1. Introduction

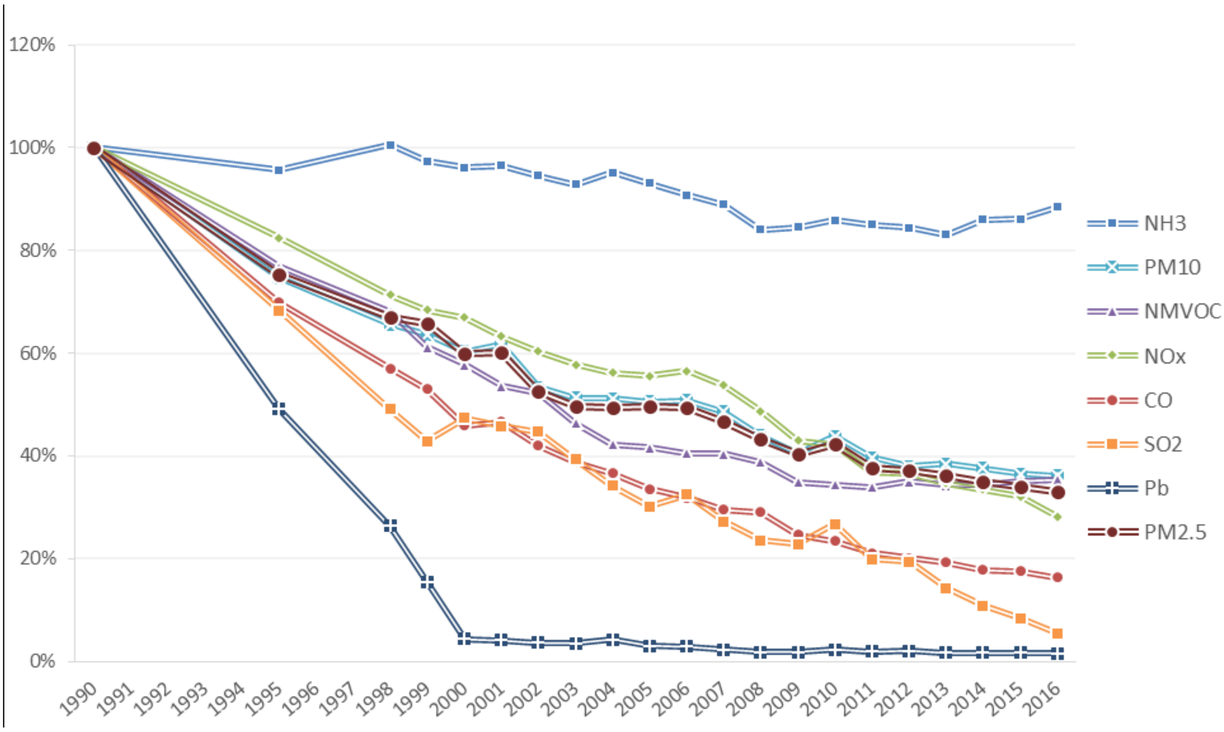
1.1 This note provides background information on the current state of air pollution in Scotland, environmental impacts and environmental trends. Unless otherwise stated, all data originated from the National Atmospheric Emissions Inventory (NAEI), 2019[1].

2. Emission trends in Scotland to 2016

Scotland summary to 2016

2.1 Emissions of the 8 main air pollutants show that levels are lower in 2016 than they were in 1990. This rate of decline is relatively similar for Particulate matter (PM_{10} and $_{2.5}$), oxides of nitrogen (NO_x), Non-methane volatile organic compounds (NMVOC), sulphur dioxide (SO_2) and carbon monoxide (CO). Lead (Pb) shows a much higher rate of reduction from 1990 to 2000 coinciding with the phase-out of leaded petrol from 2000 while ammonia (NH_3) emissions have declined at a slower rate than other pollutants.

Figure 1 – Pollutant trends in Scotland from 1990 onwards



Individual pollutant trends to 2016

NO_x

2.2 Emissions of NO_x were estimated to be 90 kilotonnes (kt) in 2016 (10% of the United Kingdom (UK) total) declining by 72% since 1990. Reductions have been due to improved emissions control on vehicles (e.g. catalytic converters); however,

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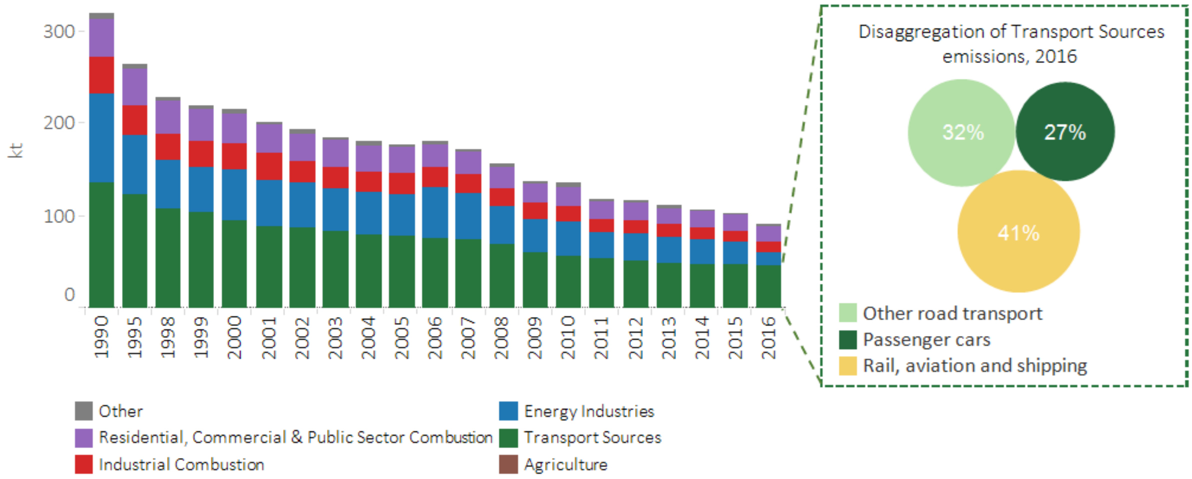
1 National Atmospheric Emissions Inventory, Air Pollutant Inventories for England, Scotland, Wales, and Northern Ireland: 1990-2016 (October, 2018) - http://naei.beis.gov.uk/reports/

