SCOTTISH AIR QUALITY DATABASE

Annual Report 2021

Report for: Scottish Government

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EXECUTIVE SUMMARY

In April 2007, Ricardo Energy & Environment (Ricardo) were commissioned by the Scottish Government to undertake a three-year project (Apr 2007 – Apr 2010) to develop an Air Quality Database and Website for Scotland. This contract has been renewed in consecutive years, with the latest contract running from 2019-2023.

This report brings together all the Scottish Air Quality Database data for calendar year 2021 and associated work relating to project deliverables including: data management; QA/QC services; liaison with stakeholders; website development; spatial analysis of air quality data; trend analysis.

In addition, this year's report provides updated analysis on how the Covid-19 pandemic affected air quality in Scotland. This analysis follows on from the 2020 annual report Covid-19 analysis.

Legislation and Policy

Air quality management is shaped by requirements of EU, UK and Scottish legislation and policies. Following the UK's exit from the EU, under retained EU law, the UK is required to continue to meet limit and target values for a range of air pollutants and other legal obligations covered by EU directives.

In July 2021, accompanied by a Delivery Plan, and replacing "Cleaner Air for Scotland – The Road to a Healthier Future", the Scottish Government published Scotland's second air quality strategy called "Cleaner Air for Scotland 2 – Towards a Better Place for Everyone" (CAFS2). CAFS2 is shaped around 10 general themes. These are:

1. Health – A Precautionary Approach
2. Integrated Policy
3. Placemaking
4. Data
5. Public Engagement and Behavioural Change
6. Industrial Emissions Regulation
7. Tackling Non-Transport Emission Sources
8. Transport
9. Governance, Accountability and Delivery
10. Further Progress Review

Air Quality Monitoring in Scotland

Air pollution data for 99 automatic monitoring sites throughout Scotland are available in the database for all or part of 2021. All automatic data maintained within the Scottish database are subject to the same QA/QC procedures as the UK Automatic Urban and Rural Network (AURN).

In 2021, of the 73 sites with data capture of greater than 75% one automatic monitoring site (Glasgow Kerbside (Hope Street) exceeded the annual mean objective for NO_2. In 2021, five passive diffusion tube monitoring sites exceeded the NO_2 annual mean objective. These four sites were located in the four major Scottish cities.

In 2021, no automatic monitoring sites measuring Particulate Matter (PM_{10} and $PM_{2.5}$) measured exceedances of the Scottish 24 hour or annual mean objectives for both PM_{10} and $PM_{2.5}$.

As with 2020, the pattern of measured concentrations in 2021 for both NO_2 and Particulate Matter (PM) is not consistent with previous years. A significant decline in concentrations, especially in NO_2, is attributed to the Covid-19 pandemic lockdown restrictions that continued at different levels during 2021.

In 2021, no exceedances of AQS objectives were observed for the pollutants Ozone (O_3), Sulphur Dioxide (SO_2), Carbon Monoxide (CO), benzene, 1,3-butadiene, benzo(a)pyrene, and Lead (Pb).

Air Quality Mapping of Scotland

The 2020 annual mean NO_2 concentrations for Scotland were modelled for background and roadside locations for NO_2, PM_{10} and $PM_{2.5}$.

For NO_2, there were no modelled exceedances of the Scottish annual mean objective of 40 µg m^{-3} at background or roadside locations.

For PM_{10}, there were no modelled exceedances of the Scottish annual mean PM_{10} objective of 18 µg m^{-3} at background or roadside locations.

For $PM_{2.5}$, there were also no modelled exceedances of the Scottish annual mean $PM_{2.5}$ objective of 10 µg m^{-3} at both background and roadside locations.

Air Quality Trends for Scotland

NO_2

Trend analysis of nitrogen dioxide concentrations at Scotland's five long-running urban non-roadside sites shows that NO_2 concentrations are displaying highly significant decreasing trends. More recent years analysis (2017 to 2021) show a less consistent trend across the country with one site showing increasing trends contradicting the perception that NO_2 concentrations are decreasing at all urban background sites

Analysis shows that NO_2 concentrations at Scotland's three long-running rural sites showed small decreasing trends.

Of the eight selected NO_2 urban traffic monitoring sites selected for analysis; all eight sites showed highly significant decreasing trends. Examination of trends at the same eight sites over the most recent five years indicates that the patterns were very similar to the 10-year trends.

PM_{10}

PM_{10} trend analysis at Scotland's eight long-running urban/Industrial background sites showed highly significant decreasing trends at all sites. Seven out of Scotland's eight long-running urban traffic sites also showed statistically highly significant decreasing trends at all sites. The exception being Glasgow Byres Road.

Examination of trends in PM_{10} at the same eight sites over the most recent five years indicates that, at some of these, the decreasing trends have continued but at others they have weakened or levelled off.

$PM_{2.5}$

By the end of 2021 there were four sites with 10 consecutive years of $PM_{2.5}$ data. Aberdeen Errol Place, Edinburgh St Leonards, and Grangemouth sites show slight but highly statistically significant decreasing trends for $PM_{2.5}$. Contrary to this, the rural site, Auchencorth Moss, showed no obvious trend over the past 10 years.

Looking at a selection of nine urban background and traffic sites with five years' worth of data. Four sites have highly significant decreasing trends. Four other sites, though decreasing, have no real identifiable statistically significant trend. The South Lanarkshire Uddingston site however has an increasing trend though not statistically significant.

Ozone

Ozone has been measured at three rural sites in Scotland for 30 years. Two sites showed small but statistical highly significant increasing trends whereas the other showed no obvious trend. Ozone has been measured for the past 10 years at six rural sites. In contrast to the 30-year trends, the 10-year trends were less consistent. Four sites have increasing trends in O_3 concentrations at varying levels of statistical significance. The other two sites have slight decreasing trends

10-year trend analysis of ozone concentrations showed increasing trends (at varying statistical significance) at all three Scottish urban background sites.

Additional Trend Analysis

Additional trend analysis was carried out at four sites located within the four major cities in Scotland. This analysis was carried out using the Openair analysis tool and compared 2021 data with data from the previous 10 years using a variety of analytical techniques.

Emissions of Pollution Species

Emissions of **NOx** in Scotland are estimated to have declined by 61% since 2005 and were estimated to be 82 kt in 2020, representing 12% of the UK total. The decline is mainly due to changes in transport sources. Declines in emission from the Energy industry (linked to the Boosted Over-Fire Air (BOFA) abatement systems) has also contributed to the decline in emissions.

Emissions of **PM_{10}** have declined by 46% since 2005 and in 2020 and were estimated to be 11 kt (8% of the UK total). Emissions from energy industries (and its movement away from coal use) and transport sources (the fleet increasing compliance with Euro emission standards) have had the most notable impact on the trend. Emissions levels between 2015 and 2019 plateaued before decreasing again in 2020.

Emissions of **$PM_{2.5}$** have declined by 52% since 2005 and in 2020 were estimated to be 6 kt (8% of the UK total). The primary drivers for the decline in emissions since 2005 are the continued switch from coal to natural gas in electricity generation, and reductions in emissions from the transport sector due to the introduction of progressively more stringent emissions standards through time. As with PM_{10}, Emissions levels between 2015 and 2019 plateaued before decreasing again in 2020.

Emissions of **CO** in Scotland were estimated to be 87 kt in 2020 (7% of the UK total) and have declined by 62% since 2005. This decline in emissions stems from changes in the contribution of transport sources, particularly in the road sector where emissions have declined by 92% since 2005. This decline is primarily due to the penetration into the fleet of vehicles compliant with more recent Euro standards, which required the fitting of emission controls in new petrol vehicles.

Emissions of **SO_2** in Scotland were estimated to be 8 kt in 2020, representing 6% of the UK total in 2020 for sulphur dioxide. Emissions have declined by 92% since 2005 mainly due to continued changes in the power generation sector. Since 2005, SO_2 emissions from power stations have reduced by 99%.

Emissions of **Ammonia** have declined by only 10% since 2005 and were estimated to be 32 kt (12% of the UK total) in 2020. Agriculture sources dominate throughout the time-series. The initial trends in NH_3 emissions were primarily driven by decreases in livestock numbers and declines in the use of nitrogen-based fertilisers. After 2010, however, this decline began to be offset by increased application of urea-based and organic fertilisers such as digestate to agricultural soils causing fluctuating emissions totals since 2008, with no significant trends across these years.

Emissions of **Non-Methane Volatile Organic Compounds (NMVOCs)** have declined 19% since 2005 and were estimated to be 142 kt in 2020 (19% of the UK total). This reduction is a result of reductions in fugitive and transport emissions which have declined 72% and 84% respectively since 2005. There has been an increasing trend in NMVOCs since 2011. This has been attributed to the increase emissions from the food and drink sector specifically the storage and production of whisky (53% of emissions in 2020).

Covid-19 lockdown and its effect on air Quality in Scotland

During the first half of 2021, varying levels of restrictions were still in place across Scotland, as a result of the Covid-19 pandemic. Traffic data from Glasgow and Edinburgh areas indicate that there was an increase in annual vehicle miles travelled in these areas in 2021, after the decrease in 2020. However, traffic has not reached the levels observed pre-lockdown.

The analysis of meteorologically normalised trends in NO_2 concentrations from a selection of sites in the Glasgow and Edinburgh areas shows a similar change to that of the traffic levels. NO_2 concentrations decreased sharply at most sites during the first lockdown in 2020, followed by an increase around summertime. However, NO_2 concentrations in 2021 remain below the levels measured in 2019. The largest decreases in NO_2 concentrations are seen at sites with historically higher concentrations.

CONTENTS

Appendices

1 INTRODUCTION

The Scottish Government undertakes considerable monitoring of a wide range of air pollutant species as part of a joint UK programme run in conjunction with Defra, the Welsh Government and the Department of the Environment in Northern Ireland. In addition, a large number of local authorities in Scotland monitor air quality within their geographical boundaries as part of the requirements of the Local Air Quality Management system. Prior to 2006, air quality data in Scotland outside of the nationally operated sites, were collected by a wide range of organisations for many purposes and were widely dispersed. Consequently, and following experience gained across the rest of the UK, it was recognised that a comprehensive centralised resource providing air quality information for Scotland would serve to improve the quality of research and data analysis required to support Scottish air quality policy. Hence, in 2006, the Scottish Government contracted AEA, now Ricardo Energy & Environment, to undertake a pilot programme to develop an air quality database for Scotland.

The pilot study developed the initial Scottish Air Quality Database (SAQD) and Website, undertook stakeholder feedback and assessed the air quality data available across Scotland. The key recommendations that were developed from this initial study were based around the methodology for successful harmonisation of existing air quality monitoring data. It was suggested that a programme for Scotland should include the following components:

- Independent audits of every site - to include checks on both the analysers and the site calibration cylinders.
- Regular data checks; and
- Longer term data checking and adjustment where necessary.

Following this pilot study, Ricardo Energy & Environment were commissioned to undertake the next stage which was to further develop and extend the SAQD and website incorporating all stakeholder comments and to bring selected local authority sites in line with the national Quality Assurance and Quality Control (QA/QC) requirements. Reports relating to the earlier years of the project are available on the Air Quality Scotland website (http://www.scottishairquality.scot/).

This annual report summarises the progress made during 2021 in the on-going project tasks and also highlights the new work undertaken during 2021 and into early 2022.

Section 2 of this report provides a breakdown of the legislation and policy that drives Local Air Quality Management within Scotland.

Section 3 provides a summary of the latest annual Air Quality in Scotland seminar.

The network of sites within the SAQD is dynamic and regularly changing to address the requirements of the local authorities to deal with air pollution issues. Section 4 describes in detail the structure of the database in terms of number and type of sites as well as pollutants measured, and how it has changed during 2021.

QA/QC is an integral part of the SAQD project. Since conception of the SAQD project, the QA/QC programme has expanded and adapted to encompass the dynamicity of the database and the changing best practice guidance and regulations. Section 5 of this report provides detailed information on the QA/QC process and how this was applied to the SAQD during 2021.

A statistical summary of all the available 2021 Scottish air quality data is provided in Section 6. This includes all pollutants covered under the Air Quality Strategy as well as other monitoring networks.

As the number of monitoring sites in Scotland has significantly increased since 2006, it has become feasible to undertake pollution climate mapping of NO_x, NO_2 and PM_{10} using solely Scottish measurement data. As part of the SAQD, Ricardo Energy & Environment provide mapped concentrations of modelled background air pollutant concentrations on a 1 km x 1 km basis for the whole of Scotland. The Scottish pollution climate mapping work carried out in 2021 is described in Section 7.

Section 8 of this report provides a discussion of trends in pollutant concentrations across Scotland, based on the latest available data. The trend analysis focuses on roadside and urban background locations across Scotland and the pollutants nitrogen dioxide (NO_2), particulate matter (PM_{10} and $PM_{2.5}$) and ozone (O_3).

Section 9 provides most up to date and historical data on emissions of pollutants into the atmosphere in Scotland. The data is obtained from the UK National Atmospheric Emissions Inventory (NAEI) and the Scottish Pollution Release Inventory (SPRI).

In addition to the standard layout to the SAQD annual report series stated above, the 2021 report provides updated analysis on how the Covid-19 pandemic affected air quality in Scotland. This analysis follows on from the 2020 annual report Covid-19 analysis.

2 LEGISLATION AND POLICY

Air quality management is shaped by requirements of EU, UK and Scottish legislation and policies. In the UK, air quality is a devolved matter, with the Scottish Government having responsibility for the development of air quality policy and legislation for Scotland. At EU level, the following air quality directives and policies are relevant:

- Directive 2008/50/EC - on ambient air quality and cleaner air for Europe (the Air Quality Directive).
- Industrial Emissions Directive 2010/75/EC – Controls emissions from industrial activities.
- National Emission Ceilings Directive 2016/2284/EU – sets emission limits for five important air pollutants
- Clean Air Policy Package and Clean Air Programme for Europe - new air quality objectives to 2030, to improve air quality within cities.

Following the UK's exit from the EU, under retained EU law, the UK is required to continue to meet limit and target values for a range of air pollutants and other legal obligations covered by EU directives.

A substantial review of the EU's air quality policy, including the Air Quality Directive, was undertaken in 2013 with the European Commission adopting a new Clean Air Policy Package, including a new Clean Air for Europe programme with measures to ensure that existing targets are met in the short term and new air quality objectives for the period up to 2030. The Package also includes support measures to help cut air pollution, with a focus on improving air quality in cities, supporting research and innovation, and promoting international cooperation.

Domestic air quality legislation is largely derived from the requirements of the Environment Act 1995.

2.1 AIR QUALITY STANDARDS AND OBJECTIVES

A set of air quality standards and objectives has been developed for several pollutants of concern for human health. The objectives are derived from the standards and are a compromise between what is desirable purely on health grounds and what is practical in terms of feasibility and costs. Each objective has a date by when it must be achieved. The objectives adopted in Scotland for the purpose of Local Air Quality Management are set out in the Air Quality (Scotland) Regulations 2000, the Air Quality (Scotland) Amendment Regulations 2002 and the Air Quality (Scotland) Amendment Regulations 2016. Similar targets are set at EU level, where there are called limit or target values. These limit values are set out in the 2008 ambient air quality Directive (2008/50/EC) and transposed into Scottish legislation. It is the responsibility of EU Member States to achieve the limit and target values. A summary of the current Scottish air quality objectives is provided in Table 2-1.

Table 2-1 Summary of Scotland's Air Quality Objectives

AQ Objective-Pollutant	Concentration	Measured as	Date to be achieved by
Nitrogen Dioxide (NO_2)	200 µg m^{-3} not to be exceeded more than 18 times a year	1-hour mean	31.12.2005
	40 µg m^{-3}	Annual mean	31.12.2005
Particulate Matter (PM_{10})	50 µg m^{-3}, not to be exceeded more than 7 times a year	24-hour mean	31.12.2010
	18 µg m^{-3}	Annual mean	31.12.2010
Particulate Matter ($PM_{2.5}$)	10 µg m^{-3}	Annual mean	31.12.2020
Sulphur Dioxide (SO_2)	350 µg m^{-3}, not to be exceeded more than 24 times a year	1-hour mean	31.12.2004

AQ Objective-Pollutant	Concentration	Measured as	Date to be achieved by
	125 µg m^{-3}, not to be exceeded more than 3 times a year	24-hour mean	31.12.2004
	266 µg m^{-3}, not to be exceeded more than 35 times a year	15-minute mean	31.12.2005
Benzene	3.25 µg m^{-3}	Running annual mean	31.12.2010
1,3 Butadiene	2.25 µg m^{-3}	Running annual mean	31.12.2003
Carbon Monoxide	10.0 mg m^{-3}	Running 8-Hour mean	31.12.2003
Lead	0.25 µg m^{-3}	Annual Mean	31.12.2008
Poly Aromatic Hydrocarbons*	0.25 ng m^{-3}	Annual Mean	31.12.2010
Ozone*	100 µg m^{-3} not to be exceeded more than 10 times a year*	daily maximum 8-hour running mean	31.12.2005

* not required to be monitored or assessed by local authorities under LAQM, however is a UK requirement under retained EU law

2.2 CLEANER AIR FOR SCOTLAND-THE ROAD TO A HEALTHIER FUTURE

The "Cleaner Air for Scotland – The Road to a Healthier Future" (CAFS) strategy was published by the Scottish Government in November 2015. The purpose of CAFS was to provide a national framework which sets out how the Scottish Government and its partner organisations propose to achieve further reductions in air pollution and fulfil their legal responsibilities to achieve the air quality objectives. It recognises that although progress has been made through Scotland, areas of poorer air quality still exist within towns and cities.

CAFS considered the impact of air quality on health and looks at the estimated costs as well as the premature deaths associated with poor air quality.

Since the Cleaner Air for Scotland strategy was published in 2015, it has:

- Introduced the most ambitious legislation in the world to end Scotland's contribution to climate change by 2045.
- Published an Environment Strategy which emphasises the fundamental role our natural environment plays in supporting a fairer, healthier, more inclusive society.
- Updated the National Transport Strategy.
- Established Scotland's first Low Emission Zone in Glasgow.
- Become the first country in Europe to include the World Health Organization guideline value for $PM_{2.5}$ in domestic legislation.
- Put in place a national $PM_{2.5}$ monitoring network.
- Committed to reducing motor vehicle kilometres by 20% by 2030.
- Increased our active travel funding to £500 million over five years from 2020-21; and
- Taken major steps to reform Scotland's planning system.

In total, 36 of the 40 actions set out in CAFS have been fully completed.

Starting in late 2018 the Scottish Government commissioned an in-depth independently led review of CAFS and the findings were published in July 2019. The Scottish Government used the conclusions and recommendations arising from this review to develop a draft updated air quality strategy in the first part of 2020. In October 2020 Scottish Government this draft was published for consultation. Following the consultation, in July 2021, accompanied by a Delivery Plan, and replacing "Cleaner Air for Scotland – The Road to a Healthier Future", the Scottish Government published Scotland's second air quality strategy "Cleaner Air for Scotland 2 – Towards a Better Place for Everyone" (CAFS2).

2.3 CLEANER AIR FOR SCOTLAND 2 (CAFS2) STRATEGY

CAFS2 sets out how the Scottish Government and its partner organisations propose to further reduce air pollution to protect human health and fulfil Scotland's legal responsibilities over the period 2021-2026. CAFS2 aims to achieve the ambitious vision for Scotland "to have the best air quality in Europe".

The CAFS2 key partner organisations are:

- Scottish Government
- Transport Scotland
- Scottish Environment Protection Agency (SEPA)
- Public Health Scotland
- Local authorities

Engagement and support from a wide range of stakeholders including representatives from the transport and planning sectors and Non-Governmental Organisations is also vital to achieving the aims of CAFS2.

Progress is supported by the CAFS2 Delivery Group, which is directly accountable to a Ministerial Group, and actions are managed by specific sub-groups and policy leads across partner organisations tasked with delivering actions across the 10 overarching policy themes set out in CAFS2.

2.4 CAFS2 – OVERVIEW

The ten general themes largely reflect the high-level recommendations arising from the Cleaner Air for Scotland (CAFS) review. These are:

1. Health – A Precautionary Approach

The current weight of evidence justifies adopting a precautionary public health approach to air pollution reduction. As a minimum, compliance is required with domestic and international air quality standards but, where practicable and feasible, there should be continued efforts to reduce preventable air pollution still further beyond these limits.

2. Integrated Policy

Strategies, policies and plans being developed and implemented by central government for placemaking, climate change mitigation and adaptation, and related polices such as noise reduction, should be closely coordinated and aligned with those for air quality in order to maximise co-benefits.

Local government, which is largely responsible for implementing the Local Air Quality Management system, besides its planning, transport delivery, public health and regulatory roles, also has a key role to play.

3. Placemaking

National Planning Framework 4 (NPF4) will transform how Scotland's planning system shapes our places and society over the years and decades to come. The Planning (Scotland) Act 2019 requires that the National Planning Framework must have regard to minister's national strategy for the improvement of air quality, so it will provide an important context within which further effort on air quality improvement in CAFS 2 will be delivered, supported by the Place Principle and the Place Standard tool.

4. Data

There are gaps in both quality and coverage of air quality, transport and human health data in Scotland. Addressing these gaps will help to improve public awareness and engagement, modelling, reporting and ultimately, policy implementation. A greater focus on collecting and presenting traffic data in a way that supports air pollutant emissions understanding will have similar benefits. Health data also require careful consideration so that Scotland-specific interpretations, plans and interventions are strengthened. Wider utilisation of low-cost sensor technology, including citizen science initiatives, has a role to play too.

5. Public Engagement and Behaviour Change.

More research is needed to provide clear evidence on levels of knowledge, attitudes, and concern related to air pollution, as well as on willingness to change behaviours which contribute toward air pollution. Many of the key drivers and incentives/disincentives will be closely related to those associated with climate change, but at the same time there will be differences in focus and approach. Development of complementary and co-ordinated public engagement strategies is therefore essential to deliver the required behavioural change outcomes and to avoid confusing or conflicting messages.

6. Industrial Emissions Regulation.

The Scottish Government has made clear its commitment to maintain or exceed EU standards, following the UK's departure from the European Union (EU). The Scottish Government is committed to ensuring that EU environmental principles continue to sit at the heart of environmental policy and law in Scotland. The UK Withdrawal from the European Union (Continuity) (Scotland) Act 2021 will bring the guiding European principles on the environment into force in Scots law, including the precautionary principle, polluter pays principle, prevention principle, rectification at source principle and the integration principle. In relation to current regulation, retained EU law will continue to apply, as will domestic regulations made to transpose EU Directives.

7. Tackling Non-Transport Emission Sources.

Domestic (household) burning and agriculture are two sectors not addressed in detail in CAFS, but which make an important contribution to air pollution. Consideration is needed of performance and standards for domestic fires, stoves and fuels, and local authority powers to permit and control these, and a refreshed approach to good agricultural practice, which includes aiming for increased nitrogen use efficiency in farming. Together, these have the potential to deliver significant improvements in air quality beyond current regulatory and management approaches.

8. Transport.

Increasing modal shift to active travel and public transport is key to further reductions in transport emissions. This will mean, amongst other objectives, providing a transport system that facilitates active travel choices, better public transport provision, embracing new technologies, and constraints upon private vehicle use, especially in urban centres where pollution and congestion are most acute. Establishment of Low Emission Zones in our four biggest cities is also important in this context.

The new National Transport Strategy (NTS2), published in February 2020, sets out an ambitious and compelling vision for Scotland's transport system for the next 20 years. The four NTS2 priorities – reducing inequalities, taking climate action, helping deliver inclusive economic growth and improving our health and wellbeing – will underpin our efforts to deliver additional air quality improvements in CAFS 2.

The Climate Change Plan update, published in December 2020, will also make a significant contribution to achieving this vision, including the commitment to reduce motor vehicle kilometres by 20% by 2030.

9. Governance, Accountability and Delivery.

Simple and effective governance arrangements and a focus on practical joined up delivery are imperative for CAFS 2. We need to be clear on who is doing what, who is leading, who is supporting and who is ultimately responsible if CAFS 2 is to be delivered as a coherent, integrated and successful strategy.

10. Further Progress Review.

As in the original version of CAFS, the intention is that CAFS 2 will have a five-year lifespan. A further review of progress on air quality improvements will commence during 2024 to track progress on delivering the actions in the new strategy, besides allowing Scotland to keep abreast of developments in the evidence base, technological advances and societal attitudes, so that new challenges and actions can be identified.

2.5 NATIONAL MODELLING FRAMEWORK

The National Modelling Framework (NMF) will provide a two-tiered standardised approach to modelling air quality in Scotland. Detailed models for the first four cities covering Glasgow, Edinburgh, Aberdeen and Dundee will provide evidence for taking direct actions at the city scale to reduce street-level emissions. The regional model will provide a tool for screening and assessing the potential air quality impacts associated with large-scale planned developments across local authority areas. The NMF will help with providing evidence for actions developed through the National Low Emission Framework.

2.6 NATIONAL LOW EMISSION FRAMEWORK

The National Low Emission Framework (NLEF) has been developed to assist in the appraisal of air quality improvement options related to transport. Together with the National Modelling Framework, it provides guidance on the appraisal of such measures to help facilitate consistent assessment and implementation across Scotland.

The Scottish Government published the NLEF framework in January 2019 and it is available at https://www.scottishairquality.scot/technical-reports/national-low-emissions-framework-january-2019. The framework provides a methodology for local authorities to undertake air quality assessment to inform decisions on transport related actions.

2.7 LOW EMISSION ZONES

In September 2017, the Scottish Government in their Programme for Government, committed to the introduction of Low Emission Zones (LEZs) into Scotland's four biggest cities (Glasgow, Edinburgh, Aberdeen and Dundee) by 2020 and into all other Air Quality Management Areas (AQMAs) by 2023 where the National Low Emissions Framework appraisal advocates such mitigation. On 31st December 2018, the first Scottish LEZ was introduced into Glasgow city centre and applied to buses only (phase 1). After delays resulting from the Covid-19 pandemic LEZs were also introduced across Aberdeen, Dundee, and Edinburgh on 31st May 2022, together with an expansion in scope of the Glasgow LEZ. Local grace periods now apply until enforcement begins at the dates provide

- **Glasgow (all other vehicle types) - 1st June 2023**
- **Dundee – 30th May 2024**
- **Aberdeen – 1st June 2024**
- **Edinburgh – 1st June 2024**

More information on LEZs is available here: https://www.lowemissionzones.scot/about.

2.8 LOCAL AIR QUALITY MANAGEMENT

The LAQM process places an obligation on all local authorities to regularly review and assess air quality in their areas, and to determine whether or not the air quality objectives are likely to be achieved. Where an exceedance is considered likely the local authority must:

- Declare an Air Quality Management Area (AQMA)
- Assess and identify the reasons for the problem, quantifying the sources of emissions

- Develop an Air Quality Action Plan (AQAP) to help address the problem.

The Scottish Government has produced updated Technical Guidance (2022) and Policy (2016 with further revisions in 2018) Guidance for the LAQM regime in Scotland. One of the main changes was to the LAQM reporting process. An Annual Progress Report (APR) has replaced the previous three-year cyclical process. The latest versions of the LAQM Policy and Technical Guidance are available at http://www.scottishairquality.scot/air-quality/legislation.

3 AIR QUALITY SEMINAR

As part of the Scottish Air Quality Database project, Ricardo Energy & Environment, on behalf of the Scottish Government, organise an annual air quality seminar. Due to the on-going Covid-19 pandemic it was not possible to hold the seminar in the usual single venue as done in previous years. It was therefore decided to hold the event online and separate the day long agenda into three two-hour webinars, over a three-week period. Using the Teams Events platform, the event was held on the 16th, 23rd and 30th March 2022 and attended by between 80 - 100 delegates representing the Scottish Government, local authorities, Health Protection Scotland, SEPA, consultancy, academia and students. The objective of the seminar was to discuss some of the most recent work carried out under the Scottish Air Quality Database and Website project and consider a number of other topical air quality issues that affect Scotland.

The seminar covered a number of very interesting topics in the field of air quality presented by highly respected dignitaries. These subjects included amongst others; indoor air pollution (Prof Nicola Carslaw (University of York)), impacts of Covid-19 (Prof Duncan Lee (University of Glasgow)) and brake and tyre wear emissions research (Claudio Chesi (Department for Transport) and Dr Louise Kramer (Ricardo)).

In addition to the presenters stated, the Scottish Government and Ricardo were able to arrange for Rosamund Kissi Debrah of the Ella Roberta Family Foundation and Dr Dorota Jarosinska from the World Health Organisation to speak at the seminar.

Recordings of all three webinars can be found on the Scottish air Quality website (http://www.scottishairquality.scot/). The full agendas are shown in Figure 3-1.

3.1 ANNUAL NEWSLETTER

In addition to this report, an annual newsletter (Air Pollution in Scotland) is also produced as part of this project. This sets out the legislative and policy background to air quality in Scotland and briefly reviews the latest available air quality monitoring and key results. Trends and mapping of air quality are also summarised along with recent developments and information on how to stay informed with regards to air quality matters (i.e. forecasts, health alerts and social media)

Figure 3-1 Agenda for the Scottish Air Quality Seminar 2022

SCOTTISH AIR QUALITY ANNUAL SEMINAR 2022

Wednesday 16th, 23rd, and 30th March 2022 (10:00am to 12:00pm)

Via MS Teams

Agenda

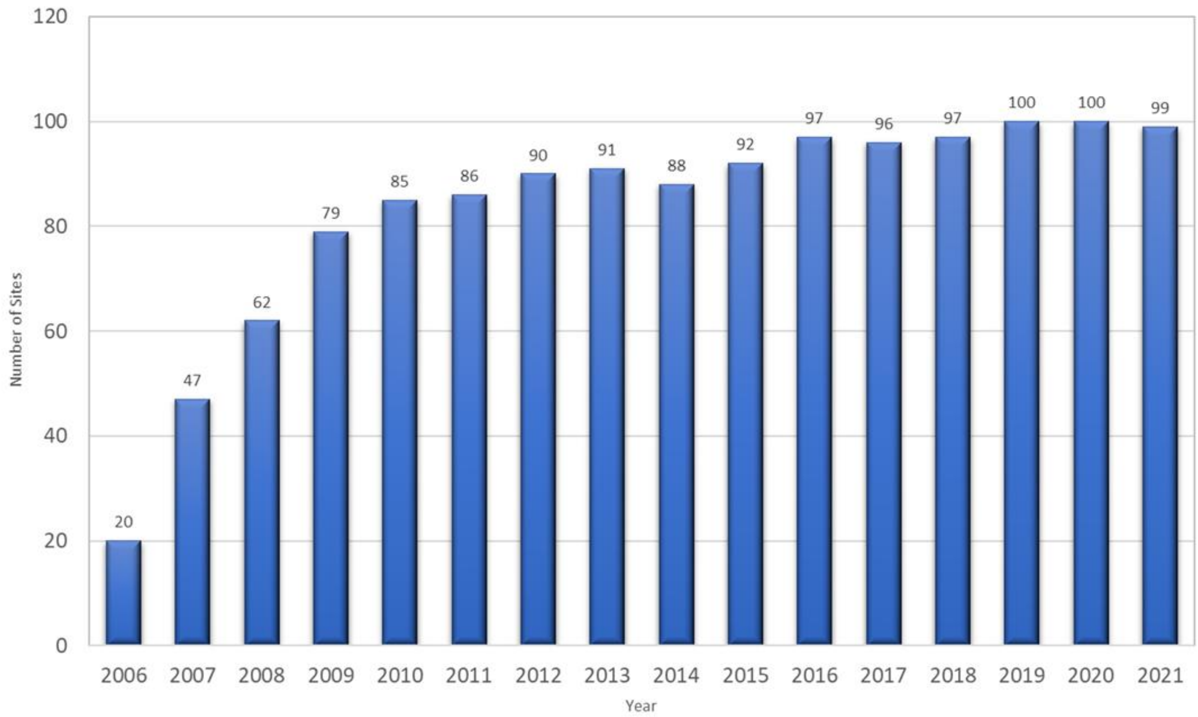
	Webinar 1: Health and Guidelines	
10:00	Welcome/Introduction	Ricardo Energy and Environment
10:05	Scottish Government Update	Andrew Taylor (Scottish Government)
10:15	TBC	
10:30	Ella Roberta Family Foundation	Rosamund Kissi Debrah (Ella Roberta Family Foundation)
10:55	WHO Global Air Quality Guidelines 2021	Dr Dorota Jarosinska, (World Health Organisation)
11:20	Reflections from working with Clean Air Zone cities	Guy Hitchcock (Ricardo)
11:45	Clean Air Day 2022	John Bynorth, (Environmental Protection Scotland)
11:50	Questions and Answer Session	
	Webinar 2: Data sources for the improvement of air quality	
10:00	Welcome/Introduction	Ricardo Energy and Environment
10:05	The AIRLAB Microsensors Challenge	Adrian Arfire (Airparif)
10:30	Indoor Air Pollution: the dirty secret lurking in your home	Prof Nicola Carslaw (University of York)
10:55	Quantifying the impact of air pollution on Covid-19 hospitalisation and death rates in Scotland	Prof Duncan Lee (University of Glasgow)
11:20	Transport Scotland Remote Sensing Project	Yoann Bernard (ICCT)
11:45	Questions and Answer Session	
	Webinar 3: Innovation and Research	
10:00	Welcome/Introduction	Ricardo Energy and Environment
10:05	NEMO – a new initiative to improve air quality and reduce noise in cities	Javier Buhigas (OPUS RSE)
10:30	CARES – City Air Remote Emission Sensing Project	Ake Sjodin (IVL Swedish Environmental Research Institute)
10:55	Brake and Tyre wear Emissions Research Project	Claudio Chesi (Department for Transport) & Dr Louisa Kramer (Ricardo)
11:20	Glasgow Hope street Sensor Monitoring and PM intercomparison project update	Stephen Stratton (Ricardo)
11:45	Questions and Answer Session	

4 DATA AVAILABILITY 2021

4.1 HOURLY DATA FOR NITROGEN DIOXIDE, CARBON MONOXIDE, SULPHUR DIOXIDE, OZONE, PM_{10} AND $PM_{2.5}$

At the end of 2021 the Scottish Air Quality Database contained data for of 99 automatic monitoring sites. In total, two new monitoring sites were added to the network: Aberdeen Errol Park and Perth Bridgend and three sites were decommissioned and removed from the network during 2021: Aberdeen Errol Place, N Lanarkshire Coatbridge Sunnyside Road and Perth Bridgend. Figure 4.1 shows the growth of the SAQD from 20 sites in 2006 pilot study to 99 sites during 2021.

Figure 4.1 Number of Monitoring Sites within the Scottish Air Quality Database Network 2006 – 2021



For the 22 National Network AURN monitoring stations in the Scottish Database, the data are available from the commencement of these stations, which in some cases is as long ago as 1986. However, for local authority monitoring stations, data are only available from when the station joined the database project. In many cases the stations commenced monitoring much earlier and these earlier data may be available from the relevant local authority.

Data availability for 2021, in terms of site, pollutants and months available, is summarised in Table 4.1. The full 12-figure OS grid reference and the site location classification are also provided for each site and the monitoring network the site is affiliated to; either the Scottish Air Quality Database Network (SAQD) or the Automatic Urban and Rural Network (AURN).

Table 4.1 also provides the start date for each site. However, not all pollutants are measured over the same period at all sites – measurements of some pollutants may commence or cease during the lifetime of monitoring at a particular site. The dates of availability of data for each pollutant measured at each site can be found by selecting the site on the 'Latest Data' page of the SAQD website (http://www.scottishairquality.scot/latest/) and then selecting the "site details" tab.

In addition, some sites may join a network or change network during their lifetime and hence, earlier data from a site may be available elsewhere. At a small number of sites, different pollutants are in different networks. This is due to the differing requirements of specific networks. The data from closed sites are available in the database for their period of operation.

Table 4-1 Scottish Air Quality Database Data Availability in 2021

Site Name	Type	East	North	Pollutants	Network	Start Year#	Data in 2021
Aberdeen Anderson Dr	RS	392506	804186	NO_2 PM_{10} $PM_{2.5}$	SAQD	2004	Jan – Dec
Aberdeen Errol Place	UB	394416	807408	NO_2 O_3 PM_{10} $PM_{2.5}$	AURN	1999	Jan – Sept
Aberdeen Errol Park	UB	394366	807396	NO_2 O_3 PM_{10} $PM_{2.6}$	AURN	2021	Oct - Dec
Aberdeen King Street	RS	394333	808770	NO_2 PM_{10} $PM_{2.5}$	SAQD	2008	Jan – Dec
Aberdeen Market Street 2	RS	394535	805687	NO_2 PM_{10} $PM_{2.5}$	SAQD	2009	Jan – Dec
Aberdeen Union St~	RS	393655	805984	NO2, PM_{10}, $PM_{2.5}$	AURN / SAQD	2005	Jan – Dec
Aberdeen Wellington Road	RS	394395	804779	NO_2 PM_{10} $PM_{2.5}$	SAQD	2008	Jan – Dec
Alloa A907	RS	288689	693068	NO_2 PM_{10} $PM_{2.5}$	SAQD	2016	Jan – Dec
Angus Forfar Glamis Road	RS	345248	750385	PM_{10}	SAQD	2016	Jan – Dec
Auchencorth Moss	R	322167	656123	13BD BENZ O_3 PM_{10} $PM_{2.5}$ TOL XYL	AURN	2006	Jan – Dec
Bush Estate	R	324626	663880	NO_2 O_3	AURN	1986	Jan – Dec
Dumfries	RS	297012	576278	NO_2	AURN	2001	Jan – Dec
Dundee Broughty Ferry Road	RS	341970	730997	PM_{10} SO_2	SAQD	2006	Jan – Dec
Dundee Lochee Road	KS	330773	738861	NO_2 PM_{10} $PM_{2.5}$	SAQD	2006	Jan – Dec
Dundee Mains Loan	UB	340972	731893	NO_2 PM_{10} $PM_{2.5}$	SAQD / AURN	2006	Jan – Dec
Dundee Meadowside	RS	340241	730654	NO_2 PM_{10} $PM_{2.5}$	SAQD	2011	Jan – Dec
Dundee Seagate	KS	340487	730446	NO_2 PM_{10} $PM_{2.5}$	SAQD	2006	Jan – Dec
Dundee Whitehall Street	KS	330155	740279	NO_2 PM_{10} $PM_{2.5}$	SAQD	2006	Jan – Dec
East Ayrshire Kilmarnock St Marnock St	RS	242742	637705	NO_2 PM_{10} $PM_{2.5}$	SAQD	2012	Jan – Dec
East Dunbartonshire Bearsden	RS	254269	672067	NO_2 PM_{10} $PM_{2.5}$	SAQD	2005	Jan – Dec
East Dunbartonshire Bishopbriggs	RS	260995	670130	NO_2 PM_{10} $PM_{2.5}$	SAQD	2003	Jan – Dec

Site Name	Type	East	North	Pollutants	Network	Start Year#	Data in 2021
East Dunbartonshire Kirkintilloch	RS	265700	673500	NO_2 PM_{10} $PM_{2.5}$	SAQD	2007	Jan – Dec
East Dunbartonshire Milngavie	RS	255325	674115	NO_2 PM_{10} $PM_{2.5}$	SAQD	2011	Jan – Dec
East Lothian Musselburgh N High St	RS	333941	672836	NO_2 PM_{10}	SAQD	2008	Jan – Dec
Edinburgh Currie	UB	317575	667874	NO_2 PM_{10} $PM_{2.5}$	SAQD	2013	Jan – Dec
Edinburgh Glasgow Road	RS	313101	672651	NO_2 PM_{10} $PM_{2.5}$	SAQD	2012	Jan – Dec
Edinburgh Gorgie Road	RS	323121	672314	NO_2	SAQD	2005	Jan – Dec
Edinburgh Nicolson Street	RS	326145	673038	NO_2 PM_{10} $PM_{2.5}$	SAQD / AURN	2017	Jan – Dec
Edinburgh Queensferry Road	RS	318734	674931	NO_2 PM_{10}	SAQD	2011	Jan – Dec
Edinburgh Salamander St	RS	327621	676342	NO_2 PM_{10} $PM_{2.5}$	SAQD	2009	Jan – Dec
Edinburgh St John's Road	KS	320100	672890	NO_2 PM_{10} $PM_{2.5}$	SAQD	2007	Jan – Dec
Edinburgh St Leonards	UB	326250	673132	CO NO_2 O_3 PM_{10} $PM_{2.5}$ SO_2	AURN	2003	Jan – Dec
Edinburgh Tower Street	RS	327460	676531	PM_{10} $PM_{2.5}$	SAQD	2018	Jan- Dec
Eskdalemuir	R	323552	603018	NO_2 O_3	AURN	1986	Jan – Dec
Falkirk Bo'ness	UI	299827	681462	SO_2	SAQD	2016	Jan – Dec
Falkirk Grangemouth MC	UB	292816	682009	NO_2 PM_{10} $PM_{2.5}$ SO_2	SAQD	2003	Jan – Dec
Falkirk Grangemouth Zetland Park	UI	292969	681106	SO_2 PM_{10} $PM_{2.5}$	SAQD	2016	Jan – Dec
Falkirk Haggs	RS	278977	679271	NO_2 PM_{10} $PM_{2.5}$	SAQD	2009	Jan – Dec
Falkirk Hope St	RS	288688	680218	NO_2 PM_{10} $PM_{2.5}$ SO_2	SAQD	2007	Jan – Dec
Falkirk Main St Bainsford	RS	288569	681519	NO_2 PM_{10} $PM_{2.5}$	SAQD	2015	Jan – Dec
Falkirk West Bridge Street	RS	288457	680064	NO_2 PM_{10} $PM_{2.5}$	SAQD	2007	Jan – Dec
Fife Cupar	RS	337401	714572	NO_2 PM_{10} $PM_{2.5}$	SAQD	2005	Jan – Dec
Fife Dunfermline	RS	309912	687738	NO_2 PM_{10} $PM_{2.5}$	SAQD	2007	Jan – Dec
Fife Kirkcaldy	RS	329143	692986	NO_2 PM_{10} $PM_{2.5}$	SAQD	2011	Jan – Dec
Fife Rosyth	RS	311752	683515	NO_2 PM_{10} $PM_{2.5}$	SAQD	2008	Jan – Dec
Fort William	S	210849	774421	NO_2 O_3	AURN	2006	Jan – Dec
Glasgow Anderston	UB	257925	665487	NO_2 PM_{10} $PM_{2.5}$	SAQD	2005	Jan – Dec
Glasgow Broomhill	RS	255030	667195	PM_{10} $PM_{2.5}$	SAQD	2007	Jan – Dec
Glasgow Byres Road	RS	256553	665487	NO_2 PM_{10} $PM_{2.5}$	SAQD	2005	Jan – Dec

Site Name	Type	East	North	Pollutants	Network	Start Year#	Data in 2021
Glasgow Dumbarton Road	RS	255030	666608	NO_2 PM_{10} $PM_{2.5}$	SAQD	2012	Jan – Dec
Glasgow Kerbside	KS	258708	665200	NO_2 PM_{10} $PM_{2.5}$	SAQD / AURN	1997	Jan – Dec
Glasgow Great Western Road	RS	258007	666650	NO_2	AURN	2016	Jan – Dec
Glasgow High Street	RS	260014	665348	NO_2 PM_{10} $PM_{2.5}$	AURN	2016	Jan – Dec
Glasgow Nithsdale Road	RS	257883	662673	NO_2 PM_{10} $PM_{2.5}$	SAQD	2007	Jan – Dec
Glasgow Townhead	UB	259692	665899	NO_2 O_3 PM_{10} $PM_{2.5}$	AURN	2013	Jan – Dec
Glasgow Waulkmillglen Reservoir	R	252520	658095	NO_2 O_3 PM_{10} $PM_{2.6}$	SAQD	2005	Jan – Dec
Grangemouth	UI	293837	681035	NO_2 PM_{10} $PM_{2.5}$ SO_2	AURN	2001	Jan – Dec
Grangemouth Moray~	UB	293469	681321	NO_2	AURN	2009	Jan – Dec
Grangemouth Moray Scot Gov~	UB	293469	681321	SO_2	SAQD	2007	Jan – Dec
Inverclyde Greenock A8	RS	229335	675710	NO_2 PM_{10} $PM_{2.5}$	SAQD	2016	Jan – Dec
Inverness*	RS	265720	845680	NO_2 PM_{10} $PM_{2.5}$	AURN	2001	Jan – Dec
Inverness Academy Street	RS	266644	845440	NO_2	SAQD	2016	Jan – Dec
Inverness Academy Street 1st Floor	RS	266644	845440	NO_2	SAQD	2019	Jan – Dec
Lerwick~	R	445337	1139683	O_3	AURN	2005	Jan – Dec
N Lanarkshire Airdrie Kenilworth Dr	RS	277385	665831	NO_2 PM_{10}	SAQD	2019	Jan – Dec
N Lanarkshire Chapelhall	RS	278174	663124	NO_2 PM_{10} $PM_{2.5}$	SAQD	2005	Jan – Dec
N Lanarkshire Coatbridge Sunnyside Rd	RS	273054	665234	NO_2 PM_{10}	SAQD	2019	Jan – Feb
N Lanarkshire Coatbridge Whifflet	UB	273668	663938	NO_2 PM_{10} $PM_{2.5}$	SAQD	2007	Jan - Dec
N Lanarkshire Croy	RS	272775	675738	NO_2 PM_{10} $PM_{2.5}$	SAQD	2006	Jan – Dec
N Lanarkshire Kirkshaws	RS	272522	663029	NO_2 PM_{10} $PM_{2.5}$	SAQD	2016	Jan – Dec
N Lanarkshire Motherwell	RS	275460	656785	PM_{10} $PM_{2.5}$	SAQD	2007	Jan – Dec
N Lanarkshire Motherwell Adele Street	RS	275642	656147	NO_2 PM_{10} $PM_{2.5}$	SAQD	2020	Jan – Dec
N Lanarkshire Shawhead Coatbridge	RS	273411	662997	NO_2 PM_{10} $PM_{2.5}$	SAQD	2009	Jan – Dec
N Lanarkshire Uddingston New Edinburgh Rd	RS	269145	661499	NO_2 PM_{10} $PM_{2.5}$	SAQD	2019	Jan – Dec
North Ayrshire Irvine High Street	KS	232142	638892	NO_2 PM_{10} $PM_{2.5}$	SAQD	2009	Jan – Dec
Paisley Gordon Street	RS	248316	663611	NO_2 PM_{10}	SAQD	2004	Jan – Dec
Peebles	S	324812	641083	NO_2 O_3	AURN	2009	Jan – Dec
Perth Atholl Street	RS	311582	723931	NO_2 PM_{10} $PM_{2.5}$	SAQD	2004	Jan – Dec
Perth Bridgend	RS	312254	724159	NO_2 PM_{10} $PM_{2.5}$	SAQD	2021	Mar – Dec

Site Name	Type	East	North	Pollutants	Network	Start Year#	Data in 2021
Perth Crieff	RS	286363	721614	NO_2 PM_{10} $PM_{2.5}$	SAQD	2010	Jan – Dec
Perth High Street	RS	311688	723625	NO_2 $PM_{2.5}$	SAQD	2003	Jan –Mar
Perth Muirton	UB	311688	723625	PM_{10} $PM_{2.5}$	SAQD	2012	Jan – Dec
Renfrew Cockels Loan	RS	250467	665943	NO_2	SAQD	2013	Jan – Dec
Renfrew Inchinnan Road	RS	250567	667558	NO_2	SAQD	2019	Jan – Dec
Renfrewshire Johnston	RS	243002	663183	PM_{10} $PM_{2.5}$	SAQD	2017	Jan – Dec
Shetland Lerwick~	R	445337	1139683	NO_2 SO_2	SAQD	2012	Jan – Dec
South Ayrshire Ayr Harbour	RS	233617	622749	NO_2 PM_{10} $PM_{2.5}$	SAQD	2012	Jan – Dec
South Ayrshire Ayr High St	RS	233725	622120	NO_2 PM_{10} $PM_{2.5}$	SAQD	2007	Jan – Dec
South Lanarkshire Blantyre	RS	250567	667558	NO_2 PM_{10} $PM_{2.5}$	SAQD	2019	Jan – Dec
South Lanarkshire Cambuslang	KS	264340	660496	NO_2 PM_{10} $PM_{2.5}$	SAQD	2015	Jan – Dec
South Lanarkshire East Kilbride	RS	264390	655658	NO_2 PM_{10} $PM_{2.5}$	SAQD	2008	Jan – Dec
South Lanarkshire Hamilton	RS	272298	655289	NO_2 PM_{10} $PM_{2.5}$	SAQD	2013	Jan – Dec
South Lanarkshire Lanark	RS	288427	643701	NO_2 PM_{10}, $PM_{2.5}$	SAQD	2012	Jan – Dec
South Lanarkshire Raith Interchange 2	KS	271065	658087	NO_2 PM_{10}, $PM_{2.6}$	SAQD	2016	Jan – Dec
South Lanarkshire Rutherglen	RS	261113	661690	NO_2 PM_{10}, $PM_{2.5}$	SAQD	2012	Jan – Dec
South Lanarkshire Uddingston	RS	269657	660305	NO_2 PM_{10}, $PM_{2.5}$	SAQD	2013	Jan – Dec
Stirling Craig's Roundabout	RS	279955	693012	NO_2 PM_{10}	SAQD	2009	Jan – Dec
Strath Vaich	RS	234829	874785	O_3	AURN	1987	Jan – Dec
West Dunbartonshire Clydebank	RS	249724	672042	NO_2 PM_{10} $PM_{2.5}$	SAQD	2007	Jan – Dec
West Dunbartonshire Glasgow Road	RS	240234	675193	NO_2	AURN	2010	Jan – Dec
West Lothian Broxburn	RS	308364	672248	NO_2 PM_{10} $PM_{2.5}$	SAQD	2008	Jan – Dec
West Lothian Linlithgow High St 2	RS	300419	677120	NO_2 PM_{10} $PM_{2.5}$	SAQD	2013	Jan – Dec
West Lothian Newton	RS	309258	677728	NO_2 PM_{10} $PM_{2.5}$	SAQD	2012	Jan – Dec

+ Sites added to database in 2021
* Sites changed monitoring
^Changes in number of measured pollutants or monitoring method during 2021
This is the date of the site joining the network. Data for some pollutants may not be available from this date. Also, data for some pollutants may be available from earlier dates from the Local Authority other networks. The period of availability for data for each pollutant measured at each site can be seen on www.scottishairquality.scot by selecting the site and the "site details" tab.
~ At these sites, some pollutants are affiliated to the AURN network, and some pollutants are affiliated the SAQD Network.
KS – Kerbside
R – Rural
RS – Roadside
S – Suburban
UB – Urban Background
UI – Urban Industrial

4.1.1 Summary of Changes to Monitoring Sites within the Database during 2021

Details of changes to monitoring sites included within the SAQD are summarised below.

