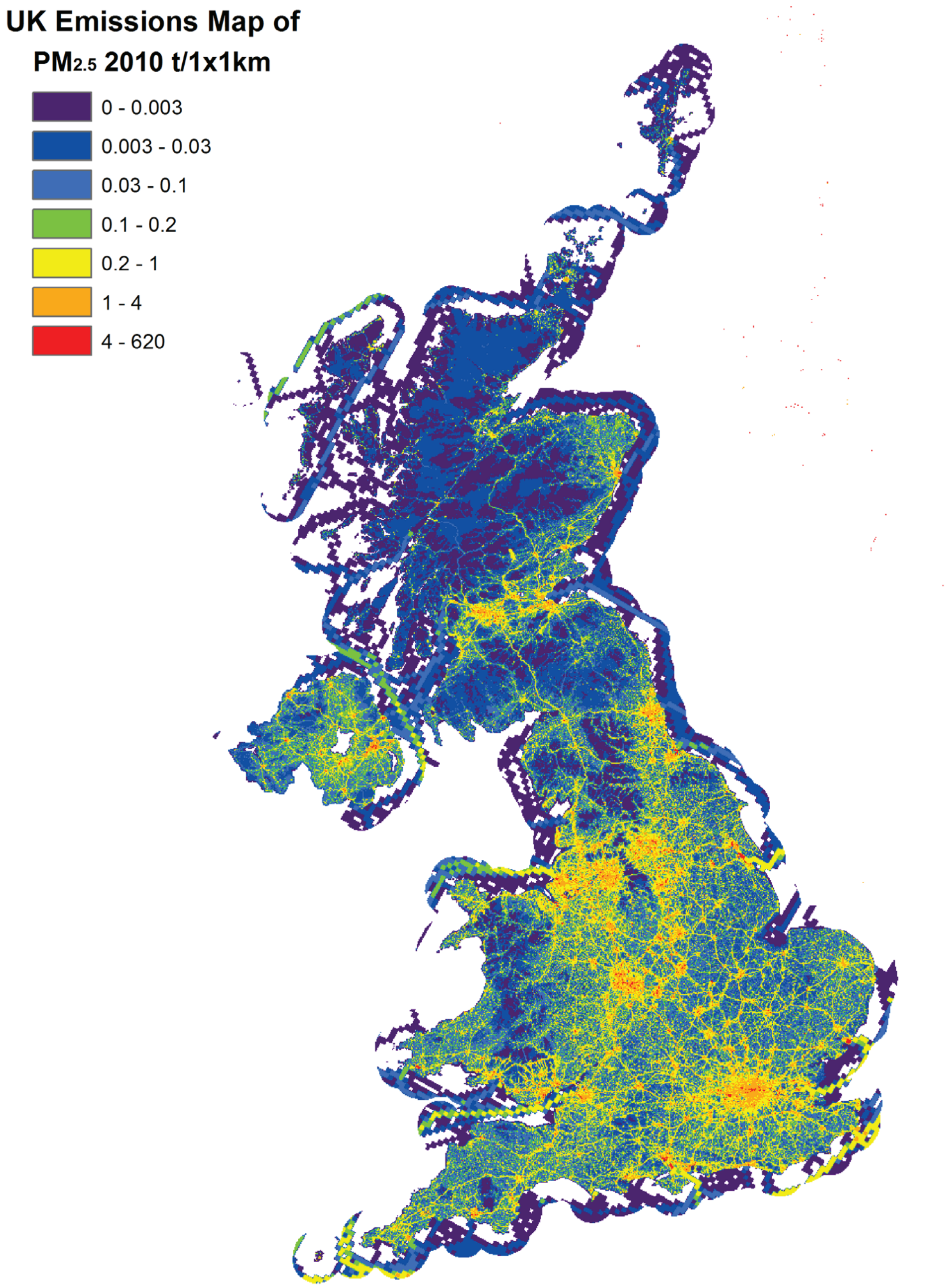


Figure 2.5.2 shows the spatial disaggregation of $PM_{2.5}$ emissions in the UK, with emissions coming from a broad range of sources and diverse locations. The impact of transport is visible in major urban locations, whilst emissions are also generated from a large number of industrial point sources across the country.