reductions have been offset by an increased proportion of diesel vehicles in the fleet and diesel emissions control systems not performing in real world driving scenarios (86% of vehicle emissions of NO_x from cars are due to diesel). Transport now provides the greatest source of NO_x in Scotland.

2.3 Emissions of NO_X emissions from combustion activities have consistently decreased since 1990 due mainly to the addition of abatement systems to coal-fired generating stations (Cockenzie and Longannet) and their subsequent closure in 2013 and 2016 respectively. Levels of NO_x are likely to continue to fall with improved emissions control systems on vehicles and the shift towards electric and hybrid vehicles.

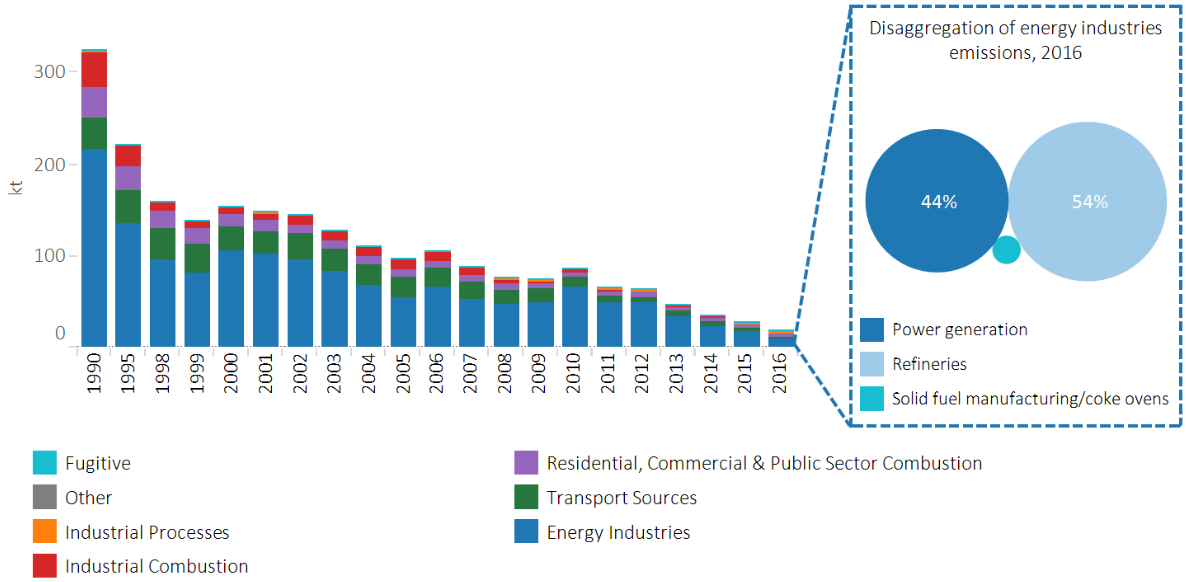
Figure 2 – NO_x trends in Scotland from 1990 onwards



SO_2

2.4 Emissions of SO_2 were estimated to be 18kt in 2016 (10% of the UK total) declining by 94% since 1990. Reductions have almost entirely been due to changes in the energy generation sector. As with NO_x, emissions reductions were initially achieved by emissions abatement (and change of fuel type) and subsequent closure of generating stations. Controls have also been placed on sulphur content of fuels (oil, gas, petrol, etc.) which have helped achieve these reductions. This downward trend is likely to continue with the move away from fossil fuel use, regulation of previously unregulated sectors (e.g. shipping) and increasingly tight controls on sulphur content of fuels.