Sites opened during 2021:

- Aberdeen Errol Park NO_2 O_3 PM_{10} $PM_{2.5}$ on 01/10/2021
- Perth Bridgend NO_2 PM_{10} $PM_{2.5}$ on 17/03/2021

Sites closed during 2021:

- Aberdeen Errol Place NO_2 O_3 PM_{10} $PM_{2.5}$ on 20/09/2021
- N Lanarkshire Coatbridge Sunnyside Road NO_2 PM_{10} on 17/02/2021
- Perth High Street NO_2 $PM_{2.5}$ on 20/09/2021

Sites changes during 2021:

Monitoring of $PM_{2.5}$ in addition to PM_{10} using a FIDAS analyser at the following sites:

- Aberdeen Anderson Drive on 20/07/2021
- N Lanarkshire Uddingston New Edinburgh Road on 16/11/2021
- South Ayrshire Ayr Harbour on 26/08/2021
- South Ayrshire Ayr High Street on 26/08/2021

4.2 NO_2 AND PM_{10} DATA CAPTURE RATES

Figures 4.2 and 4.3 show the average data capture rates achieved between 2008 and 2021 for NO_2 and PM_{10} sites, respectively. Note that 2006 and 2007 data capture rates have not been included due to the rapid change in site numbers.

With the introduction of a harmonised QA/QC regime, the data capture rates for NO_2 and PM_{10} monitoring improved year on year. The exception to this is 2021 where a significant drop in NO_2 data capture was recorded. Initial investigations into why this is indicates that it is a result of the following factors;

- Delaying resulting from sites closing and new sites opening.
- An increase in poor NO_2 analyser performance and a delay in replacement parts/analysers (partially due to supply change issues relating to the Covid-19 pandemic).
- Poor site performance (mainly air conditioning failures during summer) causing monitoring to be stopped periodically.

The sudden increase in PM_{10} data capture in 2017 and 2019 has been attributed to the change in analyser type measuring Particulate Matter (PM) at a significant number of local authority sites. Likewise, a number of new PM sites were introduced, and analysers decommissioned partially through 2018 resulting in a decrease in the average data capture rate. The drop in PM data capture has been attributed to the issues mentioned above relating to NO_2 data capture in 2021.

Figure 4.2 Network data capture rate for NO_2 monitoring, 2008 – 2021

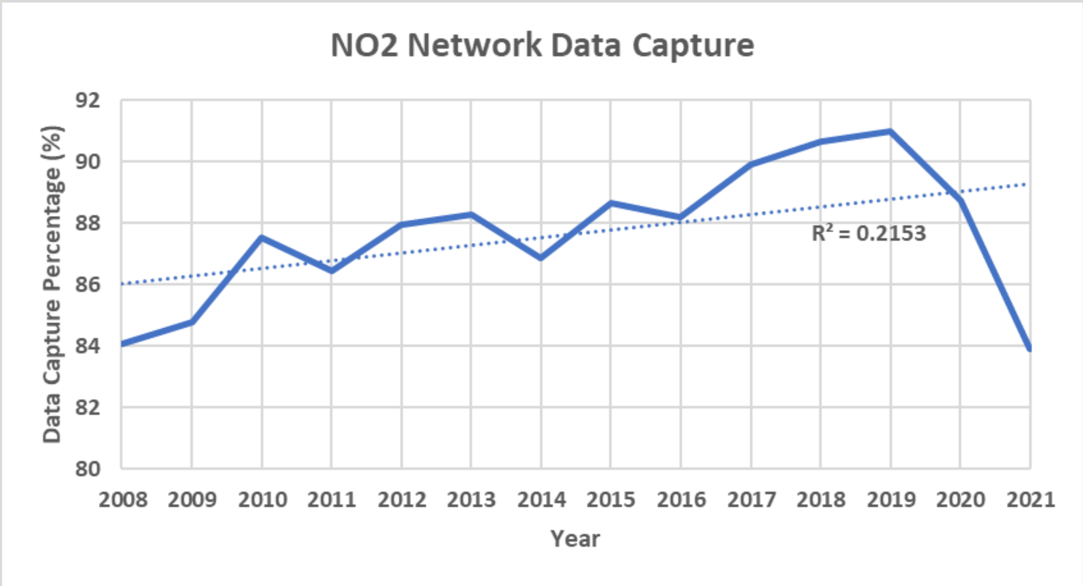
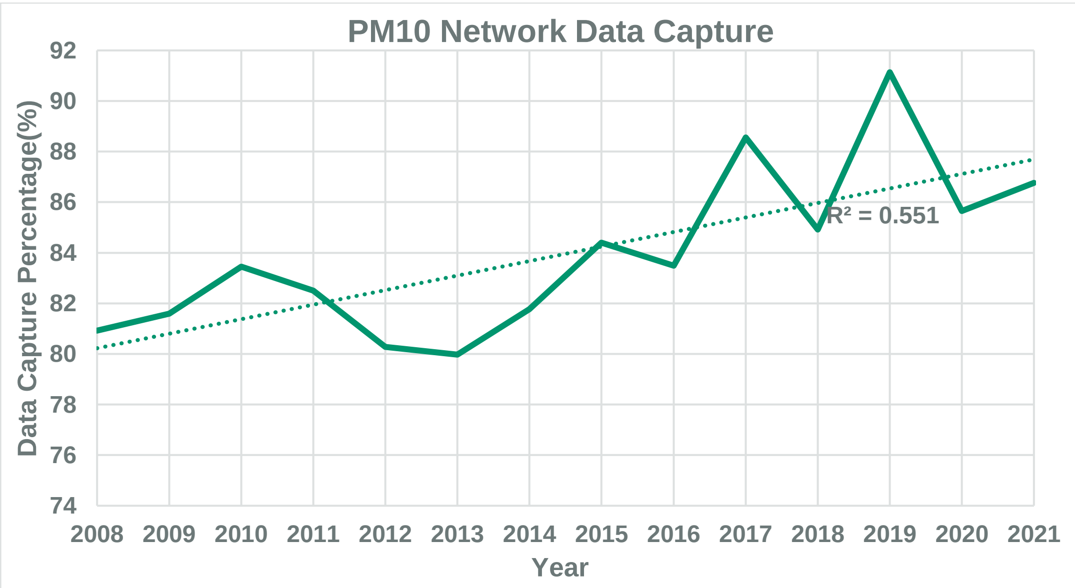


Figure 4.3 Network data capture rate for PM_{10} monitoring, 2008 – 2021



5 QA/QC OF THE SCOTTISH DATABASE

In order that all data within the Scottish Air Quality Database are harmonised to the same quality standard, the QA/QC procedures adopted within the UK Automatic and Rural Network (AURN) are provided for all local authority sites within the database.

The main elements of the QA/QC programme are on-site analyser and calibration gas inter-calibrations every 6-months, daily automatic data collection and validation and data ratification in 3-monthly blocks.

5.1 ON-SITE ANALYSER AND CALIBRATION GAS AUDITS

The automatic air quality monitoring stations located throughout Scotland employ a wide variety of different analyser types and site infrastructure. Intercalibration of the stations provides essential input to the data management process, to ensure that data across Scotland are harmonised, consistent in quality and traceable to a recognised gas calibration standard.

Monitoring station audits evaluate analysers to obtain an assessment of their performance level on the date of test. This information, in conjunction with the full analyser data set and additional calibration and service records, helps ensure data quality specifications have been met during the preceding data period.

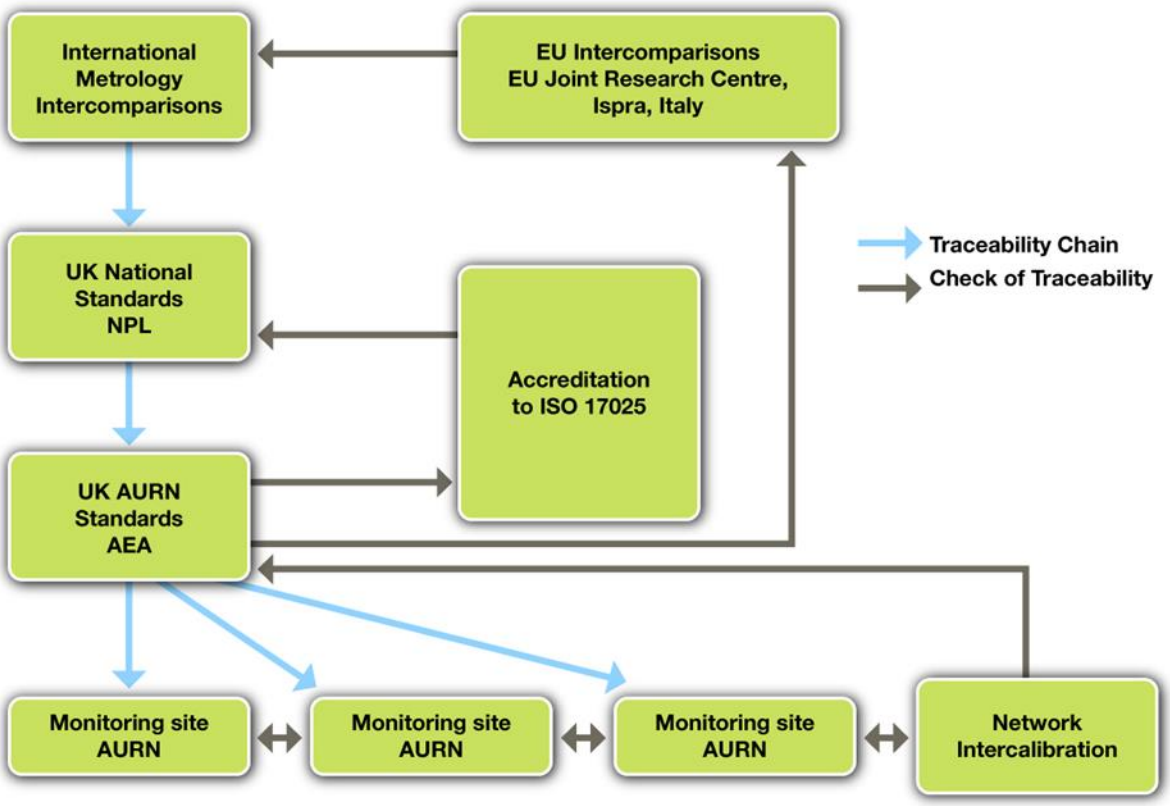
The assessment of the on-site calibration cylinder concentrations against accredited and traceable Ricardo Energy & Environment gas standard cylinders provides the essential final link in the measurement traceability chain (Figure 5.1). This process ensures that all monitoring stations in Scotland are traceable to reference gas standards held at Ricardo Energy & Environment. These in turn are traceable to UK national reference standard gases held by the National Physical Laboratory who, in turn regularly inter-compare these standards internationally. Ricardo Energy & Environment also participate in EU level inter-comparisons at the EU Joint Research Centre at Ispra, Italy. Hence, there is an unbroken traceability chain from each monitoring site in Scotland to internationally agreed gas calibration standards. This check also identifies any unstable gas cylinders which may need to be recertified or discarded.

The aims and objectives of the audit and intercalibration exercise can be summarised as follows:

- Ensure the correct operation of analysers at each monitoring station
- Ensure harmonisation of data throughout the network (i.e. that a NO_X analyser at one station measuring 40 $\mu g\ m^{-3}$ of NO_2 would also measure 40 $\mu g\ m^{-3}$ of NO_2 at any other site)
- Ensure traceability of all stations in the network to national and international standards
- Provide information on any necessary adjustments to data into the ratification process
- Report any faults found to the site operator.

Detailed audit procedures are provided in Appendix 1.

Figure 5-1 Traceability chain for the SAQD monitoring stations



5.2 DATA MANAGEMENT

The following sections describe the data management package applied to the data from the Scottish local authority monitoring stations. This is the same data management package, using the same data ratification procedures, that is applied to the AURN network stations across the UK.

The process includes the following tasks:

- Data acquisition
- Data validation
- Ratification

The data acquisition and management system consist of a central computer and telemetry facility that has been developed by Ricardo Energy & Environment specifically for the UK's air quality monitoring programmes. The database used in this system is backed-up on a 24-hour basis to independent network servers to ensure data security.

A wide range of data management activities are routinely performed, and these are integrated into the streamlined automatic data management system. Data are retrieved automatically from the Scottish air quality monitoring stations (*data acquisition*). The data are then rapidly processed by applying the latest available calibration factors (*data scaling*) and carefully screened using specifically developed computer algorithms to identify suspect data or equipment faults (*data validation*). These validated data are then appended to the site database and uploaded to the Scottish Database and Website. These operations are carried out automatically by computer systems, with all output manually checked by data management experts.

The validated data are then updated to the Scottish Air Quality Database – and accessible via the web - as provisional data. These data are therefore available to all users on a day-to-day basis. This gives the local authority the opportunity to easily view both their own data and data from other stations throughout Scotland. This will assist in dealing with day-to-day requests for information on specific data or the overall pollution situation either locally or throughout Scotland. In particular the automatic data summary bulletin, available by email from the website, and the plotting package incorporated into this, will be useful to authorities to rapidly evaluate their data against that from other stations.

5.3 DATA RATIFICATION

The validated data, which have been screened and scaled, are fit for day-to-day use and provide a good indication of pollution levels. However, the final stage of data management is a comprehensive and detailed critical review of the data and is generally termed 'ratification'. Note that ratification necessarily includes the results from the site audits and inter-calibrations – ratified data must be shown to be traceable to national gas standards.

The aim of data ratification is to make use of all of the available information to identify and remove any faulty data, ensuring that remaining measurement data meet the accuracy and precision specifications of the Scottish Government for detailed Review and Assessment (LAQM.TG(22)).

The policy on data rejection opted by Ricardo Energy & Environment is that all data are assumed to be correct unless there is good evidence to suggest otherwise. This prevents the ratification process from erroneously removing any important air pollution episode data. The ratification process is comprehensive and is outlined step-by-step in Appendix 1.

Data ratification of the Scottish local authority station data is undertaken on a three-monthly basis in line with AURN, based on calendar year timetables (January through to December). The process of ratification can take up to six weeks - we therefore aim to have the finalised datasets from all network sites ready by 31st March of the following year. This fits with the timetable for local authority reporting under the Review and Assessment process.

The ratified data are uploaded to the Scottish database and overwrites the provisional data. Summary statistics of these ratified data are available from the website to assist local authorities complete their Air Quality Review and Assessment reports.

5.3.1 Volatile Correction Model

An important part of the ratification process for Particulate Matter measurements obtained using TEOM analysers, is correcting the data using the Volatile Correction Model (VCM). More information on the Volatile Correction Model and the work carried out for the SAQD is provided in Appendix 3. Over recent years the number of sites that use TEOM analysers has significantly reduced to the point that in 2021 only one site, Aberdeen Anderson Drive used the technique, and this was replaced with FIDAS in July 2021. In turn, the role that VCM has in the ratification process of Particulate Matter data in the SAQD has massively reduced over the last few years.

5.4 QA/QC DURING 2021

As discussed above, site inter-calibrations and audit visits are undertaken at six-monthly intervals. However, where a site joins the database part way through a year then it is possible that only one audit will be conducted during the year. Table 5.2 shows the full list of inter-calibrations and audits undertaken on air quality sites in the Scottish Database during 2021.

The majority of analysers and sites were found to be operating satisfactorily during the audits. However, inevitably some problems were identified at some sites. These are summarised in Table 5.1.

Table 5-1 Monitoring site faults identified during the 2021 audits

Site Faults Identified 2021	Number of Monitoring Sites Winter 2020/21	Number of Monitoring Sites Summer 2021
Particulate Analyser calibration faults	0	0
Particulate Analyser*** flow out by >10%	10	0
NOx analyser converter <97% efficiency	10	11
NO cylinder out by >10%	2	9
SO_2 cylinder out by >10%	0	0
CO cylinder out by >10%	0	0
O_3 Analyser out by >5%	1	0

* Filter Dynamics Measurement System
** Tapered Element Oscillating Microbalance
*** These include TEOM, FDMS, FIDAS and Beta Attenuation Monitors (BAM)

In many cases, the results from the audit and intercalibration visits provide the information necessary to correct for these issues at the data ratification stage so that the data can be corrected and retained, rather than being deleted as erroneous data. A summary of the site inter-calibrations and audits undertaken during 2021 is provided in Appendix 2.

6 AIR POLLUTION IN SCOTLAND IN 2021

In this section we present a statistical summary of the available air quality data for Scotland as follows:

- Section 6.1 - Automatic monitoring of the pollutants NO_2, PM_{10}, $PM_{2.5}$ CO, SO_2 and O_3 summary data for 2021.
- Section 6.2 - Other pollutants covered by the Air Quality Strategy – PAH (benzo[a]pyrene), Benzene, 1,3-butadiene and lead and summary statistics for 2021.
- Section 6.3 - Other pollutants and/or other methods of monitoring:
    1. NO_2 Diffusion Tube Samplers
    2. Non-methane Volatile Organic Compounds (NMVOC)
    3. Poly-aromatic Hydrocarbons (PAH)
    4. Toxic Organic Micropollutants (TOMPS)
    5. Metals (Urban network)
    6. Metals (Rural and deposition network)
    7. United Kingdom Eutrophying & Acidifying Pollutants Network:
        i. The Precipitation Network
        ii. NO_2 Rural Diffusion Tube Network
        iii. Acid Gases and Aerosol Network (AGANET)
        iv. National Ammonia Monitoring Network

6.1 AUTOMATIC MONITORING OF POLLUTANTS NO_2, PM_{10}, $PM_{2.5}$, CO, SO_2 AND O_3

Table 6-1 to Table 6-7 show the 2021 annual average data statistics for NO_2, PM_{10}, $PM_{2.5}$, CO, SO_2 and O_3 for the ratified automatic data from monitoring sites included in the SAQD. These are shown along with the corresponding data capture for the year.

These data will have been used by local authorities to assess air quality within their area as part of the review and assessment process. Where any of the air quality objectives for Scotland have been exceeded, at locations where there is relevant exposure of the general public, then the authority will need to carry out a more detailed assessment as an addendum to their Annual Progress Report to confirm the exceedance and estimate its extent. Where the exceedance is confirmed then the authority will declare an Air Quality Management Area (AQMA). At the time of writing, 14 local authorities in Scotland have declared a total of 33 AQMAs (see https://www.scottishairquality.scot/laqm/aqma). Based on the data in the database, a summary of the air quality situation throughout Scotland, is provided in the following sections for each separate pollutant.

6.1.1 Nitrogen Dioxide

Table 6-1 shows nitrogen dioxide data for 93 sites utilising automatic monitoring during 2021. Although, data for 20 of these are only available for part of the year with the overall data capture less than 75%. These include sites which opened or closed during the year and sites which were closed for part of the year due to instrument problems.

Of the remaining 73 sites with 75% data capture or more, one site – Glasgow Kerbside - exceeded the annual mean objective for NO_2 (40 µg m^{-3}). The objective of not more than 18 exceedances of 200 µg m^{-3} for the hourly mean was also not exceeded at any site.

The highest annual average concentrations were measured at Glasgow Kerbside, with a measured concentration of 45.1 µg m^{-3}. The greatest number of exceedances of the hourly mean objective was measured at South Ayrshire Ayr Harbour with one exceedance. This is however well with the 18 annual exceedances permitted annually.

Table 6-1 Ratified data annual average concentration and data capture for NO_2 in 2021 for monitoring sites in the SAQD

Site Name	Type	Annual Average NO_2 2021 ($\mu g\ m^{-3}$)	No. hours >200 $\mu g\ m^{-3}$	Data capture NO_2 2021 (%)
Aberdeen Anderson Dr	RS	13.4	0	91.9
Aberdeen Errol Place	UB	13.9	0	68.9
Aberdeen Erroll Park	UB	20.8	0	25.1
Aberdeen King Street	RS	16.6	0	84.1
Aberdeen Market Street 2	RS	26.8	0	99.7
Aberdeen Union Street Roadside	RS	25	0	98.0
Aberdeen Wellington Road	RS	27.8	0	99.6
Alloa A907	RS	18.8	0	58.6
Bush Estate	R	4.3	0	98.3
Dumfries	RS	22.2	0	98.0
Dundee Broughty Ferry Road	RS	12.6	0	52.5
Dundee Lochee Road	RS	31.7	0	99.7
Dundee Mains Loan	UB	8.5	0	98.5
Dundee Meadowside	RS	27.1	0	81.0
Dundee Seagate	KS	30.3	0	99.7
Dundee Whitehall Street	KS	27.5	0	99.7
E Ayrshire Kilmarnock St Marnock St	RS	20.3	0	97.8
East Dunbartonshire Bearsden	RS	24.3	0	98.2
East Dunbartonshire Bishopbriggs	RS	18.6	0	56.7
East Dunbartonshire Kirkintilloch	RS	19.6	0	99.7
East Dunbartonshire Milngavie	RS	16.2	0	96.7
East Lothian Musselburgh N High St	RS	16	0	99.6
Edinburgh Currie	UB	5.1	0	92.7
Edinburgh Glasgow Road	RS	16.6	0	98.8
Edinburgh Gorgie Road	RS	18.2	0	89.9
Edinburgh Nicolson Street	RS	28.5	0	50.5
Edinburgh Queensferry Road	RS	29.2	0	99.3
Edinburgh Salamander St	RS	22.1	0	99.2

Site Name	Type	Annual Average NO_2 2021 ($\mu g\ m^{-3}$)	No. hours >200 $\mu g\ m^{-3}$	Data capture NO_2 2021 (%)
Edinburgh St John's Road	KS	28.7	0	93.8
Edinburgh St Leonards	UB	13.7	0	61.7
Eskdalemuir	R	1.8	0	41.1
Falkirk Grangemouth MC	UB	13.4	0	98.1
Falkirk Haggs	RS	21	0	92.0
Falkirk Hope St	RS	15.5	0	97.9
Falkirk Main St Bainsford	RS	19.7	0	94.8
Falkirk West Bridge Street	RS	31.4	0	99.8
Fife Cupar	RS	20	0	92.0
Fife Dunfermline	RS	16.1	0	95.4
Fife Kirkcaldy	RS	14.1	0	99.9
Fife Rosyth	RS	19.3	0	98.4
Fort William	S	6.3	0	95.7
Glasgow Anderston	UB	21.2	0	64.8
Glasgow Byres Road	RS	25.7	0	99.3
Glasgow Dumbarton Road	RS	29.1	0	95.3
Glasgow Great Western Road	RS	21.6	0	98.6
Glasgow High Street	RS	23.2	0	98.0
Glasgow Kerbside	KS	45.1	0	98.0
Glasgow Nithsdale Road	RS	24	0	90.1
Glasgow Townhead	UB	18	0	99.0
Glasgow Waulkmillglen Reservoir	R	7.5	0	94.5
Grangemouth	UI	13.1	0	52.6
Grangemouth Moray	UB	13.8	0	88.6
Inverclyde Greenock A8	RS	24.4	0	56.3
Inverness	RS	13.6	0	92.9
Inverness Academy Street	RS	29.4	0	93.3
Inverness Academy Street 1st Floor	RS	27.8	0	69.3
Lerwick	R	3.2	0	79.2
N Lanarkshire Airdrie Kenilworth Dr	RS	11.9	0	96.5
N Lanarkshire Chapelhall	RS	15.5	0	99.5
N Lanarkshire Coatbridge Sunnyside Rd	RS	25.6	0	12.9

Site Name	Type	Annual Average NO_2 2021 ($\mu g\ m^{-3}$)	No. hours >200 $\mu g\ m^{-3}$	Data capture NO_2 2021 (%)
N Lanarkshire Coatbridge Whifflet	UB	11.5	0	96.6
N Lanarkshire Coatbridge Whifflet A725	RS	13.9	0	59.7
N Lanarkshire Croy	RS	10	0	99.3
N Lanarkshire Kirkshaws	RS	13.6	0	96.2
N Lanarkshire Motherwell	RS	10.8	0	93.6
N Lanarkshire Motherwell Adele St.	RS	9	0	78.8
N Lanarkshire Shawhead Coatbridge	RS	14.2	0	91.1
N Lanarkshire Uddingston New Edinburgh Rd	RS	16.6	0	98.3
North Ayrshire Irvine High St	RS	12.6	0	97.6
Paisley Gordon Street	RS	18	0	15.9
Peebles	S	4.7	0	81.5
Perth Atholl Street	RS	31.1	0	98.3
Perth Bridgend	RS	19.3	0	74.9
Perth Crieff	RS	13	0	94.2
Perth High Street	RS	23.4	0	20.3
Renfrew Cockels Loan	RS	24.5	0	97.8
Renfrew Inchinnan Road	RS	19	0	99.5
South Ayrshire Ayr Harbour	RS	8.5	1	75.3
South Ayrshire Ayr High St	RS	11.9	0	91.8
South Lanarkshire Blantyre	RS	21.8	0	99.7
South Lanarkshire Cambuslang	RS	27.2	0	99.6
South Lanarkshire East Kilbride	RS	24.8	0	98.5
South Lanarkshire Hamilton	RS	24.2	0	75.5
South Lanarkshire Lanark	RS	16.7	0	83.1
South Lanarkshire Raith Interchange 2	RS	14.3	0	77.7
South Lanarkshire Rutherglen	RS	25.5	0	76.3
South Lanarkshire Uddingston	RS	18.1	0	76.7

Site Name	Type	Annual Average NO_2 2021 ($\mu g\ m^{-3}$)	No. hours >200 $\mu g\ m^{-3}$	Data capture NO_2 2021 (%)
Stirling Craig's Roundabout	RS	15.5	0	96.1
West Dunbartonshire Clydebank	RS	17.5	0	50.1
West Dunbartonshire Glasgow Road	RS	13.6	0	96.7
West Lothian Broxburn	RS	22.5	0	89.5
West Lothian Linlithgow High Street 2	RS	23.4	0	22.0
West Lothian Newton	RS	15.6	0	28.2

Shaded sites indicate data only available for part year and/or <75% data capture

Highlighted figures (in yellow) indicate exceedances of Scottish Air Quality Objectives

6.1.1.1 NO_2 Diffusion Tube data 2021

The NO_2 diffusion tube database and map were released on the Air Quality in Scotland website in June 2019. The map provides bias corrected annual mean data previously published in local authority annual progress reports. The database and map bring together local authority diffusion tube monitoring for each year, enabling the user to easily identify where monitoring has been carried out, what the concentrations are for the current year and compare it against historical data, and identify which sites have exceeded the annual mean objective of 40 µg m^{-3}.

In 2021, five diffusion tube sites exceeded the annual mean objective for NO_2, and are listed in Table 6-2. This is significantly down from previous years as illustrated in Figure 6-1. The reason for the significant decrease in sites exceeding during 2020 and 2021 is attributed to the Covid-19 lockdown restrictions.

For more information on the 2021 data and historical diffusion tube data, go the Diffusion Tube site map on the Air Quality in Scotland website (http://www.scottishairquality.scot/latest/diffusion-sites). The diffusion tube data can also now be downloaded via the data selector tool (http://www.scottishairquality.scot/data/data-selector).

It should be noted that it is the responsibility of the local authority to provide the Scottish Government with the data to be included in the map. Therefore, it could be the case that diffusion tube monitoring taken place during 2021 or any other year is not represented in the database. To identify if this is the case, please refer to the local authority's Annual Progress Report for the year in question.

Figure 6-1 Number of NO_2 diffusion tube sites exceeding the Annual Mean Objective since 2013

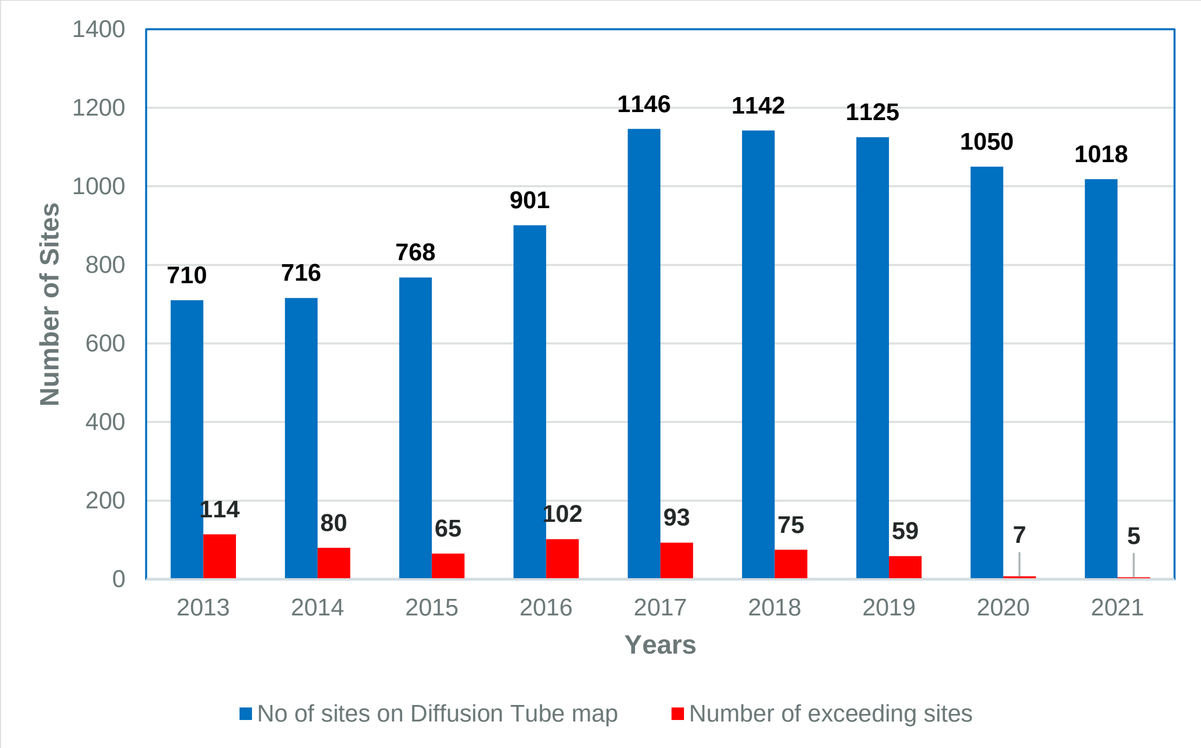


Table 6-2 NO_2 diffusion tube sites exceeding the Annual Mean Objective in 2021

Site Name	Annual Mean Concentration (µg m^{-3})	Local Authority Name
39 Market Street	42	Aberdeen City Council
Victoria Rd/Hilltown	41	Dundee City Council
London Road/East Norton Place	41	City of Edinburgh Council
Hope Street	44	Glasgow City Council
Gordon Street	40*	Glasgow City Council

* report as an exceedance by Glasgow City Council as actual figure is 40.2 µgm^{3}
(Data sourced from http://www.scottishairquality.scot/latest)

6.1.2 Particulate Matter – PM_{10}

Table 6-3 shows the 2021 gravimetric equivalent PM_{10} data from 84 sites utilising automatic monitoring. Of these sites, 18 have less than 75% data capture. As discussed in Section 4.2.2, all TEOM data have been adjusted using the VCM.

Of the 66 sites with 75% or greater data capture, no sites exceeded the annual average PM_{10} objective of 18 µg m^{-3}. The daily mean objective of 50 µg m^{-3} not to be exceeded more than seven times in a year was also not exceeded at any site. The maximum PM_{10} annual mean concentration was measured at Edinburgh Salamander St with a measured annual mean concentration of 15.4 µg m^{-3}.

Table 6-3 Ratified data annual average concentration and data capture for PM_{10} in 2021 for monitoring sites in the Scottish Air Quality Database

Site Name	Type	PM_{10} Analyser Type*	Annual Average PM_{10} 2021 ($\mu g\ m^{-3}$)	No. Days > 50 $\mu g\ m^{-3}$	Data Capture (%)
Aberdeen Anderson Dr	RS	FIDAS	8.6	0	94.3
Aberdeen Errol Place	UB	FIDAS	10.9	0	69.5
Aberdeen Erroll Park	UB	FIDAS	9.5	1	25.2
Aberdeen King Street	RS	FIDAS	12.4	0	49.7
Aberdeen Market Street 2	RS	FIDAS	10.5	0	97.8
Aberdeen Union Street Roadside	RS	FIDAS	10.0	0	52.0
Aberdeen Wellington Road	RS	FIDAS	12.3	0	99.4
Alloa A907	RS	FIDAS	10.7	3	99.9
Angus Forfar Glamis Rd	RS	FIDAS	8.9	0	55.7
Auchencorth Moss	R	FIDAS	5.5	0	99.7
Dundee Broughty Ferry Road	RS	FIDAS	10.1	0	85.8
Dundee Lochee Road	KS	FIDAS	10.7	0	99.7
Dundee Mains Loan	UB	FIDAS	7.5	0	98.9
Dundee Meadowside	RS	FIDAS	10.1	0	96.4
Dundee Seagate	KS	FIDAS	11.0	0	99.7
Dundee Whitehall Street	KS	FIDAS	8.3	0	99.7
E Ayrshire Kilmarnock St Marnock St	RS	FIDAS	9.9	0	81.6
East Dunbartonshire Bearsden	RS	FIDAS	9.5	0	99.8
East Dunbartonshire Bishopbriggs	RS	FIDAS	10.2	0	99.8
East Dunbartonshire Kirkintilloch	RS	FIDAS	10.7	0	99.8
East Dunbartonshire Milngavie	RS	FIDAS	8.7	0	96.7
East Lothian Musselburgh N High St	RS	BAM (heated)	10.0	0	85.4
Edinburgh Currie	UB	FIDAS	7.3	0	99.6
Edinburgh Glasgow Road	RS	FIDAS	10.2	0	99.7
Edinburgh Nicolson Street	RS	FIDAS	10.1	0	98.0
Edinburgh Queensferry Road	RS	FIDAS	12.0	0	99.6
Edinburgh Salamander St	UB	FIDAS	15.4	3	99.7
Edinburgh St John's Road	UB	FIDAS	11.0	0	97.8
Edinburgh St Leonards	RS	FIDAS	8.5	0	99.3
Edinburgh Tower Street	RS	FIDAS	9.9	0	100.0
Falkirk Grangemouth MC	UB	FIDAS	8.8	0	96.3
Falkirk Grangemouth Zetland Park	UI	FIDAS	8.6	0	90.6
Falkirk Haggs	RS	FIDAS	10.4	0	98.8
Falkirk Hope St	RS	FIDAS	9.0	0	90.9
Falkirk Main St Bainsford	RS	FIDAS	11.1	0	82.9
Falkirk West Bridge Street	RS	FIDAS	9.2	0	99.9
Fife Cupar	RS	FIDAS	13.0	0	95.8
Fife Dunfermline	RS	FIDAS	9.6	0	96.7
Fife Kirkcaldy	RS	FIDAS	9.4	0	99.9
Fife Rosyth	RS	FIDAS	10.0	0	54.4
Glasgow Anderston	UB	FIDAS	10.5	0	99.0
Glasgow Broomhill	RS	FIDAS	9.8	0	98.2
Glasgow Byres Road	RS	FIDAS	11.2	0	96.6

Site Name	Type	PM_{10} Analyser Type*	Annual Average PM_{10} 2021 ($\mu g\ m^{-3}$)	No. Days > 50 $\mu g\ m^{-3}$	Data Capture (%)
Glasgow Dumbarton Road	RS	FIDAS	12.0	0	68.5
Glasgow High Street	RS	FIDAS	10.3	0	99.6
Glasgow Kerbside	KS	FIDAS	13.1	0	98.2
Glasgow Nithsdale Road	RS	FIDAS	9.1	0	99.2
Glasgow Townhead	UB	FIDAS	9.2	0	99.5
Glasgow Waulkmillglen Reservoir	R	FIDAS	7.0	0	99.1
Grangemouth	UI	BAM (heated)	9.3	0	84.8
Inverclyde Greenock A8	RS	FIDAS	11.4	0	99.7
Inverness	RS	FIDAS	9.0	1	99.8
N Lanarkshire Airdrie Kenilworth Dr	RS	BAM	10.2	0	62.2
N Lanarkshire Chapelhall	RS	FIDAS	9.4	0	99.3
N Lanarkshire Coatbridge Whifflet	RS	FIDAS	8.5	0	99.9
N Lanarkshire Coatbridge Whifflet A725	RS	FIDAS	9.4	0	59.9
N Lanarkshire Croy	RS	FIDAS	8.5	0	99.9
N Lanarkshire Kirkshaws	RS	FIDAS	8.9	0	99.9
N Lanarkshire Motherwell	RS	FIDAS	9.6	0	88.9
N Lanarkshire Motherwell Adele St.	RS	FIDAS	8.8	0	96.8
N Lanarkshire Shawhead Coatbridge	RS	FIDAS	9.1	0	99.1
N Lanarkshire Uddingston New Edinburgh	RS	FIDAS	9.5	0	10.6
North Ayrshire Irvine High St	RS	FIDAS	10.8	0	97.4
Paisley Gordon Street	RS	FDMS	11.8	0	3.4
Perth Atholl Street	RS	FIDAS	14.0	7	99.4
Perth Bridgend	RS	FIDAS	9.6	0	79.2
Perth Crieff	RS	FIDAS	8.9	0	88.6
Perth Muirton	RS	FIDAS	8.0	0	98.1
Renfrewshire Johnstone	RS	FIDAS	13.7	1	36.2
South Ayrshire Ayr Harbour	RS	FIDAS	11.3	1	33.5
South Ayrshire Ayr High St	RS	FIDAS	8.7	0	34.7
South Lanarkshire Blantyre	RS	FIDAS	12.1	0	92.1
South Lanarkshire Cambuslang	RS	FIDAS	10.7	0	97.8
South Lanarkshire East Kilbride	RS	FIDAS	9.8	0	97.7
South Lanarkshire Hamilton	RS	FIDAS	10.0	0	96.5
South Lanarkshire Lanark	RS	FIDAS	8.8	0	99.8
South Lanarkshire Raith Interchange 2	RS	FIDAS	9.1	0	99.0
South Lanarkshire Rutherglen	RS	FIDAS	12.4	0	69.4
South Lanarkshire Uddingston	RS	FIDAS	9.8	0	89.7
Stirling Craig's Roundabout	RS	FIDAS	9.1	0	99.8
West Dunbartonshire Clydebank	RS	FIDAS	8.7	0	70.3
West Lothian Broxburn	RS	FIDAS	11.8	0	96.9
West Lothian Linlithgow High Street 2	RS	FIDAS	9.3	0	41.9
West Lothian Newton	RS	FIDAS	11.8	0	53.6

Shaded sites indicate data only available for part year and/or <75% data capture
FIDAS and FDMS data are equivalent to gravimetric and hence are not adjusted

6.1.3 Particulate Matter – $PM_{2.5}$

Table 6-4 shows the 2021 gravimetric equivalent $PM_{2.5}$ data from 83 sites utilising automatic monitoring. Following the introduction of the $PM_{2.5}$ annual mean objective of 10 µg m^{-3} in April 2016, local authorities continue to expand $PM_{2.5}$ monitoring, with the number of $PM_{2.5}$ sites increasing from 74 to 83 between 2020 and 2021. Data capture rates of less than 75% were measured at 17 sites. $PM_{2.5}$ concentrations in excess of the objective were not measured at any site. Figure 6-2 shows the 2021 annual average $PM_{2.5}$ and PM_{10} concentrations for all SAQD monitoring sites.

Table 6-4 Ratified data annual average concentration and data capture for $PM_{2.5}$ in 2021 for monitoring sites in the Scottish Air Quality Database

Site Name	Type	$PM_{2.5}$ Analyser Type	Annual Average $PM_{2.5}$ 2021 (µg m^{-3} gravimetric equivalent)	Data Capture (%)
Aberdeen Anderson Dr	RS	FIDAS	4.7	44.5
Aberdeen Errol Place	UB	FIDAS	5.7	69.5
Aberdeen Erroll Park	UB	FIDAS	4.5	25.2
Aberdeen King Street	RS	FIDAS	6.3	49.7
Aberdeen Market Street 2	RS	FIDAS	5.2	97.8
Aberdeen Union Street Roadside	RS	FIDAS	5.9	52.0
Aberdeen Wellington Road	RS	FIDAS	6.1	99.4
Alloa A907	RS	FIDAS	5.6	99.9
Angus Forfar Glamis Rd	RS	FIDAS	4.7	55.7
Auchencorth Moss	R	FIDAS	3.5	99.7
Dundee Broughty Ferry Road	RS	FIDAS	4.9	85.8
Dundee Lochee Road	KS	FIDAS	5.7	99.7
Dundee Mains Loan	UB	FIDAS	4.4	98.9
Dundee Meadowside	RS	FIDAS	5.3	96.6
Dundee Seagate	KS	FIDAS	5.6	99.7
Dundee Whitehall Street	KS	FIDAS	4.7	99.7
E Ayrshire Kilmarnock St Marnock St	RS	FIDAS	5.2	81.6
East Dunbartonshire Bearsden	RS	FIDAS	5.2	99.8
East Dunbartonshire Bishopbriggs	RS	FIDAS	5.9	99.8
East Dunbartonshire Kirkintilloch	RS	FIDAS	5.4	99.8
East Dunbartonshire Milngavie	RS	FIDAS	4.8	96.7
Edinburgh Currie	UB	FIDAS	4.3	99.6
Edinburgh Glasgow Road	RS	FIDAS	5.1	99.7
Edinburgh Nicolson Street	RS	FIDAS	5.4	98.0
Edinburgh Queensferry Road	RS	FIDAS	5.5	99.6
Edinburgh Salamander St	UB	FIDAS	5.9	99.7
Edinburgh St John's Road	UB	FIDAS	5.5	97.8
Edinburgh St Leonards	RS	FIDAS	4.8	99.3
Edinburgh Tower Street	RS	FIDAS	4.7	100.0
Falkirk Grangemouth MC	UB	FIDAS	4.7	96.3
Falkirk Grangemouth Zetland Park	UI	FIDAS	5.2	90.6
Falkirk Haggs	RS	FIDAS	5.7	98.8
Falkirk Hope St	RS	FIDAS	5.1	91.0
Falkirk Main St Bainsford	RS	FIDAS	6.1	84.5
Falkirk West Bridge Street	RS	FIDAS	4.9	100.0
Fife Cupar	RS	FIDAS	6.3	95.8

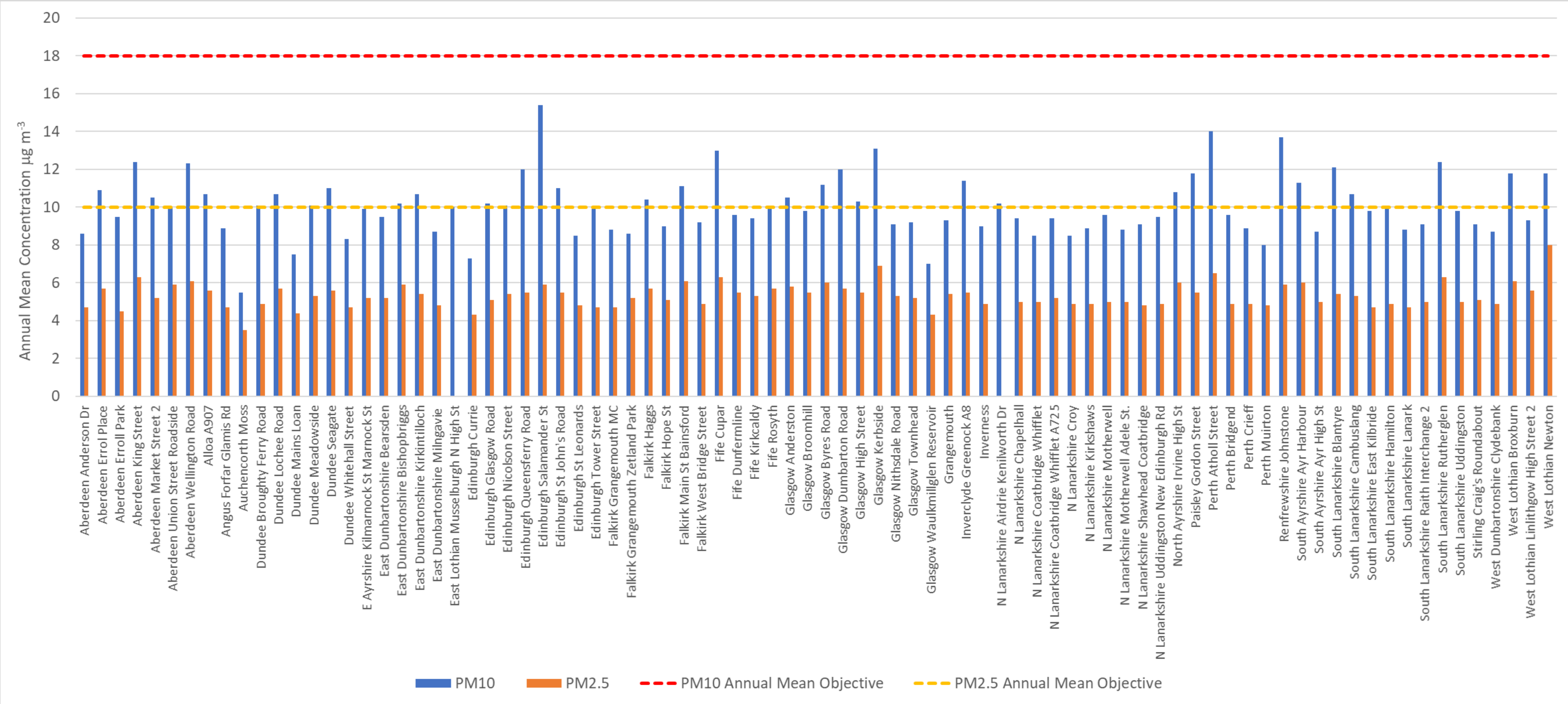
Site Name	Type	$PM_{2.5}$ Analyser Type	Annual Average $PM_{2.5}$ 2021 ($\mu g\ m^{-3}$ gravimetric equivalent)	Data Capture (%)
Fife Dunfermline	RS	FIDAS	5.5	96.7
Fife Kirkcaldy	RS	FIDAS	5.3	99.9
Fife Rosyth	RS	FIDAS	5.7	54.6
Glasgow Anderston	UB	FIDAS	5.8	99.0
Glasgow Broomhill	RS	FIDAS	5.5	98.2
Glasgow Byres Road	RS	FIDAS	6.0	96.7
Glasgow Dumbarton Road	RS	FIDAS	5.7	68.5
Glasgow High Street	RS	FIDAS	5.5	99.6
Glasgow Kerbside	KS	FIDAS	6.9	98.2
Glasgow Nithsdale Road	RS	FIDAS	5.3	99.2
Glasgow Townhead	UB	FIDAS	5.2	99.5
Glasgow Waulkmillglen Reservoir	R	FIDAS	4.3	99.1
Grangemouth	UI	BAM (heated)	5.4	93.6
Inverclyde Greenock A8	RS	FIDAS	5.5	99.7
Inverness	RS	FIDAS	4.9	99.8
N Lanarkshire Chapelhall	RS	FIDAS	5.0	99.3
N Lanarkshire Coatbridge Whifflet	RS	FIDAS	5.0	99.9
N Lanarkshire Coatbridge Whifflet A725	RS	FIDAS	5.2	59.9
N Lanarkshire Croy	RS	FIDAS	4.9	99.9
N Lanarkshire Kirkshaws	RS	FIDAS	4.9	99.9
N Lanarkshire Motherwell	RS	FIDAS	5.0	88.9
N Lanarkshire Motherwell Adele St.	RS	FIDAS	5.0	96.8
N Lanarkshire Shawhead Coatbridge	RS	FIDAS	4.8	99.1
N Lanarkshire Uddingston New Edinburgh Rd	RS	FIDAS	4.9	10.6
North Ayrshire Irvine High St	RS	FIDAS	6.0	97.3
Paisley Gordon Street	RS	FDMS	5.5	29.3
Perth Atholl Street	RS	FIDAS	6.5	99.4
Perth Bridgend	RS	FIDAS	4.9	79.2
Perth Crieff	RS	FIDAS	4.9	88.6
Perth High Street	RS	FIDAS	6.3	20.4
Perth Muirton	RS	FIDAS	4.8	98.1
Renfrewshire Johnstone	RS	FIDAS	5.9	36.2
South Ayrshire Ayr Harbour	RS	FIDAS	6.0	95.4
South Ayrshire Ayr High St	RS	FIDAS	5.0	84.3
South Lanarkshire Blantyre	RS	FIDAS	5.4	92.1
South Lanarkshire Cambuslang	RS	FIDAS	5.3	97.8
South Lanarkshire East Kilbride	RS	FIDAS	4.7	97.7
South Lanarkshire Hamilton	RS	FIDAS	4.9	96.5
South Lanarkshire Lanark	RS	FIDAS	4.7	99.8
South Lanarkshire Raith Interchange 2	RS	FIDAS	5.0	99.0
South Lanarkshire Rutherglen	RS	FIDAS	6.3	69.4
South Lanarkshire Uddingston	RS	FIDAS	5.0	89.7
Stirling Craig's Roundabout	RS	FIDAS	5.1	99.8
West Dunbartonshire Clydebank	RS	FIDAS	4.9	70.3

Site Name	Type	$PM_{2.5}$ Analyser Type	Annual Average $PM_{2.5}$ 2021 ($\mu g\ m^{-3}$ gravimetric equivalent)	Data Capture (%)
West Lothian Broxburn	RS	FIDAS	6.1	96.9
West Lothian Linlithgow High Street 2	RS	FIDAS	5.6	46.1
West Lothian Newton	RS	FIDAS	8.0	53.6

Shaded sites indicate data only available for part year and/or <75% data capture

FIDAS and FDMS data are equivalent to gravimetric and hence are not adjusted

Figure 6-2 Annual Average PM_{10} and $PM_{2.5}$ concentrations (µg m^{-3}) for all SAQD sites in 2021



6.1.4 Carbon monoxide

Table 6-5 shows carbon monoxide was monitored using automatic techniques at one site during 2021. Edinburgh St Leonard's achieved the Air Quality Strategy objective for this pollutant.