3 International Context

3.1 International performance against 2010 NECD

As shown previously in Table 1.3, the UK achieved its 2010 NECD targets for all four pollutants. Table 3.1 compares performance across EU member states. A number of countries currently report emission estimates that exceed their 2010 ceilings, with only Italy successfully meeting all targets out of the other 'big 5' EU countries (UK, France, Germany, Italy and Spain). The ceilings for NOx emissions proved most difficult to accomplish, with 11 out of the 27 countries reporting NOx emission estimates in exceedence of their respective targets.

Table 3.1: Achievement of 2010 NECD across EU member states[3]

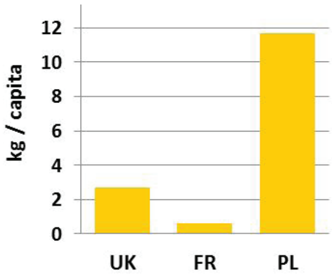
Member State	NOx	NMVOCs	SO_2	NH_3
United Kingdom	✓	✓	✓	✓
Austria	×	✓	✓	✓
Belgium	×	✓	✓	✓
Bulgaria	✓	✓	✓	✓
Cyprus	✓	✓	✓	✓
Czech Republic	✓	✓	✓	✓
Denmark	×	✓	✓	✓
Estonia	✓	✓	✓	✓
Finland	✓	✓	✓	×
France	×	✓	✓	✓
Germany	×	×	✓	✓
Greece	✓	✓	✓	✓
Hungary	✓	✓	✓	✓
Ireland	×	✓	✓	✓
Italy	✓	✓	✓	✓
Latvia	✓	✓	✓	✓
Lithuania	✓	✓	✓	✓
Luxembourg	×	✓	✓	✓
Malta	×	✓	✓	✓
Netherlands	×	✓	✓	✓
Poland	✓	✓	✓	✓
Portugal	✓	✓	✓	✓
Romania	✓	✓	✓	✓
Slovakia	✓	✓	✓	✓
Slovenia	✓	✓	✓	✓
Spain	×	×	✓	×
Sweden	×	✓	✓	✓

[3] European Environment Agency: http://www.eea.europa.eu/highlights/air-pollutant-emission-limits-exceeded

3.2 International comparison and emissions drivers

Sources and quantities of emissions vary across countries. A wide range of factors determine both the pollutants and emission quantities produced from specific sources – factors such as the fuels used to generate electricity, the amount cars are used and the types of animals farmed will all have an influence. This section looks at the driving forces behind some of these examples and the implications for Air Quality inventories and decision-making.

Example 1: Per capita SO_2 emissions from electricity use

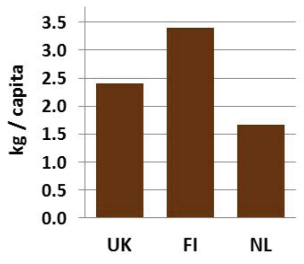


The UK fuel mix for generating electricity is dominated by gas, coal and to a lesser extent, nuclear power – with the combustion of coal being a key source of SO_2. As a direct comparison, France uses a fuel mix which is dominated by nuclear power and produces far fewer SO_2 emissions as a result. Emissions per capita are shown on the graph.

In comparison, Poland relies much more heavily than the UK on coal for electricity generation, and their power stations lack the abatement technology found in a number of other European countries including the UK such as flue-gas desulphurisation (FGD). This means that they produce greater emissions of SO_2 for every unit of coal consumed.

The result is that individuals using the same amount of electricity in the UK, France and Poland will be indirectly responsible for generating significantly different emissions.

Example 2: Per person NOx emissions from passenger cars



Emissions from passenger cars are related to the distances driven, among other factors, and, at a national level, the emissions of NOx per person can highlight the variation of car use between countries. The graph shows three contrasting stories of NOx emissions per person from passenger cars, with Finland producing greater per capita emissions than the UK and Netherlands in turn.

At an individual level, factors such as the age of the car, engine size and driving style can impact on emissions, but these factors tend to even out across large groups of people at the national level.

Geographical differences are the likely cause of the international differences illustrated above. Finland has low population density and it would be reasonable to assume that the need to use a car (for example to travel to the local town for amenities) will therefore be greater. The reverse would be true in the Netherlands. An increased population density, with the majority of people living either in or around major cities and conurbations can reduce the need to travel long distances. Links to public transport may also be more accessible and cycling is more common.