Figure 3 – SO_2 trends in Scotland from 1990 onwards

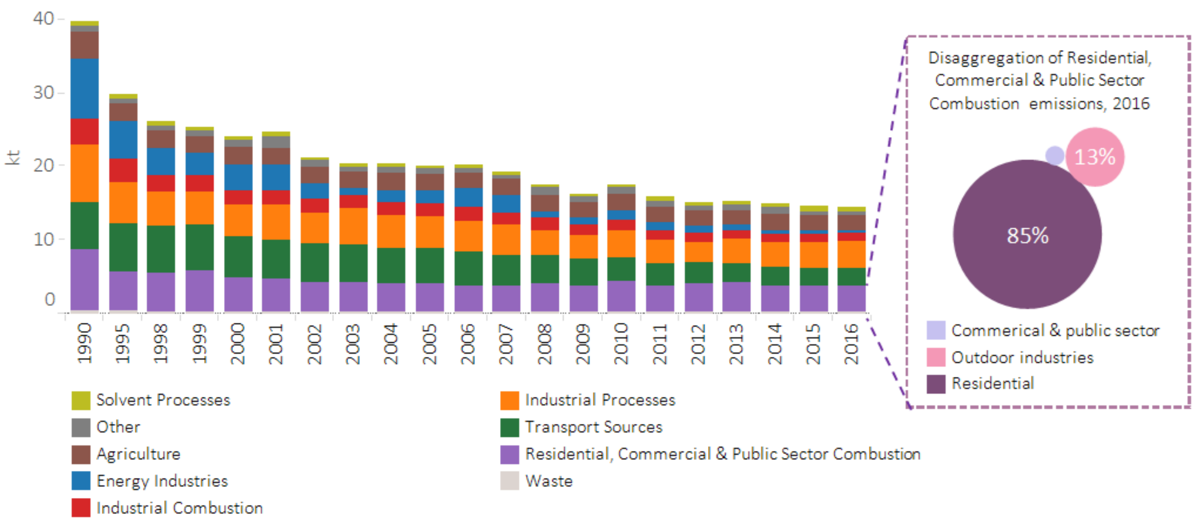


PM$_{10}$ and $_{2.5}$

2.5 Emissions of PM$_{10}$ were estimated to be 14kt in 2016 (8% of the UK total) declining by 64% since 1990. As with NO_x and SO_2 changes to the energy generation (abatement and closure) and transport (abatement) sectors have had a significant impact, but due to the range of sources of PM other contributions have now become more prominent.

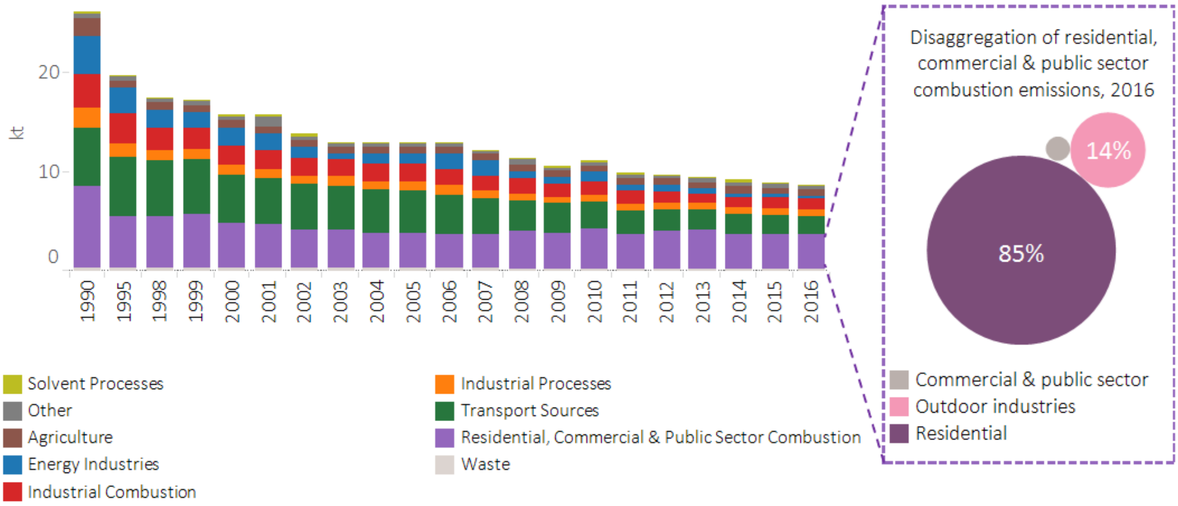
2.6 The transport, residential, commercial and public sector combustion, industrial combustion and industrial processes sectors each accounted for over 10% of total emissions in 2016. Additionally where a source of PM$_{10}$ has been reduced (e.g. power generation, exhaust emissions) other sources have replaced them and become more prominent (e.g. domestic combustion, non-exhaust vehicle emissions – brake/tyre wear, road abrasion). As a result the trend in reductions has levelled off over recent years. Transboundary sources of PM also mean that PM trends can be unpredictable (due to origin of sources and meteorology).

Figure 4 – PM$_{10}$ trends in Scotland from 1990 onwards



2.7 Emissions of PM$_{2.5}$ were estimated to be 9kt in 2016 (8% of the UK total) declining by 67% since 1990. PM$_{2.5}$ and PM$_{10}$ emissions have similar sources, however combustion activities provide for a greater contribution to PM$_{2.5}$ emissions. Emissions have declined due to the change in nature of energy generation (fuel types, abatement, and closure of stations) and abatement controls on vehicles. However, as for PM_{10} reductions have levelled off due to greater contributions from non-exhaust transport sources and increases in small-scale combustion activities (residential, commercial and public sectors). As with PM_{10}, transboundary sources also mean that $PM_{2.5}$ trends can be unpredictable.

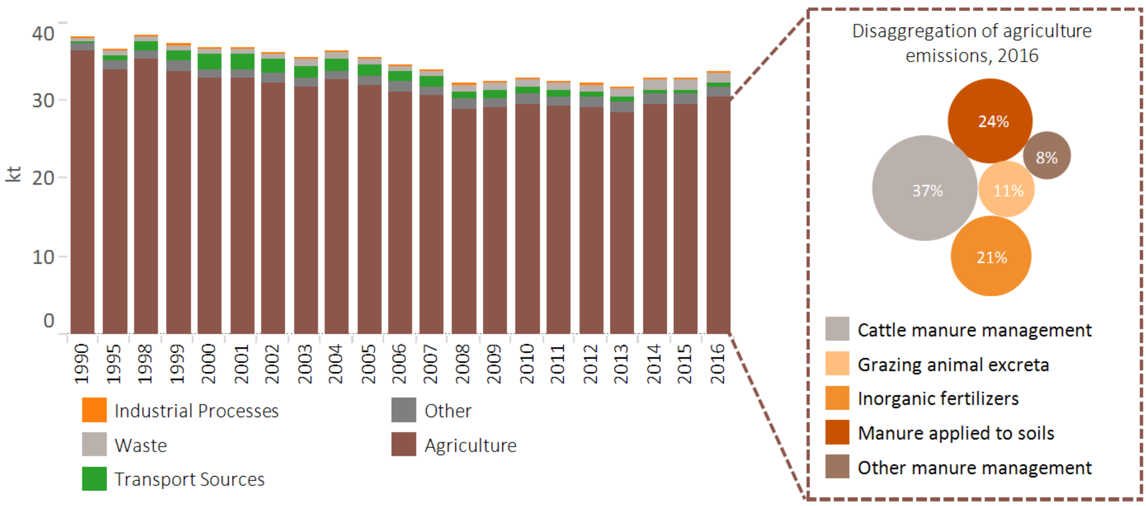
Figure 5 – $PM_{2.5}$ trends in Scotland from 1990 onwards