Table 6-5 Ratified data annual average concentration and data capture for CO in 2021 for monitoring sites in the Scottish Air Quality Database

Site Name	Type	Annual Average CO 2021 (mg m^{-3})	Max. Running 8hr Mean CO 2021 (mg m^{-3})	Data Capture (%)
Edinburgh St Leonards	UB	0.09	0.12	61.1

6.1.5 Sulphur dioxide

Table 6-6 shows sulphur dioxide data from the eight sites utilising automatic monitoring for 2021 of which two did not achieve a data capture rate of greater than 75%. Of the remaining six sites, all met the requirements of the Air Quality Strategy as there were no exceedances for the 15-minute (no more than 35 times), 1-hour (no more than 24 times) and 24-hour mean (no more than 3 times) SO_2 objectives in 2021.

Table 6-6 Ratified data annual average concentration and data capture for SO2 in 2021 for monitoring sites in the Scottish Air Quality Database

Site Name	Type	Annual Average SO_2 2021 (µg m^{-3})	No. 15 min SO_2 > 266µg m^{-3} 2021	No. 1 hr SO_2 > 350µg m^{-3} 2021	No. 24 hr SO_2 > 125µg m^{-3} 2021	Data Capture (%)
Edinburgh St Leonard's	UB	0.8	0	0	0	91.4%
Falkirk Bo'ness	UI	1.1	0	0	0	96.2%
Falkirk Hope St	UB	1.1	0	0	0	96.7%
Falkirk Grangemouth Zetland Park	UI	0.6	0	0	0	94.2%
Falkirk Grangemouth MC	RS	1.4	0	0	0	97.4%
Grangemouth Moray	UI	2.0	0	0	0	51.5%
Grangemouth	UB	1.1	6	0	0	94.2%
Lerwick	R	1.4	0	0	0	33.7%

Shaded sites indicate data only available for part year and/or <75% data capture

6.1.6 Ozone

Table 6-7 shows ozone data from 11 sites utilising automatic monitoring for 2021, of which four did not achieve a data capture rate of greater than 75%. Aberdeen Erroll Place closed in September 2021 and was replaced by Aberdeen Errol Park. The location of this new site is provided in the Air Quality in Scotland website. Ozone (O_3) is a secondary pollutant formed by reactions involving other pollutant gases in the presence of sunlight and over several hours; it may persist for several days and be transported over long distances. This means that local authorities have little control over ozone levels in their area. In 2021, the Air Quality Strategy objective of not more than 10 days with a maximum 8-hour running mean greater than 100 µg m^{-3} was not exceeded at any site.

Table 6-7 Ratified data annual average concentration and data capture for O_3 in 2021 for monitoring sites in the Scottish Air Quality Database

Site Name	Type	Annual Average O_3 2021 ($\mu g\ m^{-3}$)	No of days with Maximum running 8-hr mean >100 ug m^{-3}	Data capture O_3 2021 (%)
Aberdeen Errol Place	UB	53.1	0	68.2%
Aberdeen Erroll Park	UB	44.0	0	29.8%
Auchencorth Moss	R	60.7	5	95.5%
Bush Estate	R	61.1	3	98.5%
Edinburgh St Leonards	UB	53.2	0	98.3%
Eskdalemuir	R	59.0	0	24.4%
Fort William	S	51.9	3	91.8%
Glasgow Townhead	UB	44.7	1	96.6%
Glasgow Waulkmillglen Reservoir	R	56.5	1	79.4%
Lerwick	R	69.3	3	39.6%
Peebles	S	54.9	6	98.8%
Strath Vaich	R	67.4	5	90.1%

Shaded sites indicate data only available for part year and/or <75% data capture
Highlighted figures (in yellow) indicate exceedance of Scottish Air Quality Objectives

6.2 OTHER POLLUTANTS COVERED BY THE AIR QUALITY STRATEGY – PAH (BENZO[A]PYRENE), BENZENE, 1,3-BUTADIENE AND LEAD

In this section, we present a summary of data from a range of national monitoring networks. Summaries are provided for pollutants covered by the Air Quality Strategy. As some of these networks are based on sampler measurement techniques and subsequent chemical analysis there is often a considerable delay in the availability of data. Where other pollutants are also monitored in these networks, these pollutants are listed, but the data are not provided in this report. Data, Statistics and site information on these networks sites can be accessed via the Air Quality In Scotland Website "other Networks" interactive map (https://www.scottishairquality.scot/latest) and also the data selector function (https://www.scottishairquality.scot/data/data-selector).

6.2.1 PAH Monitoring Network[1]

The UK Monitoring and Analysis Network monitor some 39 Polycyclic Aromatic Hydrocarbon (PAH) species at 33 sites (see Table A.4 3, Appendix 4). Monitoring of the PAH benzo[a]pyrene is undertaken to provide data in compliance with retained EU law. An air quality objective for this PAH is also set in the Air Quality Strategy. A wide range of other PAH species are also monitored in the particulate phase and in the gaseous phase at some sites, for research purposes.

The airborne PAH monitoring is undertaken using Digitel DHA-80 Air Sampling System with PM_{10} inlet. Particulate collection is undertaken on a filter and at some sites, vapour-phase collection is also undertaken using polyurethane foam in addition to filter. At two sites, deposition samplers are also used to determine deposited PAH material.

[1] Conolly C. et al Final Contract Report for the UK PAH Monitoring and Analysis Network (2004-2010) [online] Available at http://uk-air.defra.gov.uk/reports/cat05/1103040911_AEA_PAH_Network_Report_2010_Final_v3.1.pdf [Accessed no 30/05/2012]

The PAH monitoring sites in Scotland are shown in Table 6-8. The sites at Edinburgh and Glasgow are co-located with the Edinburgh St Leonards and Glasgow Townhead AURN sites respectively. The site at Kinlochleven is located close to the closed aluminium works and the site at Auchencorth Moss is a rural EMEP site as discussed in the automatic hydrocarbon section.

Table 6-8 PAH monitoring sites in Scotland

Site	Address	Grid Reference
Auchencorth Moss	Rural site in Scotland, south of Edinburgh	322167,656123
Edinburgh	145 Pleasance, Edinburgh, EH8 9RU	326265, 673136
Glasgow Townhead	Not available	259692, 665899
Kinlochleven	Electrical Substation, Kinlochleven	219305,761905

Annual average concentrations for Benzo(a)pyrene (B(a)P) for 2019 to 2021 are shown in Table 6-9. As can be seen, the Air Quality objective for B(a)P of 0.25 ng m^{-3} as an annual average or the EU Directive target value of 1 ng m^{-3} was not exceeded at any site in 2021.

Table 6-9 Annual average Benzo(a)Pyrene concentrations for 2019 - 2021 at four sites in Scotland

Site	2019 Annual Mean B(a)P Concentration (ng m^{-3})	2020 Annual Mean B(a)P Concentration (ng m^{-3})	2021 Annual Mean B(a)P Concentration (ng m^{-3})
Auchencorth Moss	0.014	0.010	0.029
Edinburgh St Leonards	0.061	0.0368	0.049
Glasgow Townhead	0.108	0.0577	0.075
Kinlochleven	0.277	0.240	0.220

6.2.2 Benzene

6.2.2.1 Non-automatic hydrocarbon monitoring

Monitoring of benzene is undertaken on a two-weekly basis with pumped tube samplers at 36 sites throughout the UK – The UK Non-automatic Hydrocarbon Network. Two of these sites are located in Grangemouth and Glasgow Kerbside and are co-located with the Grangemouth and Glasgow Kerbside AURN sites. The non-automatic monitoring network provides benzene data for compliance with retained EU law and Scottish objective of 16.25 μg m^{-3} as an annual mean.

The benzene monitoring method used in this network involves pumping ambient air at a rate of 10 ml min^{-1} through nominally duplicate tubes containing the sorbent Carbopack X, with subsequent laboratory analysis of the benzene content of the tubes. Results for this site for 2019 to 2021 are provided in Table 6-10.

Table 6-10 Annual mean Benzene concentrations for 2019 - 2021 at two sites in Scotland in the UK Non-Automatic Hydrocarbon Network

Site Name	Annual Mean benzene for 2019 (μg m^{-3})	Annual Mean benzene for 2020 (μg m^{-3})	Annual Mean benzene for 2021 (μg m^{-3})
Glasgow Kerbside	0.68	0.52	0.50
Grangemouth	0.78	0.58	0.68

6.2.2.2 Automatic Hydrocarbon Monitoring

Table 6-11 gives the site details for the one automatic hydrocarbon monitoring station in Scotland - Auchencorth Moss: a rural site south of Edinburgh. The data from this site are used both to provide data for ozone precursor hydrocarbon species, in compliance with retained EU law. In addition, this site is one of the two European Monitoring and Evaluation Programme (EMEP) level II sites (EMEP "supersites") in the UK. The other EMEP supersite is located at Chilbolton in Hampshire. A much wider range of hydrocarbon species is monitored at Auchencorth Moss. However, the rural nature of this site means that often the concentrations are below the detection limit and hence, the data capture is low. Data for the full range of hydrocarbon species monitored at Auchencorth Moss can be downloaded from https://www.scottishairquality.scot/.

Table 6-11 Location of Automatic Hydrocarbon Monitoring Sites in Scotland

Site Name	Site Type	Species Measured
Auchencorth Moss	RURAL	Benzene and 1,3-butadiene and 24 other ozone precursor hydrocarbon species*

*EU requirement and part of the EMEP long-range transboundary air pollution monitoring programme.

Table 6-12 indicates that it is unlikely that the EU limit value for benzene of 5 $\mu g\ m^{-3}$ and the Scottish Objective of 3.25 $\mu g\ m^{-3}$ for the annual running mean concentration have been exceeded at Auchencorth Moss during 2021.

Table 6-12 Annual Average Benzene Concentration at Auchencorth Moss in the UK Automatic Hydrocarbon Network, for 2021

Site	Benzene Annual mean concentration for 2021 ($\mu g\ m^{-3}$)	Benzene Maximum running annual concentration for 2021 ($\mu g\ m^{-3}$)
Auchencorth Moss	0.16	1.1

6.2.3 1,3-Butadiene

The species 1,3-butadiene is also measured as part of the UK Automatic Hydrocarbon Network at the same sites as for Benzene. Table 6-13 shows that 1,3-butadiene concentrations less than the Scottish Air Quality objective of 2.25 $\mu g\ m^{-3}$ were measured during 2021. There is no EU Directive target for 1,3-butadiene.

Table 6-13 Annual Average 1,3-butadiene Concentration at Auchencorth Moss in the UK Automatic Hydrocarbon Network, for 2021

Site	1,3-butadiene Annual mean concentration for 2021 ($\mu g\ m^{-3}$)	1,3-butadiene maximum running annual concentration for 2021 ($\mu g\ m^{-3}$)
Auchencorth Moss	0.017	0.75

6.2.4 Heavy Metals

Lead and a wide range of other metals are monitored in two UK networks – the UK Heavy Metals Monitoring Network (mainly urban sites) and the National Monitoring Network for Heavy Metals (mostly rural sites). The urban network determines airborne particulate concentrations of 15 metals, including the metals lead, nickel, arsenic, cadmium and mercury which are covered by the EU Directive (Directives 2008/50/EC for lead and Directive 2004/107/EC for other metals). The rural network determines the concentration of more than 20 metals both as airborne particulate matter and as deposited material in rainwater samples. Results for all metals monitored in the UK Heavy Metals Monitoring Network and for a selection of metals monitored in the National Monitoring Network for Heavy Metals are available from the data selector on the Air Quality in Scotland website https://www.scottishairquality.scot/data/data-selector.

6.2.4.1 Rural Heavy Metals

In the National Monitoring Network for Heavy Metals, particles are collected using either single sample or multiple-sample FH95 samplers which draw air through a PM_{10} head at a flow rate of 1 m^3 h^{-1}. Particulate metals are collected on a filter paper for subsequent analysis. The sampling period is normally one week. Rainwater collectors are used to collect samples for rainwater analysis of metals to determine metal deposition. Details of the two rural sites in Scotland are provided in Table 6-14 and data for the measurement of lead, nickel, arsenic and cadmium in 2021 are provided in Table 6-15.

Table 6-14 Rural Network metals monitoring sites in Scotland

Site	Address	Grid Reference
Auchencorth Moss	Rural site, SE Scotland	322167,656123
Eskdalemuir	The Met Office Eskdalemuir Observatory, Langholm, Dumfries & Galloway, DG13 0QW	323552,603018

Table 6-15 Annual mean metal concentrations 2021 (Rural Network)

Site	Annual Mean Arsenic Concentration ($ng\ m^{-3}$)	Annual Mean Cadmium Concentration ($ng\ m^{-3}$)	Annual Mean Nickel Concentration ($ng\ m^{-3}$)	Annual Mean Lead Concentration ($ng\ m^{-3}$)
Auchencorth Moss	0.19	0.021	0.14	0.80
Eskdalemuir	0.15	0.02	0.26	0.77

The results from these networks show that the EU limit value for lead, and the target values for nickel, arsenic and cadmium were not exceeded at any site in Scotland. The air quality objectives for lead (500 ng m^{-3} for 2004 and 250 ng m^{-3} for 2008) were also not exceeded at any site in Scotland.

6.3 DISCUSSION OF ADDITIONAL POLLUTANTS MONITORED AND/OR OTHER METHODS OF MONITORING

This section discusses other air pollution measurements made in Scotland. Detailed results are not provided but are available in the annual reports of the various networks. The following additional pollutants or additional monitoring methods are discussed:

1. NO_2 diffusion tube samplers
2. Non- methane Volatile Organic Compounds (NMVOC)
3. Poly aromatic hydrocarbons (PAH)
4. Toxic Organic Micropollutants (TOMPS)
5. Metals (Urban network)
6. Metals (Rural and deposition network)
7. United Kingdom Eutrophying & Acidifying Pollutants Network:
    i. The Precipitation Network
    ii. NO_2 rural diffusion tube Network
    iii. Acid Gases and Aerosol Network (AGANET)
    iv. National Ammonia Monitoring Network

6.3.1 NO_2 Diffusion Tube Results

There is no specific requirement for local authorities to provide their NO_2 diffusion tube data to a central storage facility. However, through the local authority air quality support contract, a mechanism has been provided for authorities to provide these data. This data entry system is available from http://airquality.aeat.com/NO2admintools/logon. Where these data are provided by the authorities, they are then available for download from the Scottish air quality website (https://www.scottishairquality.scot/). For the latest NO_2 diffusion tube data see section 6.1.1.1.

6.3.2 Non-Methane Volatile Organic Compounds (NMVOC)

At Auchencorth Moss a much wider range of NMVOCs are monitored to provide ozone precursor pollutant concentrations in compliance with retained EU law. The following compounds are monitored:

- Ethane
- Ethene
- Propane
- Propene
- Ethyne
- 2-Methylpropane
- n-Butane
- trans-2-Butene
- 1-Butene
- cis-2-Butene
- 2-Methylbutane
- n-Pentane
- 1,3-Butadiene
- trans-2-Pentene
- 1-Pentene
- 2-Methylpentane
- n-Hexane
- Isoprene
- Benzene
- 2,2,4-trimethylpentane
- n-Heptane
- n-Octane
- Toluene
- Ethylbenzene
- (m+p)-Xylene
- o-Xylene
- 1,3,5-Trimethylbenzene
- 1,2,4-Trimethylbenzene
- 1,2,3-Trimethylbenzene

Hourly data for all these species are available on the Scottish Air Quality Database website.

6.3.3 Polycyclic Aromatic Hydrocarbons (PAH)

As discussed in Section 6.2.1, a wide range of particulate and gaseous PAH compounds are monitored within the UK PAH network. The following PAH species are sampled on a daily basis (but bulked into monthly results after analysis) at the four PAH sites in Scotland:

- Benzo(c)phenanthrene
- Benzo(a)anthracene
- Chrysene
- Cyclopenta(c,d)pyrene
- Benzo(b)naph(2,1-d)thiophene
- 5-Methyl Chrysene
- Benzo(b+j)fluoranthene
- Benzo(k)fluoranthene
- Benzo(e)pyrene
- Benzo(a)pyrene
- Perylene
- Indeno(1,2,3-cd)pyrene
- Dibenzo(ah.ac)anthracene
- Benzo(ghi)perylene
- Dibenzo(al)pyrene
- Dibenzo (ae)pyrene
- Dibenzo(ai)pyrene
- Dibenzo(ah)pyrene
- Coronene
- Cholanthrene
- Dibenzo(al)pyrene

6.3.4 Toxic Organic Micropollutants

Toxic Organic Micropollutants (TOMPs) include Polychlorinated Dibenzo-p-Dioxins, Polychlorinated Dibenzofurans (PCDD/Fs), PAHs, and Polychlorinated Biphenyls (PCBs). PCDD/Fs and PAHs are formed as unwanted by-products during various industrial, chemical and combustion processes. PCBs were formerly manufactured for use in a wide range of electrical and other products until 1986. These highly toxic and persistent species are ubiquitous in the environment, but are normally present at extremely low concentrations, the atmosphere being the principal route for their redistribution in the environment. The TOMPs network provides data on concentrations of these species in the air throughout the UK. There were six sites in the TOMPs network during 2021: one in Scotland at Auchencorth Moss.

The TOMPs network samples are analysed for PCDD/Fs and PCBs. Portions from the extracts of samples are also analysed for PAHs as part of the PAH network. The sampling method is based around the use of a modified Andersen GPS-1 sampler with subsequent chemical analysis requiring the use of a range of sophisticated chemical analysis techniques. These include gas chromatography coupled with high-resolution mass spectrometry for the PCDD/Fs and for those PCBs with dioxin-like effects and low-resolution mass spectrometry for the other PCBs.

6.3.5 Heavy Metals Network

As discussed in Section 6.2.5 a wide range of metals are monitored in both air and rainwater within the National Monitoring Network for Heavy Metals. At the two sites in Scotland, Auchencorth Moss and Eskdalemuir, the following metals are monitored:

Arsenic (As), Cadmium (Cd), Cobalt (Co), Chromium (Cr), Copper (Cu), Iron (Fe), Lead (Pb), Manganese (Mn), Nickel (Ni), Selenium (Se), Vanadium (V) and Zinc (Zn).

6.3.6 United Kingdom Eutrophying & Acidifying Pollutant Network (UKEAP)

This network focuses on the measurement of Eutrophying & Acidifying Pollutants in rural areas. The number of sites in Scotland is different for the various species measured.

The UKEAP has four component networks:

- The Precipitation Network (PrecipNet),
- Rural NO_2 network (NO_2-Net),
- Acid Gas and Aerosol Network (AGANET),
- National Ammonia Monitoring Network (NAMN),
- Automatic Mercury Network.

Each network functions on a national scale, however with differing spatial and temporal resolution which reflects the spatial and temporal heterogeneity of the atmospheric pollutant concerned.

6.3.7 The Precipitation Network (Precip-Net)

There are 41 sites in PrecipNet at which the chemical composition of precipitation (i.e., rainwater) is measured. Six of the sites, Lochnagar, Llyn Llagi, Scoat Tarn, Loch Chon/Tinker, River Etherow, Beaghs Burn and Crai Reservoir (Head of the Valleys) were specifically located within sensitive ecosystems. The network allows estimates of wet deposition of sulphur and nitrogen chemicals.

Fortnightly precipitation samples are collected at 41 sites throughout the UK, of which 10 are in Scotland (see Table A.4 7, Appendix 4). Sampling is undertaken with using a bulk rainwater collector. The collected rainwater samples are analysed for sulphate, nitrate, chloride, phosphate, sodium, magnesium, calcium, potassium, pH and conductivity.

6.3.8 Rural NO_2 Network (NO_2-Net)

The nitrogen dioxide measurements are made at 24 of the Precip-Net composition sites. Diffusion tubes are used to measure nitrogen dioxide. The tubes are mounted on the upright of the rain collector stand and exposed for four or five-week periods throughout each year.

Triplicate nitrogen dioxide diffusion tube measurements are run at three AURN sites with co-located automatic instruments (Yarner Wood, Harwell and Eskdalemuir). The annual average NO_2 concentration measured at the Eskdalemuir automatic monitoring site was 1.7 µg m^{-3} in 2021 with a data capture rate of 100%. Nitrogen dioxide is measured with diffusion tube samplers at nine sites in Scotland. The annual average concentrations measured in 2021 are provided in Table 6-16.

Table 6-16 NO_2 annual average concentrations 2021 at rural monitoring sites

Site	Annual Mean NO_2 for 2021 (ug m^{-3})	Data Capture for 2021 (%)
Allt a'Mharcaidh	0.793	100
Balquhidder 2	1.253	100
Eskdalemuir	1.661	100
Forsinard RSPB	0.982	88
Glensaugh	1.788	100
Loch Dee	1.485	100
Polloch	0.643	92
Strathvaich	0.558	100
Whiteadder	2.145	90

6.3.9 Acid Gas and Aerosol Network (AGANET)

The UK Acid Gases and Aerosols Monitoring Network has been in operation since September 1999, providing monthly measurement data of acid gases and aerosols.

An extension of the CEH Denuder for Long Term Atmospheric sampling (DELTA) system at the network sites is used to additionally sample gaseous HNO_3, SO_2, HCl and particulate NO_3^-, SO_4^{2-}, Cl^-, Na^+, Ca^{2+}, Mg^{2+}. The new expanded network includes measurements of gaseous SO_2 and particulate SO_4^{2-}.

The nine sites in this network located in Scotland are listed in Table A.4 8 in Appendix 4.

6.3.10 National Ammonia Monitoring Network (NAMN)

Established in 1996, the objectives of the network are to quantify temporal and spatial changes in air concentrations and deposition in NH_3 and NH_4^+ (included since 1999) on a long-term basis. The monitoring provides a baseline in the reduced nitrogen species (NH_3 + NH_4^+), which is necessary for examining responses to changes in the agricultural sector and to verify compliance with targets set by international agreements. The 17 sites in this network located in Scotland are listed in Table A.4 8 in Appendix 4.

7 AIR QUALITY MAPPING FOR SCOTLAND

As part of the Scottish Air Quality Database project, Ricardo Energy & Environment provide mapped concentrations of modelled background air pollutant concentrations on a 1 km x 1 km basis for the whole of Scotland. Modelled roadside air pollutant concentrations are provided for urban major road links in Scotland. The air pollution maps are derived from a combination of measurements from Scotland's network of air quality monitoring stations, and spatially disaggregated emissions information from the UK National Atmospheric Emissions Inventory (NAEI). They provide estimated pollutant concentrations for the whole of Scotland. The methodology for producing the Scottish maps is based on the UK Pollution Climate Mapping (PCM) approach, used for producing air pollution maps for the whole UK for the purposes of annual compliance reporting under the Air Quality Standards Regulations 2010.

The PCM methodology has been applied to provide pollution maps of Scotland for the Scottish Government for 2020 using measurements exclusively from Scottish air quality monitoring sites. The maps provide spatial representation of the annual mean concentrations of:

- PM_{10} (gravimetric equivalent)
- $PM_{2.5}$ (gravimetric equivalent)
- NO_X and NO_2.

The air pollution measurements used to prepare the maps presented here consist of appropriately scaled PM_{10} and $PM_{2.5}$ monitoring data (FIDAS, FDMS, Beta Attenuated Monitors (BAM) and VCM corrected TEOM data) and automatic monitoring measurements for NO_X and NO_2 from the model year. The model also uses meteorology data from the Weather Research and Forecasting (WRF) model to create the Scotland-specific maps.

In 2009 Ricardo undertook a short study[2] on behalf of the Scottish Government which demonstrated the use of Scotland-specific air quality maps for Local Air Quality Management Review and Assessment (LAQM) purposes. This study recommended the use of air pollutant source apportionment data and forward-projected concentrations of air pollutants using Scotland-specific data. Updates to these Scotland-specific air pollutant source apportionment data and forward-projected concentrations have been made and are available for LAQM from a base year of 2018 at: https://www.scottishairquality.scot/data/mapping/data. Please note the available projections from a base year of 2018 are based on assumptions that were applicable prior to the Covid-19 pandemic, and as such, do not reflect short- or long-term impacts of the pandemic and associated lockdowns on emissions in 2020 and beyond.

7.1 AIR QUALITY MAPS FOR SCOTLAND 2020

The details of the methodology and full results of the mapping study are provided in a separate report[3]. In this report, we summarise the main findings of this work.

7.1.1 NO_2 maps for 2020

The 2020 annual mean NO_2 concentrations for Scotland were modelled for background and roadside locations. Figure 7.1 and Figure 7.2 show modelled annual mean NO_2 concentrations in Scotland, for background and roadside locations respectively.

[2] Stevenson, K., Kent, A.J., and Stedman, J. (2010). Investigation of the possible effect of the use of Scottish specific air quality maps in the LAQM process in four selected Local Authorities. AEA Report AEAT/ENV/R/2948. https://www.scottishairquality.scot/sites/default/files/orig/publications/reports2/258100203_la_mapping_report_issue_1_final.pdf

[3] Wareham, J., Pepler, A. Stedman, J., Morris, R. and Hector, D. (2022). Scottish Air Quality Maps. Annual mean NO_X, NO_2, PM_{10} and $PM_{2.5}$ modelling for 2020. https://www.scottishairquality.scot/sites/default/files/orig/assets/documents/Scottish_mapping_report_2020.html

Figure 7.1 Background NO_2 map for 2020, µg m^{-3} (Scotland-specific model)

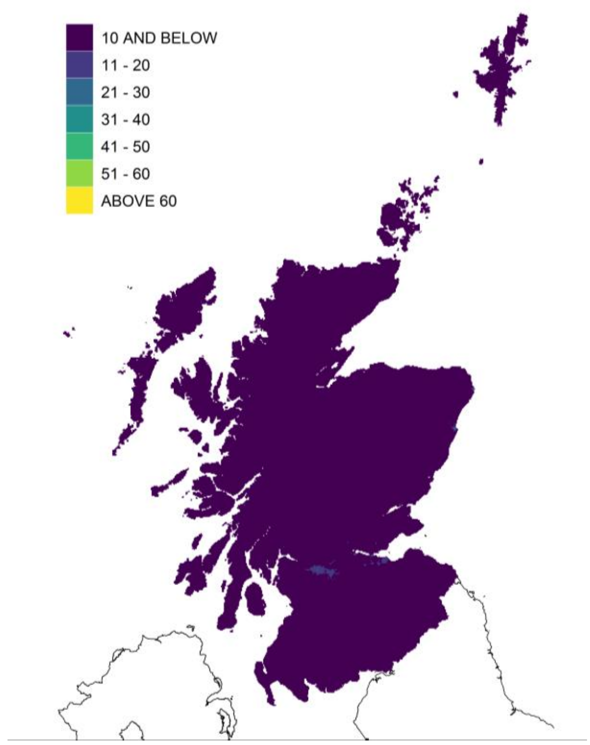


Figure 7.2 Roadside NO_2 map for 2020, µg m^{-3} (Scotland-specific model)

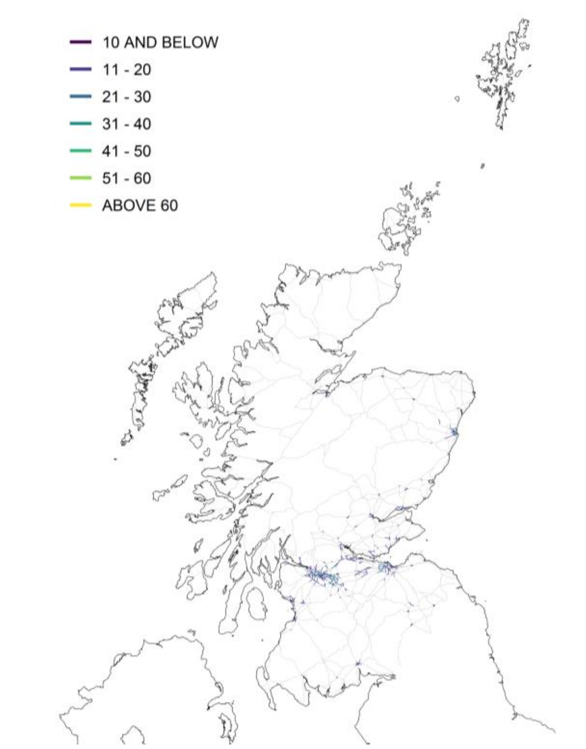


Table 7.1 shows that there were no modelled exceedances of the Scottish annual mean NO_2 objective of 40 µg m^{-3} at background locations. Table 7.2 shows that there were no modelled exceedances of the Scottish annual mean NO_2 objective of 40 µg m^{-3} at roadside locations. Interactive versions of the maps showing the background and roadside annual mean NO_2 concentrations can be found in the Scottish Air Quality Mapping report for 2020[4].

Table 7.1 Annual mean exceedance statistics for background NO_2 in Scotland based on the Scotland-specific model, 2020.[1]

Zone or agglomeration	Total		>40 µg m^{-3}	
	Area (km^2)	Population	Area (km^2)	Population
Glasgow Urban Area	367	1,147,602	0	0
Edinburgh Urban Area	134	512,331	0	0
Central Scotland	10,064	1,995,307	0	0
North East Scotland	19,057	1,149,258	0	0
Highland	44,116	394,632	0	0
Scottish Borders	11,404	263,760	0	0
Total	**85,142**	**5,462,888**	**0**	**0**

[1] Note: Totals may differ from sum of individual sub-totals due to rounding.

[4] https://www.scottishairquality.scot/sites/default/files/orig/assets/documents/Scottish_mapping_report_2020.html

Table 7.2 Annual mean exceedance statistics for roadside NO_2 in Scotland based on the Scotland-specific model, 2020.[2]

Zone or agglomeration	Total		>40 µg m^{-3}	
	Road links	Length (km)	Road links	Length (km)
Glasgow Urban Area	305	429.6	0	0
Edinburgh Urban Area	71	117.9	0	0
Central Scotland	329	505.2	0	0
North East Scotland	180	261.9	0	0
Highland	45	67.4	0	0
Scottish Borders	51	56.4	0	0
Total	**981**	**1,438.4**	**0**	**0**

[2] Note: Totals may differ from sum of individual sub-totals due to rounding.

7.1.2 PM_{10} maps for 2020

2020 annual mean PM_{10} concentrations for Scotland were modelled for background and roadside locations. The modelling methodology used to calculate the annual mean PM_{10} concentration was similar to that used in previous years and used a mixture of appropriately scaled PM_{10} monitoring (FIDAS, FDMS, Beta Attenuated Monitors (BAM) and VCM corrected TEOM) data. Many of the chemical components of the PM_{10} model are not affected by the Scotland-specific changes to the UK PCM model. This includes the contribution to the total PM_{10} mass from the following components:

- secondary inorganic aerosols (SIA, e.g., sulphate, nitrate, ammonium-based particles)
- secondary organic aerosols (SOA)
- primary particles from long-range transport
- sea salt aerosol, and
- iron and calcium-rich dusts.

Maps of the modelled 2020 annual mean PM_{10} concentrations for Scotland's background and roadside locations are shown in Figures 7.3 and 7.4, respectively.

Table 7.3 shows that there were no modelled exceedances of the Scottish annual mean PM_{10} objective of 18 µg m^{-3} at background locations. Table 7.4 shows that there were no modelled exceedances of the Scottish annual mean PM_{10} objective of 18 µg m^{-3} at roadside locations.

Figure 7.3 Background PM_{10} map for 2020, µg m^{-3} (Scotland-specific model)

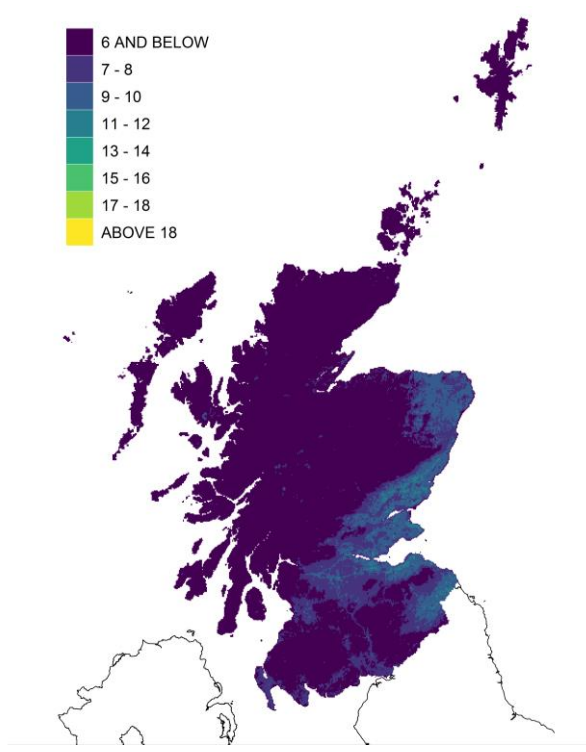


Figure 7.4 Roadside PM_{10} map for 2020, µg m^{-3} (Scotland-specific model)

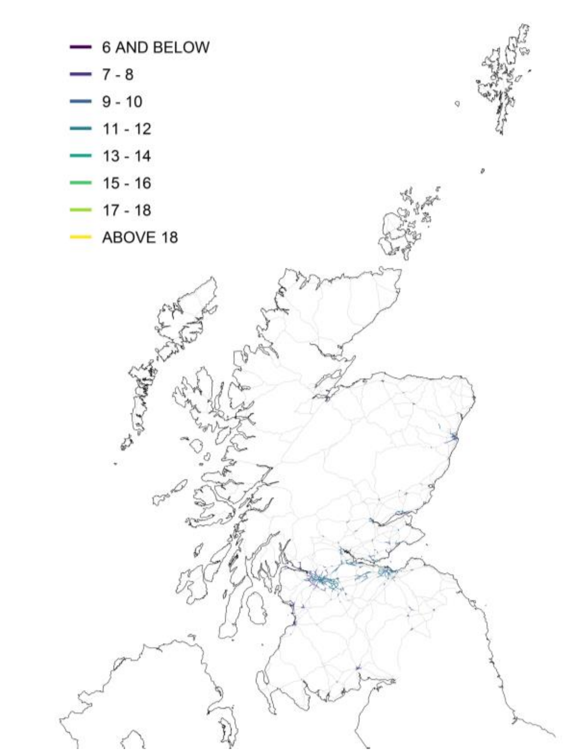


Table 7.3 Annual mean exceedance statistics for background PM_{10} in Scotland based on the Scotland-specific model, 2020.[3]

Zone or agglomeration	Total		>18 µg m^{-3}	
	Area (km^2)	Population	Area (km^2)	Population
Glasgow Urban Area	367	1,147,602	0	0
Edinburgh Urban Area	134	512,331	0	0
Central Scotland	10,064	1,995,307	0	0
North East Scotland	19,057	1,149,258	0	0
Highland	44,116	394,632	0	0
Scottish Borders	11,404	263,760	0	0
Total	**85,142**	**5,462,888**	**0**	**0**

[3] Note: Totals may differ from sum of individual sub-totals due to rounding.

7.1.3 $PM_{2.5}$ Maps for 2020

2020 annual mean concentrations of $PM_{2.5}$ were modelled for Scotland at background and roadside locations. The modelling methodology used is consistent with the PM_{10} model and further detail can be found in the 2020 UK mapping report[5]. The 2020 maps have been calibrated using measurements from sites for which co-located PM_{10} measurements are also available.

[5] Pugsley, K. L., J. R. Stedman, D. M. Brookes, A. J. Kent, R. J. Morris, S. L. Whiting, J. V. Wareham, and A. Goodhand. 2022. "Technical Report on UK Supplementary Modelling Assessment Under the Air Quality Standards Regulations 2010 for 2020." Ricardo Energy & Environment. https://uk-air.defra.gov.uk/library/reports?report_id=1022.

Maps of the modelled 2020 annual mean $PM_{2.5}$ concentrations for Scotland's background and roadside locations are shown in Figures 7.5 and 7.6, respectively.

Table 7.5 shows that there were no modelled exceedances of the Scottish annual mean $PM_{2.5}$ objective of 10 µg m^{-3} at background locations. Table 7.6 shows that there were no modelled exceedances of the Scottish annual mean $PM_{2.5}$ objective of 10 µg m^{-3} at roadside locations.

Figure 7.5 Background $PM_{2.5}$ map for 2020, µg m^{-3} (Scotland-specific model)

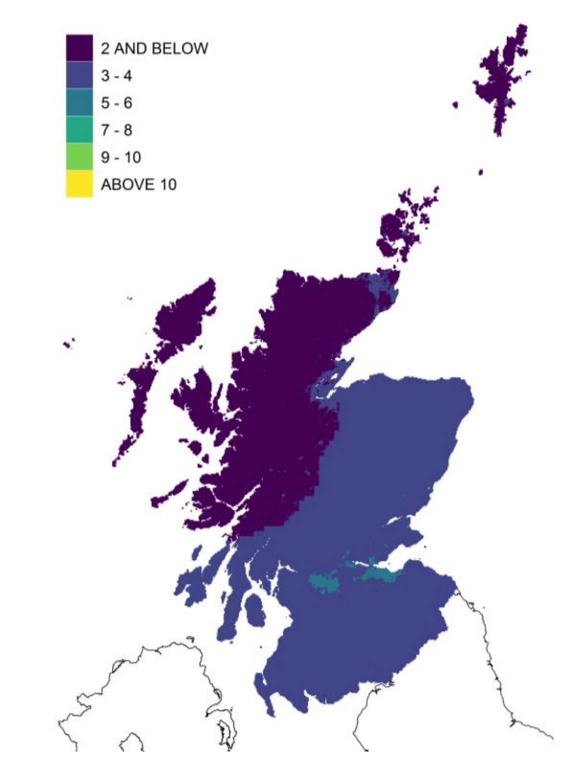


Figure 7.6 Roadside $PM_{2.5}$ map for 2020, µg m^{-3} (Scotland-specific model)

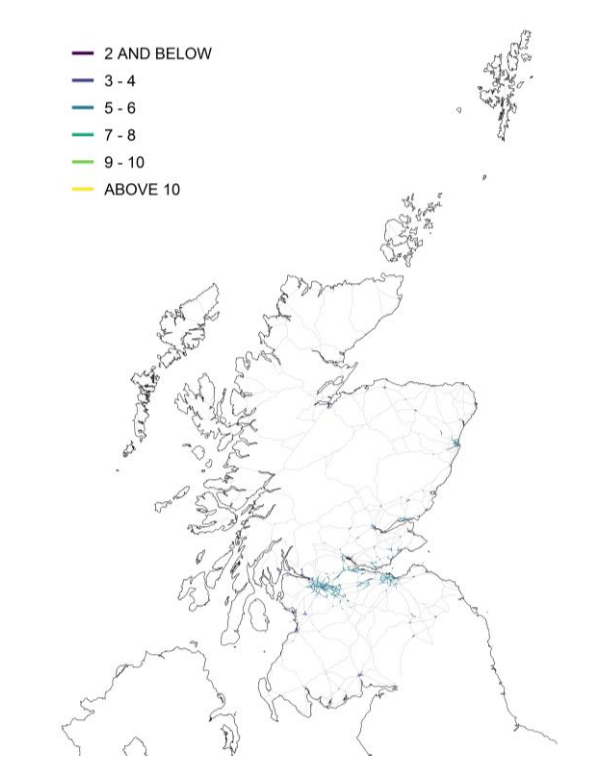


Table 7.5 Annual mean exceedance statistics for background $PM_{2.5}$ in Scotland based on the Scotland-specific model, 2020.[5]

Zone or agglomeration	Total		>10 µg m^{-3}	
	Area (km^2)	Population	Area (km^2)	Population
Glasgow Urban Area	367	1,147,602	0	0
Edinburgh Urban Area	134	512,331	0	0
Central Scotland	10,064	1,995,307	0	0
North East Scotland	19,057	1,149,258	0	0
Highland	44,116	394,632	0	0
Scottish Borders	11,404	263,760	0	0
Total	**85,142**	**5,462,888**	**0**	**0**

[5] Note: Totals may differ from sum of individual sub-totals due to rounding.

Table 7.6 Annual mean exceedance statistics for roadside $PM_{2.5}$ in Scotland based on the Scotland-specific model, 2020.[6]

Zone or agglomeration	Total		>10 µg m^{-3}	
	Road links	Length (km)	Road links	Length (km)
Glasgow Urban Area	305	429.6	0	0
Edinburgh Urban Area	71	117.9	0	0
Central Scotland	329	505.2	0	0
North East Scotland	180	261.9	0	0
Highland	45	67.4	0	0
Scottish Borders	51	56.4	0	0
Total	**981**	**1,438.4**	**0**	**0**

[6] Note: Totals may differ from sum of individual sub-totals due to rounding.

7.1.4 Forward projections from a base year of 2018

Forward projections of air pollutant concentrations to future years are not produced annually and were not carried out from a base year of 2020. The most recently available forward projections are from a base year of 2018. Background maps of PM_{10}, NO_X and NO_2 for the years 2018 to 2030 are provided to assist Scottish local authorities in support of the review and assessment of local air quality. These are available for download from the Data for Local Authority Review and Assessment purposes page on the Air Quality in Scotland website[6]. Please note the available projections from 2018 are based on assumptions that were applicable prior to the Covid-19 pandemic, and as such, do not reflect short- or long-term impacts of the pandemic and associated lockdowns on emissions in 2020 and beyond.

[6] https://www.scottishairquality.scot/data/mapping/data

8 AIR POLLUTION TRENDS FOR SCOTLAND

This section of the report summarises how air quality in Scotland has changed in recent years. It focuses on those pollutants which have exceeded their Air Quality Strategy objectives in recent years in Scotland. These pollutants are NO_2 and PM_{10}. As well as PM_{10}, trend analysis will also be carried out for $PM_{2.5}$. Ozone will also be analysed as previous trend analysis has indicated an increasing trend in some instances.

Automatic monitoring of oxides of nitrogen and of ozone has been routinely carried out in Scotland since 1987, with automatic PM_{10} monitoring carried out since the 1990s. However, until 2000 there were relatively few automatic monitoring sites. Subsequent years have seen the number of monitoring sites in the Scottish Air Quality database increase from 20 sites (in 2000) to the current total of 100 sites (as of May 2022). The data produced by these monitoring sites have improved our understanding of Scotland's pollution climate. However, the increase in site numbers potentially complicates the investigation of trends in air quality. If trend investigation is based on all available data, the apparent trends we see may not reflect real changes in Scotland's air quality; instead, they may be due to the changes in the number of sites (and their distribution). Therefore, in reports in this series from 2010 onwards, investigation of trends has been based on subsets of long-running sites.

These subsets are separated by site type classification as stated in the LAQM Technical Guidance (TG22). The subsets are Urban Background (UB), Rural Background (RB), and Urban Traffic (UT). Other site classifications used within this analysis also include Urban industrial (UI) and Suburban (S). There are two set of site classification used within the UK networks, the LAQM description and the 2008 Air Quality Directive description. A description of these classifications is provided in Table 8-1.

Table 8-1 Site classifications

AQD 2008 Directive	LAQM Description	Description
Urban Background	Urban Background and centre	Sites in an urban area away from major roads that are representative of exposure of the general population. Urban background sites should not be dominated by single sources and should be representative of a wide area
Rural Background	Rural	Sites in a rural area away from roads that are representative of exposure of the general population. Rural background sites should not be influenced by agglomerations or industrial sources and should be representative of a wide area
Urban Traffic	Roadside and Traffic	Sites in an urban area at least 25 metres from the edge of major junctions and no more than 10 metres from the kerbside
Urban Industrial	Industrial	Site in an urban residential area downwind of specific industrial source
Suburban	Suburban Background	Sites in a suburban area away from major roads that are representative of exposure of the general population. A suburban area is defined as a location type situated in a residential area on the outskirts of a town or city. Suburban background sites should not be dominated by single sources and should be representative of a wide area

(Local Air Quality Management Technical Guidance (TG16), Feb 2018)

All the sites featured in this section have been in operation for a minimum of five consecutive years, as this is usually considered to be the minimum required in order to assess long-term trends at a monitoring site. In most cases it is now possible to do trend analysis for longer periods, for example ten years.

The trend analysis presented in this section has been carried out using Openair: a free, open-source software package of tools for analysis of air pollution data. Openair was initially funded by the Natural

Environment Research Council (NERC), with additional funds from Defra[7]. The Openair project is now maintained by Dr David Carslaw, of Ricardo Energy & Environment/ University of York and Dr Karl Ropkins of the University of Leeds. A range of Openair tools are available on the "Air Quality in Scotland" website: for more information on the tools and how to use them, please see:

https://www.scottishairquality.scot/data/openair

For this and previous reports the Openair "TheilSen" analysis tool was used. This uses the Theil-Sen statistical method to determine trends in pollutant concentrations over several years. The trend analysis is based on monthly mean pollutant concentrations. Openair includes an option to "de-seasonalise" the data (i.e. statistically modify the plotted data to remove the influence of seasonal cycles, thus providing a clearer indication of the overall trend over the relevant time). The "de-seasonalise" option has been used in all the Theil-Sen trend graphs presented here. When the de-seasonalise option is used, Openair fills in any gaps in the data using a linear interpolation method.

In these plots the trend line is shown by a solid red line, with 95% confidence intervals for the trend shown by dotted red lines. The trend is given at the top of the plot in green, with confidence intervals shown in square brackets. The trend is given as units (i.e. $\mu g\ m^{-3}$) per year, over the period shown. This may be followed by a number of stars, with * indicating that the trend is statistically significant at the 0.05 level (low significance), ** indicating significance at the 0.01 level (significant) and *** indicating significance at the 0.001 level (highly significant). The symbol + indicates that the trend is significant at the 0.1 level.

8.1 NITROGEN DIOXIDE

In Scotland (as elsewhere in the UK) the largest number of Air Quality Management Areas (AQMAs) has been declared in response to exceedances of objectives for nitrogen dioxide (NO_2). This is also reflected in the number of monitoring stations (both automatic and passive) historically reporting exceedances (in particular the annual mean NO_2 objective of 40 $\mu g\ m^{-3}$) for this pollutant. It is therefore important to understand how concentrations of this pollutant are varying with time.