There are numerous factors that determine the emissions and hence air quality within and across countries. It is therefore extremely important to consider both natural and human factors when assessing national inventories, and the compilation of high quality national activity and emissions data is a crucial part of this.

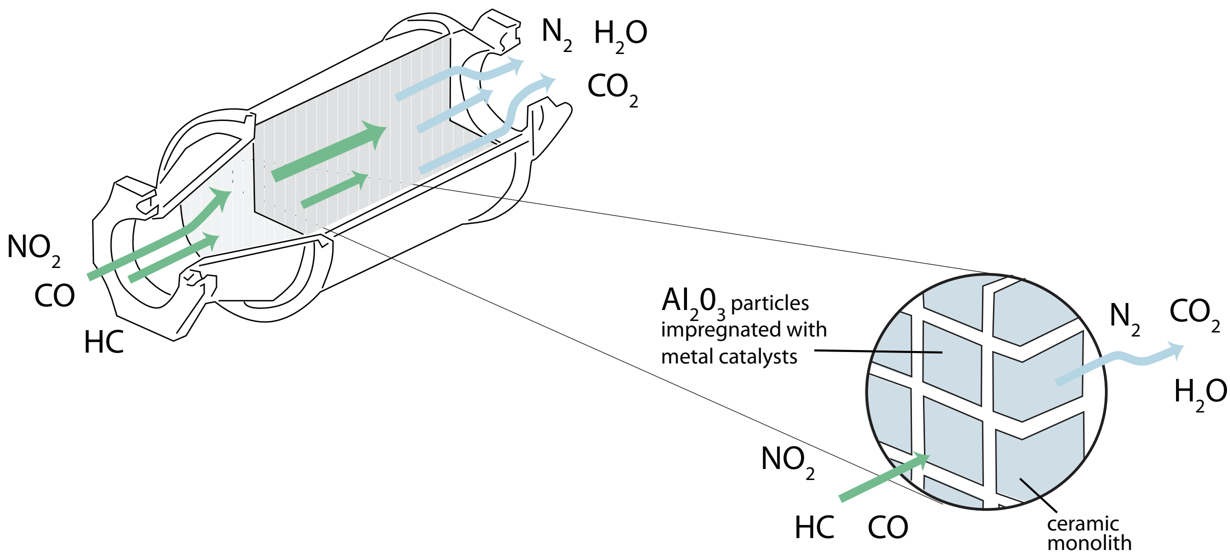
4 Feature Article: Impact of the 3-way catalytic converter

Emissions from the road transport sector rose steadily to a peak in 1989, reflecting the overall growth in road traffic in the UK. Since then, road traffic has still grown over time but there has been a general decline in emissions due to vehicle and fuel quality legislation.
Of particular importance was the introduction of the Euro 1 standard in 1989 (required under EU Directive 91/441/EEC), which effectively mandated the fitting of three-way catalysts to petrol vehicles.

Three-way catalysts are named as such as they simultaneously control the emissions of carbon monoxide, nitrogen oxides and NMVOCs. The use of a three-way catalyst when working effectively reduces NOx emissions by between 80 – 90%. The reactions occur most efficiently when the exhaust gas is close to stoichiometric (when the fuel and air are chemically balanced) and are only effective when the engine has reached a temperature of between 250 – 300 degrees centigrade. It is estimated that about 5% of catalysts fail and that up until 2008 these were not all replaced correctly. The introduction of the Regulations Controlling Sale and Installation of Replacement Catalytic Converters in 2009 has since ensured that catalysts are replaced to a high standard.

Unwanted reactions can occur in the catalyst leading to an increase in ammonia emissions. This was of particular concern with the earlier catalysts. However, emissions of this pollutant are projected to fall across the next few years as the second generation of catalysts (which emit less ammonia than first generation catalysts) penetrate the vehicle fleet.

Figure 4: Three-way catalytic converter



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://www.defra.gov.uk/environment/quality/air/air-quality/**

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-AEA with contributions from Aether, AMEC and SKM Enviros on behalf of Defra.

Department for Environment Food & Rural Affairs

Aether

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