NH₃

2.8 Emissions of NH_3 were estimated to be 34kt in 2016 (12% of the UK total) declining by 12% since 1990. Agriculture is the main source of NH_3 through management of animal wastes and application of these and artificial fertilisers to land. Where changes have occurred in animal numbers and fertiliser use these have been offset by use of urea-based fertilisers and contributions from processes such as anaerobic digestion (and land spreading of the digestate). Transport sources continue from exhaust emissions and the use of ammonia-based chemicals in exhaust abatement systems.

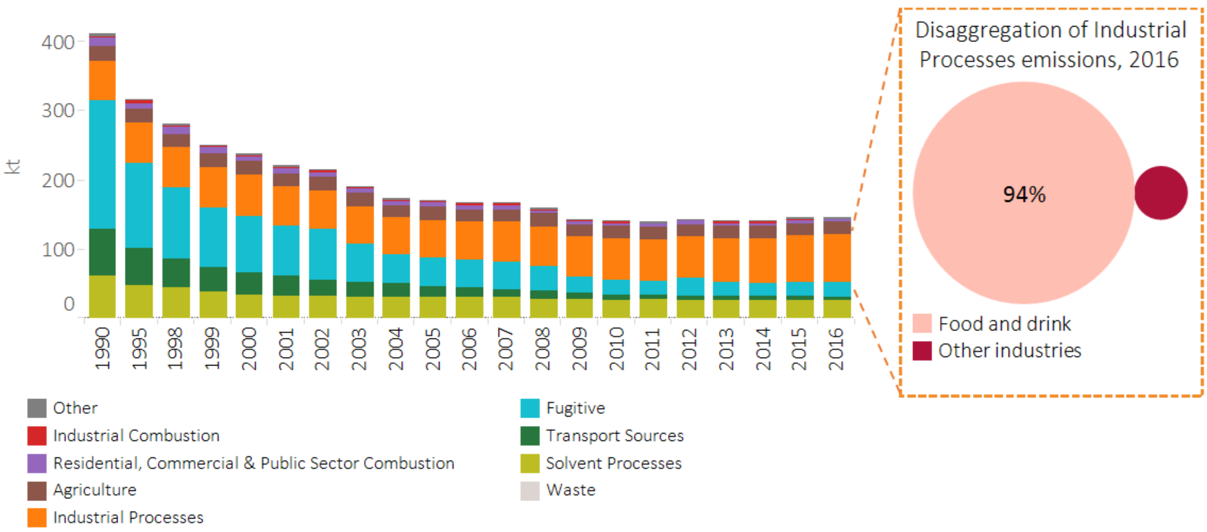
Figure 6 – NH_3 trends in Scotland from 1990 onwards



NMVOCs

2.9 Emissions of NMVOCs were estimated to be 146kt in 2016 (18% of the UK total) declining by 65% since 1990. Reductions in emissions (mostly fugitive) from activities such as oil production and transportation have been offset by increases in production of food and drink, primarily whisky, which now account for almost half of Scottish NMVOCs. Transport sources have also declined with the introduction of vapour recovery systems at refineries and petrol stations.

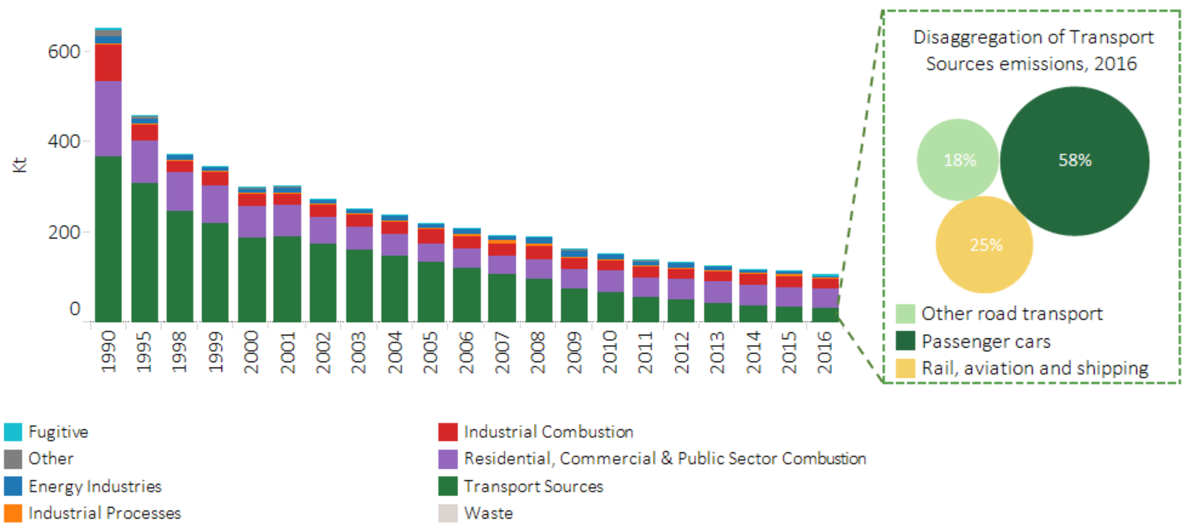
Figure 7 – NMVOC trends in Scotland from 1990 onwards