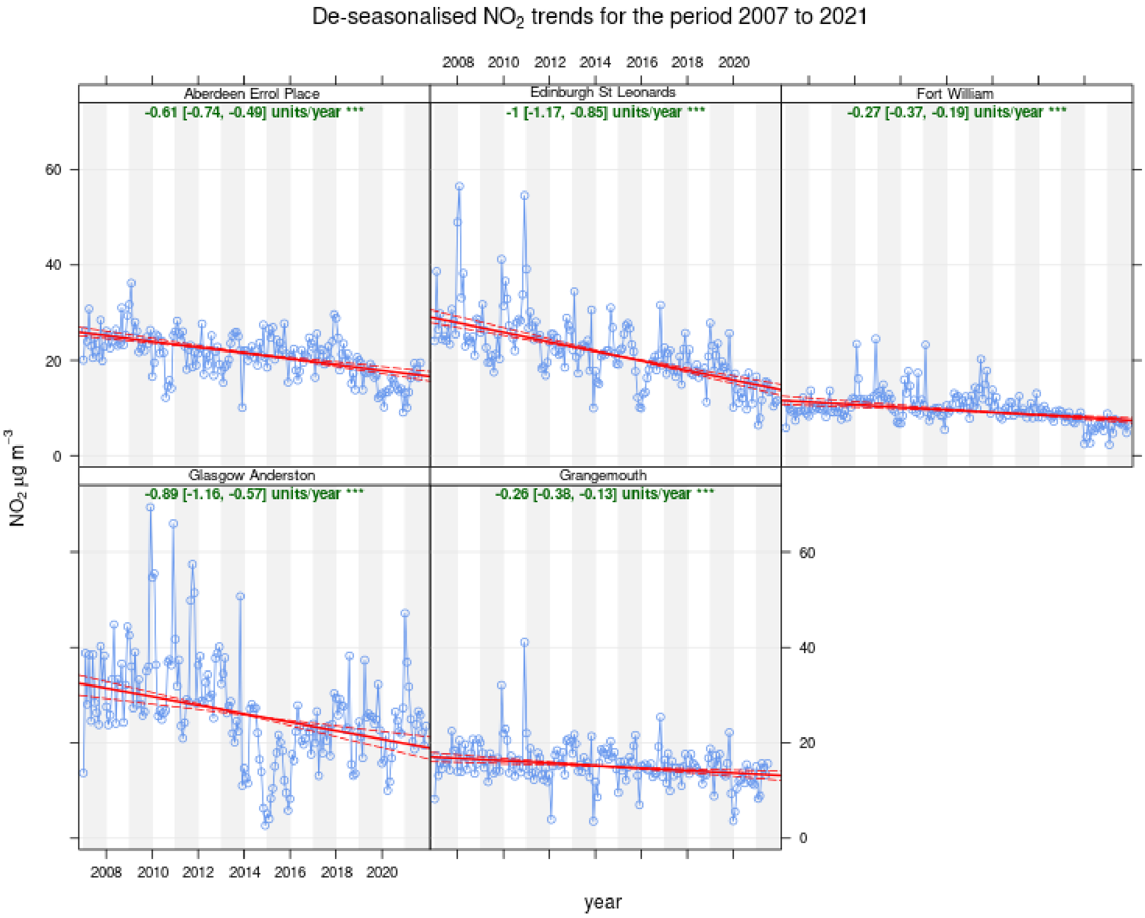
8.1.1 NO_2 at Urban Background Sites

There are relatively few long-running urban background monitoring stations in Scotland. Five urban non-roadside sites have been in operation for the past 15 years. These are as follows: Aberdeen Errol Place, Edinburgh St Leonards, Fort William, Glasgow Anderston and Grangemouth. Fort William is classified as a 'suburban' site, Grangemouth is an 'urban industrial' site, and the other three are 'urban background'.

The Openair Theil-Sen function has been used to quantify trends in NO_2 at these five urban non-roadside monitoring stations, over the 15-year period 2007-2021: the trend plots for NO_2 are shown in Figure 8-1. *Please note that both Edinburgh St Leonards and Glasgow Anderston have large gaps in their 2014 and 2015 datasets: as stated above, where there are gaps in the data, Openair fills these in using an interpolation method*.

[7] Carslaw DC and Ropkins K (2012). "Openair — An R package for air quality data analysis." Environmental Modelling & Software, 27–28(0), pp. 52–61. ISSN 1364-8152, doi: 10.1016/j.envsoft.2011.09.008.

Figure 8-1 Trends in NO_2 concentrations at five long-running Urban Non-Roadside sites, 2007-2021

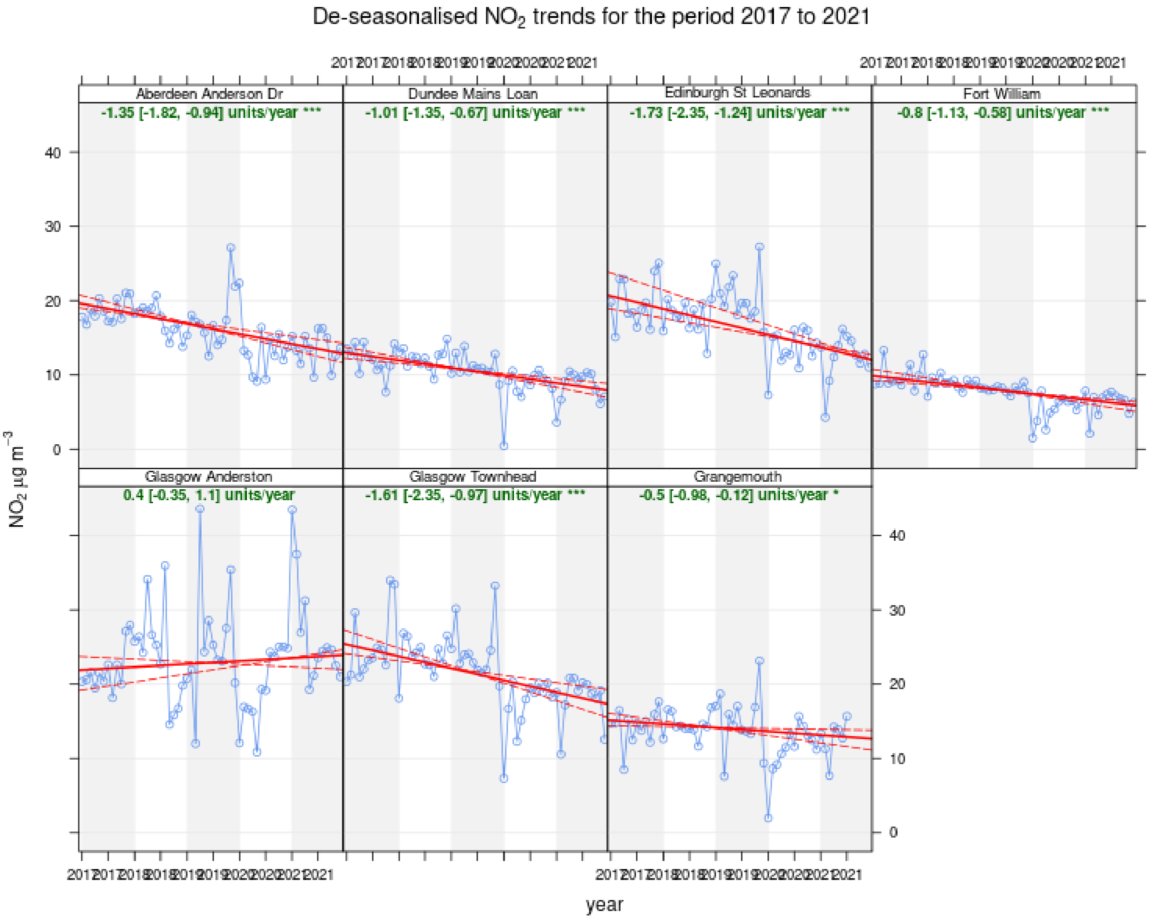


All sites display highly significant negative trends (at the 0.001 level) over the last 15 years. This analysis indicates that the decreasing trend in NO_2 concentrations is becoming more substantial over this time period.

Figure 8-2 takes into consideration all urban background sites in Scotland over the past five years, including the sites at Dundee Mains Loan and Glasgow Townhead. In the last five years Glasgow Anderston has switched from a decreasing trend in NO_2 concentrations to an increasing trend, although this is not statistically significant. This contradicts the perception that NO_2 concentrations are decreasing at all urban background sites in the long-term. The decreasing trend at Grangemouth is also no longer highly significant and is only significant at the 0.05 level.

The impact of the Covid-19 lockdowns was a dramatic decrease in concentrations in the first half of 2020 and early 2021. Concentrations then quickly returned to what could be considered pre-lockdown levels once restrictions were lifted.

Figure 8-2 Trends in NO_2 concentrations at all Urban Background sites, 2017-2021

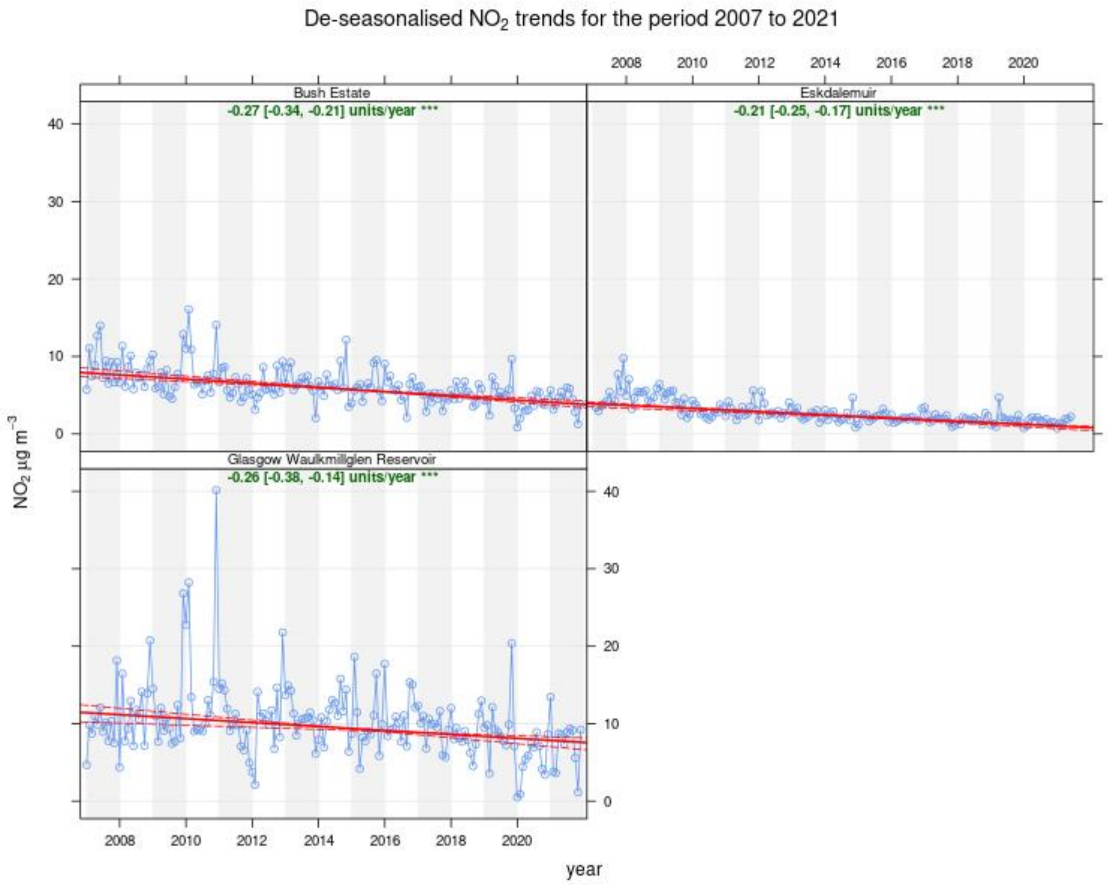


8.1.2 NO_2 at Rural Sites

There are three long-running rural sites which have monitored oxides of nitrogen for more than 10 years: Bush Estate (to the south of Edinburgh close to the Pentland Hills Regional Park), Eskdalemuir and Glasgow Waulkmillglen Reservoir. Figure 8-3 shows trends in NO_2 concentration at these sites.

All three sites show small but highly significant decreasing trends. In previous years Glasgow Waulkmillglen Reservoir showed no significant downward trend however there is now a highly significant decreasing trend. The drop in concentrations seen in 2020 and 2021 due to the lockdown restrictions may have influenced this change.

Figure 8-3 Trends in NO_2 concentrations at three Rural sites, 2007 – 2021



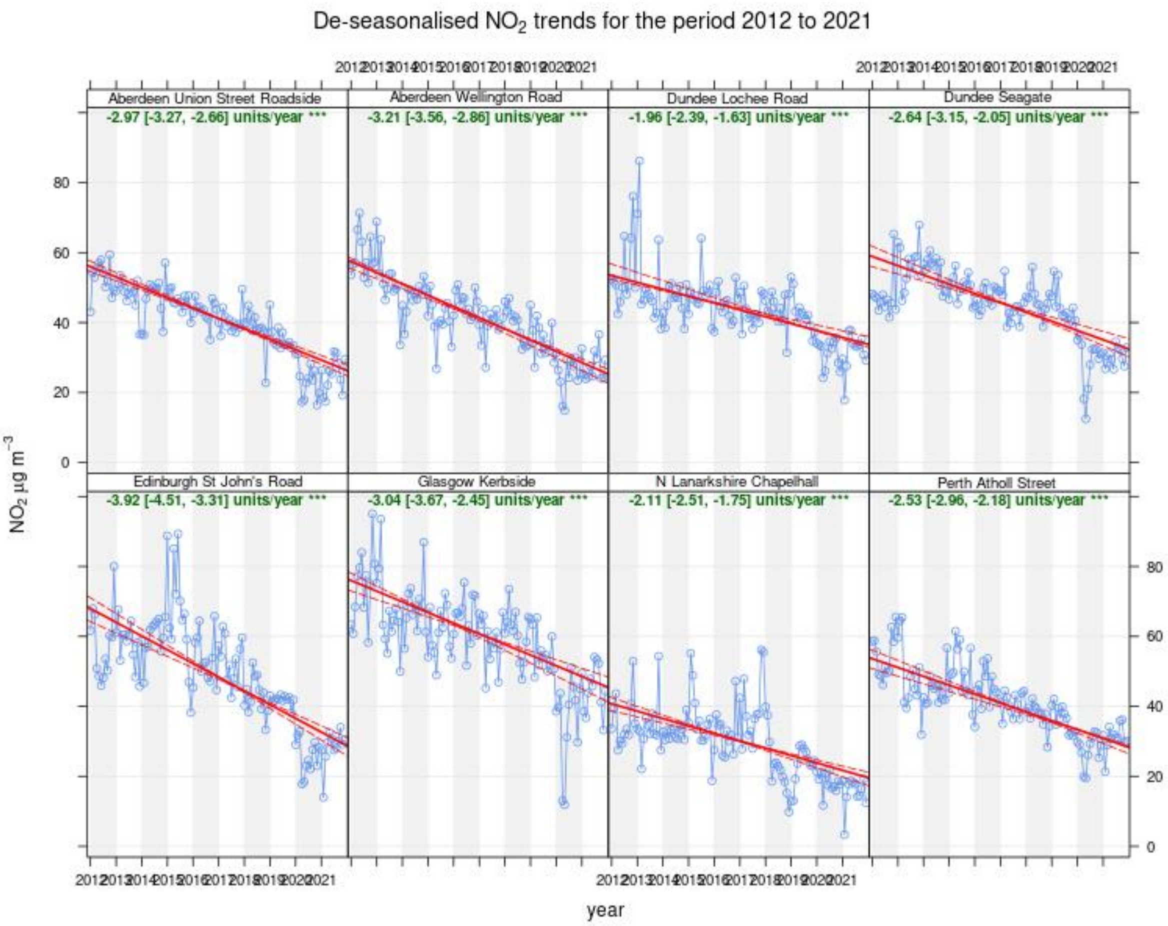
8.1.3 NO_2 at Urban Traffic Sites

There are now over 40 roadside or kerbside monitoring stations that have been in operation for 10 years or more and are still in operation. These are as follows:

- Aberdeen Anderson Drive
- Aberdeen King Street
- Aberdeen Market Street
- Aberdeen Union Street
- Aberdeen Wellington Road
- Dumfries
- Dundee Lochee Road
- Dundee Seagate
- Dundee Whitehall Road
- East Dunbartonshire Bearsden
- East Dunbartonshire Bishopbriggs
- East Dunbartonshire Kirkintilloch
- Edinburgh Gorgie Road
- Edinburgh Salamander Street
- Edinburgh St John's Road
- Falkirk Haggs
- Falkirk Hope Street
- Falkirk Park Street
- Falkirk West Bridge Street
- Fife Cupar
- Fife Dunfermline
- Fife Rosyth
- Glasgow Byres Road
- Glasgow Kerbside (Hope Street)
- Inverness
- North Lanarkshire Chapelhall
- North Lanarkshire Shawhead Coatbridge
- North Lanarkshire Croy
- North Ayrshire Irvine High Street
- Paisley Gordon Street
- Perth Atholl Street
- Perth High Street
- South Ayrshire Ayr High St
- South Lanarkshire East Kilbride
- Stirling Craig's Roundabout
- West Dunbartonshire Clydebank
- West Dunbartonshire Glasgow Road
- West Lothian Broxburn
- West Lothian Linlithgow High Street

There are a large number of long-running sites in operation, therefore for the purposes of this report eight were selected based on measured exceedances of the Air Quality Strategy Objective for annual mean NO_2 (40 µg m^{-3}) in recent years. These are as follows: Aberdeen Union Street, Aberdeen Wellington Road, Dundee Lochee Road, Dundee Seagate, Edinburgh St John's Road, Glasgow Kerbside (Hope Street), N Lanarkshire Chapelhall and Perth Atholl Street. Figure 8-4 shows highly significant decreasing trends (at the 0.001 level) at all eight sites.

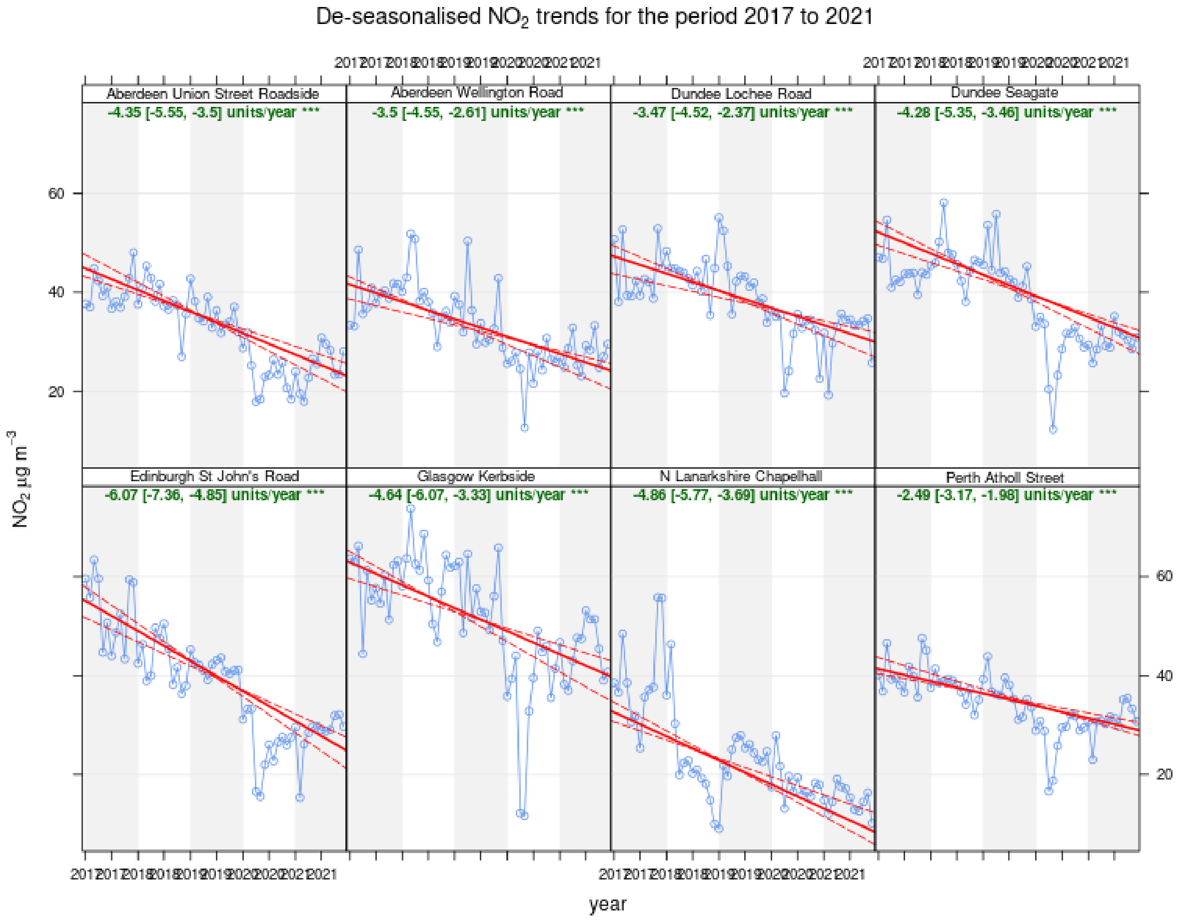
Figure 8-4 Trends in NO_2 concentrations at eight long-running Urban Traffic sites with exceedances, 2012 – 2021



Trends over the most recent five complete years, 2017 – 2021, have also been examined for these sites. These are shown in Figure 8-5. Comparing the ten-year and five-year trends, both show decreasing trends of high significance. At all sites, the decreasing trend has become greater in magnitude over the past five years compared to the past ten.

The influence of the lockdowns in 2020 and early 2021 is far more evident at the urban traffic sites which has resulted in the significant increase in the decreasing trends when looking at the past five years' data. It also shows the difference the lockdown has had between urban and background/rural sites. Whereas at background sites the drop is only really seen in the first half of 2020, at urban sites the step change is seen across the whole year.

Figure 8-5 Recent trends in NO_2 concentrations at eight long-running Urban Traffic sites with exceedances, 2017-2021



8.2 PARTICULATE MATTER AS PM_{10}

This pollutant is of particular interest because:

- Current evidence suggests that there is no safe level of particulate matter in terms of human health effects.
- Scotland's current annual mean PM_{10} objective is 18 µg m^{-3}, which is more stringent than the objective of 40 µg m^{-3} adopted in the rest of the UK.
- In 2016 Scotland opted to make its annual mean $PM_{2.5}$ objective more stringent, by reducing it from 12 µg m^{-3} to 10 µg m^{-3} in line with the World Health Organization guideline.

During the period covered by this trend analysis, many of Scotland's monitoring sites have used the Tapered Element Oscillating Microbalance (TEOM) to monitor PM_{10}. For the reasons discussed in Section 5 it is necessary to correct TEOM data for possible evaporation of the volatile component (due to the high operating temperature of the TEOM, necessary to prevent condensation on the filter). For years up to and including 2008 the conventional way of doing this was to apply a factor of 1.3 to the data, and the data presented here for those years have been adjusted in this way. However, in 2009 a better correction method became available: the King's College Volatile Correction Model (VCM), which can be found at http://www.volatile-correction-model.info/ . This model uses measurements from nearby FDMS-TEOM instruments (which measure both the volatile and non-volatile fraction) to calculate and apply a correction to the daily or hourly dataset. This is now the recommended method and has been used for the data presented here for years 2009 onwards, from sites where the TEOM are still being used. Over the past four years the number of TEOM and FDMS-TEOM used to measure particulate matter has significantly reduced with only one, Paisley Gordon Street remaining in 2021

8.2.1 PM_{10} at Urban Background Sites

There are now eight urban background sites in Scotland that have been monitoring PM_{10} for ten years or longer. These are: Aberdeen Errol Place (TEOM, converted to FDMS in 2009, and then to FIDAS in November 2019), Dundee Broughty Ferry Road (TEOM, data VCM corrected, converted to FIDAS in January 2020), Dundee Mains Loan (TEOM, data VCM corrected, converted to FIDAS in October 2017), Edinburgh St Leonards (FDMS, converted to a FIDAS in July 2019), Glasgow Anderston (FDMS since 2011, converted to FIDAS in November 2018), Grangemouth (FDMS since 2009, changed to BAMs June 2018), Falkirk Grangemouth MC (TEOM, converted to FIDAS in May 2020), and North Lanarkshire Coatbridge Whifflet (TEOM, converted to FIDAS in January 2020). Dundee Broughty Ferry Road and Grangemouth are urban industrial; the rest are urban background.

Figure 8-6 shows trends in de-seasonalised monthly mean PM_{10} at this subset of long-running sites. All eight sites showed a highly statistically significant (at the 0.001 level) decreasing trend. Trends in the most recent five years are also examined in Figure 8-7. Although the decreasing trend is still evident at all sites over the past five years it is no longer highly significant at all sites.

Figure 8-6 Trends in PM_{10} concentrations at six long-running Urban Background and Urban Industrial sites, 2008 – 2021

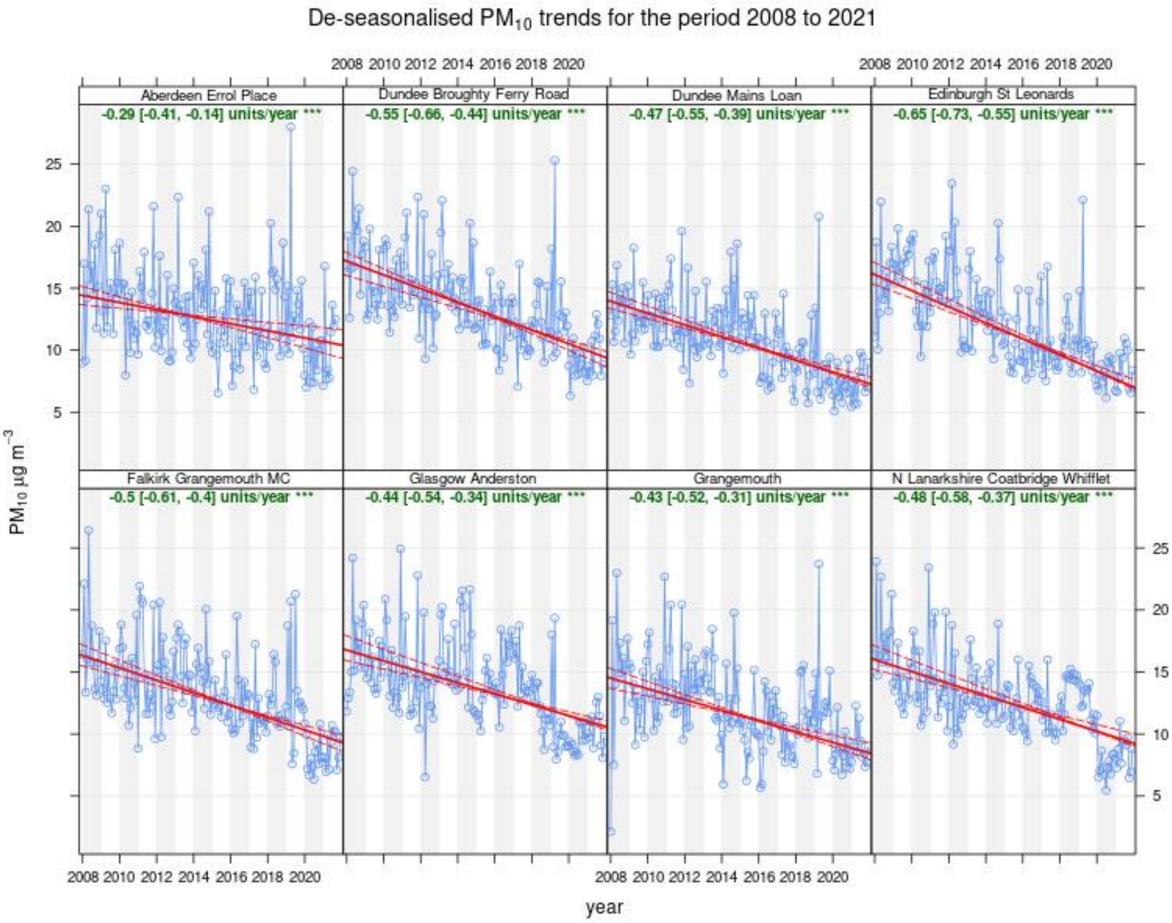
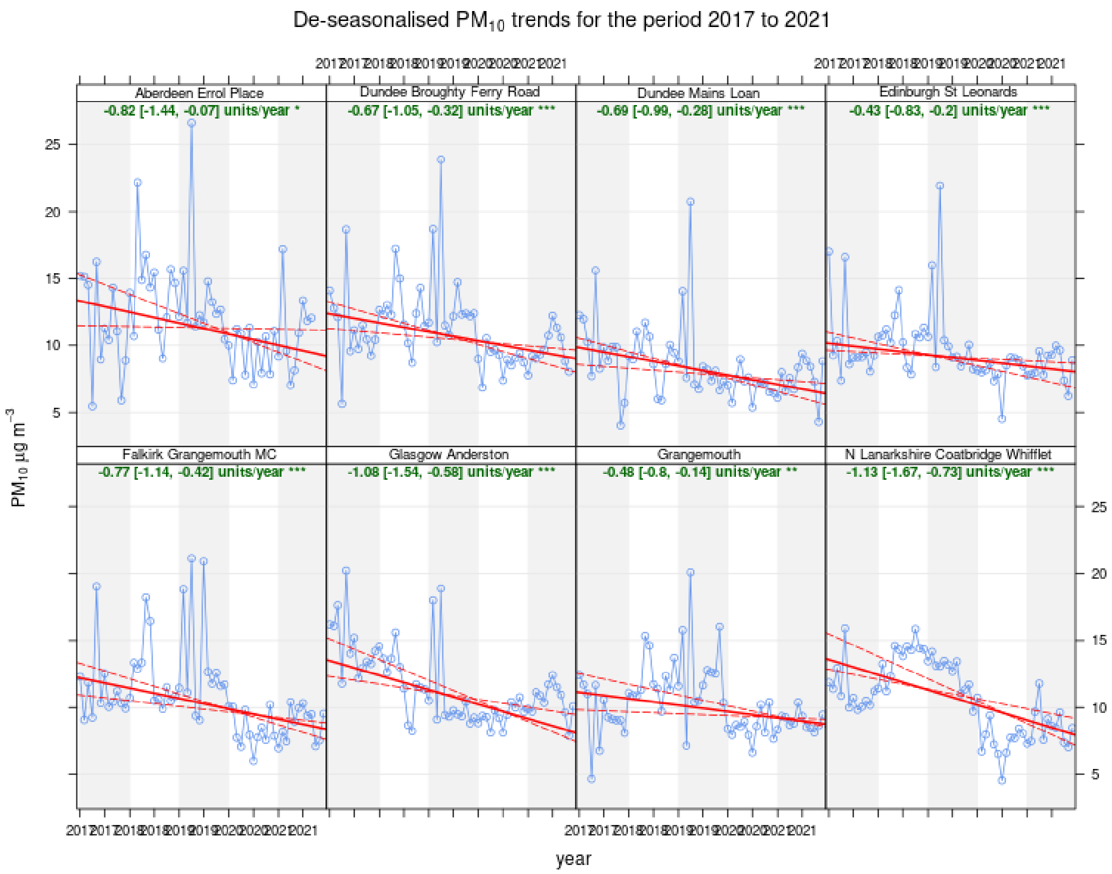


Figure 8-7 Trends in PM_{10} concentrations at six long-running Urban Background and Urban Industrial sites, 2017 – 2021



8.2.2 PM_{10} at Urban Traffic Sites

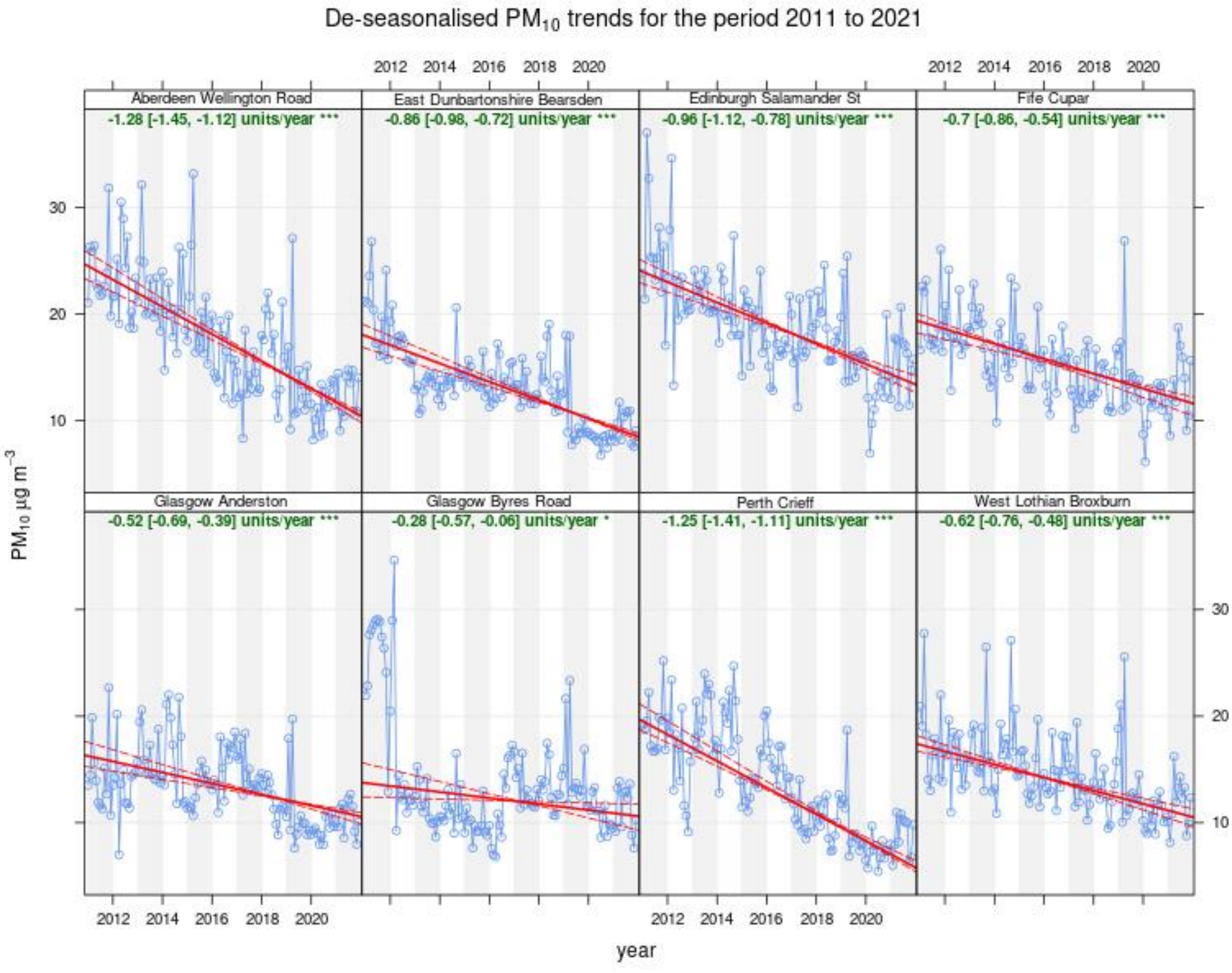
There are 34 PM_{10} monitoring sites in Scotland that have been monitoring for over 10 years. These are as follows:

- Angus Forfar
- Aberdeen King Street
- Aberdeen Union Street Roadside
- Aberdeen Wellington Road
- Alloa
- East Dunbartonshire Bearsden
- East Dunbartonshire Bishopbriggs
- East Dunbartonshire Kirkintilloch
- East Lothian Musselburgh N High St
- Edinburgh Salamander St
- Falkirk Hope St
- Falkirk Park St
- Falkirk West Bridge Street
- Fife Cupar
- Fife Rosyth
- Glasgow Abercromby Street
- Glasgow Anderston
- Glasgow Broomhill
- Glasgow Byres Road
- Glasgow Nithsdale Road
- Glasgow Waulkmillglen Reservoir
- Grangemouth Moray
- N Lanarkshire Coatbridge Whifflet
- N Lanarkshire Shawhead Coatbridge
- North Ayrshire Irvine High St
- Paisley Gordon Street
- Perth Atholl Street
- Perth Crieff
- Perth High Street
- South Ayrshire Ayr High St
- South Lanarkshire East Kilbride
- Stirling Craig's Roundabout
- West Dunbartonshire Clydebank
- West Lothian Broxburn
- West Lothian Whitburn

Trends in de-seasonalised monthly mean PM_{10} concentrations for eight traffic-related sites in operation since 2009 or earlier are shown in Figure 8-8. The sites selected for this analysis are Aberdeen Wellington Road (FDMS, Converted to FIDAS in September 2016), East Dunbartonshire Bearsden (Aberline, converted to FIDAS in January 2019), Edinburgh Salamander (TEOM, Converted to December 2020), Fife Cupar (FDMS, converted to FIDAS in December 2016) , Glasgow Anderston (FDMS, converted to FIDAS in November 2018), Glasgow Byres Road (FDMS, converted to FIDAS in December 2017), Perth Crieff (BAM, converted to FIDAS in December 2017) and West Lothian Broxburn (FDMS, Converted to FIDAS in September 2017). These sites were selected for analysis because of the length of time they have been monitoring (10 years or more), present or historical exceedances of the annual mean objective and geographical coverage.

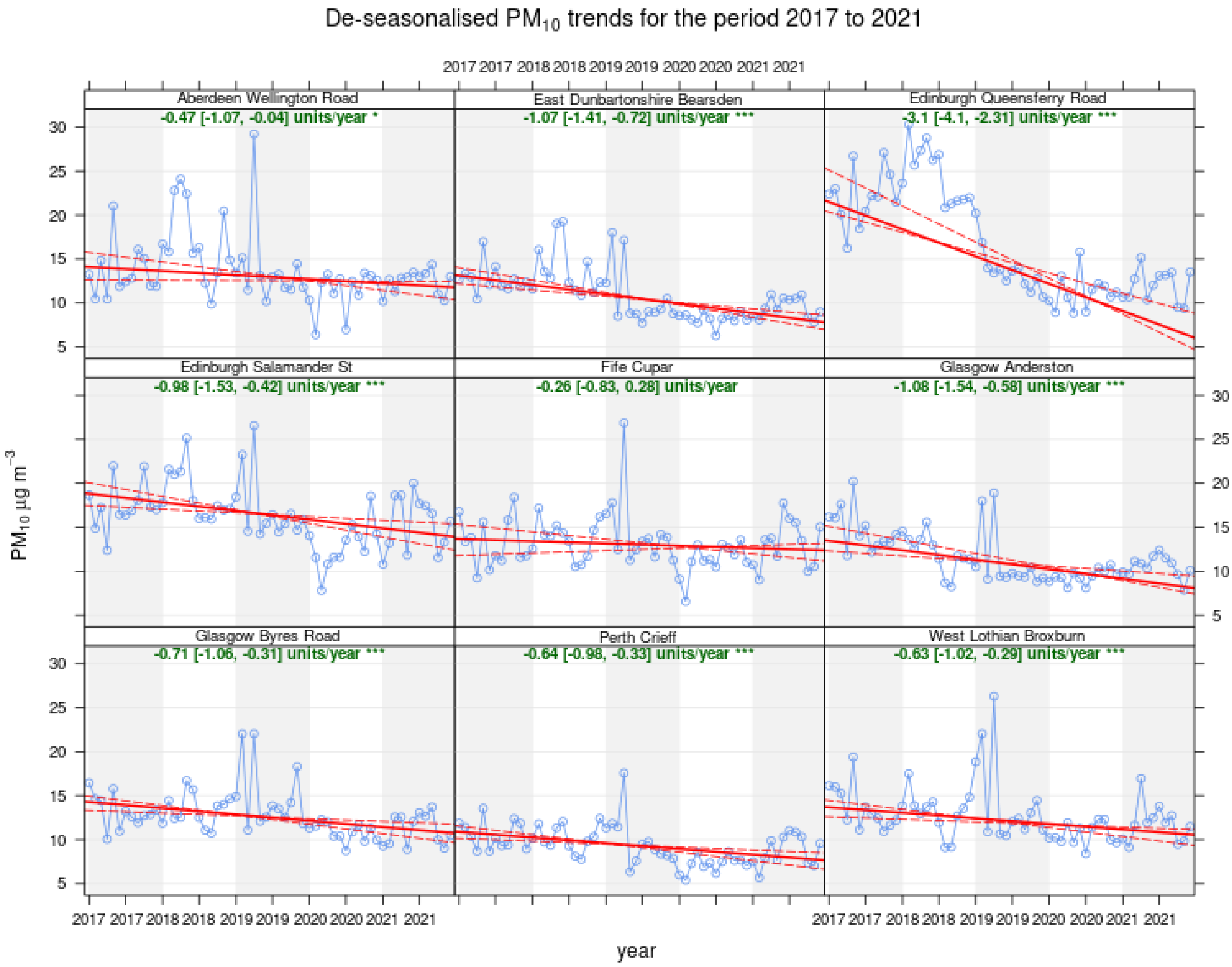
All sites showed highly statistically significant decreasing trends (at the 0.001 level), with the exception of Glasgow Byres Road which is only significant at the 0.05 level. The trends indicate that PM_{10} over the past 10 years is decreasing year on year at the majority of these roadside sites.

Figure 8-8 Trends in PM_{10} concentrations at eight long-running Urban Traffic sites, 2012 – 2021



Trends in de-seasonalised monthly mean PM_{10} concentrations for the same eight sites (plus Edinburgh Queensferry Road), for the most recent five complete years 2017 – 2021, are shown in Figure 8-9. At these sites, PM_{10} concentrations over the past five years also show a highly significant decreasing trend with the exception of Aberdeen Wellington Road and Fife Cupar sites. Here the trend is still decreasing however not statistically significant, indicating a levelling off.

Figure 8-9 Trends in PM_{10} concentrations at eight long-running Urban Traffic sites, 2017 – 2021

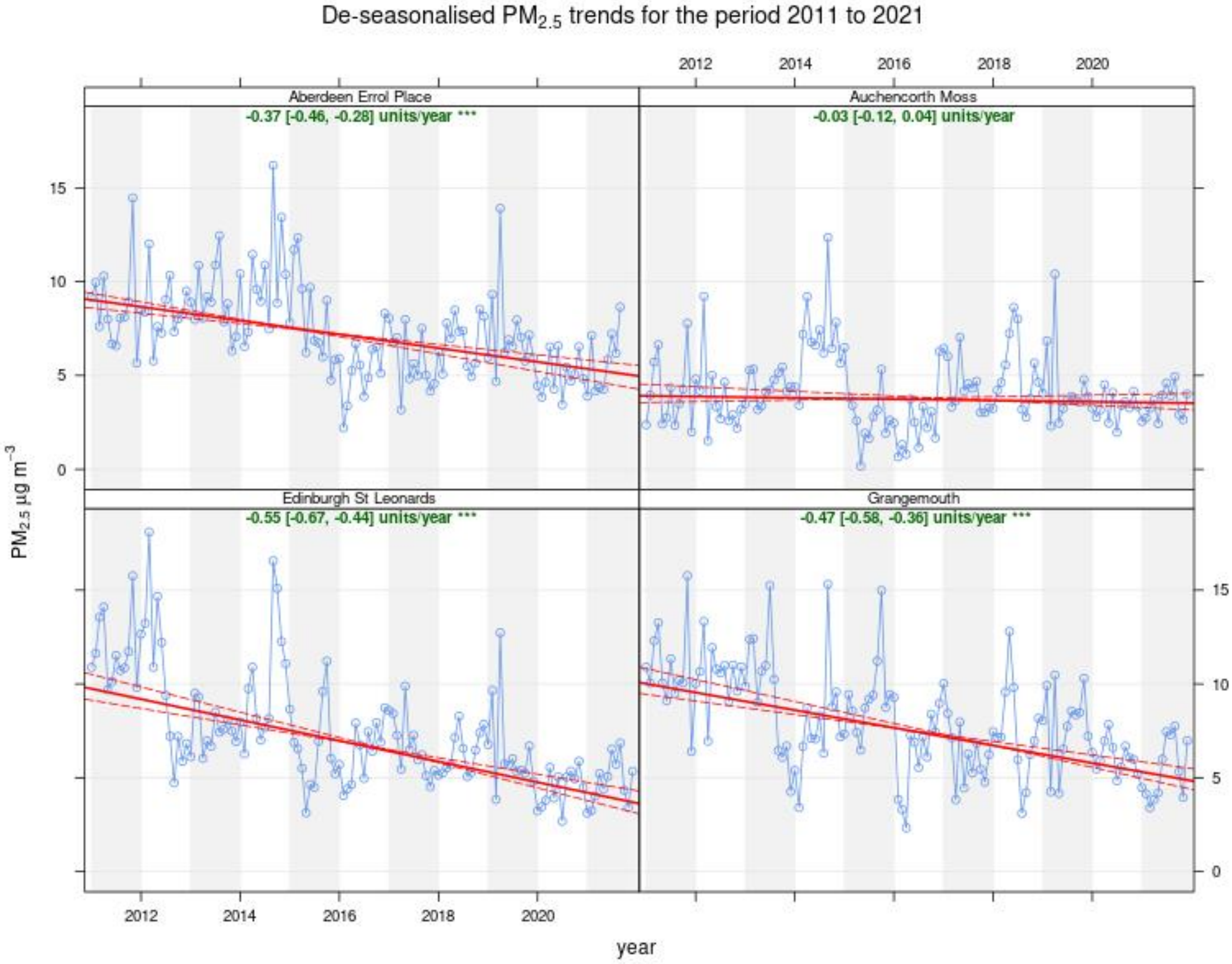


8.3 PARTICULATE MATTER AS $PM_{2.5}$

In earlier years, most monitoring of particulate air pollution was focused on the PM_{10} size fraction. However, the finer fractions such as $PM_{2.5}$ are now of more interest in terms of health effects. Fine particles can be carried deep into the lungs where they can cause inflammation and a worsening of the condition of people with heart and lung diseases. They may also carry harmful compounds, adsorbed on their surfaces, into the lungs.

At the time of writing this report there are 83 sites monitoring $PM_{2.5}$ in Scotland. However, the vast majority of these sites started monitoring in the last five years with the introduction of the $PM_{2.5}$ objective and the requirement for local authorities to measure the pollutant. By the end of 2021 there were four sites with 10 consecutive years of $PM_{2.5}$ data. These sites are as follows: Aberdeen Errol Place (UB), Auchencorth Moss (RB), Edinburgh St Leonards (UB), and Grangemouth (UI). The trend plot for these sites is shown in Figure 8-10.

Figure 8-10 Trends in $PM_{2.5}$ concentrations at four long-running monitoring sites, 2011 – 2021

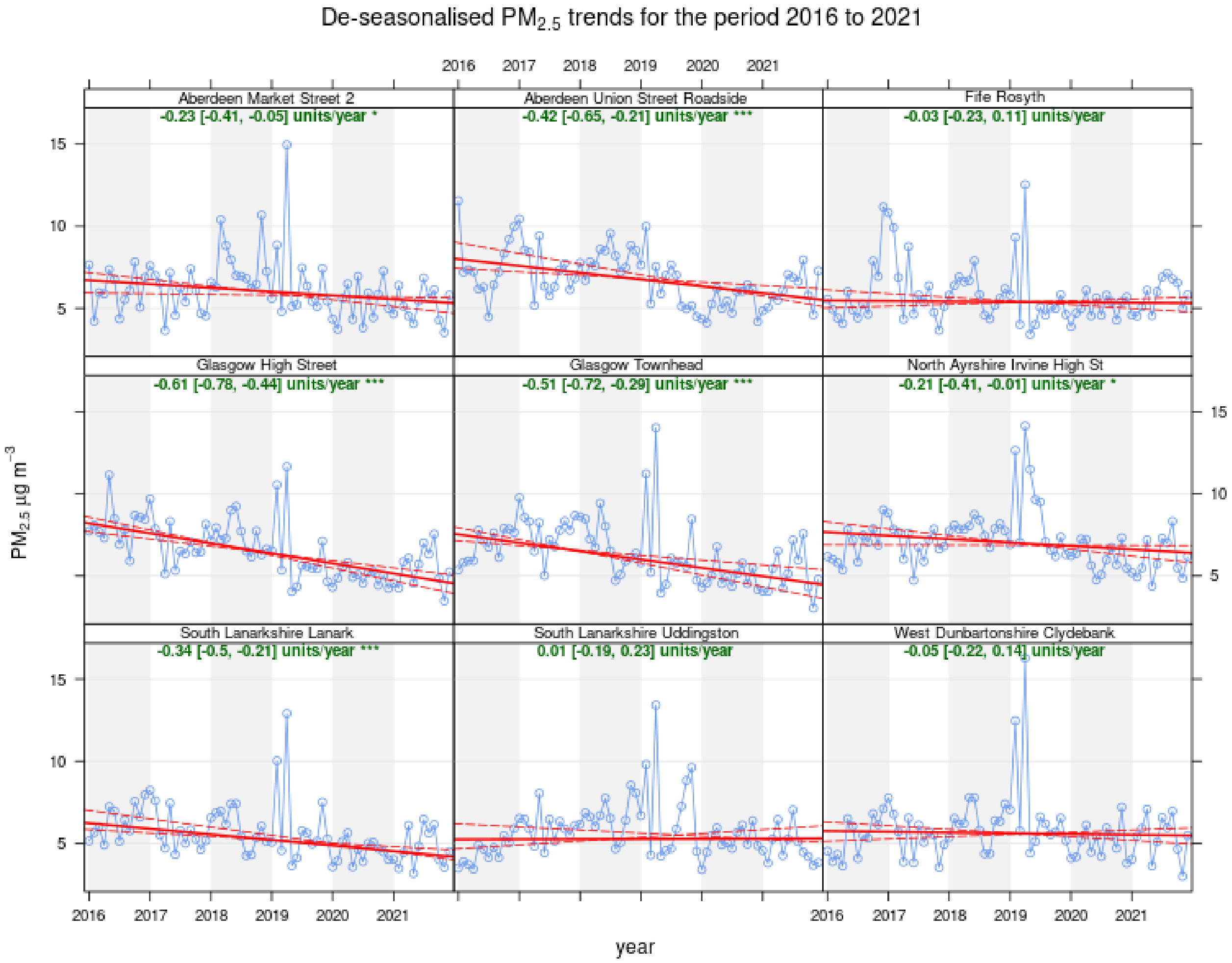


Aberdeen Errol Place, Edinburgh St Leonards, and Grangemouth sites show slight but highly statistically significant (at the 0.001 level) decreasing trends for $PM_{2.5}$. Contrary to this, the rural site Auchencorth Moss shows no trend indicating no real change in concentrations over the past 10 years.

As of the end of 2021, there were an additional nine sites with five years' worth of data, the minimum required for trend analysis. The sites are Glasgow Townhead, Aberdeen Union Street, Aberdeen Market Street (UT) Glasgow High Street, West Dunbartonshire Clydebank, South Lanarkshire Lanark, South Lanarkshire Uddingston, North Ayrshire Irvine High Street, and Fife Rosyth. All sites are Urban traffic sites with the exception of Glasgow Townhead which is Urban Background.

