

Particulate Matter in Scotland - an assessment of the evidence, ambition and prospects

February 2024

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Key messages

- Air pollution from particulate matter (PM) damages both human health and the environment. Scotland is currently largely meeting its objectives and limit values for concentrations of PM.
- In 2021, the World Health Organisation (WHO) revised its guidance on the limits for PM considered necessary to protect human health. Scotland, along with most other countries, has not adopted this guidance and does not currently meet these new guidelines.
- It is because of this strengthened evidence base that Environmental Standards Scotland (ESS) now finds that a revision to the statutory standards (currently set as limit values in the Air Quality Standards (Scotland) Regulations 2010 (as amended) and as objectives in the Air Quality (Scotland) Regulations 2000 (as amended)) is necessary.
- If European Union (EU) proposals for tighter limit values for particulate matter are adopted as expected in the coming months, Scotland will need to bring forward legislative proposals for a tightening of legally enforceable limit values if it is to maintain alignment. This should result in a clear statutory obligation to achieve new limit values and ensure that the legal framework is robust, enforceable and capable of delivering the necessary improvements to Scotland's air quality.
- Progress on reducing emissions of PM from different sectors and activities varies considerably. Emissions from transport have been the focus of recent decades. Attention now needs to be broadened to other sectors which are sources of PM.
- Emissions from industrial processes, industrial combustion, residential and other combustion and agriculture are sectors with scope for significant improvement, given their relative contributions and the policy levers available to the Scottish Government to drive change.
- Progress has slowed, stalled, or is showing some signs of reversing for some emitting sectors (apart from years affected by the Covid-19 restrictions). Scotland will need to tackle the full range of sources of PM pollution if more ambitious statutory standards are to be met.

- Monitoring and modelling of PM in Scotland has been driven by a focus on transport and should be reviewed in light of the need for elevated ambition to protect human health and the importance of tackling emissions from a range of sources.
- The Retained EU Law (Revocation and Reform) Act 2023 revokes Regulations 9 and 10 of the National Emissions Ceiling Regulations 2018 (NECR). The revocation leaves a gap in accountability in demonstrating how Scotland's policies will make a proportionate contribution to UK emissions targets.

Recommendations

1. The Scottish Government should, as soon as possible, bring forward proposals for new statutory standards for particulate matter currently set as limits under the Air Quality Standards (Scotland) Regulations 2010 (as amended), in recognition of the WHO Air Quality Guidelines updated in 2021. Specifically, this revision should include:
 - introducing a new target for a 24-hour limit value for PM_{2.5}
 - raising ambition on the current annual mean limit value for PM_{2.5}
 - raising ambition on the 24-hour and annual mean limit value for PM₁₀
 - introducing an exposure reduction target to replace the expired UK one
2. The Scottish Government and the Scottish Environment Protection Agency (SEPA) should work with local authorities to consider how to make the Scottish PM monitoring network more responsive to the changing pattern of emissions sources. Specifically:
 - ensuring modelling and monitoring continues to be internationally comparablewhile
 - making independent assessments of emerging areas and sectors of concern that do not depend on where current monitoring infrastructure is located (including: industrial processes, industrial combustion, residential and other combustion and agriculture)and
 - considering where the most vulnerable people in society are spending their time
3. The Scottish Government should clarify when it will conduct and publish its planned review of the Clean Air Act 1993. ESS expects this to cover Smoke Control Areas (given the need for more focus on emissions from residential and other combustion) and to clarify when it will legislate for updated objectives.

4. The Scottish Government should consider how best to fill the gap left by the UK Government's revocation of Regulations 9 and 10 of the National Emissions Ceiling Regulations 2018. Any replacement should ensure appropriate public scrutiny of Scotland's planned policies to address future emissions projection needs. Any replacement must also include a robust mechanism for delivering a proportionate contribution to UK emissions reductions.

1. About this report

1.1 ESS' Strategic Plan identified a number of analytical priorities¹. One of these priorities is PM in air.

1.2 ESS identified progress against air quality standards for PM as a priority for analysis because of: the publication in 2021 of new (more stringent) guidelines by the WHO²; the identification of emerging polluting activities of concern; and uncertainty about how air pollution levels in Scotland might 'rebound' following the reductions seen during Covid-19 lockdowns³. Section 20 of the UK Withdrawal from the European Union (Continuity) (Scotland) Act 2021 ("the 2021 Act") sets out the scope of ESS' functions. ESS' remit is to:

- ensure public authorities, including the Scottish Government, public bodies and local authorities, comply with environmental law; and
- monitor and take action to improve the effectiveness of environmental law and its implementation

1.3 ESS has prepared this report as part of its remit to assess compliance with environmental law, and the effectiveness of environmental law or how it is implemented and applied, specifically in relation to the Air Quality Standards (Scotland) Regulations 2010 (as amended) and the Air Quality (Scotland) Regulations 2000 (as amended) in meeting the desired aim of preventing harm from particulate matter. Section 20 of the 2021 Act enables ESS to make recommendations to public authorities. ESS may also identify specific concerns that merit further investigation, or topics that will be prioritised for future analysis or ongoing monitoring.