CO

2.10 Emissions of CO were estimated to be 107kt in 2016 (7% of the UK total) declining by 84% since 1990. Emissions reductions are due mostly to the introduction of emission control systems on road vehicles and the change in fleet composition to move towards diesel-fuelled vehicles. As with PM, emissions associated with combustion from the residential, commercial and public sectors are becoming increasingly significant as other sectors reduce.

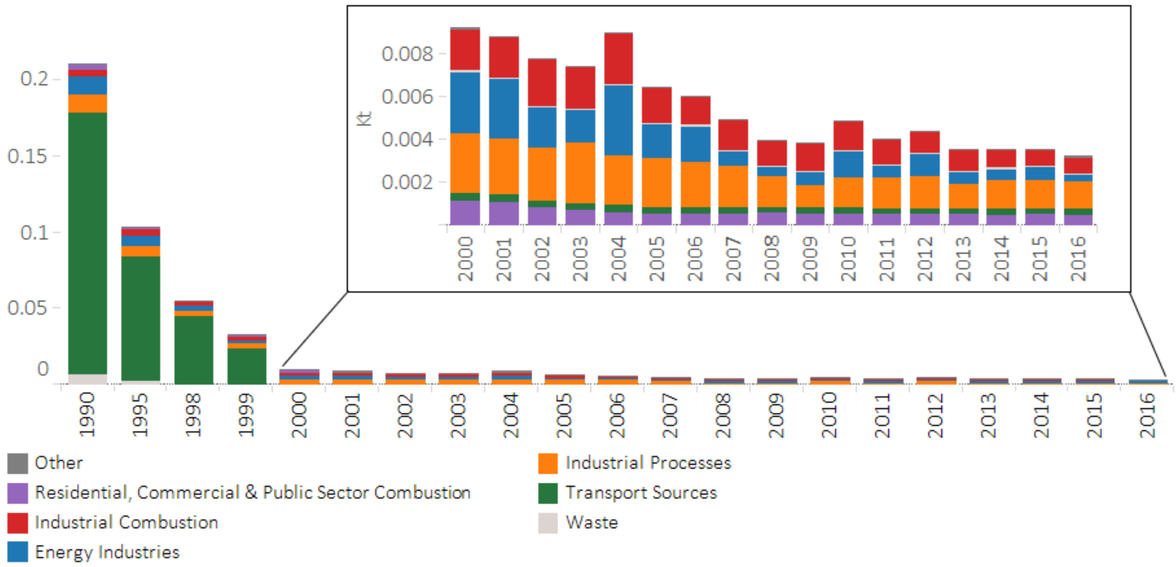
Figure 8 – CO trends in Scotland from 1990 onwards



Pb

2.11 Emissions of Pb were estimated to be 3.3 tonnes in 2016 (5% of the UK total) declining by 98% since 1990. These reduction have been almost entirely due to the phase-out and banning of lead additives in petrol and the cessation of coal burning in energy generation.

Figure 9 – Pb trends in Scotland from 1990 onwards

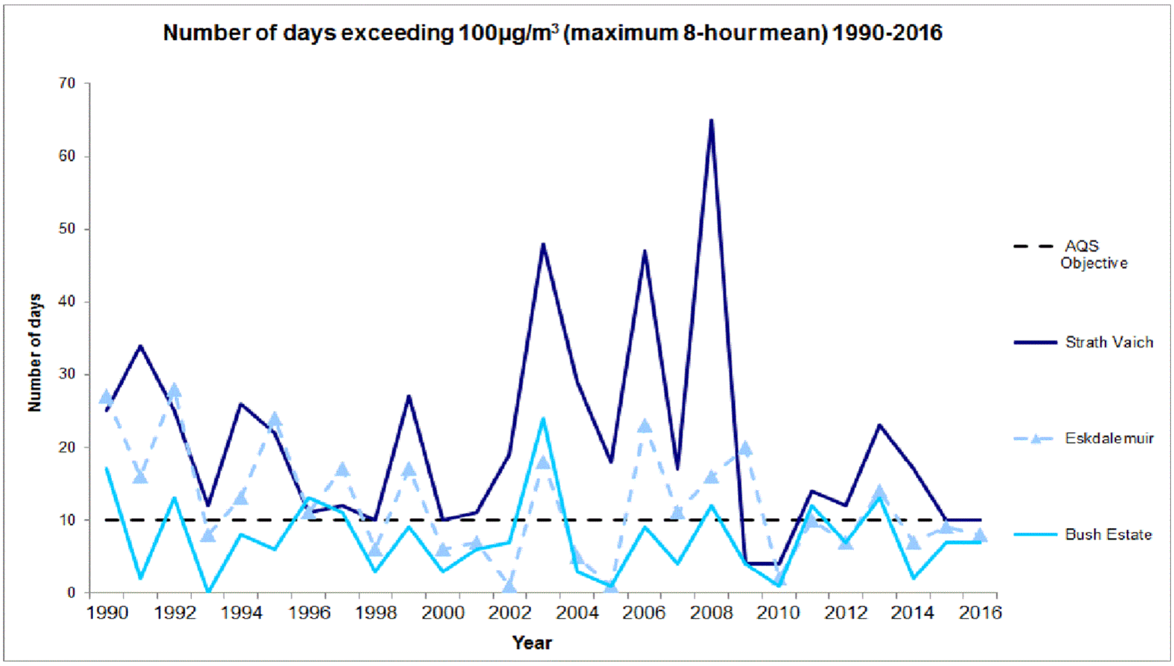


O_3[2]