Figure 8-11 illustrates the trend for the nine $PM_{2.5}$ sites. As can be seen, there are four sites (Aberdeen Union St, Glasgow High Street, Glasgow Townhead and Lanark) have highly significant decreasing trends. Four other sites, though downward, have no real identifiable statistically significant trend except Aberdeen Market Street. South Lanarkshire Uddingston has an increasing trend though not statistically significant.

Figure 8-11 Trends in $PM_{2.5}$ concentrations at nine long-running monitoring sites, 2016 – 2021



8.4 OZONE

8.4.1 Rural Ozone

Three of Scotland's rural air quality monitoring stations have been monitoring ozone for 32 years, 1986 – 2021. These are Bush Estate, Eskdalemuir and Strath Vaich. Figure 8-12 shows long-term trends in de-seasonalised monthly mean ozone (O_3) concentrations at these three exceptionally long-running rural monitoring sites. All three sites showed a small increasing trend in monthly mean rural ozone concentrations over this period. For Bush Estate and Eskdalemuir this trend was highly statistically significant. For Strath Vaich the trend was minimal and not statistically significant. The charts also show considerable fluctuation; this may reflect the fact that ozone is formed by reactions involving other pollutant gases, in the presence of sunlight. Thus, ozone concentrations depend substantially on weather conditions. There is also evidence that the "hemispheric background" concentration of O_3 has increased since the 1950s due to the contribution from human activities.[8]

Six sites have been in operation for over 10 years. These are the above three sites, plus Auchencorth Moss, Glasgow Waulkmillglen Reservoir and Lerwick. Trends in ozone concentration at these six sites are shown in Figure 8-13. The ten-year trends show that four sites have increasing trends in O_3 concentrations at varying levels of statistical significance. The other two sites (Bush Estates and Strath Vaich) have slight decreasing trends; however Bush Estate shows no real significance and Strath Vaich is significant to 0.05.

[8] See the APIS webpage "Ozone" at http://www.apis.ac.uk/overview/pollutants/overview_O3.htm

Figure 8-12 Trends in O_3 concentrations at long-running rural sites, 1986 – 2021

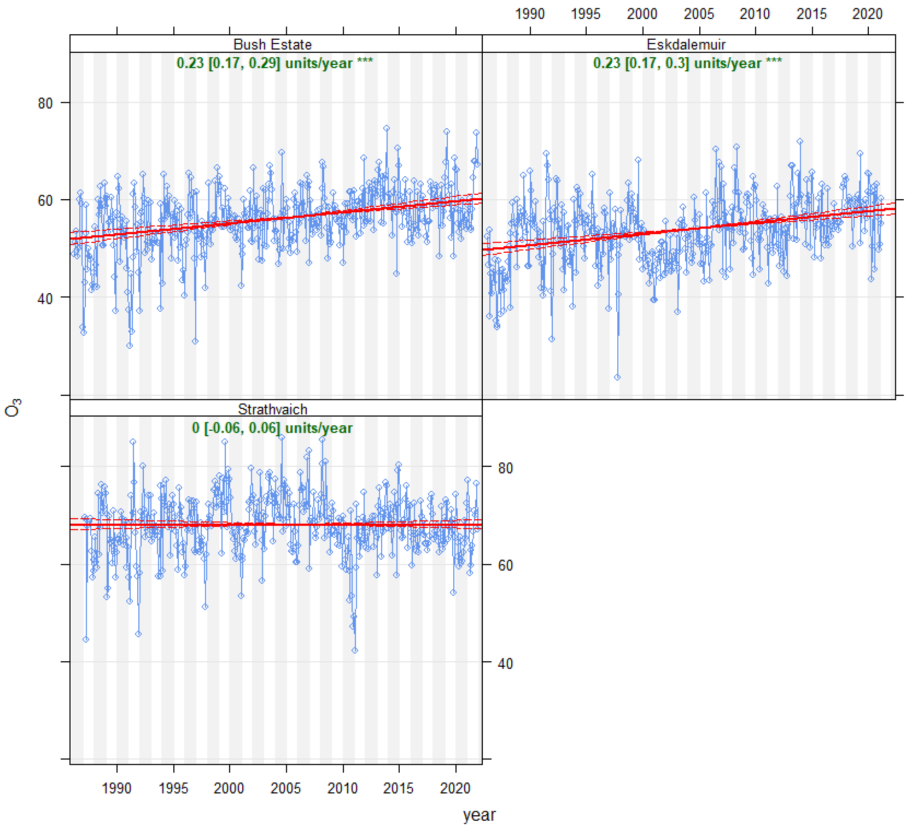
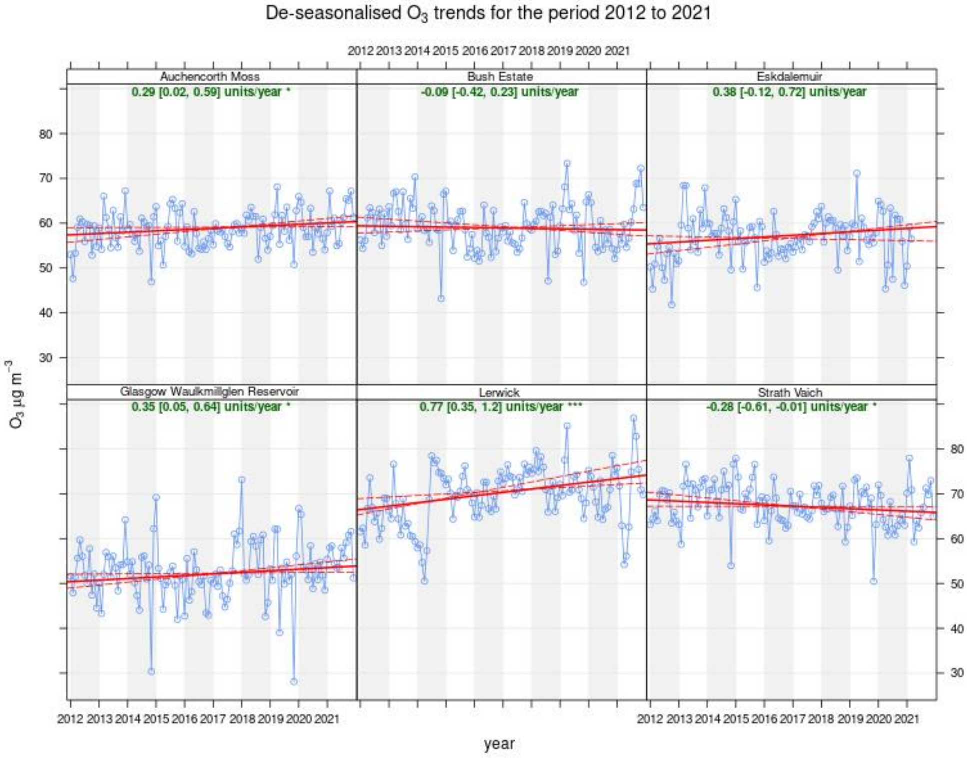


Figure 8-13 Trends in O_3 concentrations at six long-running Rural sites, 2012 – 2021



8.4.2 Urban Background Ozone

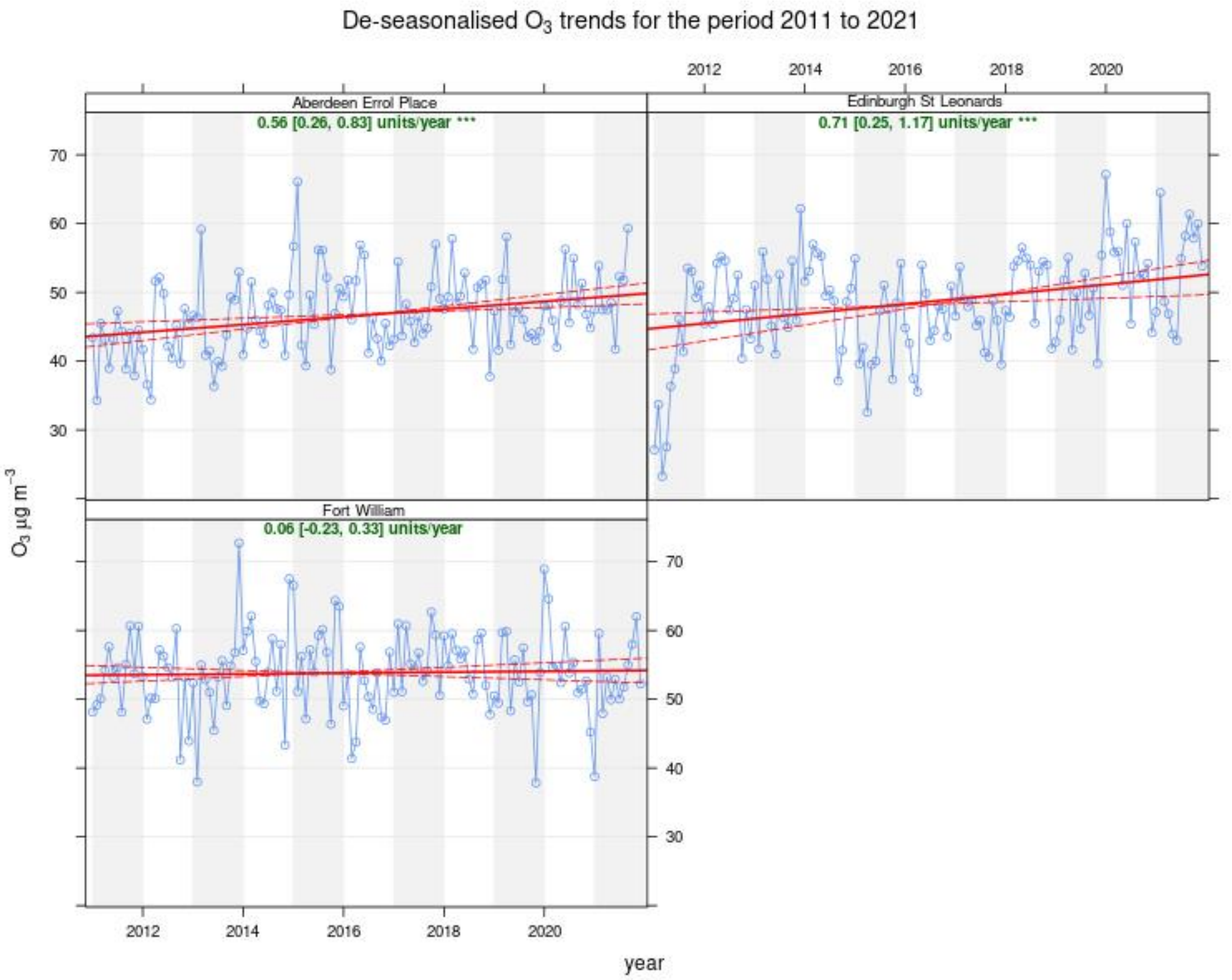
Figure 8-14 shows trends in de-seasonalised monthly mean ozone concentrations at the three Scottish urban background monitoring sites which have been monitoring ozone for the past 10 years, 2011-2021: Aberdeen Errol Place, Edinburgh St Leonards and Fort William.

There is again an increasing trend at all three sites, highly significant at Aberdeen Errol Place and St Leonards but not statistically significant at Fort William.

At Edinburgh St Leonards there was a noticeable dip in measured ozone concentrations in 2011. The reason for this is unknown and an investigation of these low data has confirmed that the analyser was operating within its usual parameters at this time. Since no reason could be found to discard the data, they must be assumed to be genuine.

Contrary to other pollutants analysed in this section, there appears to be an (though not always statistically significant) increasing trend in ozone concentrations. This is consistent with previous years' reports.

Figure 8-14 Trends in O_3 concentrations at two long-running Urban Background sites, 2011 – 2021



8.5 ADDITIONAL TREND ANALYSIS

Additional analysis can be carried out on the SAQD monitoring data using analysis tools such as Openair. Openair provides free, open-source and innovative tools to analyse, interpret and understand air pollution data using R a free and open-source programming language designed for the analysis of data (https://www.r-project.org/). The Openair tools available on the Air Quality in Scotland website (http://www.scottishairquality.scot/data/openair) can be used to readily perform complex and innovative analysis of current and archived air pollutant data, allowing powerful data visualisation and interrogation capabilities. This annual analysis is also now provided in the local authority's annual statistical reports in an interactive format. These can be found here https://www.scottishairquality.scot/laqm/statistics. For this annual report a snapshot of this analysis has been carried out for four NO_2 automatic monitoring sites, located in the largest Scottish cities, that have historically measured exceedances. These sites are Aberdeen Wellington Road, Dundee Lochee Road, Edinburgh St Johns Road, and Glasgow Kerbside (Hope Street).

The analysis carried for this report includes polar plots, time variation plots, and calendar plots. An array of additional analysis techniques is available via the Openair tool.

Time variation analysis produces four separate panes combined into a single plot: The plotted output shows the average variation by day of the week and hour of the day combined (the top-most pane), hour of the day (diurnal variation, shown in the lower left pane), month of the year (seasonal variation in the lower middle pane) and day of week (lower right pane). The variation of a pollutant by time of day and day of week can reveal useful information concerning the likely sources at a particular site. In this report, time variation plots created using 2021 NO_2 data is compared to data from the previous 10 years.

Polar plots are useful to gain a quick graphical representation of the relationship between pollutant concentrations and the meteorological conditions. This can be useful in identifying potential sources of pollution affecting the location, for example particle suspension is increased at higher wind speeds. As with the time variation plots, polar plots created using 2021 NO_2 data are compared to plots generated using data from the previous 10 years. It should be noted that when comparing polar plots, the colour index can change so concentrations may relate to different colours in different plots.

Calendar plot analysis provides a way of visualising trends in daily pollutant concentrations across a year in the familiar form of a calendar. Concentrations are represented with a colour scale and the meteorological conditions can be represented using arrows giving the vector averaged modelled wind direction. In this way pollution episodes can be identified by date and sources potentially indicated by the combination of pollutant and meteorological conditions.

Figure 8-15 to Figure 8-18 illustrate this analysis for the four sites discussed.

Figure 8-15 Openair analysis – Aberdeen Wellington Road

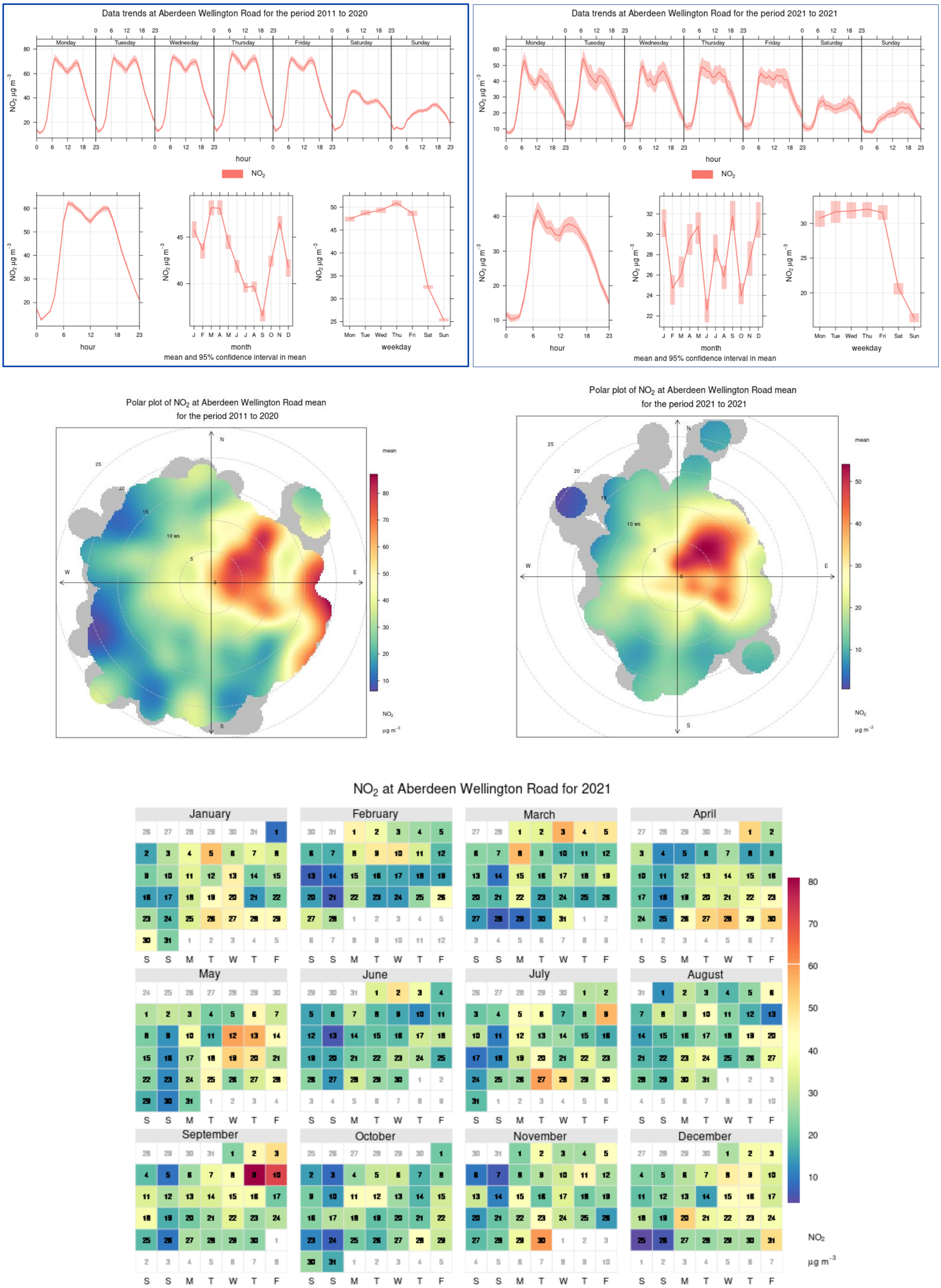
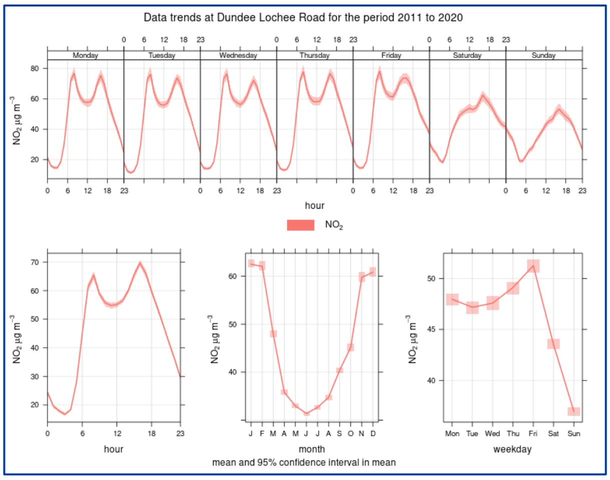
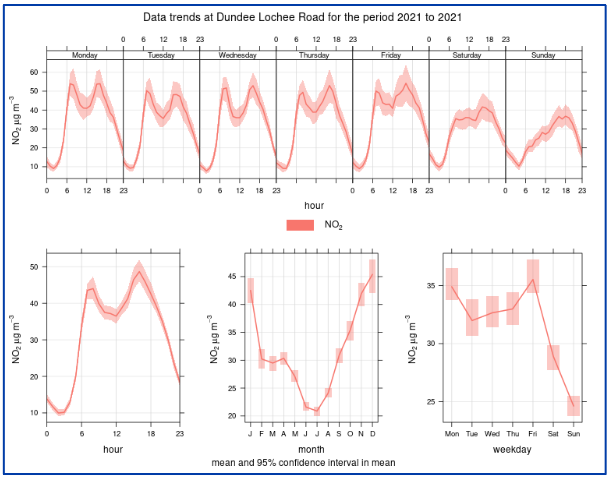
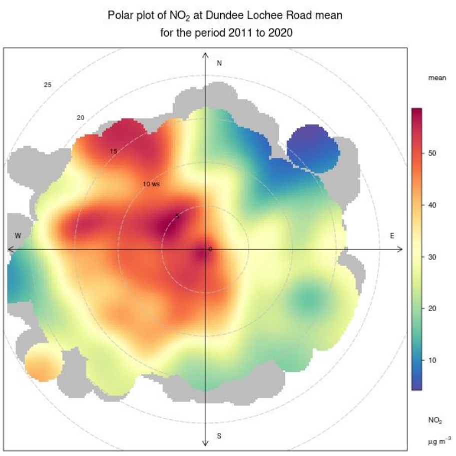
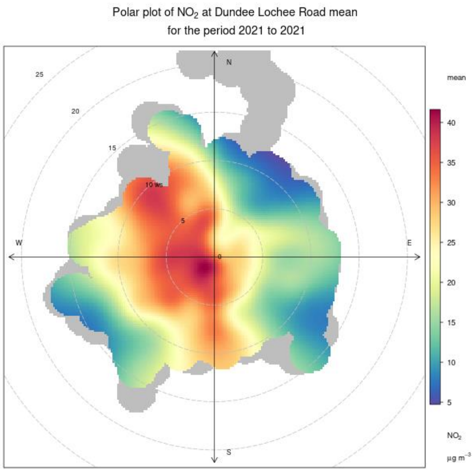


Figure 8-16 Openair Analysis – Dundee Lochee Road









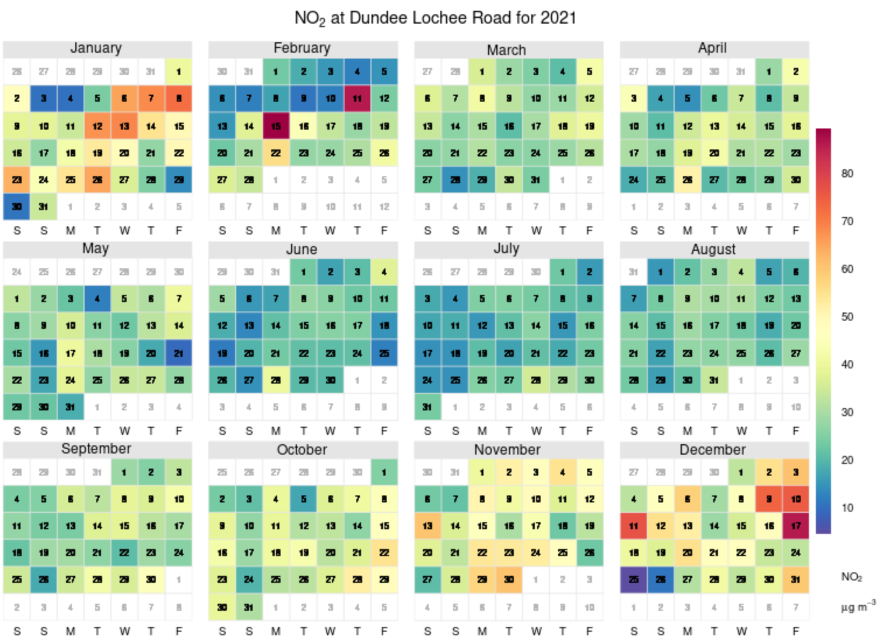


Figure 8-17 Openair Analysis – Edinburgh St Johns Road

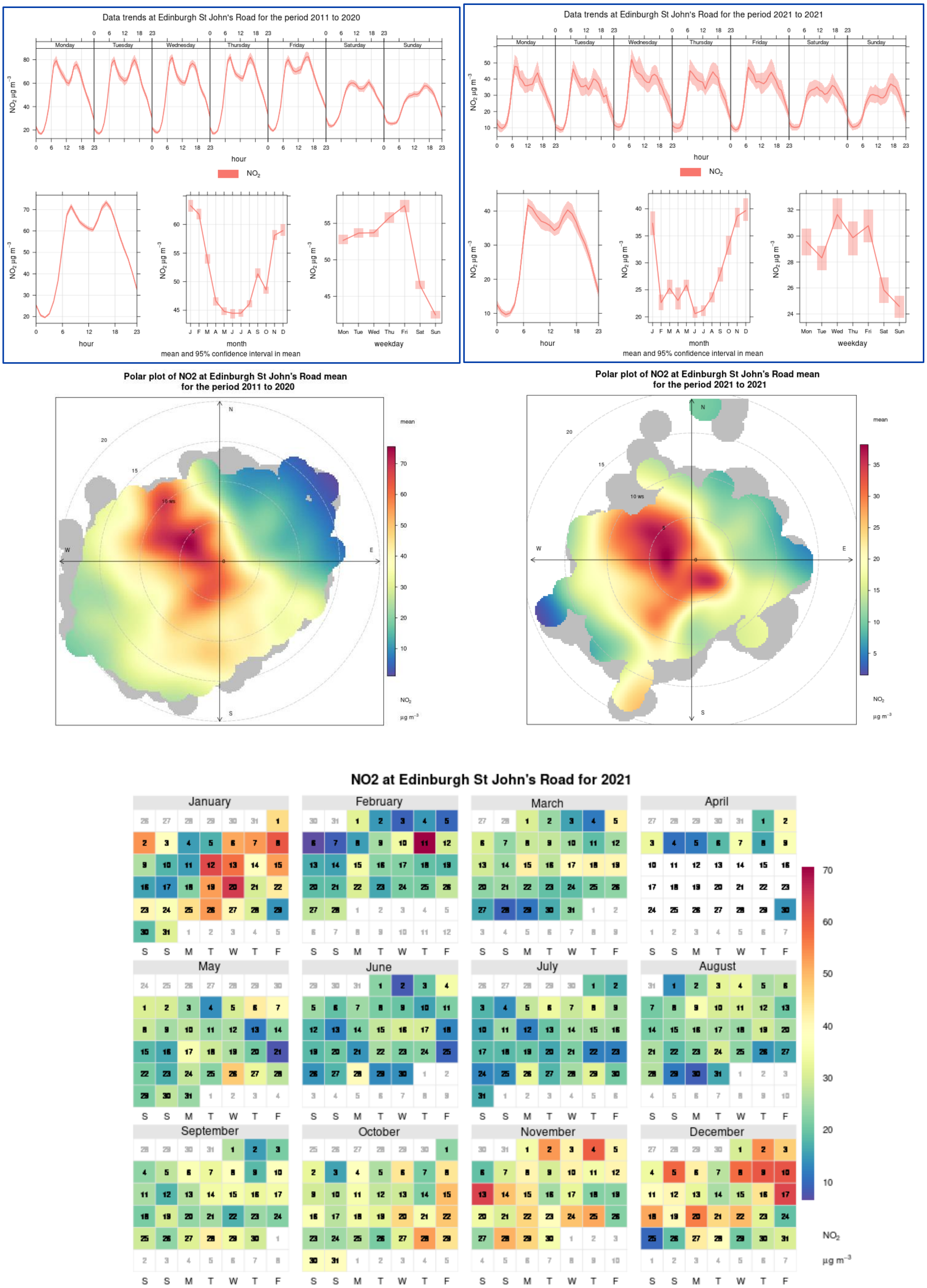
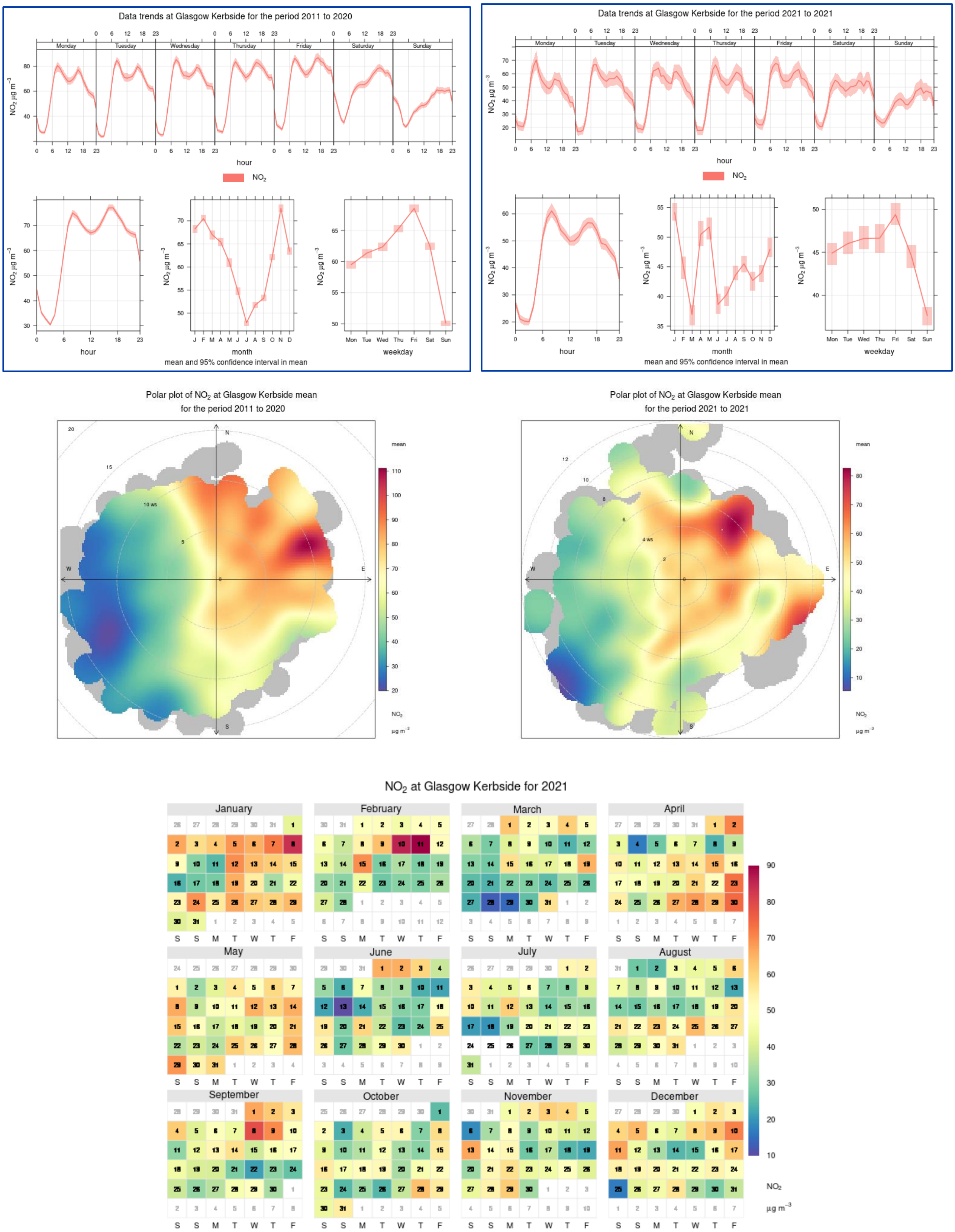


Figure 8-18 Openair Analysis – Glasgow Kerbside



9 EMISSION OF POLLUTION SPECIES

In this chapter we provide information on emissions of pollutants into the atmosphere in Scotland. The UK National Atmospheric Emissions Inventory (NAEI) calculates total emissions for the UK from a comprehensive range of sources including industry, domestic, transport etc. The UK inventory is now disaggregated into the UK constituent countries[9]. The inventory covers a wide range of pollutants, but in this report will mainly focus on NO_x, Particulate Matter (PM_{10}, and $PM_{2.5}$), Ammonia, CO, SO_2 and VOC. Data on Benzene (a) Pyrene (B(a)p), Dioxins, lead (Pb), and Mercury (Hg) can be found in appendix 5. Information on other pollutants can be found at www.naei.org.uk.

Within Scotland, SEPA collates the detailed information on emissions from industrial sources into the Scottish Pollution Release Inventory (SPRI); this includes emissions to water and soil as well as to air. Full details are available on the SEPA SPRI database:

http://www.sepa.org.uk/air/process_industry_regulation/pollutant_release_inventory.aspx

There is also a link to the SEPA SPRI website on the home page of http://www.scottishairquality.scot/data/emissions. The data from the SPRI form the basis of the industrial emission data for Scotland which are incorporated into the NAEI.

Information provided in Section 9.1 of this report on the main industrial emissions in Scotland has been compiled from the information presented on SEPA's SPRI database, with permission from SEPA. The data provided is up to 2019, which is the most recent data available at the time of writing this report.

In previous iterations of this report, data has been provided back to 1990. However, due to changes in the NAEI requirements and the fact that UK emission reduction targets for these air quality pollutants, under CLRTAP (Convention on Long-Range Transboundary Air Pollution) and the EU's NECD (National Emission Ceilings Directive) are based on a 2005 baseline, it was decided that reporting data from 1990 to 2004 was no longer required. This historic data was considered to be no longer relevant to either targets or policy.

For information on data back to 1990 and more detailed explanatory description of what is happening with individual emissions please refer to the "Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland" report series (naei.beis.gov.uk/reports/reports?report_id=1030) and also the Scottish Air Quality Database Annual Report series (https://www.scottishairquality.scot/news/reports/technical).

1.1 NAEI DATA FOR SCOTLAND

The NAEI data for Scotland are reported using the Nomenclature for Reporting (NFR) format. The Nomenclature for Reporting is a reporting structure that was introduced in 2001 and is used for submitting data to international organisations such as the United Nations Economic Commission for Europe (UNECE) and the European Monitoring and Evaluation Programme (EMEP).

Since the 2017 report, emissions data for $PM_{2.5}$ is included at the request of both the Scottish and UK Governments. It should be note however that the emissions dataset for $PM_{2.5}$ is very limited, and the inventory is heavily based on assumptions of $PM_{2.5}$ share of the PM_{10} for different emissions sources. In addition, it should also be note that the indicative uncertainty rating for both PM_{10} and $PM_{2.5}$ is "High". For more information on the uncertainty assessment see section 1.4 of "Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 2005 – 2020".

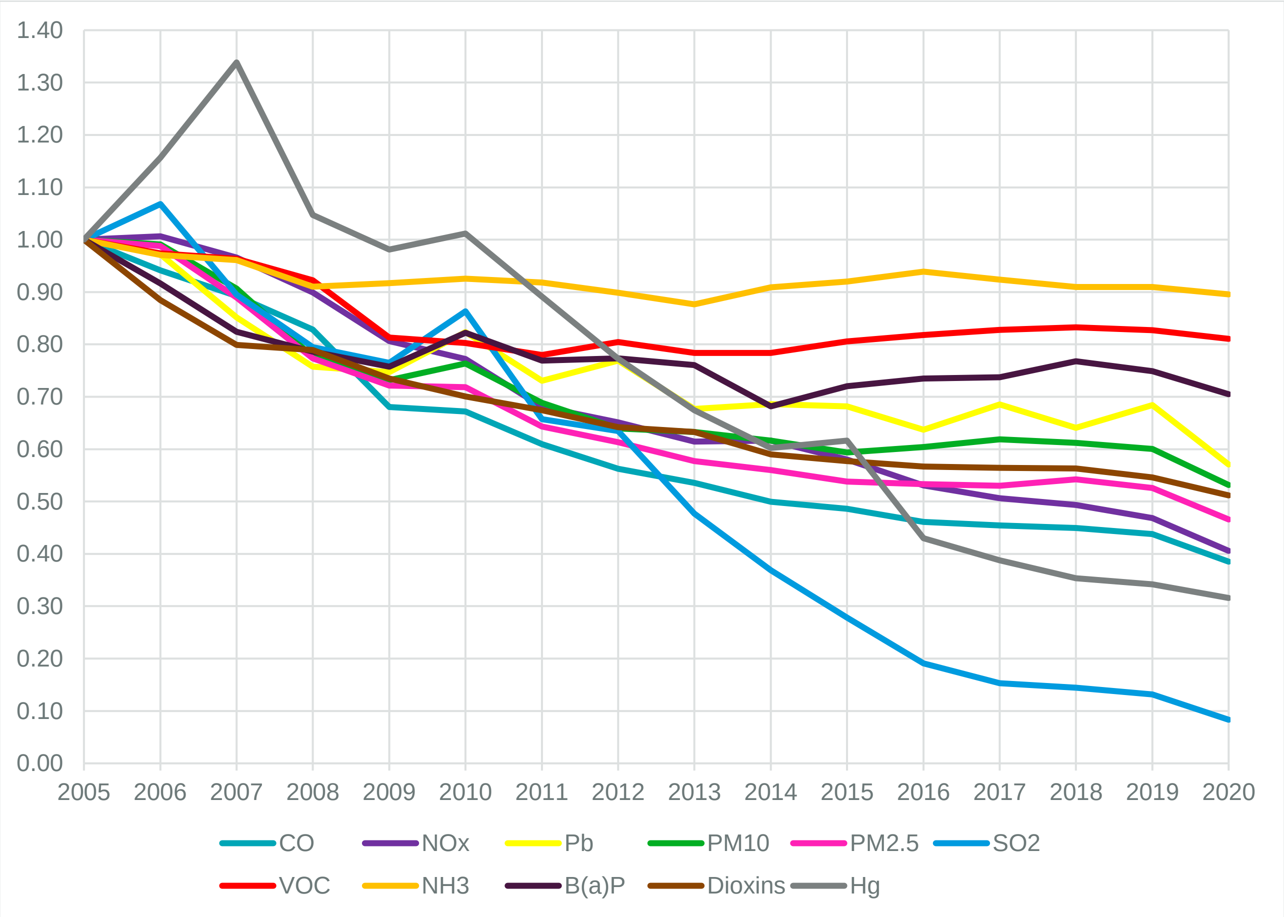
When comparing previously reported emissions with the most recent data, there may be a difference in the figures stated. This is because the emissions dataset is recalculated each year and a revision of historic time series is carried out if a more accurate and applicable data source becomes available.

[9] Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 2005 – 2020 https://naei.beis.gov.uk/reports/reports?report_id=1030

Data and graphs provide in this report can also be found as interactive figures within the Air Quality in Scotland website Emissions Inventory page.

Figure 9.1 illustrates the change in emissions since 2005 of the eight pollutants stated, normalised to provide a relative rate of change. It shows that in general all emission levels have declined since 2005, however this decline has plateaued in recent years and in some cases begun to increase. In fact, VOCs emission levels have increased since 2011. In terms of Ammonia (NH_3), emission levels have not significantly changed at all since 2005 when compared to other pollutants.

Figure 9.1 Scotland normalised trends for all monitored pollutants



Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 2005 – 2020

1.2 SCOTLAND NO_X INVENTORY BY NFR SECTOR 1990 – 2020

Table 9-2 and Figure 9.2 provides a summary of NO_x emission estimates for Scotland by category. The detailed data are available in the report and website citied in the introduction to this chapter.

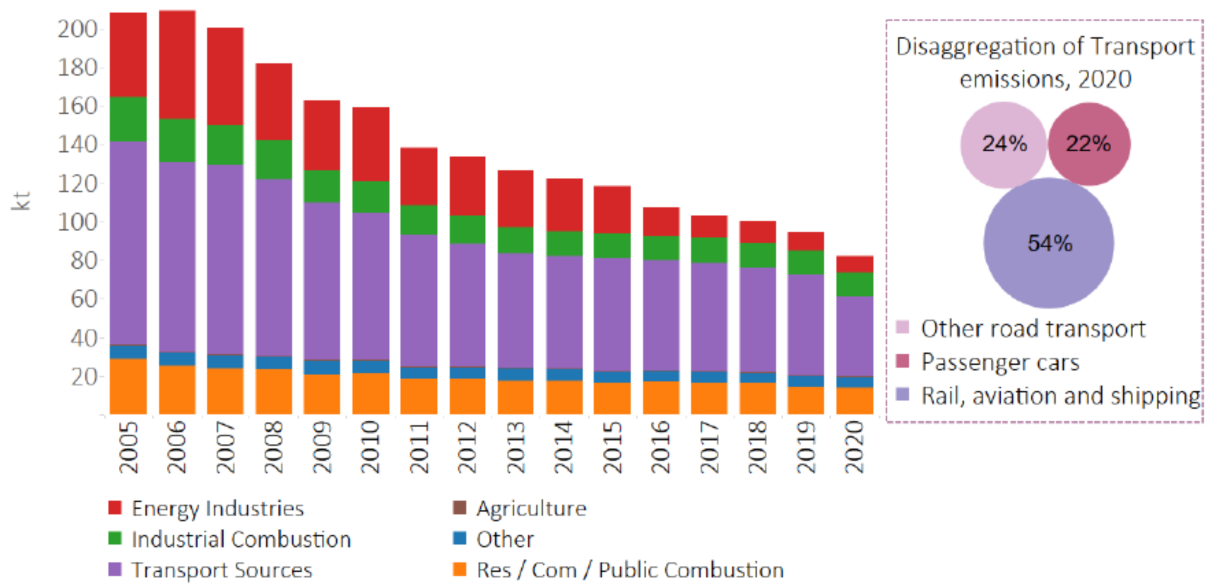
Table 9-1 Summary of NO_x emission estimates for Scotland (2005 – 2020)

Category	2005	2006	2007	2008	2009	2010	2011	2012
Energy Industries	43.61	56.15	50.01	39.77	36.54	37.99	30.13	30.83
Industrial Combustion	23.38	22.22	21.22	20.24	16.58	16.43	15.06	14.81
Transport Sources	114.28	108.43	107.81	105.29	94.25	85.17	78.13	71.05
Other	7.51	7.24	7.20	7.27	7.14	7.00	6.81	6.48
Residential & other combustion	28.98	25.12	24.09	23.29	21.03	21.57	18.22	18.55
Total:	217.7	219.2	210.3	195.9	175.5	168.2	148.4	141.7

Category	2013	2014	2015	2016	2017	2018	2019	2020
Energy Industries	29.25	27.12	24.54	14.84	11.58	11.29	9.55	8.68
Industrial Combustion	13.17	12.95	12.55	12.16	12.83	12.91	12.16	12.18
Transport Sources	67.20	70.17	66.99	65.80	63.36	61.35	59.80	47.71
Other	6.75	6.39	6.01	5.64	6.11	5.58	5.82	5.98
Residential & other combustion	17.47	17.63	16.31	17.09	16.37	16.28	14.65	13.80
Total:	133.8	134.3	126.4	115.5	110.3	107.4	102.0	88.3

Units: kilotonnes (kt)
Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 2005 – 2020

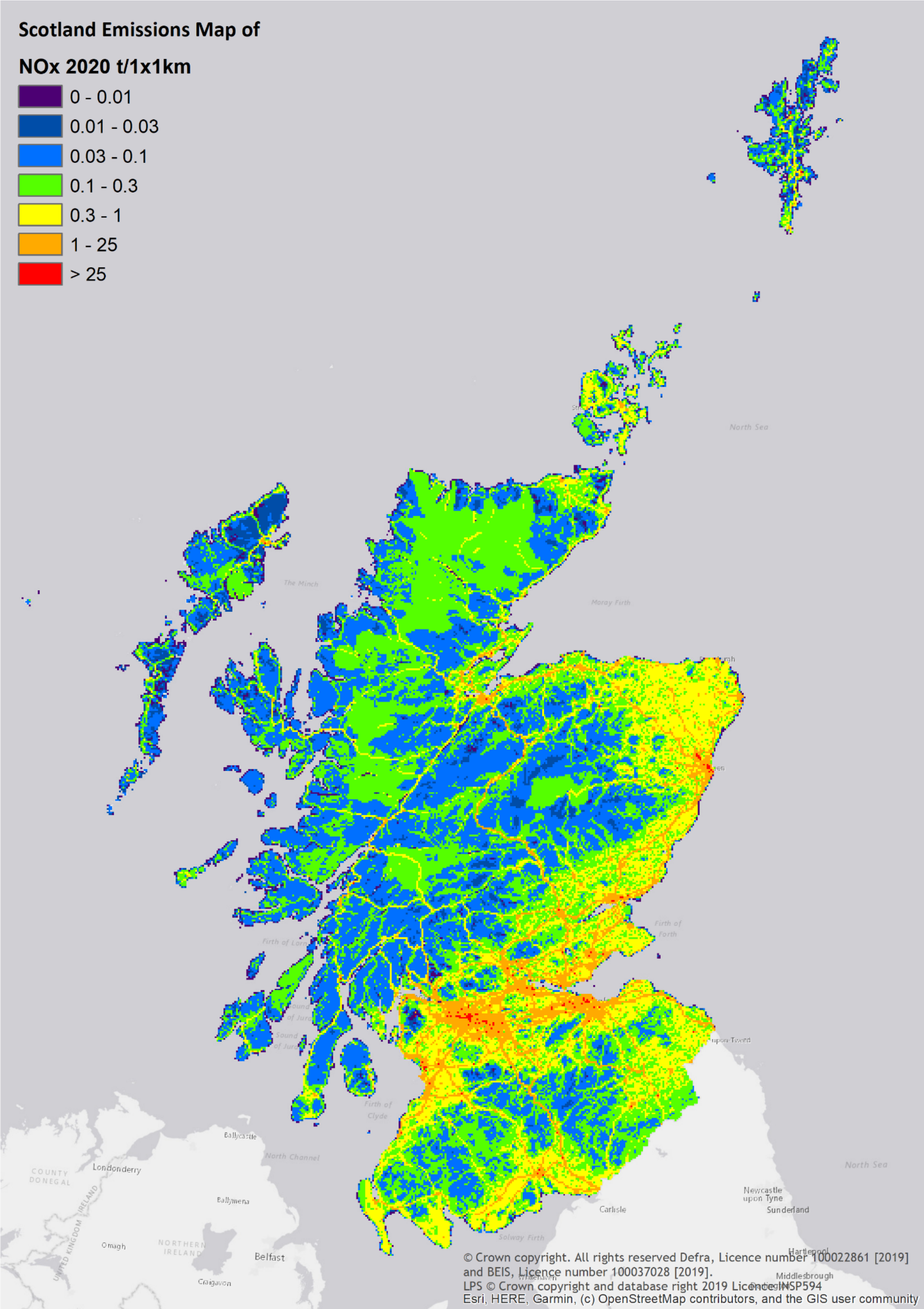
Figure 9.2 Time series of Scotland NO_x emissions 2005-2020



Emissions of nitrogen oxides in Scotland were estimated to be 82kt in 2020, representing 12% of the UK total for nitrogen oxides. Emissions have declined by 61% since 2005, mainly due to changes in transport sources, particularly in road transport. This decline is driven by the successive introduction of tighter Euro emission standards, and the continued penetration of vehicles which comply with these standards. In addition, improvements in catalyst repair rates resulting from regulations controlling the sale and installation of replacement catalytic converters and particle filters for light-duty vehicles contribute to the decline since 2008. However, the recent preferred uptake of diesel cars over petrol cars partly offsets these emissions reductions, because diesel cars emit higher NO_x relative to their petrol counterparts (94% of 2019 passenger car emissions were due to diesel cars). The peak in NO_x emissions in 2006 is due to the increased use of coal at power stations that year. There was also a small increase in coal-fired generation in 2012 due to a UK-wide shift in power generation fuel mix from gas to coal in that year (BEIS, 2021a). Energy industry emissions have declined across the time series and is linked to Boosted Over-Fire Air (BOFA) abatement systems which were fitted to all four of Longannet's units, to reduce NO_X emissions from coal-fired generation by up to 25% (Scottish Power, 2012). BOFA systems were also fitted on all four units at Cockenzie power station which then closed in 2013 (Scottish Power, 2011). Longannet power station closed in March 2016 marking the end of coal combustion for power generation in Scotland and causing a step-change in emissions between 2015 and 2016. NO_x emissions decreased by 13% between 2019 and 2020, mainly driven by the 21% decrease in emissions in this period from the transport sector. This is primarily due to travel restrictions imposed due to the COVID-19 pandemic. Despite this, 50% of the NO_x emissions were due to the transport sector in 2020.

Figure 9.3 shows a map of Scotland's NO_x emissions in 2020.

Figure 9.3 Map of NO_x Emissions in Scotland, 2020



Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 2005 – 2020

1.3 SCOTLAND PM_{10} INVENTORY BY NFR SECTOR 2005 – 2020

The Table 9-2 and Figure 9.4 give a summary of the Summary of PM_{10} emission estimates for Scotland by category. The detailed data are available in report and website cited in the introduction to this Chapter.