1.4 This report:

- analyses the data and evidence on air pollution from PM in Scotland
- assesses progress against existing statutory standards for PM in Scotland
- examines the potential for achieving more ambitious limits, in the context of revised guidance from the WHO, and considers developments in EU legislation

1.5 ESS' findings and recommendations are based on:

- analysis of the data and modelling of pollution from PM that is available from official sources up to September 2023
- evidence gathered from a review of published documents
- information provided by, and discussions with, the Scottish Government and SEPA

1.6 ESS asks the Scottish Government and SEPA to make a statement, as soon as possible and within six months of publication of this report, setting out their response to the recommendations in this report and the action they intend to take to address them.

1.7 ESS will discuss our findings with the public authorities concerned to explore their potential response to our recommendations and to inform our future assessment of progress on these, and related, issues.

1.8 The findings and recommendations in this report will be kept under review and ESS will consider, in due course, whether further analysis or investigation into the issues identified is required. Where appropriate, this analysis will also inform future work on other analytical priorities, for example, on climate change adaptation and mitigation.

1.9 Nothing in this report, or the recommendations made within it, limits ESS' ability to make decisions about further scrutiny of the issues covered, for example, in response to representations made to ESS on related matters.

2. Particulate matter damages human health and the environment

2.1 According to the WHO⁴, “air pollution is one of the biggest environmental threats to human health, alongside climate change”. In 2018, Health Protection Scotland published an assessment which estimated 1,724 deaths of adults over 25 years of age in Scotland were attributable to PM_{2.5} in 2016⁵. This estimate has largely reduced in line with the trend of slowly reducing PM concentrations in recent years. The health impact is exacerbated in the old, the young and people with pre-existing conditions⁶.

2.2 As well as the human health impacts, air pollution can damage the environment including Scotland’s sensitive habitats (for example, peatlands) by contributing to the acidification of rain, changing nutrient balances which can cause ecosystem imbalances, altering soil pH⁷, as well as generally changing the reflectivity of the atmosphere and the earth’s surfaces^{8,9,10}. However, given the variability in PM deposition, its chemical composition and differential impact on different receptors, predicting the impact of PM on these sensitive habitats is challenging and subject to uncertainty. This analysis focuses on human health impacts from PM.

2.3 PM is one form of air pollution that can impact air quality. It describes a very small collection of matter, either solid or liquid. Fine PM, or PM_{2.5}, (those with diameter up to 2.5 micrometres (μm^{11})) are particularly damaging to human health because they more easily penetrate into the lungs and circulatory system, so there is now considered no safe level of PM^{4,12,13}. PM₁₀ describes those up to 10 μm in diameter. Other size fractions of PM are now recognised as important (for example PM₁ and PM_{0.1}) but are not currently widely monitored and the evidence base is more limited. The analysis has therefore been limited to PM_{2.5} and PM₁₀.

2.4 There are a range of metrics used to measure air pollution from PM:

- **concentration** - the amount of a pollutant in a given volume of air measured directly or indirectly. Concentrations are specific to the air sample being measured at a particular place and over a particular time period (and therefore have their limitations). The quality of the air people breathe is usually reported as a concentration with respect to a particular pollutant of interest within it

- **emissions** – may refer to actual direct emissions or a modelled estimate, usually based on measurements and assumptions of the rate of release of a gas into the atmosphere. Emissions do not represent the air people will breathe, but policymakers have more control over them than concentrations, so they are also an important metric
- **population-weighted mean concentrations** - annual mean concentrations are estimated for every square kilometre (km) of the UK using the Pollution Climate Mapping (PCM) model. The population-weighted mean concentration is used as a measure of the impact of PM_{2.5} on the health of the total population by applying a weighting factor proportionate to population density within the same square km
- **limit values** – target concentrations of a pollutant to be achieved by specified dates. These generally originate from EU legislation and are transposed into domestic law. They exist either without exception or with a permitted number of exceedances in a year
- **objectives** – target concentrations of a pollutant to be achieved by specified dates and usually represent a compromise position on limit values set for human or environmental health purposes

2.5 Understanding how air quality impacts human health at a societal scale requires understanding of population dynamics, such as: age; any underlying health conditions that may be exacerbated by poor air quality; and where people with these characteristics are spending their time.