2.12 As ground-level ozone (O_3) is a secondary pollutant formed from reactions in the atmosphere (primarily from NMVOCs and NO_x) source apportionment is not possible in the same way as for other pollutants and instead, trend data is produced. Due to the complexity of ground-level ozone formation and contributing factors (e.g. sunlight intensity, meteorology) O_3 concentrations can fluctuate from year-to-year. The following graph shows the trends of O_3 since 1990 and number of days exceeding the objective are lower for the last 10 years, likely to be due to reductions in the pre-cursor pollutants.

Figure 10 – O_3 trends in Scotland from 1990 onwards

[2] Scottish Government, High Level Summary of Statistics Trend, Ground Level Ozone Concentration, (October 2017) - https://www2.gov.scot/Topics/Statistics/Browse/Environment/TrendOzone



3. Emission reductions required[3]

3.1 A revised National Emission Ceilings (NEC) Directive (2016/2284/EU) entered into force on 31 December 2016 which implements the national Emission Reduction Commitments (ERCs) agreed under the amended Gothenburg Protocol. These ERCs need to be met in two phases, from 2020 to 2029 with more stringent levels to be met from 2030 onwards (the aim being reducing the health impacts of air pollution by half compared with 2005 levels). It also ensures that the emission ceilings for 2010 set in the earlier NECD remain applicable for Member States until the end of 2019.

3.2 The UK has been fully compliant with the Directive requirements from 2010 to 2016. In February 2019 the UK Government and devolved administrations produced their draft National Air Pollution Control Programme (NAPCP) which outlines how the UK proposes to meet its obligations to 2030 and beyond. The NAPCP demonstrates that the UK is able to meet the 2020 and 2030 ERCs if the Defra Clean Air Strategy measures are applied (and effective) in England only; therefore any Scottish policies and NAPCP revisions will only increase compliance and contribute to further emission reductions.

3.3. Based on 2016 data (the most recent available) Scotland contributes between 8 to 18% of UK emissions for specific pollutants. The UK obligations and Scottish contributions are shown in Figure 11 (below).

Figure 11 – Information on NECD obligations to 2030

	UK national ERCs compared with 2005 base year (%)		UK target (kt)	UK progress (%)	Scotland's contribution to UK totals (%)
Pollutant	**2020/29**	**2030**	**2030**	**2016**	**2016**
SO_2	59	88	40 – 55	77	10
NO_x	55	73	405 – 476	48	10
NMVOC	32	39	626 – 664	33	18

[3] Defra and devolved administrations, Draft National Air Pollution Control Programme, (February 2019) - https://consult.defra.gov.uk/environmental-quality/napcp-consultation/

NH_3	8	16	214 – 277	3	12
$PM_{2.5}$	30	46	61 – 71	15	8

3.4 In the UK NAPCP the revised CAFS is stated as the key policy measure provided by the Scottish Government to contribute to meeting the requirements of the NECD.

3.5 For those pollutants not covered under the requirements of the NECD, policy measures will continue to required and implemented; however, it is also the case that further reductions will be achieved as a consequence of the measures put in place through the NAPCP and CAFS (e.g. reductions in PM_{10} and CO from controlling combustion activities aimed at reducing emissions of $PM_{2.5}$).

4. Environmental impacts[4]

4.1 Air pollutants can undergo a variety of chemical changes in the air (including the formation of secondary pollutants such as O_3 and secondary PM) before being deposited back onto the ground, where they can damage soils and vegetation. The deposition of acid and nitrogen-rich pollutants can damage habitats by acidifying the soil and water and, and also by increasing the availability of nitrogen. This can affect the type and number of species present, particularly in ecosystems sensitive to those changes. Despite reductions in emissions, we still see the impacts of airborne pollutants in many of our sensitive habitats.

Nutrient enrichment

4.2 The primary pollutants SO_2, NO and NO_2 are oxidised in the atmosphere to form sulphate (SO_4^{2-}) and nitrate (NO_3^-) respectively, while NH_3 reacts with these oxidised components to form ammonium (NH_4^+). These pollutants known as aerosols can travel long distances, and together with primary pollutants can be deposited in the form of wet or dry deposition.

4.3 Wet deposition is the process whereby pollutants are removed from the atmosphere by precipitation. Wet deposition removes most of the aerosols containing SO_4^{2-}, NO_3^- and NH_4^+, but some can be captured directly (dry deposition) at the terrestrial surface by aerodynamically rough surfaces (e.g. forests). Since rainfall efficiently removes these aerosols, parts of the country with the largest wet deposition tend to be areas of high rainfall. Dry deposition is the deposition of gases and aerosols directly to the Earth's surface. This includes most of the primary pollutants (SO_2, NO_2, NH_3 and O_3), and to a lesser extent aerosols.

4.4 Nutrient enrichment caused by pollutants such as NO_2 and NH_3 increases the availability of nitrogen for plant growth, which can result in in changes in habitats and loss of important plant species. When nitrogen availability exceeds the demand from plants, the excess is leached out, increasing the levels in our lochs and rivers. Many of Scotland's lochs have naturally low levels of nutrients, so even quite small increases can significantly alter their sensitive ecosystems. In Scotland, the addition of phosphorus to lochs has the greatest impact on water quality. Phosphorus can enter lochs through run-off or drainage from land, or directly from fish farming and sewage inputs and air pollution inputs are less significant.