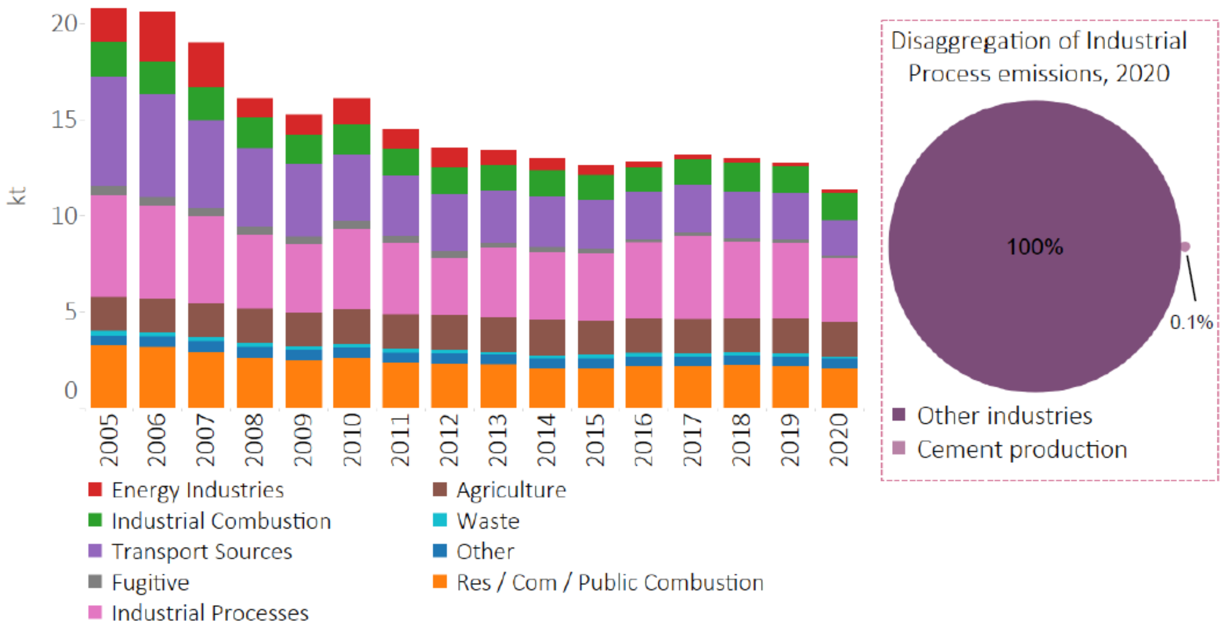
Table 9-2 Summary of PM_{10} emission estimates for Scotland (2005 – 2019)

Category	2005	2006	2007	2008	2009	2010	2011	2012
Agriculture	1.77	1.72	1.74	1.78	1.78	1.80	1.83	1.81
Energy Industry	1.75	2.59	2.32	0.97	1.03	1.37	1.05	1.03
Industrial Combustion	1.85	1.72	1.73	1.59	1.52	1.57	1.42	1.41
Transport	6.32	6.02	5.03	4.72	4.25	3.74	3.36	3.15
Industrial Processes	5.29	4.88	4.56	3.85	3.53	4.18	3.68	3.00
Solvent Processes	0.10	0.11	0.10	0.09	0.08	0.08	0.10	0.09
Residential & Other Combustion	4.44	4.28	4.03	3.69	3.55	3.68	3.38	3.27
Total:	21.5	21.3	19.5	16.7	15.7	16.4	14.8	13.8

Category	2013	2014	2015	2016	2017	2018	2019	2020
Agriculture	1.80	1.84	1.79	1.80	1.81	1.79	1.82	1.79
Energy Industry	0.77	0.66	0.50	0.30	0.24	0.25	0.21	0.17
Industrial Combustion	1.30	1.34	1.31	1.25	1.33	1.52	1.42	1.43
Transport	2.94	2.88	2.68	2.65	2.62	2.55	2.52	1.90
Industrial Processes	3.59	3.54	3.49	3.96	4.33	3.98	3.94	3.36
Solvent Processes	0.09	0.10	0.10	0.10	0.10	0.10	0.10	0.09
Residential & Other Combustion	3.11	2.90	2.88	2.93	2.88	2.96	2.90	2.70
Total:	13.6	13.3	12.8	13.0	13.3	13.2	12.9	11.4

Units: kilotonnes (kt)
Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 2005 – 2020

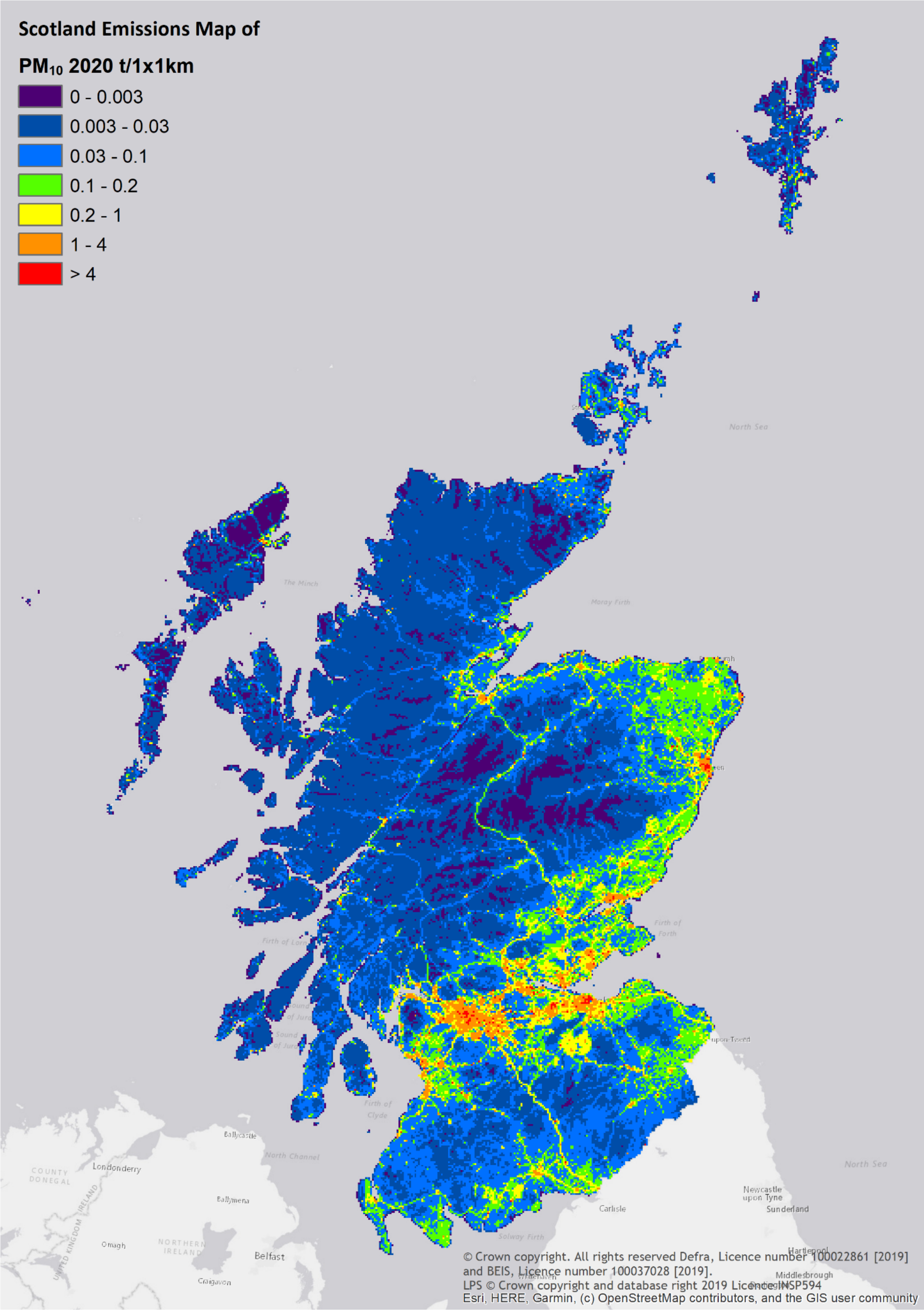
Figure 9.4 Time Series of Scotland's PM_{10} Emissions 2005-2020



Emissions of PM_{10} in Scotland were estimated to be 11 kt in 2020, declining by 46% since 2005. These emissions account for 8% of the UK total PM_{10} emissions. Unlike most other pollutants, the emissions profile of PM_{10} is diverse: transport sources, residential and industrial processes each accounted for over 14% of total PM_{10} emissions in 2020. Emissions from energy industries and transport sources have had the most notable impact on the trend. This reduction is primarily due to abatement at coal-fired stations, the increase in nuclear and renewable energy sources and the increase in the use of natural gas in energy generation (which has negligible PM_{10} emissions) in place of coal (BEIS, 2021a), as well as the continued increasing share of renewables in the energy mix. PM_{10} exhaust emissions from diesel-fuelled vehicles have been decreasing due to the continued fleet penetration of vehicles complying with more recent and more stringent Euro emissions standards. Increasingly non-exhaust sources of PM_{10} (for example tyre wear) have become more important to consider as exhaust PM_{10} has been reduced. In fact, in 2020, 84% of emissions from the road transport sector were related to non-exhaust sources. In recent years, emissions from the residential and other combustion sector have slightly increased, and this is due to an increasing quantity of wood fuel use, primarily in the residential sector (BEIS, 2021a). PM_{10} emissions decreased by 11% between 2019 and 2020, led by reductions in several sectors. The reduction in emissions from the transport sector contributed to this trend by 40%, with PM_{10} emissions decreasing by 24% from this sector between 2019 and 2020. This is primarily due to travel restrictions imposed due to the COVID-19 pandemic. PM_{10} emissions also decreased by 16% from the construction and demolition sector, accounting for 24% of the reduction in PM_{10} emissions between 2019 and 2020. From 2019 to 2020, PM_{10} emission also decreased by 88% from the aluminium production sector, accounting for 9% of the reduction in PM_{10} emissions between these years.

Figure 9.5 shows a map of PM_{10} emission in Scotland for 2020.

Figure 9.5 Map of PM_{10} Emissions in Scotland, 2020



Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 2005 – 2020

1.4 SCOTLAND $PM_{2.5}$ INVENTORY BY NFR SECTOR 2005 – 2020

Table 9-3 and figure 9.6 provides a summary of $PM_{2.5}$ emission estimates for Scotland by category. The detailed data are available in the report and website citied in the introduction to this chapter.

Table 9-3 Summary of $PM_{2.5}$ emission estimates for Scotland (2005 – 2020)

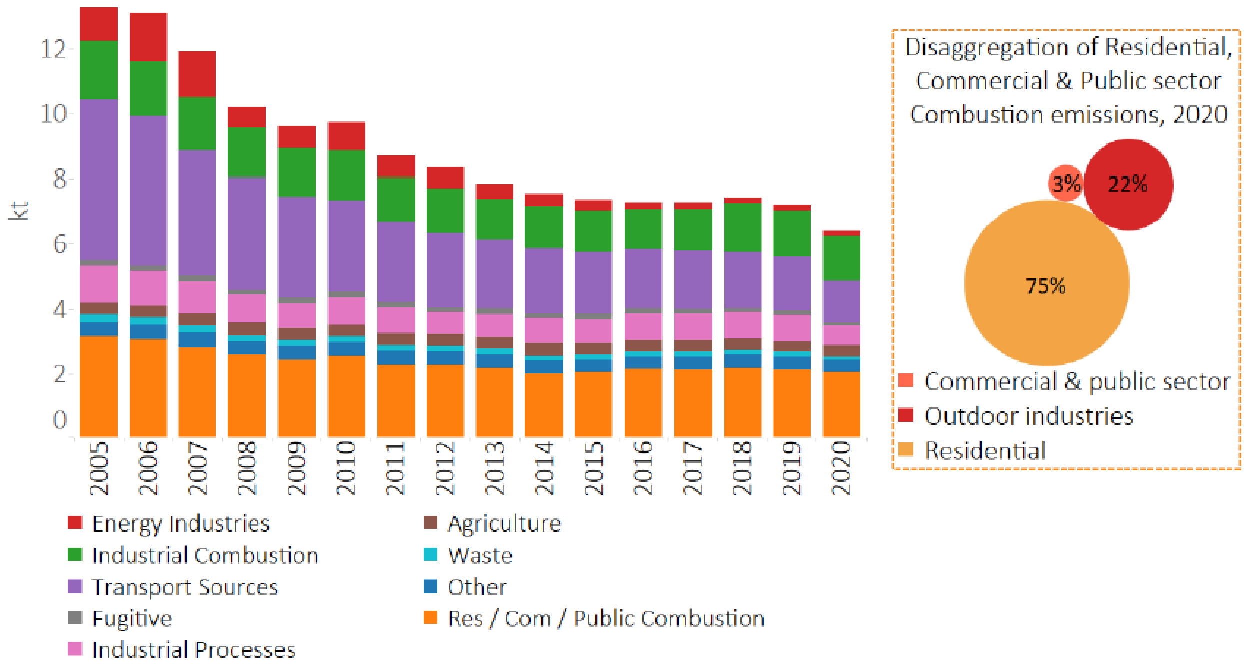
Category	2005	2006	2007	2008	2009	2010	2011	2012
Agriculture	0.39	0.38	0.38	0.38	0.37	0.38	0.38	0.38
Energy Industry	1.06	1.51	1.43	0.64	0.67	0.87	0.66	0.62
Industrial Combustion	1.80	1.66	1.63	1.54	1.47	1.51	1.36	1.36
Transport	5.54	5.23	4.27	3.98	3.54	3.07	2.70	2.50
Industrial Processes	1.12	1.06	0.98	0.86	0.78	0.84	0.79	0.69
Solvent Processes	0.03	0.03	0.03	0.03	0.03	0.02	0.03	0.03
Residential & Other Combustion	3.99	3.89	3.66	3.35	3.19	3.32	3.05	2.97
Total:	13.9	13.8	12.4	10.8	10.0	10.0	9.0	8.5

Category	2013	2014	2015	2016	2017	2018	2019	2020
Agriculture	0.37	0.37	0.37	0.37	0.37	0.36	0.36	0.36
Energy Industry	0.47	0.41	0.33	0.24	0.19	0.20	0.17	0.15
Industrial Combustion	1.25	1.28	1.26	1.20	1.28	1.47	1.38	1.39
Transport	2.30	2.22	2.03	1.98	1.92	1.86	1.82	1.34
Industrial Processes	0.73	0.77	0.73	0.81	0.83	0.80	0.78	0.62
Solvent Processes	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Residential & Other Combustion	2.90	2.70	2.74	2.81	2.76	2.84	2.79	2.60
Total:	8.0	7.8	7.5	7.4	7.4	7.6	7.3	6.5

Units: kilotonnes (kt)

Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 2005 – 2020

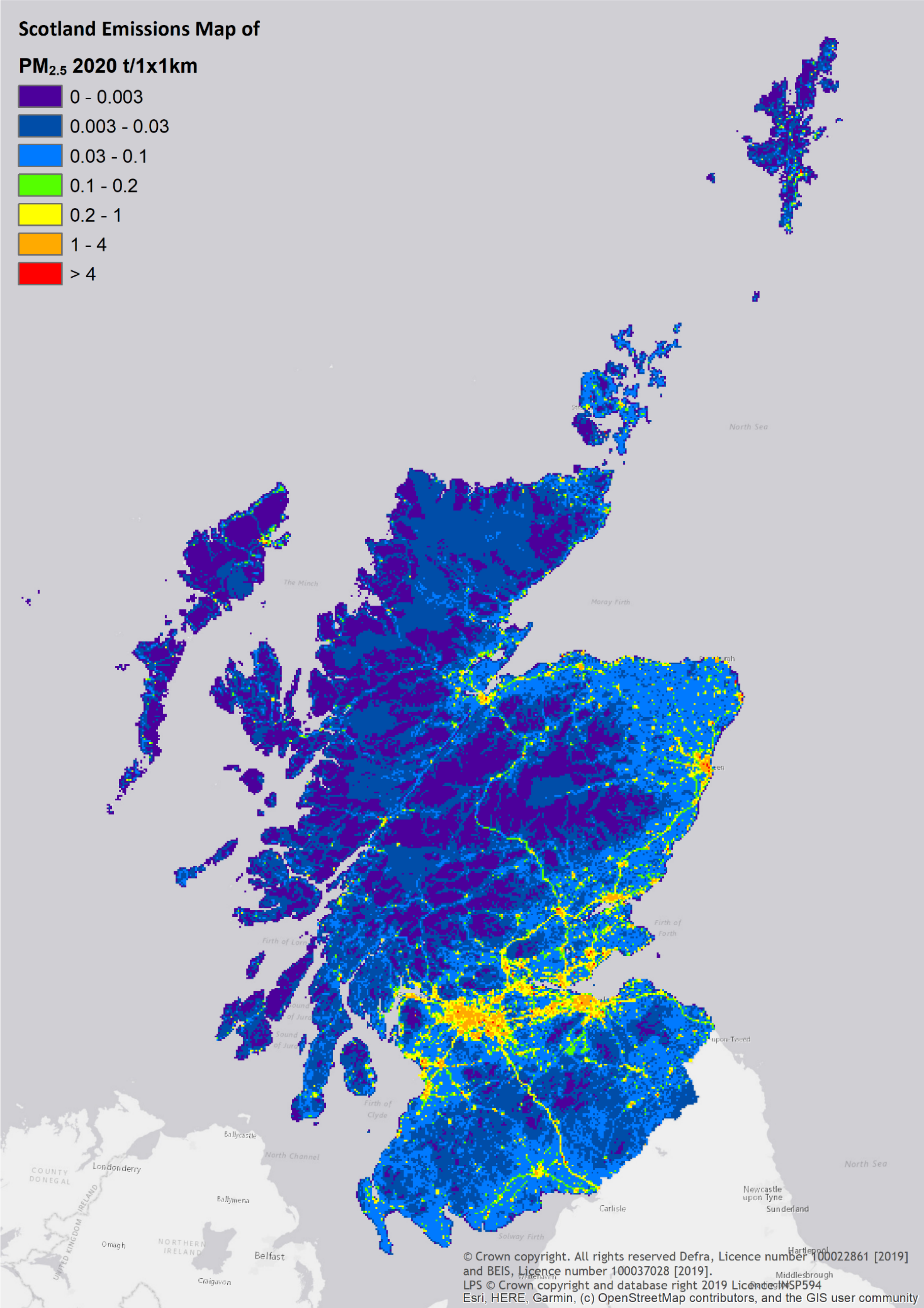
Figure 9.6 Time Series of Scotland's $PM_{2.5}$ Emissions 2005-2020



Emissions of $PM_{2.5}$ in Scotland were estimated to be 6 kt in 2020, declining by 52% since 2005. These emissions account for 8% of the UK total for $PM_{2.5}$ in 2020. As with PM_{10}, $PM_{2.5}$ emissions have a large number of significant sources. However, process emissions tend to produce coarser PM fractions and as such, combustion emissions are of greater importance for $PM_{2.5}$ compared to PM_{10}. For $PM_{2.5}$, the residential, commercial, and public sector combustion category (which includes agricultural combustion and fishing vessels – NFR code 1A4c) accounts for 32% of 2020 emissions. The primary drivers for the decline in emissions since 2005 are the continued switch from coal to natural gas in electricity generation, and reductions in emissions from the transport sector due to the introduction of progressively more stringent emissions standards through time. $PM_{2.5}$ emissions decreased by 11% between 2019 and 2020, led by reductions in several sectors. The reduction in emissions from the transport sector contributed to this trend by 54%, with $PM_{2.5}$ emissions decreasing by 25% from this sector between 2019 and 2020. This is primarily due to travel restrictions imposed due to the COVID-19 pandemic. From 2019 to 2020, $PM_{2.5}$ emission also decreased by 89% from the aluminium production sector, accounting for 12% of the reduction in $PM_{2.5}$ emissions between these years.

Figure 9.7 shows a map of $PM_{2.5}$ emissions in Scotland for 2020.

Figure 9.7 Map of $PM_{2.5}$ Emissions in Scotland, 2020



Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 2005 – 2020

1.5 SCOTLAND AMMONIA (NH_3) INVENTORY BY NFR SECTOR 2005 – 2020

Table 9-4 and figure 9.8 provides a summary of Ammonia emission estimates for Scotland by category. The detailed data are available in the report and website citied in the introduction to this chapter.

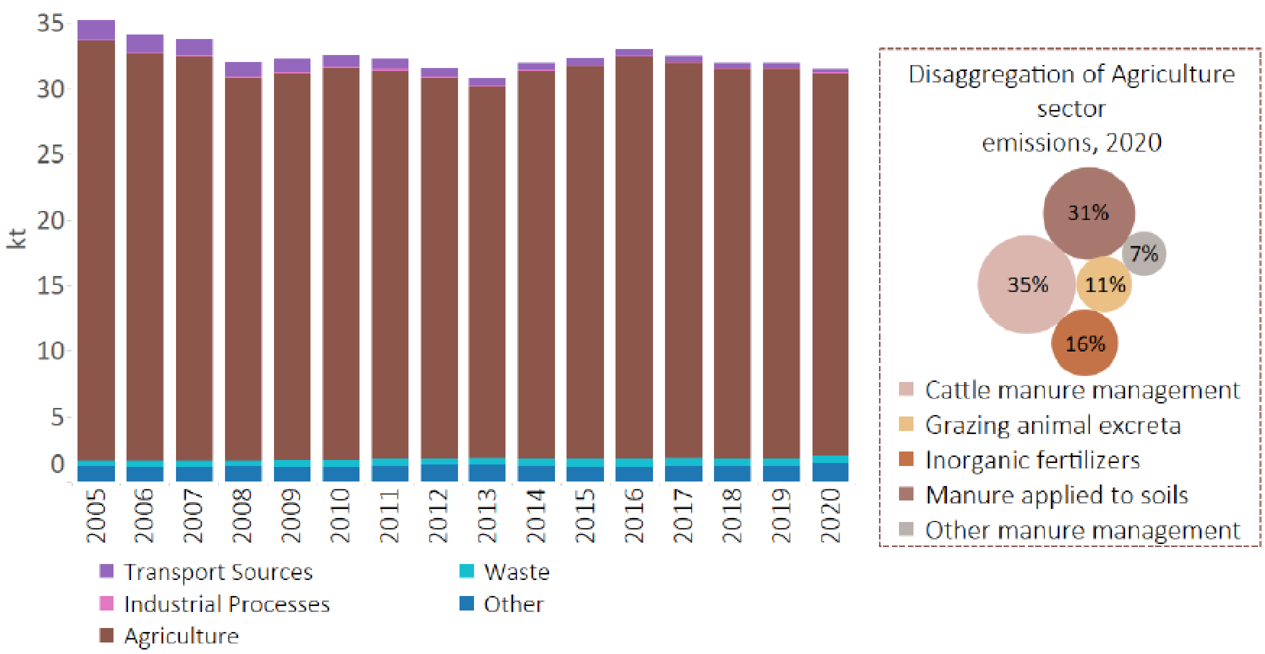
Table 9-4 Summary of Ammonia emission estimates for Scotland (2005 – 2020)

Category	2005	2006	2007	2008	2009	2010	2011	2012
Agriculture	32.01	31.09	30.89	29.25	29.49	29.90	29.63	29.04
Industrial Processes	0.10	0.08	0.08	0.07	0.07	0.08	0.10	0.07
Transport	1.47	1.39	1.26	1.10	1.05	0.93	0.81	0.72
Waste	0.43	0.43	0.42	0.40	0.47	0.48	0.49	0.50
Other	1.29	1.27	1.25	1.30	1.29	1.29	1.36	1.39
Total:	35.29	34.25	33.91	32.12	32.36	32.66	32.40	31.72

Category	2013	2014	2015	2016	2017	2018	2019	2020
Agriculture	28.31	29.57	30.05	30.73	30.20	29.73	29.78	29.13
Industrial Processes	0.06	0.06	0.05	0.05	0.05	0.07	0.06	0.05
Transport	0.63	0.56	0.51	0.49	0.44	0.43	0.43	0.31
Waste	0.52	0.58	0.57	0.58	0.60	0.57	0.53	0.53
Other	1.41	1.31	1.28	1.29	1.31	1.31	1.32	1.59
Total:	30.93	32.08	32.46	33.14	32.61	32.10	32.11	31.61

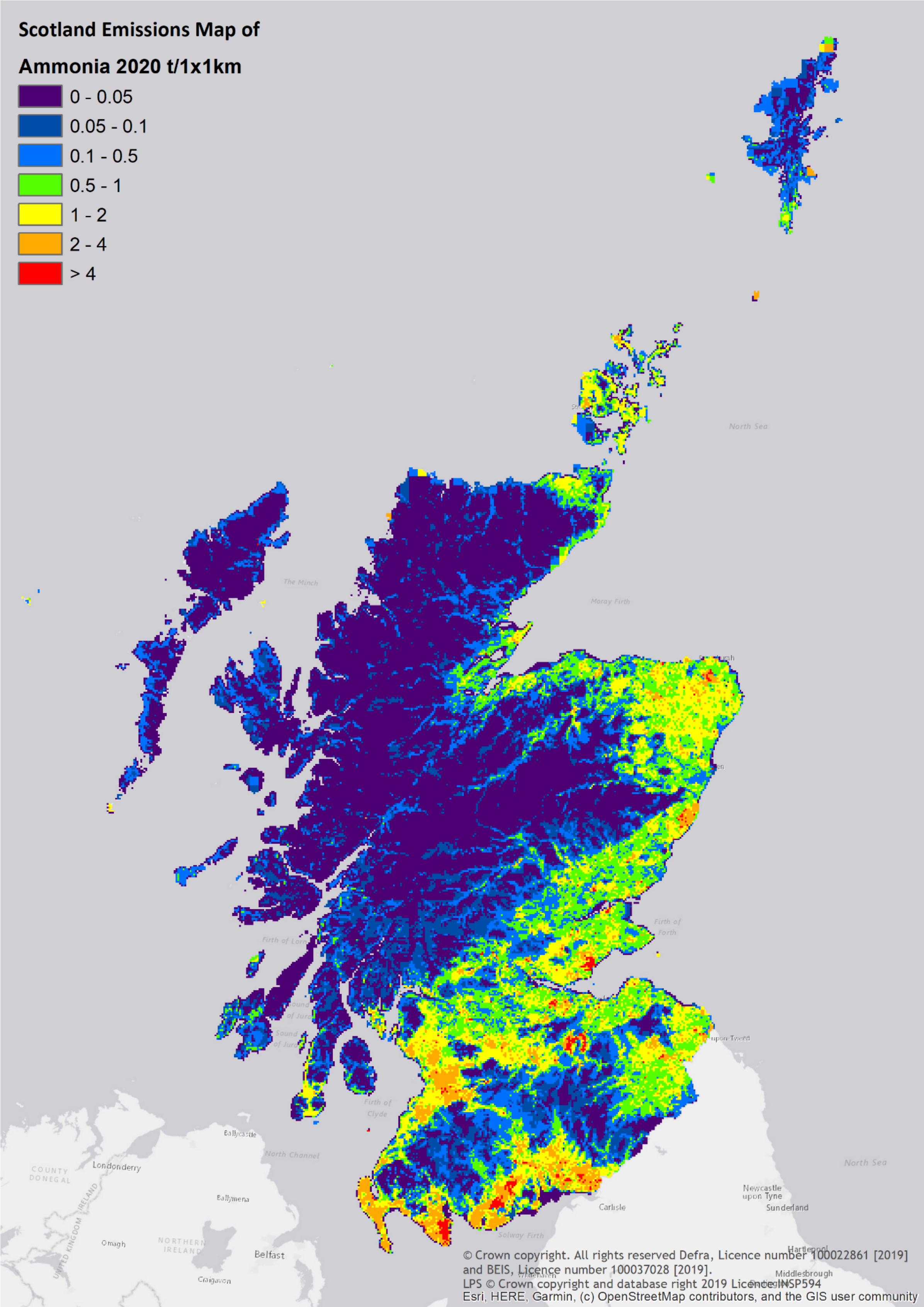
Units: kilotonnes (kt)
Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 2005 – 2020

Figure 9.8 Time series of Scotland's Ammonia emissions 2005-2020



Emissions of ammonia in Scotland were estimated to be 32 kt in 2020. These emissions have declined by approximately 10% since 2005 and accounted for 12% of the UK total for ammonia in 2020. Agriculture sources have dominated the inventory throughout the time series, with cattle manure management accounting for at least 33% of the emissions from this sector across the entire time series. The initial trends in NH_3 emissions were primarily driven by decreases in livestock numbers (except for poultry) and declines in the use of nitrogen-based fertilisers. After 2010, however, the decline began to be offset by increased application of urea-based and organic fertilisers such as digestate to agricultural soils causing fluctuating emissions totals since 2008, with no significant trends across these years.

Figure 9.9 Map of Ammonia Emissions in Scotland, 2020



Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 2005 – 2020

1.6 SCOTLAND NMVOC INVENTORY BY NFR SECTOR 2005 – 2020

Table 9-5 and figure 9.10 provides a summary of Non-Methane Volatile Organic Compounds (NMVOC) emission estimates for Scotland by category. The detailed data are available in the report and website citied in the introduction to this chapter.

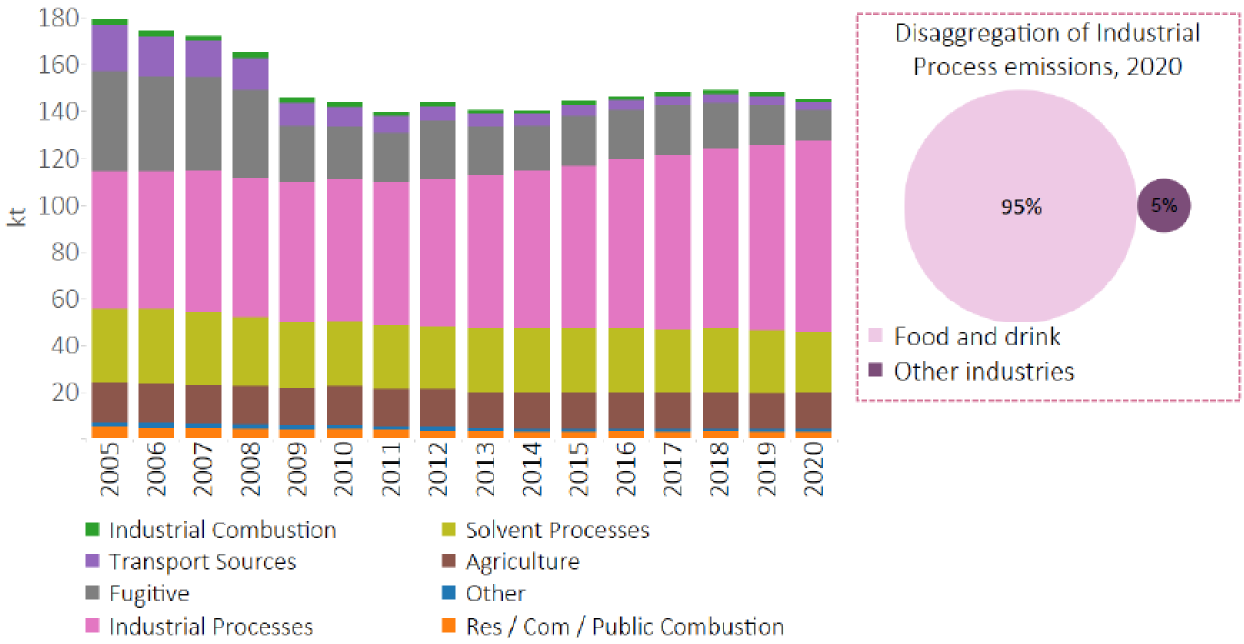
Table 9-5 Summary of NMVOC estimates for Scotland (2005 – 2020)

Category	2005	2006	2007	2008	2009	2010	2011	2012
Agriculture	17.09	16.58	16.82	16.31	16.25	16.69	16.06	16.21
Fugitive	43.17	40.65	40.29	37.55	24.20	22.34	20.97	25.07
Industrial Combustion	2.24	2.23	2.30	2.29	1.89	1.91	1.76	1.77
Industrial Processes	58.37	58.77	60.37	59.83	60.20	61.10	61.40	62.88
Residential, Commercial & Public Sector Combustion	4.94	4.75	4.52	4.27	3.94	4.07	3.65	3.56
Solvent Processes	31.68	32.10	31.01	29.55	27.65	27.61	27.14	26.94
Transport	20.02	17.66	15.85	14.04	10.17	8.81	7.47	6.52
Other	1.95	2.01	1.69	1.69	1.60	1.55	1.49	1.40
Total:	179.5	174.7	172.9	165.5	145.9	144.1	139.9	144.4

Category	2013	2014	2015	2016	2017	2018	2019	2020
Agriculture	15.46	15.76	15.67	15.78	15.58	15.59	15.53	15.82
Fugitive	21.03	19.14	21.33	21.18	21.17	19.38	16.83	13.29
Industrial Combustion	1.42	1.52	1.67	1.55	1.71	1.71	1.66	1.49
Industrial Processes	65.36	67.59	69.52	72.60	74.84	76.90	79.71	82.08
Residential, Commercial & Public Sector Combustion	3.34	3.06	3.12	3.20	3.17	3.22	3.06	2.97
Solvent Processes	26.96	26.98	27.22	26.81	26.59	27.35	26.44	25.56
Transport	5.78	5.35	4.81	4.50	4.32	4.19	4.10	3.20
Other	1.31	1.20	1.22	1.15	1.15	1.15	1.11	1.06
Total:	140.7	140.6	144.6	146.8	148.5	149.5	148.4	145.5

Units: kilotonnes (kt)
Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 2005 – 2020

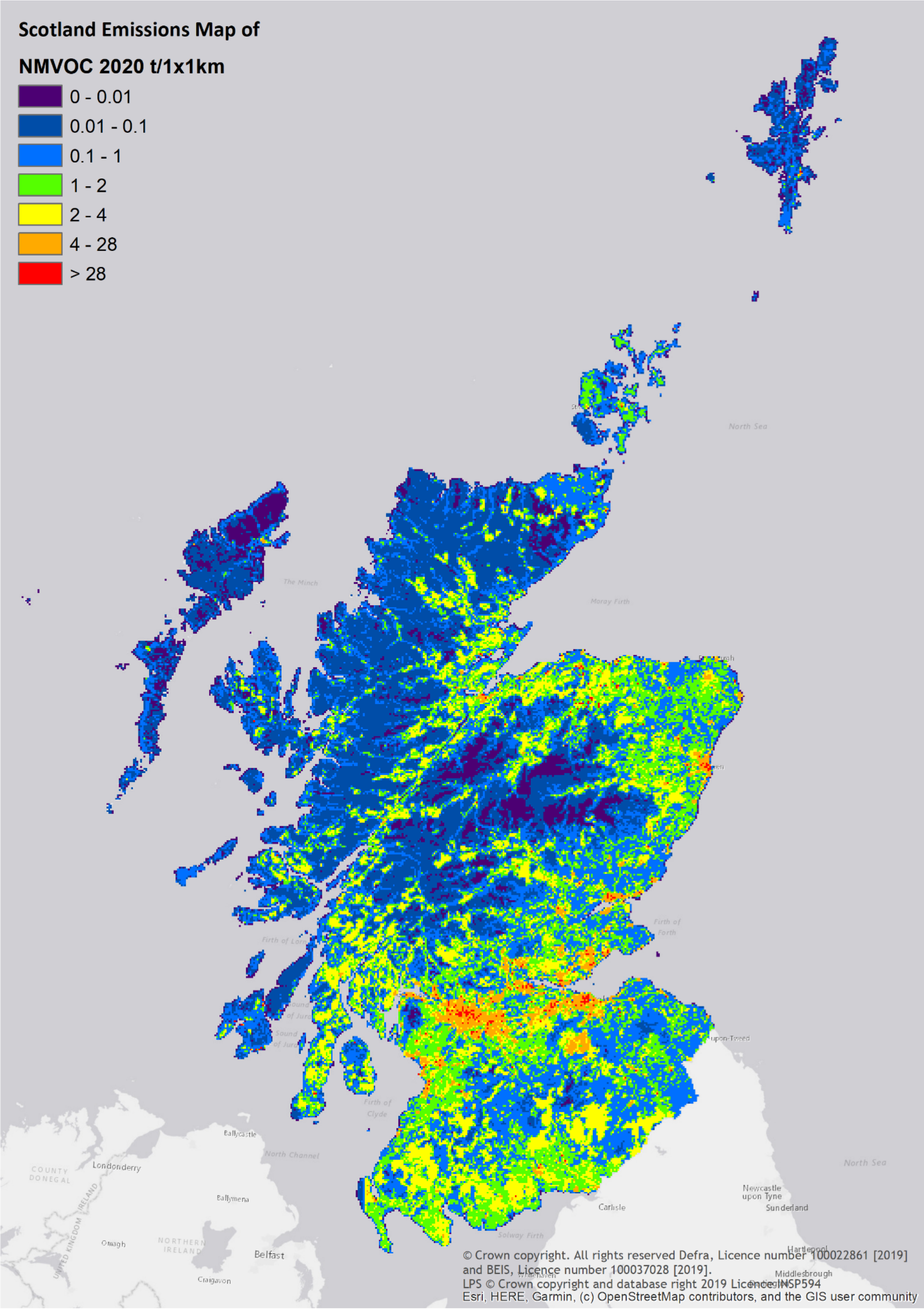
Figure 9.10 Time series of Scotland's NMVOC emissions 2005-2020



Emissions of **non-methane volatile organic compounds** in Scotland were estimated to be 142kt in 2020, representing 19% of the UK total for non-methane volatile organic compounds. Emissions have declined by 19% since 2005. This reduction is a result of reductions in fugitive and transport emissions which have declined 72% and 84% since 2005, respectively. The declining trend seen in fugitive emissions is due to the decrease in emissions from the exploration, production, and transport of oil, specifically emissions from the onshore loading of oil. The decrease between 2008 and 2009 was due to reductions in fugitive NMVOC emissions from oil loading at the Sullom Voe terminal in Shetland. Emissions from the food and drink industry (which accounts for around 87% of industrial processes emissions in 2020) have increased since 2009 due to the increased production and storage of whisky. In total, spirit manufacture contributed approximately 53% of NMVOC emissions in Scotland in 2020. Emissions from road transport sources, including evaporative losses of fuel vapour from petrol vehicles have also declined over time due to emission control technologies that have progressively been introduced in new petrol vehicles since the early 1990s. The reduction in emissions also occurs to a lesser extent due to the introduction of petrol vapour recovery systems at filling stations.

Figure 9.11 shows a map of NMVOC emissions in Scotland for 2020.

Figure 9.11 Map of NMVOC Emissions in Scotland, 2020



Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 2005 – 2020

1.7 SCOTLAND SO_2 INVENTORY BY NFR SECTOR 2005 – 2020

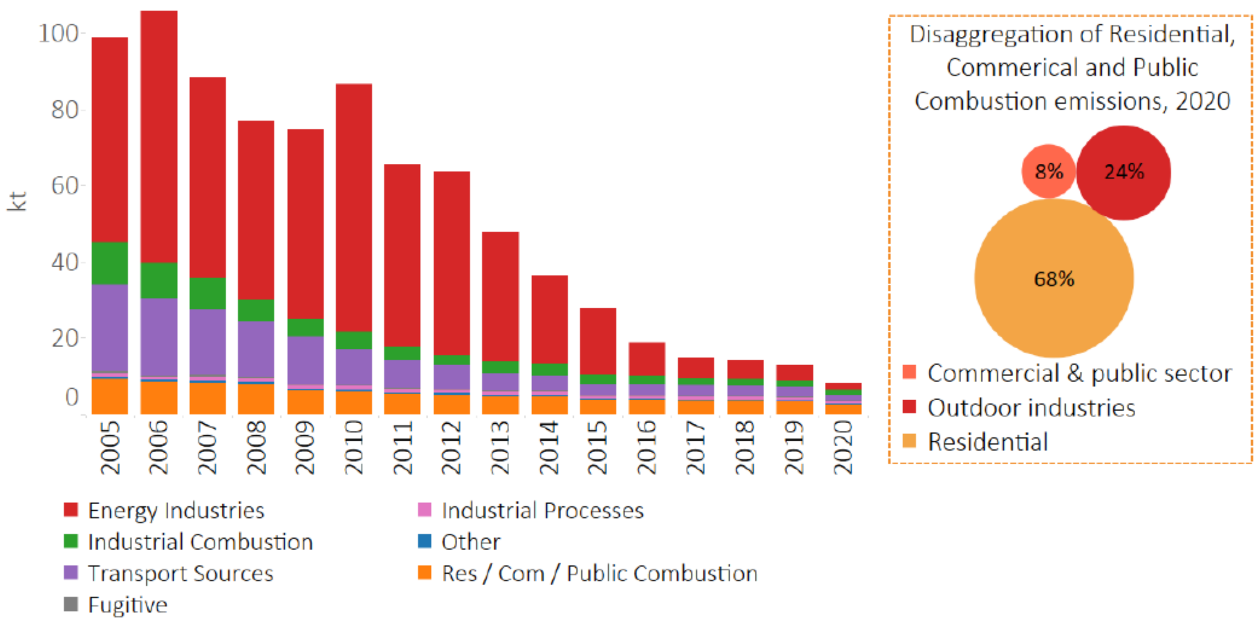
Table 9-6 and figure 9.12 provides a summary of Sulphur Dioxide (SO_2) emission estimates for Scotland by category. The detailed data are available in the report and website citied in the introduction to this chapter.

Table 9-6 Summary of SO_2 estimates for Scotland (2005 – 2020)

Category	2005	2006	2007	2008	2009	2010	2011	2012
Energy Industries	53.65	65.89	52.74	46.68	49.63	65.05	47.56	48.16
Industrial Combustion	11.15	9.26	8.08	5.86	4.60	4.49	3.83	2.76
Transport Sources	27.42	25.23	21.60	19.84	17.06	12.24	9.66	8.00
Other	2.01	1.79	1.95	1.80	1.60	1.55	1.66	1.55
Residential, Commercial & Public Sector Combustion	9.29	8.40	8.25	8.09	6.27	6.06	5.31	5.25
Total:	103.5	110.6	92.6	82.3	79.2	89.4	68.0	65.7

Category	2013	2014	2015	2016	2017	2018	2019	2020
Energy Industries	33.79	23.26	17.62	8.91	5.47	4.84	3.97	1.82
Industrial Combustion	3.06	2.91	2.21	1.92	1.96	1.76	1.58	1.38
Transport Sources	6.47	5.86	3.74	3.73	3.47	3.44	3.48	1.71
Other	1.35	1.42	1.17	1.23	1.16	1.18	1.21	1.02
Residential, Commercial & Public Sector Combustion	4.73	4.75	4.05	3.99	3.81	3.74	3.38	2.68
Total:	49.4	38.2	28.8	19.8	15.9	15.0	13.6	8.6

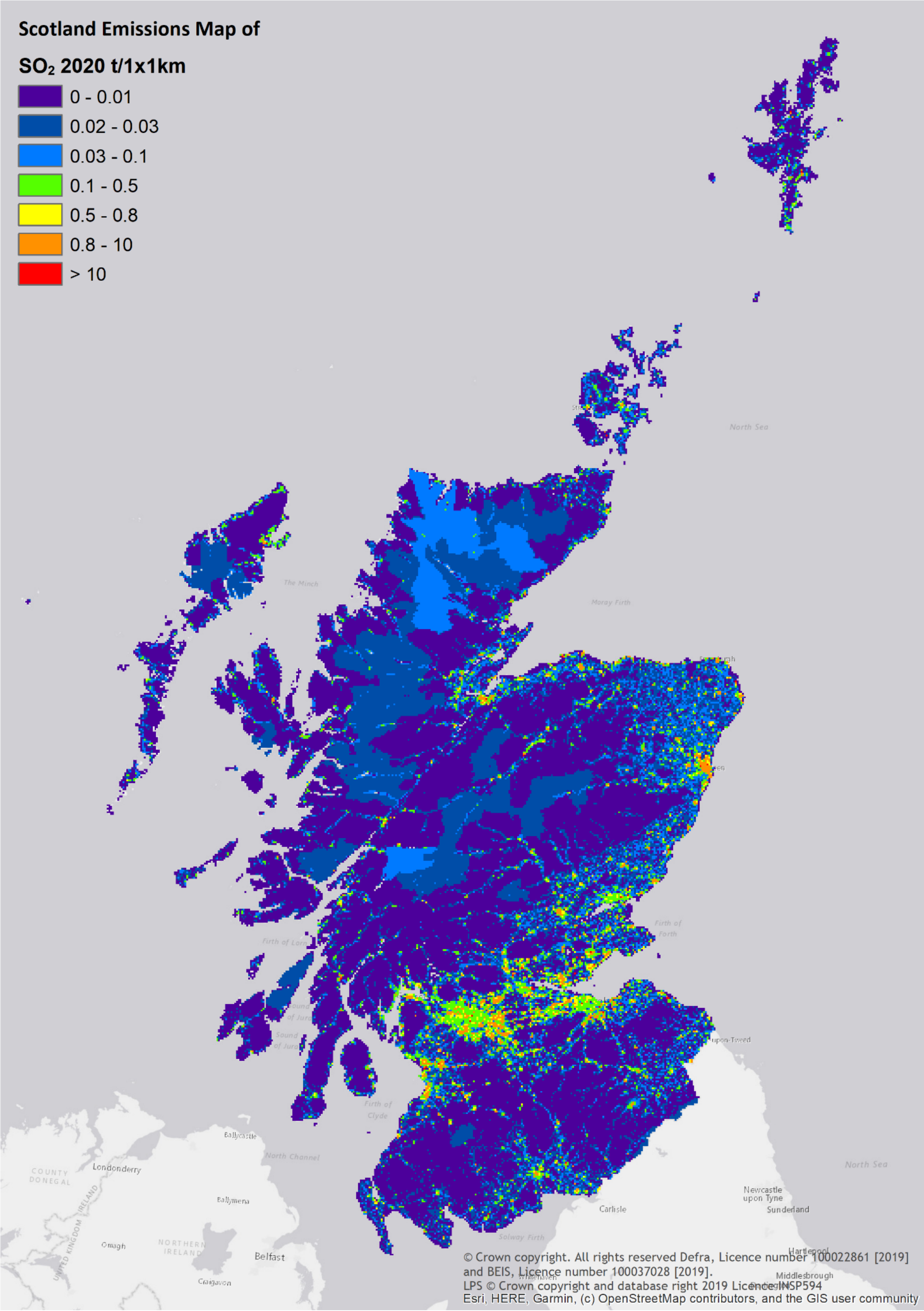
Figure 9.12 Time series of Scotland's SO_2 emissions 2005-2020



Emissions of SO_2 in Scotland were estimated to be 8kt in 2020, representing 6% of the UK total in 2020 for sulphur dioxide. Emissions have declined by 92% since 2005 because of continued changes in the power generation sector. Since 2005, SO_2 emissions from power stations have reduced by 99%. Such changes include the reduction in coal fired power relative to other sources; improved emission controls on some large coal fired plants such as the installation of an FGD (flue-gas desulphurization) plant at Longannet power station; the use of coal of lower sulphur content in later years to Cockenzie (Scottish Power, 2012) before its closure in March 2013, and finally the complete cessation of coal combustion for power generation in Scotland in 2016 after the closure of Longannet. SO_2 emissions from transport sources have also declined, coincident with the reduced sulphur content of road fuels, for both petrol and diesel. Since 2019, SO_2 emissions have decreased by 36%, primarily due to a 63% reduction in SO_2 emissions from the petroleum refining industry.

Figure 9.13 shows a map of SO_2 emissions in Scotland for 2020.

Figure 9.13 Map of SO_2 Emissions in Scotland, 2020



Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 2005 – 2020

1.8 SCOTLAND CO INVENTORY BY NFR SECTOR 2005 – 2020

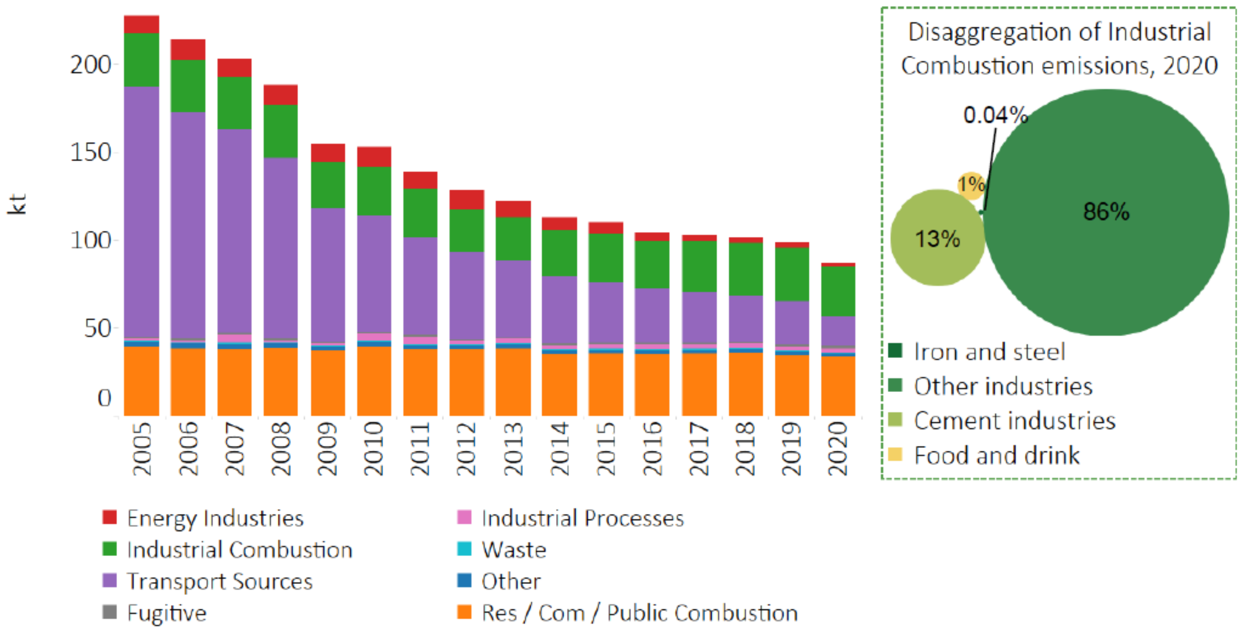
Table 9-7 and figure 9.14 provides a summary of Carbon Monoxide (CO) emission estimates for Scotland by category. The detailed data are available in the report and website citied in the introduction to this chapter.