4.5 Nitrogen is the main limiting nutrient for plant growth in most cases. In Scotland many plant species are adapted to grow in nutrient-poor conditions and habitats. Deposition

[4] CEH, Trends Report 2017: Trends in critical load and critical level exceedances in the UK

of nitrogen can result in a change to the vegetation species composition as important conservation species are outcompeted and overrun by more common species.

4.6 Nitrogen deposition in Scotland has reduced over time; however, it continues to pose a significant threat to the most sensitive habitats. Trends in nitrogen deposition for Scotland include:

- Reductions in the area of nitrogen-sensitive habitats with critical load exceedance from 59.4% in 1995-97 to 42.8% in 2013-15;

- Reductions (5-10%) in the percentage of Special Areas of Conservation (SACs) and Sites of Special Scientific Interest (SSSIs) with exceedance of nutrient nitrogen critical loads between 1995-97 and 2013-15; and

- 63-84% of designated sites currently have exceedance of nutrient nitrogen critical loads for one or more features.

Acid deposition

4.7 Acid rain is formed when SO_2 and nitrogen dioxide (NO_2) react in the atmosphere with water, oxygen and other chemicals to form various acidic compounds. These compounds are transported in the air by the wind, until they fall to the ground in either wet or dry form. When the compounds fall to the ground, they can cause damage to plants, including trees and also increase sensitivity of species to pests, pathogens and climate extremes. They can also increase the acidity levels of our soils, rivers, lochs and streams, affecting the delicate balance of ecosystems that live in these environments resulting in a reduction in biodiversity.

4.8 Water quality in some lochs, particularly those in upland locations, has been affected by atmospheric pollution since the industrial revolution. In general, acidified lochs contain fewer plant and animal species. The problem is especially acute in the south-west of Scotland where soils surrounding the lochs are unable to neutralise the acidity.

4.9 Strict controls on industrial emissions, fuel types and reduced acid deposition mean that some lochs are showing signs of recovery from acidification. However, other lochs will recover more slowly and their full recovery may be prevented by the effects of nitrogen emissions from vehicle emissions and the impacts of climate change.

4.10 The direct impacts of acid rain have almost ceased to be a problem in Scotland (due to the measures discussed above); however, acid deposition continues to impact on sensitive sites and biodiversity. Trends in acidification for Scotland include:

- Reductions in the area of acid-sensitive habitats with exceedance of acidity critical loads from 68.2% in 1995-97 to 31.4% in 2013-15;

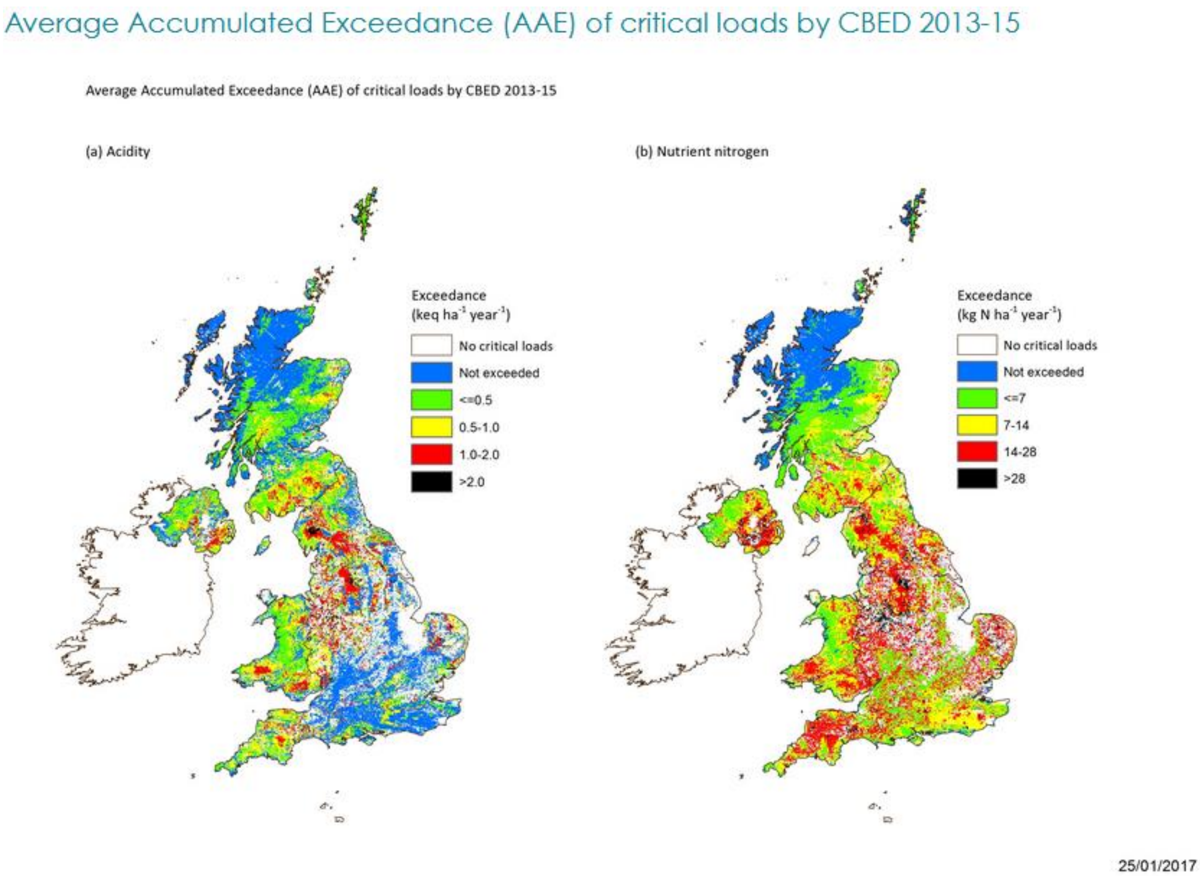
- Reductions (>25%) in the percentage of designated sites with exceedance of acidity critical loads between 1995-97 and 2013-15; and

- More than 50% of designated sites in Scotland currently have exceedance of acidity critical loads for one or more features.

Trends

4.11 Exposure of ecosystems in Scotland to acidification and nitrogen deposition has decreased significantly over recent years and we now have low levels of exposure to both environmental pressures (especially in comparison to the rest of the UK), which are likely to continue improving with the existing and new policy measures put in place to control atmospheric emissions. The following Figure shows the last UK maps illustrating exceedences of critical load for both acidity and nutrient nitrogen for all habitats combined, and based on UK 5 x 5 km deposition data averaged for 2013-2015.

Figure 12 – Critical load exceedence maps for the UK (2013 – 2015)



Ozone

4.12 Effects of ground-level ozone on vegetation include visible injury (damage to cell structures), early senescence of leaves (deterioration with age), and reduction of crop yield (with subsequent economic reductions). Exposure of plants to concentrations above 40 parts per billion (ppb) for several weeks can reduce growth and the yield of sensitive crops species. However, it is difficult to translate this kind of information into effects on crops growing in the field and on natural communities. As ground-level ozone is formed some distance away from the origin of the pre-cursor pollutants it tends to affect rural (and therefore agricultural) areas.

Particulate matter (PM)

4.13 PM emissions contribute to acidification and nutrient enrichment of habitats through their chemical composition. However, PM can also have a direct impact on the environment through deposition on plant surfaces (reducing the plant's ability to function), soiling of buildings (e.g. through soot) and also contribute to climate change (through deposition of black carbon).

Meteorology

4.14 Prevailing weather conditions can weaken or improve the impacts of air pollution. Strong winds can rapidly disperse and transport pollutants hundreds of kilometres (kms), whereas during weak wind (or mixing) circumstances, pollutants can accumulate around the source of the release (static conditions, temperature inversions). Precipitation can either clean or pollute the environment depending on the composition of the air and moisture.

4.15 Photochemical reactions are very powerful in sunshine and warm weather (assisting the formation of ground-level ozone). Fog and rain (and snow) can clean the air effectively by washing out pollutants; however, chemicals and compounds that pollute the air can also fall with rain to pollute soil and surface waters (wet deposition – see above). Mixing can also depend on topography and local circumstances.

4.16 Scotland has relatively favorable weather conditions for dealing with air pollution. Due to Atlantic depressions providing prevailing south-westerly weather systems, mostly temperate climate and relatively high rainfall the number of days of moderate/high air pollution are very few and in most cases due to changes in the prevailing meteorology (e.g. winds from the east/south transporting continental air pollution to Scotland). Meteorology also has an important part to play in dispersing localised sources of urban pollution, however this can be impeded by aspects such as topography, street layout and traffic flow (e.g. creating street canyons which are sheltered from the prevailing wind direction).

Standards and objectives for protecting health and the environment[5]

4.17 There are a wide range of terms and concepts for assessing air quality impacts (e.g. standards, objectives, target values and limit values). The Environment Act 1995 (EA95) requires definitions of “standards relating to the quality of air”, and “objectives for the restriction of the levels at which particular substances are present in the air”. Standards have been used as benchmarks or reference points for the setting of objectives.

4.18 Currently the following definitions are used for AQ standards and objectives in the UK:

- Air quality standards are the concentrations of pollutants in the atmosphere which can broadly be taken to achieve a certain level of environmental quality. Standards are based on assessment of the effects of each pollutant on human health including the effects on sensitive subgroups or on ecosystems;

- Air quality objectives are policy/legal targets often expressed as a maximum ambient concentration not to be exceeded, either without exception or with a permitted number of exceedences, within a specified timescale.

4.19 Air quality standards, as the benchmarks for setting the objectives, are based purely on scientific and medical evidence on the effects of the particular pollutant on health, or, in the appropriate context, on the wider environment, as minimum or zero risk levels. For human health this is the approach adopted by the World Health Organisation (WHO) in the formulation of their air quality guidelines and by Expert Panel on Air Quality Standards (EPAQS) in the UK.

[5] Defra and the Devolved Administrations, UK Air Quality Strategy for England, Scotland, Wales and Northern Ireland (2007) - https://www.gov.uk/government/publications/the-air-quality-strategy-for-england-scotland-wales-and-northern-ireland-volume-1

4.20 A similar approach is utilised for the development of policies and measures to reduce ecosystem damage. Standards expressed in terms of critical loads and levels are derived for habitats and exceedence of this value is used as an indication of the potential for harmful effects to systems at steady state thus giving an indication of risk to the system. They are specifically defined as:

- Critical loads are "a quantitative estimate of an exposure to one or more pollutants below which significant effects on specific sensitive elements of the environment do not occur according to present knowledge" and where pollutants are deposited to land or water. Exceedence of critical load is used as an indication of the potential for harmful effects to ecosystems; and

- Critical levels refer to gaseous concentrations of pollutants above which direct adverse effects on vegetation or ecosystems may occur according to present knowledge. Therefore, when pollutant concentrations exceed the critical level it is considered that there is risk of harmful effects.