Table 9-7 Summary of CO estimates for Scotland (2005 – 2020)

Category	2005	2006	2007	2008	2009	2010	2011	2012
Energy Industries	9.91	11.84	10.44	11.21	10.48	11.35	9.64	9.94
Industrial Combustion	30.27	30.06	29.74	30.77	25.54	26.75	26.97	24.61
Transport Sources	142.46	128.71	115.89	102.75	76.66	67.00	55.80	50.23
Other	5.56	5.55	9.32	5.45	5.34	8.32	8.86	5.69
Residential, Commercial & Public Sector Combustion	39.61	38.34	37.97	38.56	36.93	39.59	37.53	37.73
Total:	227.8	214.5	203.4	188.7	155.0	153.0	138.8	128.2

Category	2013	2014	2015	2016	2017	2018	2019	2020
Energy Industries	8.62	7.05	6.52	4.75	3.62	3.71	3.39	2.47
Industrial Combustion	24.64	26.70	27.71	27.40	29.26	30.16	30.82	28.29
Transport Sources	44.12	38.90	34.57	31.12	28.92	26.28	24.91	17.13
Other	6.46	6.31	6.68	6.60	6.27	6.30	6.22	6.32
Residential, Commercial & Public Sector Combustion	38.25	34.81	35.23	35.10	35.41	35.96	34.38	33.55
Total:	122.1	113.8	110.7	105.0	103.5	102.4	99.7	87.7

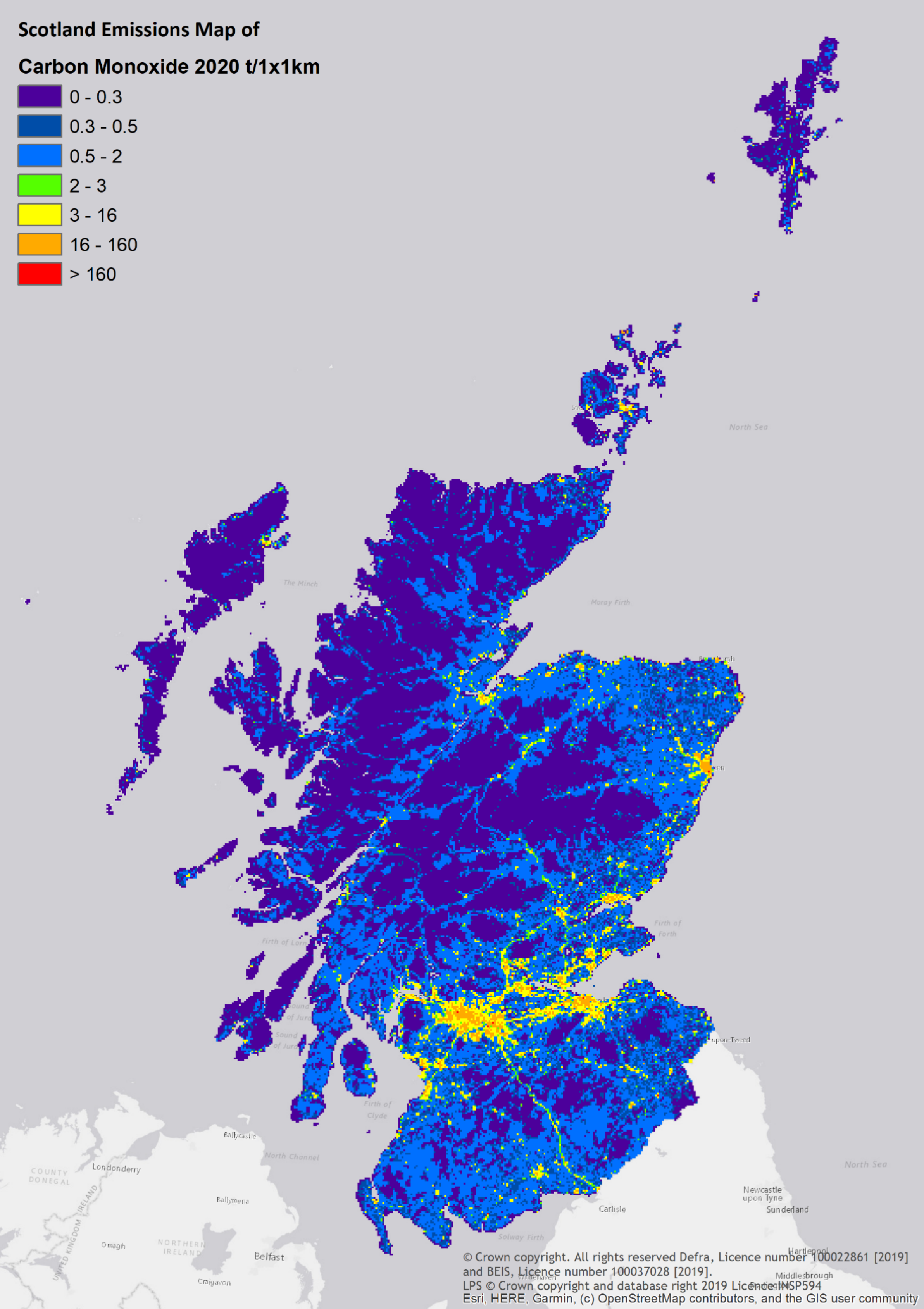
Figure 9.14 Time series of Scotland's CO emissions 2005-2020



Emissions of CO in Scotland were estimated to be 87 kt in 2020 and have declined by 62% since 2005. Emissions in Scotland accounted for 7% of the UK total for CO in 2020. This decline in emissions stems from changes in the contribution of transport sources, particularly in the road sector where emissions have declined by 92% since 2005 (contributing to 86% of the national trend in CO emissions). This decline is primarily to the penetration into the fleet of vehicles compliant with more recent Euro standards, which required the fitting of emission controls (e.g. three-way catalytic converters) in new petrol vehicles. Improved catalyst repair rates resulting from regulations controlling the sale and installation of replacement catalytic converters and particle filters for light-duty vehicles in 2008 also contribute to the trend. More recently, the switch from petrol cars to diesel cars, which have lower associated CO emissions rates, has also contributed to the observed trend. Emissions from the residential, commercial and public sector combustion have steadily increased since 2005, which corresponds with an increase in use of wood fuel in the domestic sector (BEIS, 2021a). CO emissions decreased by 12% between 2019 and 2020, mainly driven by the 31% decrease in emissions in this period from the transport sector. This is primarily due to travel restrictions imposed due to the COVID-19 pandemic.

Figure 9.13 shows a map of CO emissions in Scotland for 2020.

Figure 9.14 Map of CO Emissions in Scotland, 2020.



Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 2005 – 2020

10 COVID-19 LOCKDOWN AND ITS EFFECT ON AIR QUALITY IN SCOTLAND UPDATE - 2021

In July 2021, Ricardo produced a technical report for the Scottish Government which analysed the impact the Covid-19 lockdown measures had on air quality in Scotland[10]. This section provides an updated analysis to that report.

10.1 BACKGROUND

In the "Impact of Lockdown Measures on Scottish Air Quality in 2020" report[11] published last year, statistical models were developed to estimate the concentrations of key pollutants if Covid-19 had not occurred (i.e. a Business As Usual (BAU) scenario). When compared to measured data, the results indicated a decrease in NO_2 concentrations when compared to BAU modelled results, during the first lockdown in 2020.

Rules and restrictions on travelling continued into 2021 at varying levels. Details of the main restrictions and changes in Scotland in 2021 are provided below:

- 5th January - 'Stay at Home' restriction across mainland Scotland.
- 2nd April - 'Stay Local' replaces 'Stay at Home' restriction.
- 26th April - Scotland moves to Level 3.
- 17th May - Most of Mainland Scotland moves to Level 2.
- 5th June - Fifteen mainland local authorities moved to Level 1.
- 19th July - Restrictions lifted and mainland Scotland moves to Level 0.

This report follows on from the 2021 report and takes a look at how the lifting of restrictions has affected measured NO_2 concentrations. For the purposes of this short report and to better illustrate the changes that happened, a small selection of sites in the Glasgow and Edinburgh areas were chosen to illustrate what happened in Scotland's urban areas as a whole.

10.2 METHODOLOGY

Weather conditions have a large impact on the concentrations of air pollutants, therefore, to assess how air quality has changed over time, it is important to consider variabilities due to the weather. Fortunately, techniques have been developed that can be used to "de-weather" the data. These techniques are based on statistical models that can be used to estimate the pollutant concentrations under various meteorological conditions, and in turn to predict what the concentrations would be if the weather was always the same[12,13].

Here, the deweather R package[14], was used to build the statistical models to de-weather the data. The deweather package uses a Boosted Regression Trees approach to model air quality data. This approach enables complex relationships between variables to be easily handled.

Model inputs included the daily average concentrations from the Scottish Air Quality Database and local meteorological data (wind speed, wind direction, air temperature) from the Weather Research and Forecasting (WRF) regional scale model.

From the model outputs, the trend component can be extracted. The trend provides information on the variation in the pollutant with fixed average meteorology and can be used to investigate changes that are not due to the weather.

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[10] "Impact of Lockdown Measures on Scottish Air Quality in 2020",July 2021, Dr L Kramer http://www.scottishairquality.scot/news/reports?view=technical&id=653

[11] https://www.scottishairquality.scot/news/impact-lockdown-measures-scottish-air-quality-2020-report

[12] Grange, Stuart K., and David C. Carslaw. 2019. "Using Meteorological Normalisation to Detect Interventions in Air Quality Time Series." Science of The Total Environment 653 (February): 578–88. https://doi.org/10.1016/j.scitotenv.2018.10.344.

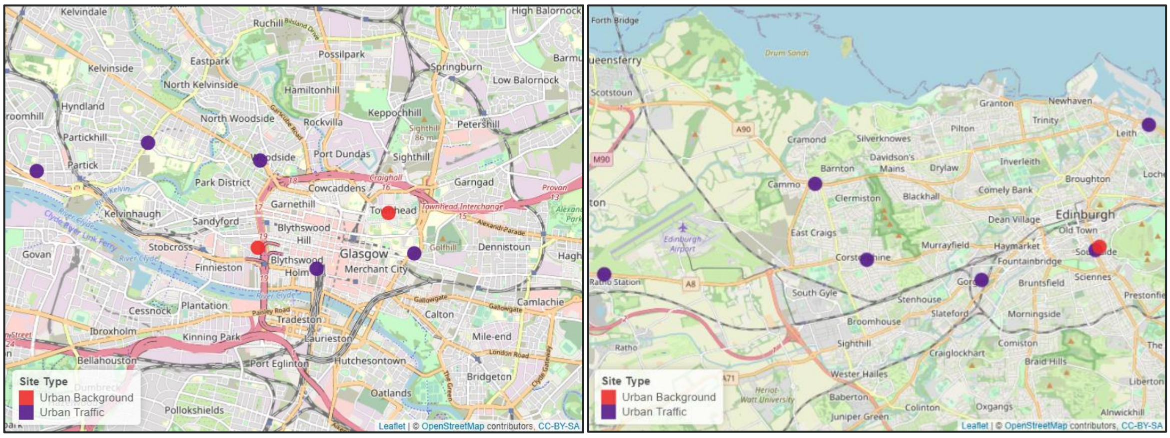
[13] Carslaw, David C., and Paul J. Taylor. 2009. "Analysis of Air Pollution Data at a Mixed Source Location Using Boosted Regression Trees." Atmospheric Environment 43 (22-23): 3563–70. https://doi.org/10.1016/j.atmosenv.2009.04.001.

[14] https://github.com/davidcarslaw/deweather

10.3 RESULTS

NO_2 measurements from fourteen monitor sites across Glasgow and Edinburgh (seven in each location) were used in the analysis presented here. The locations of the monitoring sites are shown in Figure 6.19

Figure 6.19 Location of the monitoring sites in Glasgow (left) and Edinburgh (right) selected for the analysis.



Annual traffic data from the UK Department for Transport in Glasgow and Edinburgh between 2017 to 2021 is shown in Figure 6.20. The data shows the estimated number of vehicle miles travelled for all motor vehicles, and is based on the average annual daily flow, days in the year, and length of the road[15]. The data shows a large dip in vehicle miles travelled in 2020 in both cities, followed by an increase in 2021. However, traffic levels in 2021 were still below those observed in 2019.

Figure 6.20 Annual vehicle miles (in millions) for Glasgow City and the City of Edinburgh local authorities, between 2017 and 2021 (source: Department for Transport (https://roadtraffic.dft.gov.uk/)).

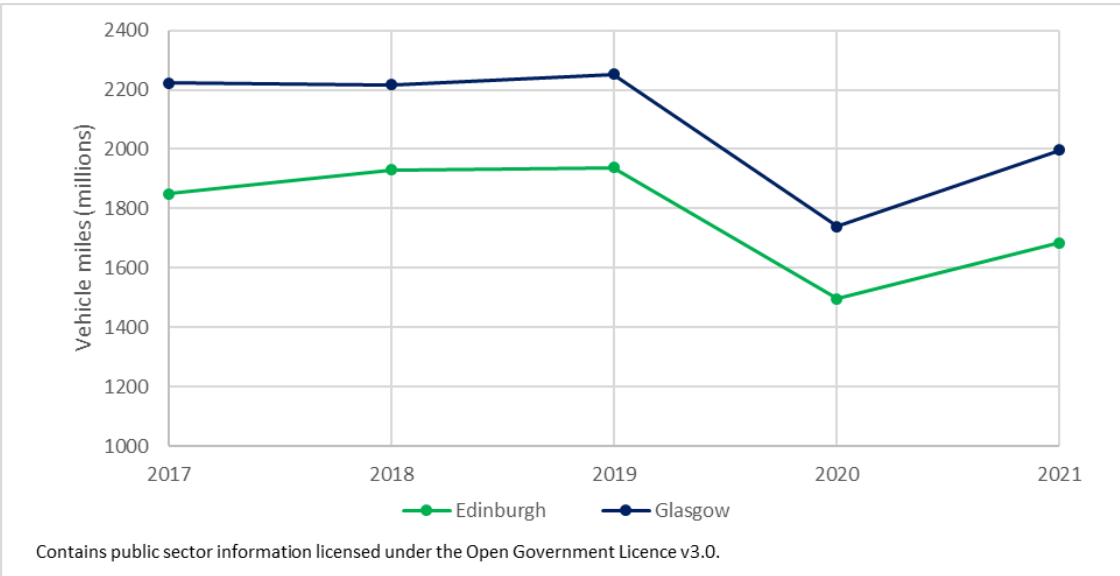


Figure 6.21 shows meteorologically normalised trends of NO_2 concentrations for urban traffic and urban background sites in the Glasgow area from 2017 to 2021. For all sites shown, there is a clear decrease in NO_2 concentrations coinciding with the start of the first lockdown in 2020. This is then followed by an increase in NO_2 concentrations during late summer. However, for most of the sites, the NO_2 concentrations have not increased to the levels observed pre-lockdown. The exception is Glasgow Anderston, an urban background site, where it can be observed that the NO_2 levels in 2021 are similar to those before lockdown. An urban

[15] https://roadtraffic.dft.gov.uk/regions/3

background site is one that is located away from major roads; therefore it is expected to be less influenced by changes in traffic volumes when compared to urban traffic sites.

The largest difference in concentrations of NO_2 between pre-lockdown and 2021 is observed at Glasgow Kerbside monitoring site. This site is located on Hope Street, next to Glasgow Central train station and as can be seen by Figure 6.3 has historically the highest concentrations of NO_2. Figure 6.22 shows the average change in NO_2 concentrations during the day (over the year stated) at Glasgow Kerbside in 2019, 2020 and 2021. Mean NO_2 concentrations during the morning rush hour (7-10 am) in 2021 are very similar to those in 2019. However, late afternoon/early evening the mean NO_2 concentrations remain lower in 2021 when compared to 2019, suggesting that traffic patterns may have changed since the lockdowns. Another possible contributing factor is that a change in the vehicle fleet may have contributed to the decrease in concentrations. However, additional analysis will need to be carried out to determine how much affect this will have had, if any.

Figure 6.21 Meteorologically normalised trends of NO_2 concentrations measured at selected sites in Glasgow from 2017 to 2021.

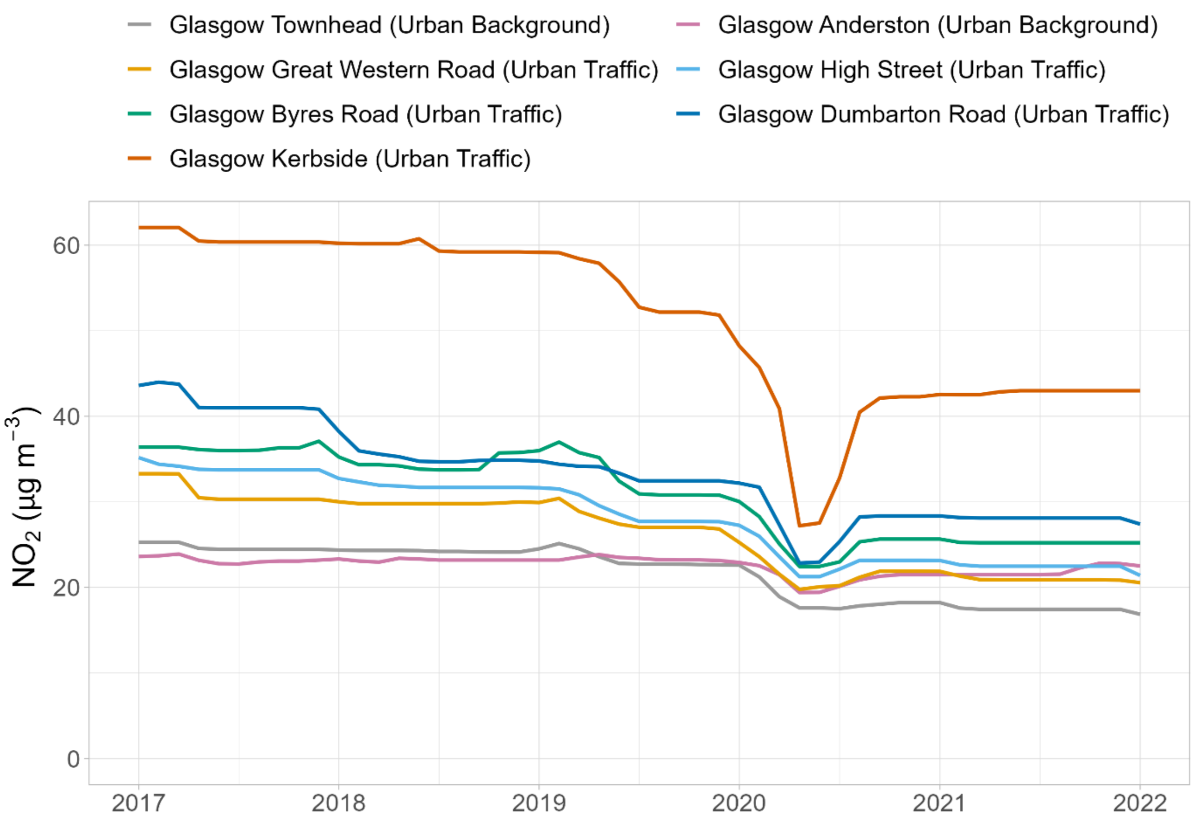
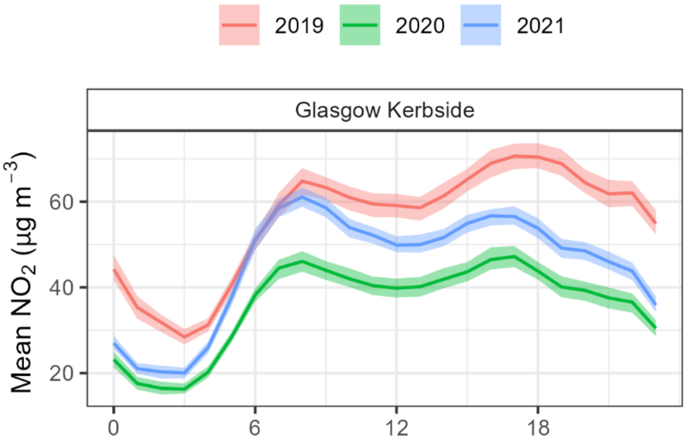


Figure 6.22 Mean NO_2 concentrations for each hour of day at Glasgow Kerbside for 2019, 2020 and 2021.The shaded region represents the 95% confidence interval in the mean.



Meteorologically normalised trends of NO_2 concentrations for urban traffic and urban background sites in the Edinburgh area are shown in Figure 6.23. The variability in NO_2 is similar to that observed in Glasgow with a decrease in NO_2 concentrations in 2020 observed at most sites, followed by an increase, but remaining below pre-lockdown levels. For three sites (Glasgow Road, Salamander Street and St Leonard's) the meteorologically normalised NO_2 concentrations increased only very slightly, or not at all after the first lockdown. The analysis also indicates that the sites that historically had the higher NO_2 concentrations experience the larger decreases.

It should be noted that although the NO_2 concentrations measured at Nicolson Street in 2020 appear to decrease earlier than at other sites, this is due to a gap in the measured data between January and April 2020.

Figure 6.23 Meteorologically normalised trend of NO_2 concentrations measured at selected sites in Edinburgh from 2017 to 2021.

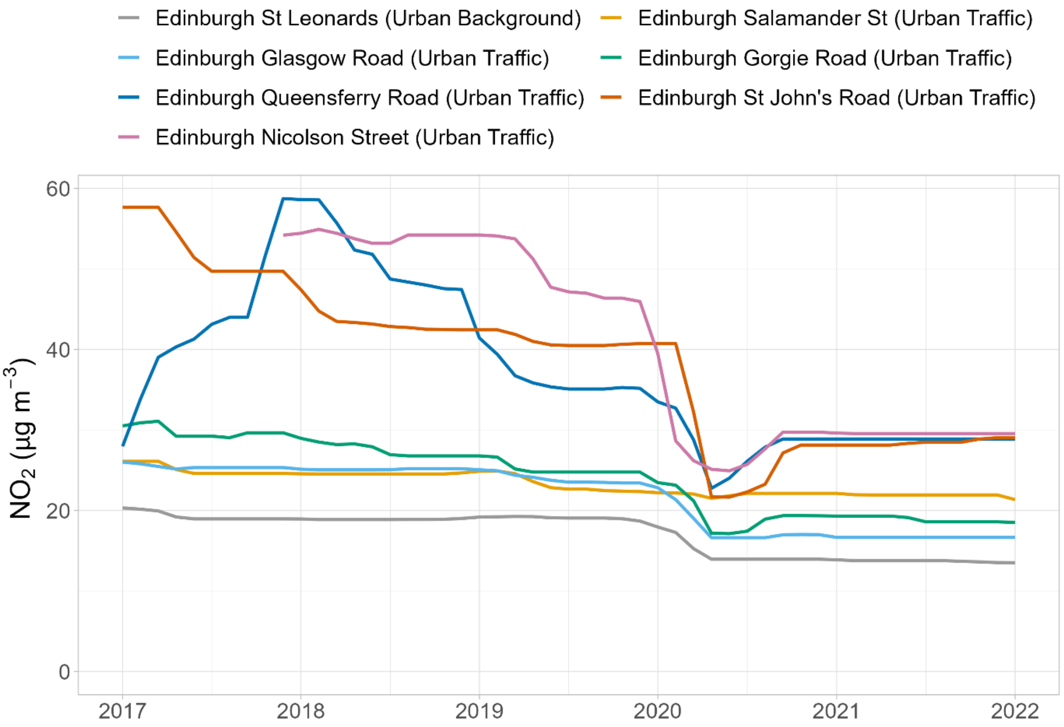
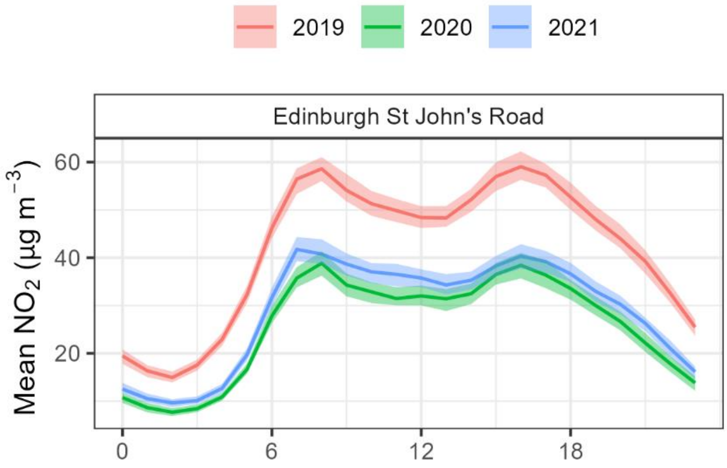


Figure 6.24 shows the average change in NO_2 concentrations during the day (over the year stated) at Edinburgh St John's Road in 2019, 2020 and 2021. As can be seen, the rush hour periods are more defined in 2019 (camel hump affect) than in 2020 and 2021. This suggests that a change in driving patterns occurred in 2020 and 2021 with less people travelling during the rush hour period and more consistently during the working day. The diurnal trend also illustrates the drop of in NO_2 concentrations in both 2020 and 2021 compared to 2019. The trend is also different to Glasgow Kerbside as the increase in concentration between 2020 and 2021 isn't as evident (only a slight increase) at St Johns Road. This is possibly due to the location type difference. Glasgow Kerbside is located in the very centre of Glasgow whereas St Johns Road is more suburban.

Figure 6.24 Mean NO_2 concentrations for each hour of day at Edinburgh St John's Road for 2019, 2020 and 2021.The shaded region represents the 95% confidence interval in the mean.



10.4 SUMMARY

During the first half of 2021, varying levels of restrictions were still in place across Scotland, as a result of the Covid-19 pandemic. Traffic data from Glasgow and Edinburgh areas indicate that there was an increase in annual vehicle miles travelled in these areas in 2021, after an initial decrease in 2020. However, traffic has not reached the levels observed pre-lockdown.

The analysis of meteorologically normalised trends in NO_2 concentrations from a selection of sites in the Glasgow and Edinburgh areas shows a similar change to that of the traffic levels. NO_2 concentrations decreased sharply at most sites during the first lockdown in 2020, followed by an increase around summertime. However, NO_2 concentrations in 2021 remain below the levels measured in 2019. The largest decreases in NO_2 concentrations are seen at sites with historically higher concentrations.

11 SUMMARY AND CONCLUSION

In April 2007, Ricardo Energy & Environment (Ricardo) were commissioned by the Scottish Government to undertake a three-year project (Apr 2007 – Apr 2010) to develop an Air Quality Database and Website for Scotland. This contract has been renewed in consecutive years, with the latest contract running from 2019-2023.

This report brings together all the Scottish Air Quality Database data for calendar year 2021 and associated work relating to project deliverables including: data management; QA/QC services; liaison with stakeholders; website development; spatial analysis of air quality data; trend analysis.

In addition, this year's report provides updated analysis on how the Covid-19 pandemic affected air quality in Scotland. This analysis follows on from the 2020 annual report Covid-19 analysis.

Legislation and Policy

Air quality management is shaped by requirements of EU, UK and Scottish legislation and policies. Following the UK's exit from the EU, under retained EU law, the UK is required to continue to meet limit and target values for a range of air pollutants and other legal obligations covered by EU directives.

In July 2021, accompanied by a Delivery Plan, and replacing "Cleaner Air for Scotland – The Road to a Healthier Future", the Scottish Government published Scotland's second air quality strategy called "Cleaner Air for Scotland 2 – Towards a Better Place for Everyone" (CAFS2). CAFS2 is shaped around 10 general themes. These are:

1. Health – A Precautionary Approach
2. Integrated Policy
3. Placemaking
4. Data
5. Public Engagement and Behavioural Change
6. Industrial Emissions Regulation
7. Tackling Non-Transport Emission Sources
8. Transport
9. Governance, Accountability and Delivery
10. Further Progress Review

Air Quality Monitoring in Scotland

Air pollution data for 99 automatic monitoring sites throughout Scotland are available in the database for all or part of 2021. All automatic data maintained within the Scottish database are subject to the same QA/QC procedures as the UK Automatic Urban and Rural Network (AURN).

In 2021, of the 73 sites with data capture of greater than 75% one automatic monitoring site (Glasgow Kerbside (Hope Street) exceeded the annual mean objective for NO_2. In 2021, five passive diffusion tube monitoring sites exceeded the NO_2 annual mean objective. These four sites were located in the four major Scottish cities.

In 2021, no automatic monitoring sites measuring Particulate Matter (PM_{10} and $PM_{2.5}$) measured exceedances of the Scottish 24 hour or annual mean objectives for both PM_{10} and $PM_{2.5}$.

As with 2020, the pattern of measured concentrations in 2021 for both NO_2 and Particulate Matter (PM) is not consistent with previous years. A significant decline in concentrations, especially in NO_2, is attributed to the Covid-19 pandemic lockdown restrictions that continued at different levels during 2021.

In 2021, no exceedances of AQS objectives were observed for the pollutants Ozone (O_3), Sulphur Dioxide (SO_2), Carbon Monoxide (CO), benzene, 1,3-butadiene, benzo(a)pyrene, and Lead (Pb).

Air Quality Mapping of Scotland

The 2020 annual mean NO_2 concentrations for Scotland were modelled for background and roadside locations for NO_2, PM_{10} and $PM_{2.5}$.

For NO_2, there were no modelled exceedances of the Scottish annual mean objective of 40 µg m^{-3} at background or roadside locations.

For PM_{10}, there were no modelled exceedances of the Scottish annual mean PM_{10} objective of 18 µg m^{-3} at background or roadside locations.

For $PM_{2.5}$, there were also no modelled exceedances of the Scottish annual mean $PM_{2.5}$ objective of 10 µg m^{-3} at both background and roadside locations.

Air Quality Trends for Scotland

NO_2

Trend analysis of nitrogen dioxide concentrations at Scotland's five long-running urban non-roadside sites shows that NO_2 concentrations are displaying highly significant decreasing trends. More recent years analysis (2017 to 2021) show a less consistent trend across the country with one site showing increasing trends contradicting the perception that NO_2 concentrations are decreasing at all urban background sites

Analysis shows that NO_2 concentrations at Scotland's three long-running rural sites showed small decreasing trends.

Of the eight selected NO_2 urban traffic monitoring sites selected for analysis; all eight sites showed highly significant decreasing trends. Examination of trends at the same eight sites over the most recent five years indicates that the patterns were very similar to the 10-year trends.

PM_{10}

PM_{10} trend analysis at Scotland's eight long-running urban/Industrial background sites showed highly significant decreasing trends at all sites. Seven out of Scotland's eight long-running urban traffic sites also showed statistically highly significant decreasing trends at all sites. The exception being Glasgow Byres Road

Examination of trends in PM_{10} at the same eight sites over the most recent five years indicates that, at some of these, the decreasing trends have continued but at others they have weakened or levelled off.

$PM_{2.5}$

By the end of 2021 there were four sites with 10 consecutive years of $PM_{2.5}$ data. Aberdeen Errol Place, Edinburgh St Leonards, and Grangemouth sites show slight but highly statistically significant decreasing trends for $PM_{2.5}$. Contrary to this, the rural site, Auchencorth Moss, showed no obvious trend over the past 10 years.

Looking at a selection of nine urban background and traffic sites with five years' worth of data. Four sites have highly significant decreasing trends. Four other sites, though decreasing, have no real identifiable statistically significant trend. The South Lanarkshire Uddingston site however has an increasing trend though not statistically significant.

Ozone

Ozone has been measured at three rural sites in Scotland for 30 years. Two sites showed small but statistical highly significant increasing trends whereas the other showed no obvious trend. Ozone has been measured for the past 10 years at six rural sites. In contrast to the 30-year trends, the 10-year trends were less consistent. Four sites have increasing trends in O_3 concentrations at varying levels of statistical significance. The other two sites have slight decreasing trends

10-year trend analysis of ozone concentrations showed increasing trends (at varying statistical significance) at all three Scottish urban background sites.

Additional Trend Analysis

Additional trend analysis was carried out at four sites located within the four major cities in Scotland. This analysis was carried out using the Openair analysis tool and compared 2021 data with data from the previous 10 years using a variety of analytical techniques.

Emissions of Pollution Species

Emissions of **NOx** in Scotland are estimated to have declined by 61% since 2005 and were estimated to be 82 kt in 2020, representing 12% of the UK total. The decline is mainly due to changes in transport sources. Declines in emission from the Energy industry (linked to the Boosted Over-Fire Air (BOFA) abatement systems) has also contributed to the decline in emissions.

Emissions of **PM_{10}** have declined by 46% since 2005 and in 2020 and were estimated to be 11 kt (8% of the UK total). Emissions from energy industries (and its movement away from coal use) and transport sources (the fleet increasing compliance with Euro emission standards) have had the most notable impact on the trend. Emissions levels between 2015 and 2019 plateaued before decreasing again in 2020.

Emissions of **$PM_{2.5}$** have declined by 52% since 2005 and in 2020 were estimated to be 6 kt (8% of the UK total). The primary drivers for the decline in emissions since 2005 are the continued switch from coal to natural gas in electricity generation, and reductions in emissions from the transport sector due to the introduction of progressively more stringent emissions standards through time. As with PM_{10}, emissions levels between 2015 and 2019 plateaued before decreasing again in 2020.

Emissions of **CO** in Scotland were estimated to be 87 kt in 2020 (7% of the UK total) and have declined by 62% since 2005. This decline in emissions stems from changes in the contribution of transport sources, particularly in the road sector where emissions have declined by 92% since 2005. This decline is primarily due to the penetration into the fleet of vehicles compliant with more recent Euro standards, which required the fitting of emission controls in new petrol vehicles.

Emissions of **SO_2** in Scotland were estimated to be 8 kt in 2020, representing 6% of the UK total in 2020 for sulphur dioxide. Emissions have declined by 92% since 2005 mainly due to continued changes in the power generation sector. Since 2005, SO_2 emissions from power stations have reduced by 99%.

Emissions of **Ammonia** have declined by only 10% since 2005 and were estimated to be 32 kt (12% of the UK total) in 2020. Agriculture sources dominate throughout the time-series. The initial trends in NH_3 emissions were primarily driven by decreases in livestock numbers and declines in the use of nitrogen-based fertilisers. After 2010, however, this decline began to be offset by increased application of urea-based and organic fertilisers such as digestate to agricultural soils causing fluctuating emissions totals since 2008, with no significant trends across these years.

Emissions of **Non-Methane Volatile Organic Compounds (NMVOCs)** have declined 19% since 2005 and were estimated to be 142 kt in 2020 (19% of the UK total). This reduction is a result of reductions in fugitive and transport emissions which have declined 72% and 84% respectively since 2005. There has been an increasing trend in NMVOCs since 2011. This has been attributed to the increased emissions from the food and drink sector specifically the storage and production of whisky (53% of emissions in 2020).

Covid-19 lockdown and its effect on air Quality in Scotland

During the first half of 2021, varying levels of restrictions were still in place across Scotland, as a result of the Covid-19 pandemic. Traffic data from Glasgow and Edinburgh areas indicate that there was an increase in annual vehicle miles travelled in these areas in 2021, after the decrease in 2020. However, traffic has not reached the levels observed pre-lockdown.

The analysis of meteorologically normalised trends in NO_2 concentrations from a selection of sites in the Glasgow and Edinburgh areas shows a similar change to that of the traffic levels. NO_2 concentrations decreased sharply at most sites during the first lockdown in 2020, followed by an increase around summertime. However, NO_2 concentrations in 2021 remain below the levels measured in 2019. The largest decreases in NO_2 concentrations are seen at sites with historically higher concentrations.

APPENDICES

Appendix 1: Ratification Procedures

Appendix 2: Sites audited, and data ratification undertaken during 2021

Appendix 3: Process used for VCM Correcting SAQD TEOM Data

Appendix 4: National Monitoring Network in Scotland 2021

Appendix 5: Pollution Emissions data for B(a)p, Dioxins, Pb, Hg

Appendix 1 Ratification Procedures

A1.1 Intercalibration and Audit procedures

The audit and intercalibration procedures adopted by Ricardo Energy & Environment rely upon the principle that a set of recently certified gas cylinders (called "audit gas") is taken to all the stations in a monitoring network. This gas is certified at the Ricardo Energy & Environment Gas Calibration Laboratory. At each station, analyser response to audit gas is recorded to check if the expected concentration (i.e. the certified value for the cylinder) is obtained. The analyser response to audit gas is obtained using calibration factors obtained from the site operator. The audit procedure checks the validity of the provisional data, the correct overall operation of the analyser and the reliability of calibrations undertaken routinely at that station. These site audit procedures are compliant with the requirements of the CEN standard methods of measurement and are used throughout the UK AURN network.

The results of the audit exercises form an integral part of the data management system and are fed directly into the data ratification process. After the audit exercise, data from all the stations visited are traceable to recently calibrated UKAS accredited gas calibration standards (the audit gas).

A1.1.1 Detailed instrumentation checks

The following instrument functional checks are undertaken at an audit:

- Analyser accuracy and precision, as a basic check to ensure reliable datasets from the analysers.
- Instrument linearity, to check that doubling a concentration of gas to the analyser results in a doubling of the analyser signal response. If an analyser is not linear, data cannot be reliably scaled into concentrations.
- Ozone analyser calibration against a traceable ozone photometer
- Instrument signal noise, to check for a stable analyser response to calibration gases.
- Analyser response time, to check that the analyser responds quickly to a change in gas concentrations.
- Leak and flow checks, to ensure that ambient air reaches the analysers, without being compromised in any way.
- NO_X analyser converter efficiency, via gas phase titration, to ensure reliable operation. The converter must be more than 95% efficient to ensure that the NO_2 data are of the required accuracy.
- TEOM k_0 evaluation. The factor is used to calculate particulate mass concentrations.
- Particulate analyser flowrates. Any error in the flow through these particulate analysers is directly reflected in an error in the final measure of particulate concentration.
- SO_2 analyser hydrocarbon interference, certain hydrocarbons are known to interfere with the SO_2 detector.
- Evaluation of site cylinder concentrations, with reference to the certified audit gas taken to the stations. This procedure allows for the correction of data from stations where the site calibration cylinder concentration is slowly changing and for identification of any unstable cylinders that require replacement.
- Assessing changes in local site environment. During the visit, a record of any changes in the site environment, for example any increase or decreased traffic flow due to road layout changes, construction activity, encroachment of the site by vegetation etc.
- Assessment of station infrastructure and operational procedures. Any deficiencies in site infrastructure or operational procedures, which may affect data quality or safe operation of the site, are noted.
- Ensure Local Site Operators (LSO) understand calibration procedures correctly. It is the calibrations by the LSOs that are used to scale pollution datasets and hence, it is important to check that these are undertaken reliably.

The procedures used to determine instrument performance are documented in Ricardo Energy & Environment Work Instructions. These methods are regularly updated and improved and have been evaluated by the United Kingdom Accreditation Service (UKAS). Tests are performed on the analysers, cylinders and ambient air inlet systems. Checks are made on the environment around the site, including the continued representative nature of the site and safety assessments. The data collected from the instrument and cylinder tests are collated on site, using a controlled and protected Excel spreadsheet, which automatically undertakes all calculations and alerts the audit staff to any unusual results. The completed spreadsheets are then returned for further checking, before being used within the data management process and in production of accredited Certificates of Calibration.

A1.1.2 UKAS Accreditation

Ricardo Energy & Environment holds UKAS accreditation to ISO 17025 for the on-site calibration of the gas analysers (NO_X, CO, SO_2, O_3), for flow rate checks on particulate (PM_{10}) analysers and for the determination of the spring constant, k_0, for the TEOM analyser.

ISO17025 accreditation provides complete confidence that the analyser calibration factors are traceable to national metrology standards, that the calibration methods are sufficient and fit for purpose, and that the uncertainties are appropriate for data reporting purposes. Ricardo Energy & Environment also holds ISO17025 accreditation for laboratory certification of NO, NO_2, CO and SO_2 gas cylinders.

A1.1.3 Zero air

The reliability of the zero-air supply at each station is of fundamental importance in the determination of ambient concentrations. A reference zero air source is held at the Ricardo Energy & Environment Gas Calibration Laboratory, which is traceable to international standards. A transfer standard, checked against this standard, is used to evaluate the site zero sources at the QA/QC audits. The zero-air supply at a site will be either:

- A zero-air cylinder.
- A series of chemical scrubbers, connected to a pumped delivery system.
- A pollutant specific chemical scrubber system to connect directly into the analyser.

A1.1.4 Ozone Photometers

Ozone photometers are calibrated every six months against the NIST Reference Photometer, held at NPL, before use at the station audits.

A1.2 Data Acquisition and Processing

The Scottish local authority monitoring stations are polled three times a day to retrieve 15-minute averages of raw output from instruments. This is a balance between regular updating of the database and web site yet minimising the associated telecoms costs. UK National network stations are polled hourly as these data are used for the air quality forecast system.

The data are transmitted via MODEM or internet connection, depending on type of logging system used at the site, and automatically appended to the air quality site database. The results of automatic overnight autocalibration checks are also retrieved and databased. Appropriate scaling factors based on the most recent calibration information are applied to the pollutant measurements to produce concentrations in the relevant units.

From the 15-minute values, the hourly averaged results are calculated. This is the averaging period used for the reporting of both validated and ratified data for all pollutants. Additionally, the 15-minute data files are provided for SO_2 to allow direct comparison with the 15-minute objective. Once the raw data from the stations has been acquired the next step in the data management process is data validation.

A1.2.1 Validation of Data

All incoming data from the monitoring station are automatically screened prior to the release of validated data sets. Experienced staff will check the data daily, to monitor satisfactory data acquisition and to investigate instances of suspect data. This daily checking ensures rapid diagnosis of any instrument malfunctions.

The automatic screening procedures, and many years' experience of our staff, enables us to ensure that only the highest quality data are released to the Scottish Air Quality Database and Website as validated data.

Should equipment or site problems be identified, it is possible for data management staff to contact the monitoring station manually, in order to access further information. If necessary, the relevant LSO is contacted to undertake further investigation.

A1.3 Data Ratification

This section provides details of the procedures and the software tools we use for data ratification.

Our software runs a number of protocols to automatically flag data anomalies in the provisional data received from the stations, these are examined in detail during the ratification process. These include identifying the following:

- Negative data
- High data peaks
- Calibrations which are more than 5% different from previous values
- Peaks with a maximum 15-minute concentration significantly above the hourly mean value
- Measurements which are outside the normal range of expected data e.g. elevated ozone concentrations during the winter months
- Long periods of constant or zero concentrations
- Data gaps of more than six hours.

A1.3.1 Ratification tasks and output

When ratifying data, the following are closely examined:

- Issues that have been flagged up automatically by the software
- zero and sensitivity factors used on each day
- General review of the result to make sure that there are no other anomalies.

A1.3.2 Ratified Data Checking

Once the data have been initially ratified proforma reports is produced and passed to the data checker The role of the data checker is to:

- Assess if there are any station problems if not the data can be marked as ratified.
- Return the station to the data ratifier if there are any issues requiring further action by the data ratifier.
- Forward the report to the project Quality Circle if there are data quality issues which require a group discussion to resolve.

Following the Quality Circle meeting the data are then corrected if required and uploaded as ratified to the database and web site.

Appendix 2 Sites audited, and data ratification undertaken during 2021

A2 1. Air quality site intercalibration and audits conducted during 2021

Site Name	Winter 2020/21	Summer 2021	Site Name	Winter 2020/21	Summer 2021
Aberdeen Anderson Dr	✓	✓	Glasgow Dumbarton Road	✓	✓
Aberdeen Errol Place	✓	✓	Glasgow Kerbside	✓	✓
Aberdeen Errol Park	-	✓	Glasgow Great Western Road	✓	✓
Aberdeen King Street	✓	✓	Glasgow High Street	✓	✓
Aberdeen Market Street 2	✓	✓	Glasgow Nithsdale Road	✓	✓
Aberdeen Union Street Roadside~	✓	✓	Glasgow Townhead	✓	✓
Aberdeen Wellington Road	✓	✓	Glasgow Waulkmillglen Reservoir	✓	✓
Alloa A907	✓	✓	Grangemouth	✓	✓
Angus Forfar Glamis Road	✓	✓	Grangemouth Moray~	✓	✓
Auchencorth Moss	✓	✓	Grangemouth Moray Scot Gov~	✓	✓
Bush Estate	✓	✓	Inverclyde Greenock A8	✓	✓
Dumbarton Roadside	✓	✓	Inverness*	✓	✓
Dumfries	✓	✓	Inverness Academy Street	✓	✓
Dundee Broughty Ferry Road	✓	✓	Inverness Academy Street 1st Floor	✓	✓
Dundee Lochee Road	✓	✓	Lerwick~	✓	✓
Dundee Mains Loan	✓	✓	N Lanarkshire Airdrie Kenilworth Dr	✓	✓
Dundee Meadowside	✓	✓	N Lanarkshire Chapelhall	✓	✓
Dundee Seagate	✓	✓	N Lanarkshire Coatbridge Sunnyside Rd	✓	-
Dundee Whitehall Street	✓	✓	N Lanarkshire Coatbridge Whifflet	✓	✓
East Ayrshire Kilmarnock St Marnock St	✓	✓	N Lanarkshire Croy	✓	✓
East Dunbartonshire Bearsden	✓	✓	N Lanarkshire Kirkshaws	✓	✓
East Dunbartonshire Bishopbriggs	✓	✓	N Lanarkshire Motherwell	✓	✓
East Dunbartonshire Kirkintilloch	✓	✓	N Lanarkshire Motherwell Adele Street	✓	✓
East Dunbartonshire Milngavie	✓	✓	N Lanarkshire Shawhead Coatbridge	✓	✓
East Lothian Musselburgh N High St	✓	✓	N Lanarkshire Uddingston New Edinburgh Rd	✓	✓
Edinburgh Currie	✓	✓	North Ayrshire Irvine High Street	✓	✓
Edinburgh Glasgow Road	✓	✓	Paisley Gordon Street	✓	✓
Edinburgh Gorgie Road	✓	✓	Peebles	✓	✓
Edinburgh Nicolson Street	✓	✓	Perth Atholl Street	✓	✓
Edinburgh Queensferry Road	✓	✓	Perth Bridgend	✓	✓
Edinburgh Salamander St	✓	✓	Perth Crieff	✓	✓
Edinburgh St John's Road	✓	✓	Perth High Street	✓	-

Site Name	Winter 2020/21	Summer 2021	Site Name	Winter 2020/21	Summer 2021
Edinburgh St Leonards	✓	✓	Perth Muirton	✓	✓
Edinburgh Tower Street	✓	✓	Renfrew Cockels Loan	✓	✓
Eskdalemuir	✓	-	Renfrew Inchinnan Road	✓	✓
Falkirk Banknock	✓	✓	Renfrewshire Johnston	✓	✓
Falkirk Bo'ness	✓	✓	Shetland Lerwick~	✓	✓
Falkirk Grangemouth MC	✓	✓	South Ayrshire Ayr Harbour	✓	✓
Falkirk Grangemouth Zetland Park	✓	✓	South Ayrshire Ayr High St	✓	✓
Falkirk Haggs	✓	✓	South Lanarkshire Blantyre	✓	✓
Falkirk Hope St	✓	✓	South Lanarkshire Cambuslang	✓	✓
Falkirk Main St Bainsford	✓	✓	South Lanarkshire East Kilbride	✓	✓
Falkirk West Bridge Street	✓	✓	South Lanarkshire Hamilton	✓	✓
Fife Cupar	✓	✓	South Lanarkshire Lanark	✓	✓
Fife Dunfermline	✓	✓	South Lanarkshire Raith Interchange 2	✓	✓
Fife Kirkcaldy	✓	✓	South Lanarkshire Rutherglen	✓	✓
Fife Rosyth	✓	✓	South Lanarkshire Uddingston	✓	✓
Fort William	✓	✓	Stirling Craig's Roundabout	✓	✓
Glasgow Abercromby Street	✓	✓	Strath Vaich	✓	✓
Glasgow Anderston	✓	✓	West Dunbartonshire Clydebank	✓	✓
Glasgow Broomhill	✓	✓	West Lothian Broxburn	✓	✓
Glasgow Burgher Street	✓	✓	West Lothian Linlithgow High St 2	-	✓
Glasgow Byres Road	✓	✓	West Lothian Newton	✓	✓

The column headings labelled Q1 – Q4 refer to the quarter periods of the calendar year:

- Q1 = January to March
- Q2 = April to June
- Q3 = July to September
- Q4 = October to December

A2 2. Data ratification undertaken during 2021

Site Name	Q1	Q2	Q3	Q4	Site Name	Q1	Q2	Q3	Q4
Aberdeen Anderson Dr	✓	✓	✓	✓	**Glasgow Kerbside**	✓	✓	✓	✓
Aberdeen Errol Place	✓	✓	✓	-	**Glasgow Great Western Road**	✓	✓	✓	✓
Aberdeen Errol Park	-	-	-	✓	**Glasgow High Street**	✓	✓	✓	✓
Aberdeen King Street	✓	✓	✓	✓	**Glasgow Nithsdale Road**	✓	✓	✓	✓
Aberdeen Market Street 2	✓	✓	✓	✓	**Glasgow Townhead**	✓	✓	✓	✓
Aberdeen Union Street Roadside~	✓	✓	✓	✓	**Glasgow Waulkmillglen Reservoir**	✓	✓	✓	✓
Aberdeen Wellington Road	✓	✓	✓	✓	**Grangemouth**	✓	✓	✓	✓
Alloa A907	✓	✓	✓	✓	**Grangemouth Moray~**	✓	✓	✓	✓

Site Name	Q1	Q2	Q3	Q4	Site Name	Q1	Q2	Q3	Q4
Angus Forfar Glamis Road	✓	✓	✓	✓	Grangemouth Moray Scot Gov~	✓	✓	✓	✓
Auchencorth Moss	✓	✓	✓	✓	Inverclyde Greenock A8	✓	✓	✓	✓
Bush Estate	✓	✓	✓	✓	Inverness*	✓	✓	✓	✓
Dumfries	✓	✓	✓	✓	Inverness Academy Street	✓	✓	✓	✓
Dundee Broughty Ferry Road	✓	✓	✓	✓	Inverness Academy Street 1st Floor	✓	✓	✓	✓
Dundee Lochee Road	✓	✓	✓	✓	Lerwick~	✓	✓	✓	✓
Dundee Mains Loan	✓	✓	✓	✓	N Lanarkshire Airdrie Kenilworth Dr	✓	✓	✓	✓
Dundee Meadowside	✓	✓	✓	✓	N Lanarkshire Chapelhall	✓	✓	✓	✓
Dundee Seagate	✓	✓	✓	✓	N Lanarkshire Coatbridge Sunnyside Rd	✓	-	-	-
Dundee Whitehall Street	✓	✓	✓	✓	N Lanarkshire Coatbridge Whifflet	✓	✓	✓	✓
East Ayrshire Kilmarnock St Marnock St	✓	✓	✓	✓	N Lanarkshire Croy	✓	✓	✓	✓
East Dunbartonshire Bearsden	✓	✓	✓	✓	N Lanarkshire Kirkshaws	✓	✓	✓	✓
East Dunbartonshire Bishopbriggs	✓	✓	✓	✓	N Lanarkshire Motherwell	✓	✓	✓	✓
East Dunbartonshire Kirkintilloch	✓	✓	✓	✓	N Lanarkshire Motherwell Adele Street	✓	✓	✓	✓
East Dunbartonshire Milngavie	✓	✓	✓	✓	N Lanarkshire Shawhead Coatbridge	✓	✓	✓	✓
East Lothian Musselburgh N High St	✓	✓	✓	✓	N Lanarkshire Uddingston New Edinburgh Rd	✓	✓	✓	✓
Edinburgh Currie	✓	✓	✓	✓	North Ayrshire Irvine High Street	✓	✓	✓	✓
Edinburgh Glasgow Road	✓	✓	✓	✓	Paisley Gordon Street	✓	✓	✓	✓
Edinburgh Gorgie Road	✓	✓	✓	✓	Peebles	✓	✓	✓	✓
Edinburgh Nicolson Street	✓	✓	✓	✓	Perth Atholl Street	✓	✓	✓	✓
Edinburgh Queensferry Road	✓	✓	✓	✓	Perth Bridgend	-	✓	✓	✓
Edinburgh Salamander St	✓	✓	✓	✓	Perth Crieff	✓	✓	✓	✓
Edinburgh St John's Road	✓	✓	✓	✓	Perth High Street	✓	-	-	-
Edinburgh St Leonards	✓	✓	✓	✓	Perth Muirton	✓	✓	✓	✓
Edinburgh Tower Street	✓	✓	✓	✓	Renfrew Cockels Loan	✓	✓	✓	✓
Eskdalemuir	✓	✓	✓	✓	Renfrew Inchinnan Road	✓	✓	✓	✓
Falkirk Banknock	✓	✓	✓	✓	Renfrewshire Johnston	✓	✓	✓	✓
Falkirk Bo'ness	✓	✓	✓	✓	Shetland Lerwick~	✓	✓	✓	✓
Falkirk Grangemouth MC	✓	✓	✓	✓	South Ayrshire Ayr Harbour	✓	✓	✓	✓
Falkirk Grangemouth Zetland Park	✓	✓	✓	✓	South Ayrshire Ayr High St	✓	✓	✓	✓
Falkirk Haggs	✓	✓	✓	✓	South Lanarkshire Blantyre	✓	✓	✓	✓
Falkirk Hope Street	✓	✓	✓	✓	South Lanarkshire Cambuslang	✓	✓	✓	✓
Falkirk Main St Bainsford	✓	✓	✓	✓	South Lanarkshire East Kilbride	✓	✓	✓	✓
Falkirk West Bridge Street	✓	✓	✓	✓	South Lanarkshire Hamilton	✓	✓	✓	✓
Fife Cupar	✓	✓	✓	✓	South Lanarkshire Lanark	✓	✓	✓	✓
Fife Dunfermline	✓	✓	✓	✓	South Lanarkshire Raith Interchange 2	✓	✓	✓	✓
Fife Kirkcaldy	✓	✓	✓	✓	South Lanarkshire Rutherglen	✓	✓	✓	✓
Fife Rosyth	✓	✓	✓	✓	South Lanarkshire Uddingston	✓	✓	✓	✓
Fort William	✓	✓	✓	✓	Stirling Craig's Roundabout	✓	✓	✓	✓
Glasgow Abercromby Street	✓	✓	✓	✓	Strath Vaich	✓	✓	✓	✓
Glasgow Anderston	✓	✓	✓	✓	West Dunbartonshire Clydebank	✓	✓	✓	✓
Glasgow Broomhill	✓	✓	✓	✓	West Dunbartonshire Glasgow Road	✓	✓	✓	✓
Glasgow Burgher Street	✓	✓	✓	-	West Lothian Broxburn	✓	✓	✓	✓
Glasgow Byres Road	✓	✓	✓	✓	West Lothian Linlithgow High St 2	✓	✓	✓	✓
Glasgow Dumbarton Road	✓	✓	✓	✓	West Lothian Newton	✓	✓	✓	✓

Appendix 3 Process used for VCM correcting SAQD TEOM data

VOLATILE CORRECTION MODEL

Background

The EU Directive on Ambient Air Quality[16] and the UK Air Quality Strategy[17] set target values and objectives respectively for PM_{10} concentrations in terms of gravimetric measurements referenced to the EU reference method of measurement (EN 12341). It has long been recognised that PM_{10} measurements made with many automatic PM_{10} monitors are not equivalent to the EU reference method. However, these analysers are widely used since they provide hourly resolved data and have many operational advantages over the manual reference method. Hence, correction factors, most noticeably the 1.3 correction factor for the TEOM analyser, have been widely used for many years. In setting the value of 1.3 as a correction factor, it was recognized that this was a conservative factor and that TEOMx1.3 data were likely to overestimate PM_{10} concentrations. In Scotland, a lower correction factor of 1.14, which was based on intercomparison data obtained in Edinburgh, has also been widely used.

The results of the formal UK PM_{10} Equivalence Study[18] carried out in 2006, showed that data from the TEOM could not be considered as equivalent to the EU reference method, whether or not a correction factor was used. The reason for this is that the TEOM heats the filter used to collect PM_{10} to 50°C in order to eliminate the possible interference from water vapour – this heating also removes some of the more volatile components of the particulate matter.

In the new modification to the TEOM – the FDMS TEOM, the volatile fraction of PM_{10} is measured separately and used to correct the data in order to obtain results that are equivalent to the EU reference method. The equivalence of the FDMS TEOM analyser to the EU reference method was confirmed in the UK Equivalence study. Note that this study also showed that a number of other PM_{10} analysers could also provide data equivalent to the EU reference method - Partisol 2025, FDMS Model B, Opsis SM200 Beta Attenuation Monitor (BAM), Opsis SM200 sampler (with slope and intercept correction) and the Met One BAM (with slope correction).

King's College London (KCL) developed a relationship utilising FDMS purge (volatile PM_{10}) measurements to correct data from nearby TEOM analysers. These corrected data were tested for equivalence with the EU reference method and shown to pass the appropriate criteria. Since then, as additional FDMS data have become available throughout the UK, the geographic range of the model has been extended and on-going tests have shown that any TEOM located within 130 km of an FDMS TEOM can be corrected with data from that analyser.

For additional information regarding this visit http://www.scottishairquality.co.uk/data.

Use of the VCM in Scotland

The VCM correction of Scottish PM_{10} data was first undertaken for the 2008 dataset. As the VCM method was relatively new and, hourly meteorological data for pressure were not readily available, the corrections were undertaken on a daily, rather than hourly basis. These corrected data were provided to the local authorities and made available on the Scottish Air Quality website as a separate data spreadsheet.

However, additional refinement of the VCM model has been undertaken and hourly meteorological data for all parameters has been sourced. As a result, VCM correction of the 2009 to 2021 datasets has been undertaken on an hourly basis. This also brings into line the processing of the Scottish local authority data with that of the AURN.

The TEOM measurements are recorded with an inbuilt correction factor of 1.03x+3 (where x is the raw TEOM measurement) as mandated by the US Environmental Protection Agency. This is first removed, and the data

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[16] *Directive 2008/50/EC Of The European Parliament and of The Council of 21 May 2008 on ambient air quality and cleaner air for Europe* http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:152:0001:0044:EN:PDF

[17] *The Air Quality Strategy for England, Scotland, Wales and Northern Ireland. July 2007. CM 7169* http://www.scotland.gov.uk/Topics/Environment/Pollution/16215/6116

[18] *UK Equivalence Programme for Monitoring of Particulate Matter. David Harrison Bureau Veritas UK Ltd. June 2006 (BV/AQ/AD202209/DH/2396)* http://www.airquality.co.uk/archive/reports/cat05/0606130952_UKPMEquivalence.pdf

are then corrected to ambient pressure and temperature (as required by the EU Directive) using meteorological data from met monitoring sites within 260 km of the TEOM.

Data from FDMS analysers within 130 km of the TEOM are then used to provide an estimate of the volatile particle concentration at the TEOM location. This estimated volatile fraction is then added back onto the TEOM measurements to give Gravimetric Equivalent mass concentrations. The following data were used as inputs to the VCM:

- Hourly average temperatures (°C)
- Hourly average pressures (mbar)
- Hourly average TEOM concentrations (μg m^{-3})
- Hourly average FDMS purge concentrations (μg m^{-3})

For the 2021 corrections, temperature and pressure data from Edinburgh Airport meteorological monitoring stations were utilised. This site was selected as a good representation of weather conditions in the central belt of Scotland.

Hourly average purge measurements from all Scottish FDMS monitoring sites within the Scottish Government-run network (SAQD) and the UK national network (AURN) were used for the correction. A total of 5 FDMS sites were used for correcting hourly average TEOM data at 1 site across Scotland. A list of the sites used to correct are.

- Glasgow Hope St FDMS
- Paisley Gordon Street
- South Ayrshire Ayr Harbour
- South Ayrshire Ayr High St

Table A3.1 provides the names of the sites where data was corrected using VCM.

Any outliers in the FDMS purge measurements were identified using Grubbs' Test[19] on daily average data. All hourly data within a day identified as an outlier were then removed from the data set and the average of each hourly purge measurement from the FDMS sites was calculated and used in the VCM calculations.

The corrected data for 2021 and calculated summary statistics have been provided to the local authorities. A flow chart showing the overall process employed for VCM correction of 2021 SAQD TEOM data is illustrated in figure A3.1. It should be noted that it is not possible to correct historical data with the VCM as measurements of volatile particle concentrations are not available prior to 2008.

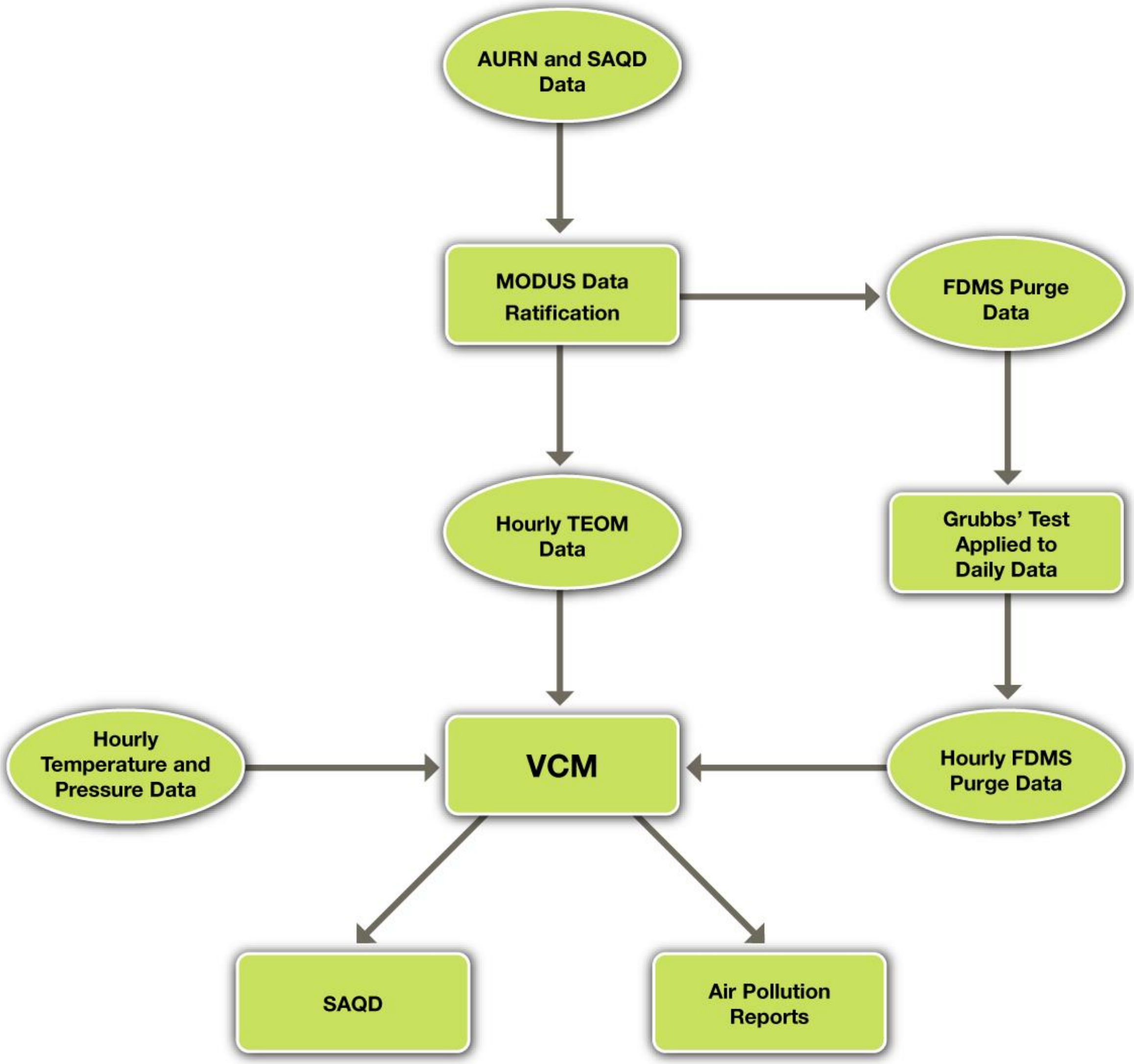
Table A3-1 TEOM sites data corrected using VCM in 2021

Site Name	Local Authority
Aberdeen Anderson Dr	Aberdeen City Council

[19] Grubbs' Test is a statistical method for identifying outliers within a dataset. For more information, visit the Engineering Statistics Handbook at:

http://www.itl.nist.gov/div898/handbook/eda/section3/eda35h.htm

A3.1. Process used for VCM correcting SAQD TEOM data



Appendix 4 National Monitoring Networks in Scotland 2021

Table A.4 1 AURN Measurement Sites in Scotland 2021

Site Name	Site Type	Species Measured	Grid Reference
Aberdeen Erroll Park	URBAN BACKGROUND	NO NO_2 NO_X O_3 PM_{10}, $PM_{2.5}$	394416,807408
Aberdeen Union St Roadside	ROADSIDE	NO NO_2 NO_X	396345,805947
Aberdeen Wellington Road	ROADSIDE	NO NO_2 NO_X	394397, 804779
Auchencorth Moss	RURAL	O_3 PM_{10} $PM_{2.5}$	322167, 656123
Bush Estate	RURAL	NO NO_2 NO_X O_3	324626,663880
Dumbarton Roadside	ROADSIDE	NO NO_2 NO_X	240234,675193
Dumfries	ROADSIDE	NO NO_2 NO_X	297012,576278
Dundee Mains Loan	URBAN BACKGROUND	NO NO_2 NO_X	340971, 731892
Edinburgh Nicolson St	ROADSIDE	NO NO_2 NO_X	326150, 673046
Edinburgh St Leonards	URBAN BACKGROUND	CO NO NO_2 NO_X O_3 PM_{10} $PM_{2.5}$ SO_2	326265, 673136
Eskdalemuir	RURAL	NO NO_2 NO_X O_3	323552,603018
Fort William	RURAL	NO NO_2 NO_X O_3	210830,774410
Glasgow Great Western Road	ROADSIDE	NO NO_2 NO_x	258007,666651
Glasgow High Street	URBAN TRAFFIC	NO NO_2 NO_X PM_{10}, $PM_{2.5}$	260014,665349
Glasgow Kerbside	KERBSIDE	NO NO_2 NO_X PM_{10}, $PM_{2.5}$	258708,665200
Glasgow Townhead	KERBSIDE	NO NO_2 NO_X PM_{10}, $PM_{2.5}$	259692,665899
Grangemouth	URBAN INDUSTRIAL	NO NO_2 NO_X PM_{10}, $PM_{2.5}$, SO_2	293840,681032
Grangemouth Moray	URBAN BACKGROUND	NO NO_2 NO_X	296436,681344
Greenock A8 Roadside	ROADSIDE	NO NO_2 NO_X	229332, 675715
Inverness	ROADSIDE	PM_{10}, $PM_{2.5}$, NO NO_2 NO_X	265720,845680
Lerwick	RURAL	O_3	445337,113968
Peebles	SUBURBAN	NO NO_2 NO_X O_3	324812,641083
Strath Vaich	REMOTE	O_3	234787,875022

Table A.4 2 Automatic Hydrocarbon Network Sites in Scotland 2021

Site Name	Site Type	Species Measured	Grid Reference
Auchencorth Moss	RURAL	Benzene and 1,3-butadiene and 24 other ozone precursor hydrocarbon species*	322167, 656123

Table A.4 3 Non-Automatic Hydrocarbon Network Sites in Scotland 2021

Site Name	Site Type	Species Measured	Grid Reference
Glasgow Kerbside	KERBSIDE	Benzene	258708, 665200
Grangemouth	URBAN INDUSTRIAL	Benzene	293840, 681032

EU requirement and part of the EMEP long-range transboundary air pollution monitoring programme.

Table A.4 4 PAH Monitoring Sites in Scotland 2021

Site	Address	Grid Reference
Auchencorth Moss	Rural site in Scotland, South of Edinburgh	322167, 656123
Edinburgh	145 Pleasance Edinburgh EH8 9RU	326265, 673136
Glasgow Townhead	Townhead Glasgow G4 0PH	259692, 665899
Kinlochleven 2	Electrical Substation Kinlochleven	219280, 761986

Table A.4 5 Heavy Metals Monitoring Network Sites in Scotland 2021

Site Name	Site Type	Species Measured	Grid Reference
Auchencorth Moss	Rural	As, Cd, Cr, Co, Cu, Fe, Mn, Ni, Pb, Se, V, Zn	322167, 656123
Eskdalemuir	Rural	As, Cd, Cr, Co, Cu, Fe, Mn, Ni, Pb, Se, V, Zn	323552, 603018

Table A.4 6 Rural Metal Deposition Monitoring sites in Scotland 2021

Site	Location Grid Ref.	Heavy metals			Mercury	
		In Particles	In Rain	In Cloud	In Air	In Rain
Inverpolly	218776, 908833		✓			
Banchory	367694, 798519	✓	✓		✓	✓
Bowbeat	328289, 647302		✓	✓		
Auchencorth Moss	322167, 656123	✓	✓		✓	✓

United Kingdom Eutrophying & Acidifying Network (UKEAP)

Table A.4 7 The Precipitation Network (PrecipNet) Sites in Scotland 2021

Site Name	Grid Reference	Species Monitored
Auchencorth Moss	322167, 656123	Na^+, Ca^{2+}, Mg^{2+}, K^+, PO_4^{3-}, NH_4^+, NO_3, SO_4^{2-}, Cl^-
Allt a'Mharcaidh	287691, 805223	
Balquhidder 2	254465, 720706	
Eskdalemuir	323552, 603018	
Forsinard RSPB	289309, 942826	
Glensaugh	366329, 780027	
Loch Dee	246907, 577768	
Polloch	179244, 768951	
Strathvaich	234787, 875022	
Whiteadder	366180, 663116	

Table A.4 8 Acid Gas and Aerosol Network (AGANet) and Ammonia Network (NAMN) Sites in Scotland 2021

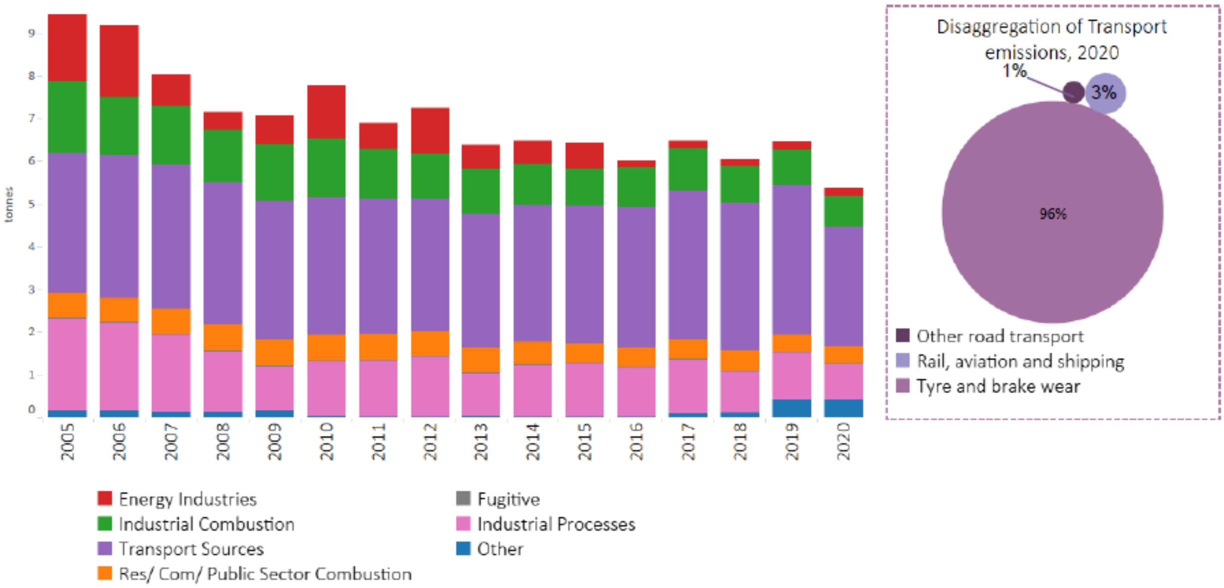
Name	Grid Ref	Ammonia	Nitric Acid
Allt a Mharcaidh	287691, 805223	✓	✓
Allt a Mharcaidh ECN	289160, 804162	✓	
Auchencorth Moss	322188, 656202	✓	✓
Auchincruive	238018, 623382	✓	
Bush	324629, 663891	✓	✓
Carradale	179870, 637801	✓	✓
Eskdalemuir	323588, 602997	✓	✓
Forsinard RSPB	289309, 942826	✓	✓
Glensaugh	366329, 780027	✓	✓
Glen Shee Dalmunzie Estate	312187, 769016	✓	
Inverpolly	218695, 908820	✓	
Loch Awe	96537, 711570	✓	
Loch Dee	246801, 577889	✓	
Oldmeldrum	383297, 827323	✓	
Polloch	179244, 768951	✓	✓
Sourhope	386796 621798	✓	
Strathvaich	234787, 875022	✓	✓

Appendix 5: Pollution Emissions data for B(a)p, Dioxins, Pb, Hg

SCOTLAND LEAD (Pb) INVENTORY BY NFR SECTOR 2005 – 2020

Figure A5.1 provides a summary of Lead (Pb) emission estimates for Scotland by category. The detailed data are available in the report and website citied in the introduction to chapter 9 of this report.

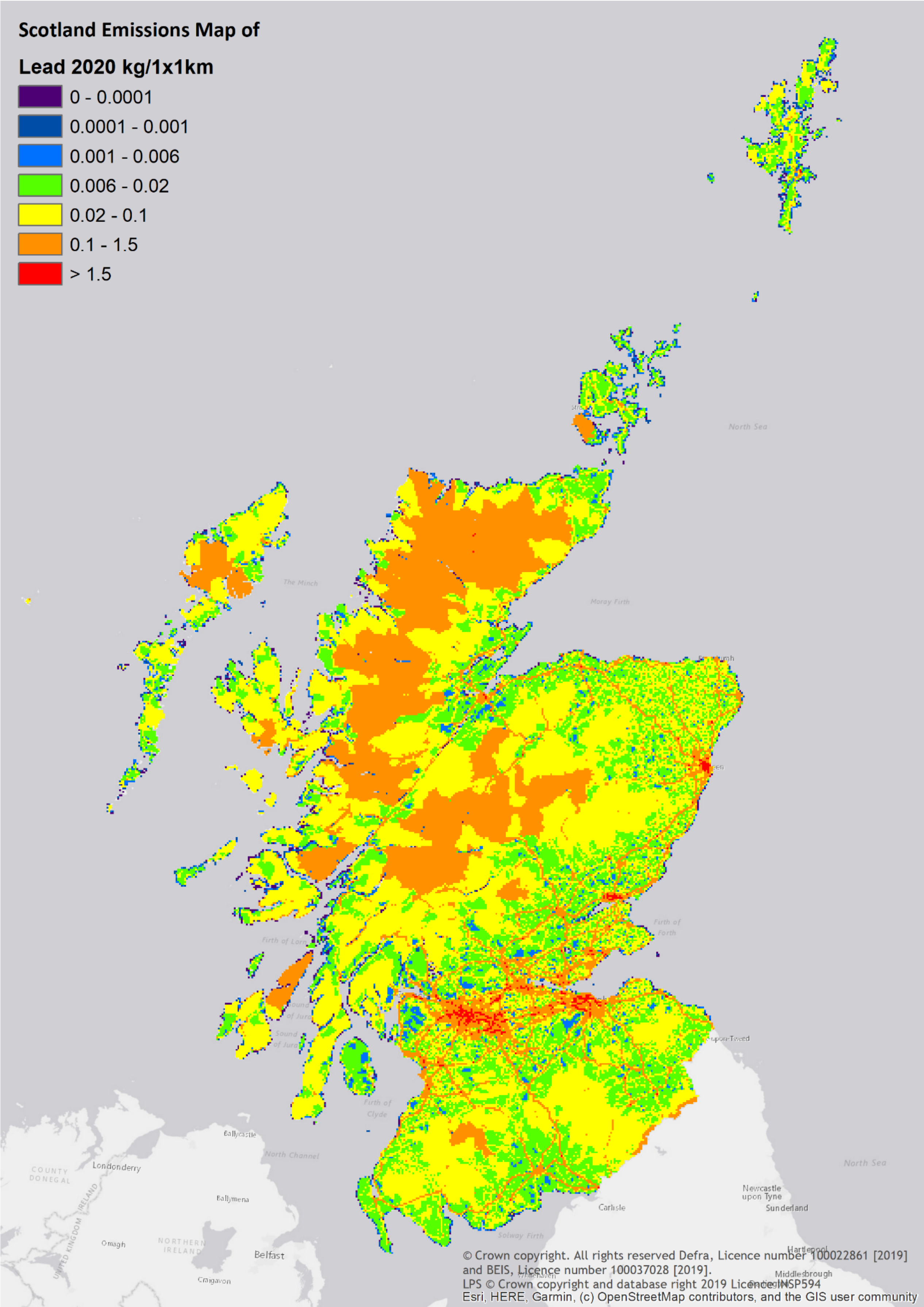
A5.1 Time Series of Scotland's Pb Emissions 2005-2020



Emissions of lead in Scotland were estimated to be 5.4 tonnes in 2020, representing 6% of the UK total in 2020 for lead. Emissions have declined by 43% since 2005 due to changes in energy sources, industrial combustion, and industrial processes. Emissions from power stations have decreased by 87% since the base year, due to the phase out of coal from the energy generation mix, with the closure of Longannet in 2016 marking the end of the use of coal in energy generation in Scotland. Transport sources, in particular non-exhaust emissions (such as tyre and brake wear) account for 96% of the transport sector, (and 50% of total lead emissions in 2020). Unlike exhaust emissions which have been subject to the continued implementation of more stringent European regulation, non-exhaust emissions are not regulated and are strongly linked to the v-km driven on Scotland's roads. Non-exhaust emissions have decreased by 11% since the 2005 baseline. Industrial combustion accounts for 14% in 2020, and use of fireworks contributes a further 6%. Three of the seven sites in the UK which manufacture fibreboard, chipboard and oriented strand board are located in Scotland, and are key sites for lead emissions due to the burning of waste wood as fuel. Lead emissions have decreased by 16% since 2019, primarily due to a 20% reduction in emission due to tyre and break wear in the transport sector. Due to the COVID-19 pandemic, travel restrictions resulted in a reduction in traffic volumes.

Figure A5.2 shows a map of Scotland's NOx emissions in 2020.

Figure A5.2 Map of Lead Emissions in Scotland, 2020

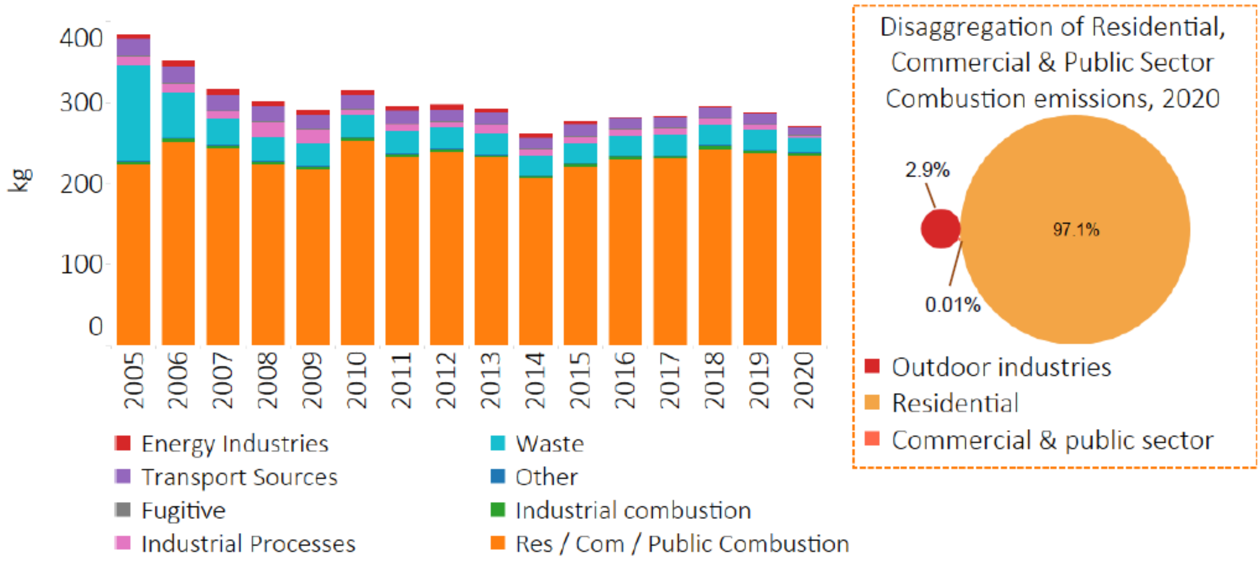


Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 2005 – 2020

SCOTLAND BENZENE (A) PYRENE (B(a)P) INVENTORY BY NFR SECTOR 2005 – 2020

Figure A5.3 provides a summary of Benzene (a) Pyrene (BaP) emission estimates for Scotland by category.

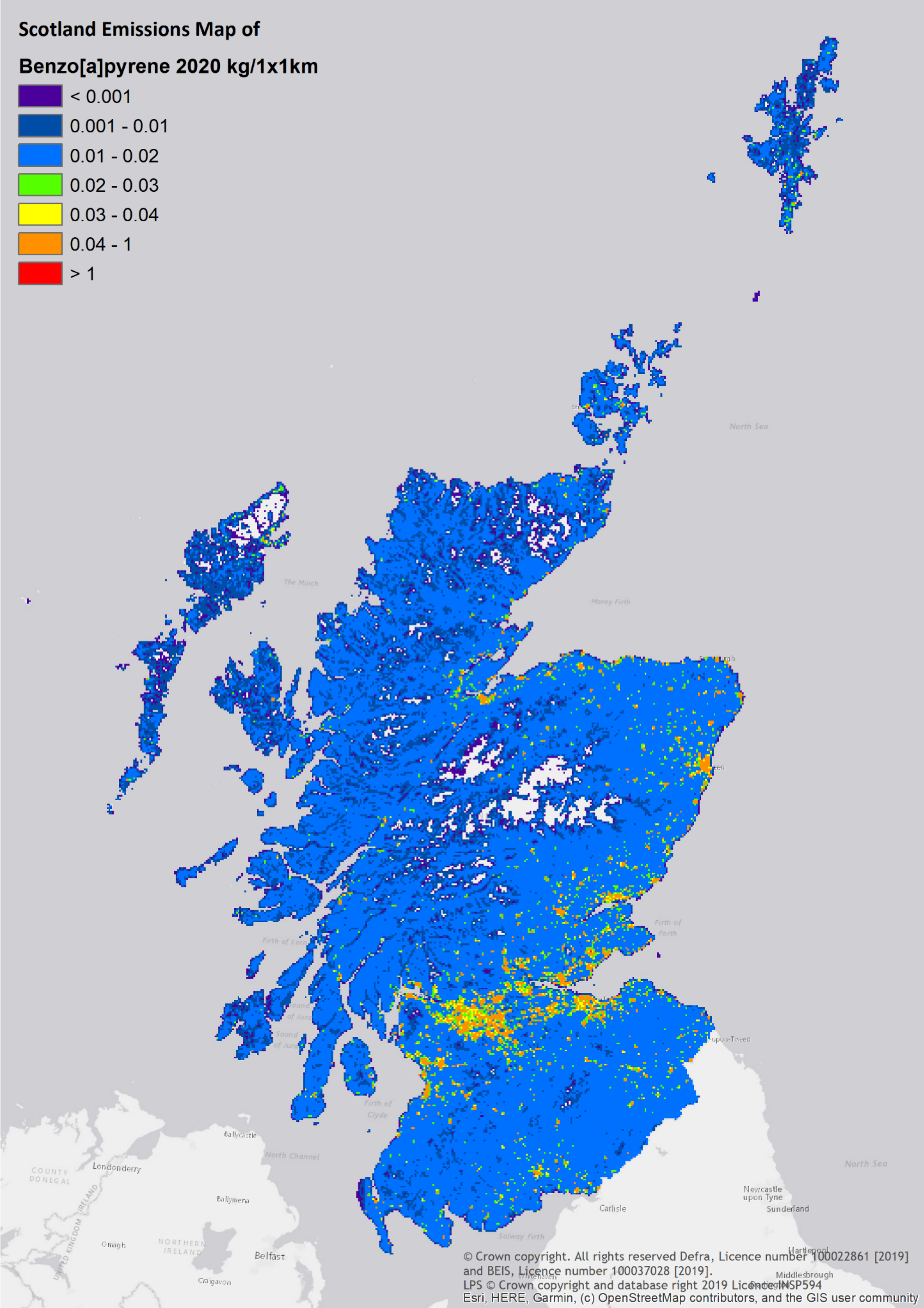
A5.3 Time Series of Scotland's B(a)P Emissions 2005-2020



Emissions of benzo(a)pyrene in Scotland were estimated to be 270 kg in 2020, representing 7% of the UK total for benzo(a)pyrene. Emissions have decreased 29% since 2005, due to B[a]P emissions decreasing by 84% over this time period primarily driven by a reduction in agricultural waste burning. Emissions from residential combustion account for 84% of the B[a]P emissions from Scotland in 2020, especially due to domestic wood and coal combustion which account for 64% and 29% of emissions within the residential sector, respectively.

Figure A5.4 shows a map of Scotland's B(a)P emissions in 2020.

Figure A5.4 Map of B(a)P Emissions in Scotland, 2020

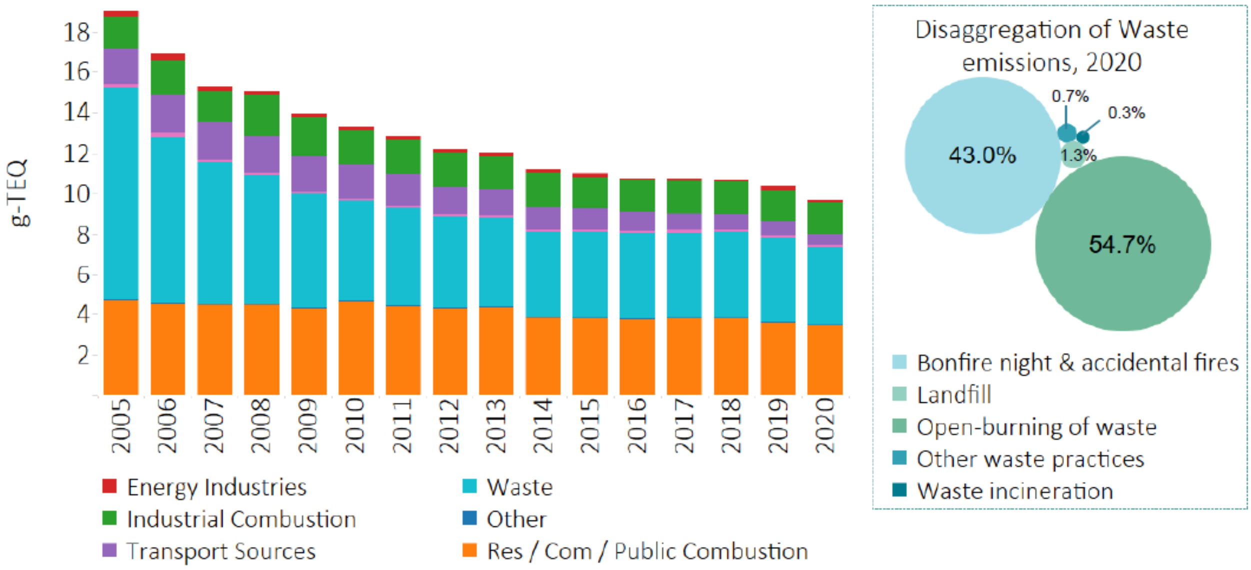


Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 2005 – 2020

SCOTLAND DIOXINS INVENTORY BY NFR SECTOR 2005 – 2020

Figure A5.5 provides a summary of Dioxins emission estimates for Scotland by category.

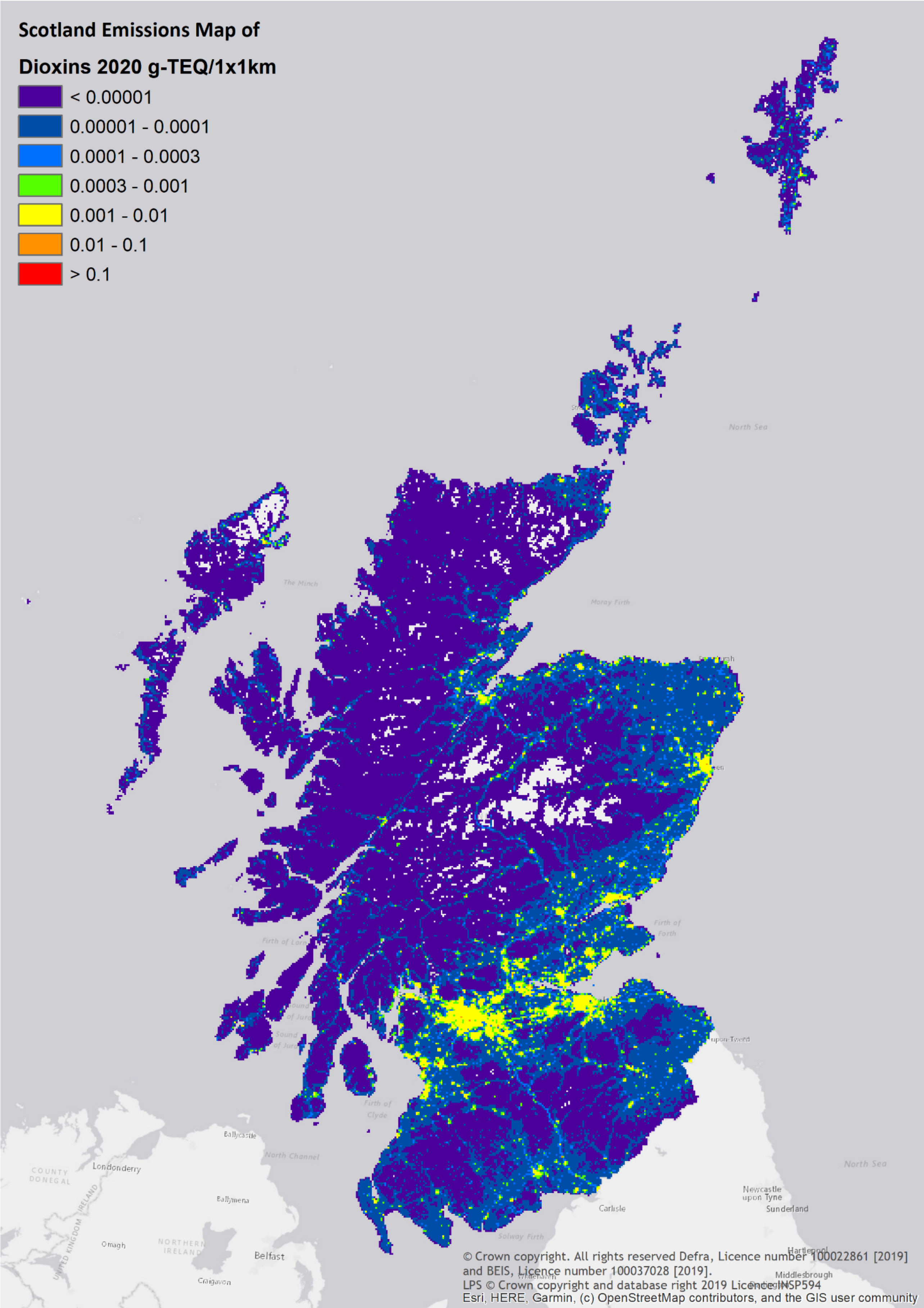
A5.5 Time Series of Scotland's Dioxins Emissions 2005-2020



Emissions of dioxins in Scotland were estimated to be 9.7g international toxic equivalents (I-TEQ)27 in Scotland in 2020, representing 7% of the UK total for dioxins. Emissions have declined by 49% since 2005, mainly driven by a reduction in emissions from the waste sector. The decline in dioxin emissions since 2005 tracks the trend of a reduction in coal use in power stations, and the introduction of more stringent regulatory controls and the promotion of alternative waste disposal and recycling streams to reduce small-scale open waste burning of household and garden waste.

Figure A5.6 shows a map of Scotland's Dioxin emissions in 2020.

Figure A5.6 Map of Dioxin Emissions in Scotland, 2020

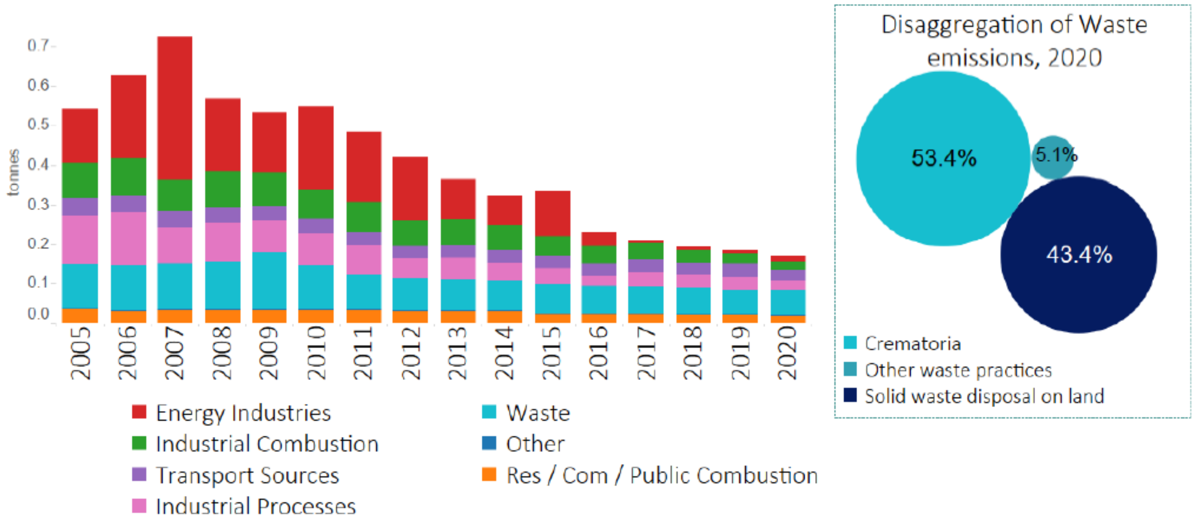


Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 2005 – 2020

SCOTLAND MERCURY (Hg) INVENTORY BY NFR SECTOR 2005 – 2020

Figure A5.7 provides a summary of Mercury (Hg) emission estimates for Scotland by category.

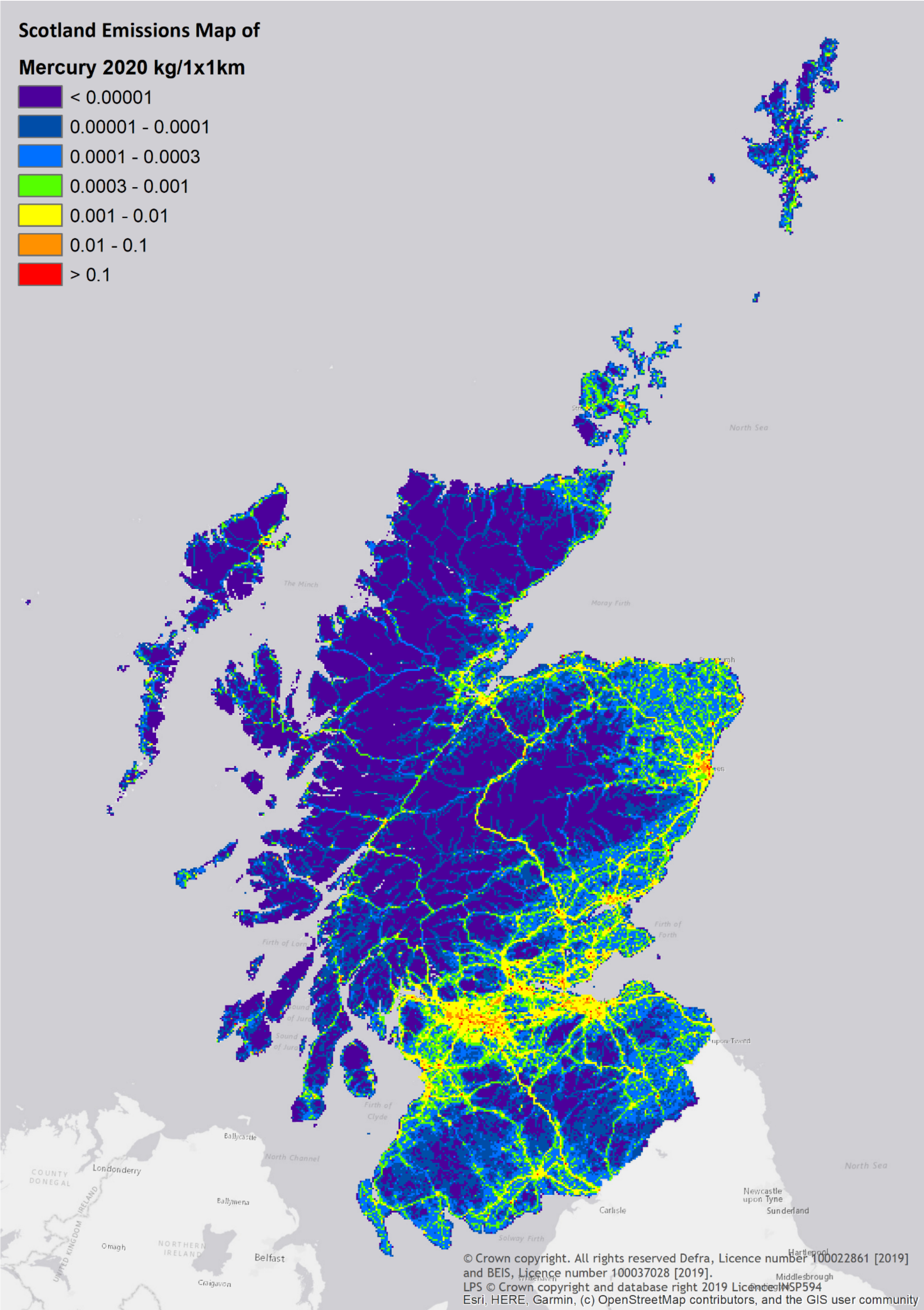
A5.7 Time Series of Scotland's Mercury Emissions 2005-2020



Emissions of Hg in Scotland were estimated to be 0.17 t in 2020 and have declined by 68% since 2005. Emissions in Scotland account for 5% of the UK total in 2020 for Hg. This decline in emissions stems from changes to combustion in power and heat generation and chloralkali process emissions, with a 32% and 24% contribution to the overall trend respectively. The decline in emissions from power and heat generation is driven by the reduction in combustion of coal. As observed above, the emissions from energy industries have been negligible since 2017 since the cessation of coal used for energy generating purposes in Scotland. Since 2016, emissions from crematoria have been the largest source of emissions, representing 21% of the Scotland total Hg emissions in 2020.

Figure A5.8 shows a map of Scotland's Hg emissions in 2020.

Figure A5.8 Map of Mercury Emissions in Scotland, 2020



Source - Air Quality Pollutant Inventories, for England, Scotland, Wales and Northern Ireland: 2005 – 2020

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