2.6 PM may be emitted, or released, as a primary pollutant already in its PM form (e.g. as carbon from combustion or dust from industrial abrasion). Alternatively, it may be created in the atmosphere as a secondary pollutant from emissions of other primary pollutants (e.g. ammonia from agriculture and sulphates from shipping). These secondary processes can be particularly driven by transport from other places, meteorology and natural emissions.²⁶ Secondary inorganic aerosol (SIA) (aerosol not containing carbon) is a major contributor to PM₁₀ and PM_{2.5} in the UK, estimated at approximately 40% of total PM_{2.5}.¹⁴ The contribution of ammonia as ammonium (NH₄) within that SIA varies in time and space and is uncertain. The relationship between emissions and the formation of SIA is known to be complex and non-linear, meaning reductions in emissions of precursors will not necessarily translate directly to better ambient air quality.¹⁵

2.7 It is these complex processes that make present and future concentrations of PM difficult to predict in comparison to other pollutants, and all secondary contributions are not yet included in the National Atmospheric Emissions Inventory (NAEI)¹⁶. This means the contribution of sectors such as agriculture is not fully captured in emissions data, and the science of source attribution is not yet mature enough to rectify this.

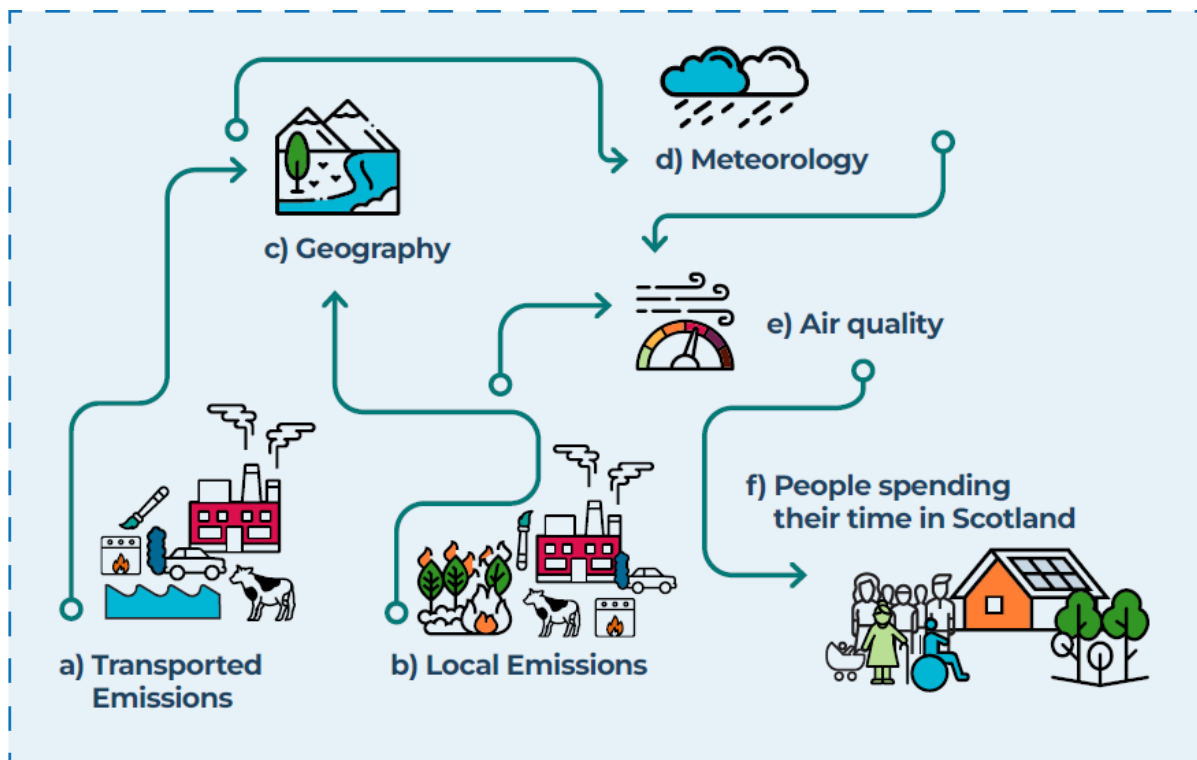


Figure 2-1– A schematic of the need to consider many factors when understanding how air quality impacts human health. How humans are impacted by air depends on their health or vulnerability, where they live and the quality of the air they are breathing over time. The quality of air (e) people will breathe, is a function of transported emissions (a), local emissions (b), geography (c), meteorology (d) and how air passes through these influences and undergoes chemical and physical transformation before it reaches people’s lungs (f).

2.8 The UK’s (and within it Scotland’s) air quality benefits from its geography, meteorology and a low population density compared to many other countries, especially its European neighbours.^{17,18,19}

2.9 The prevailing wind direction in Scotland is from the Atlantic, relatively free of its own emissions sources (“a” in Figure 2-1 tends to be over long distances) and there is generally meteorology (“d” in Figure 2-1) favourable to washing out pollutants from the atmosphere (though this can have effects on land and water).

2.10 As a result, the UK is responsible for a higher proportion of its average experienced concentrations of PM than many other countries (40% for PM_{2.5}).²⁰ This data is not available at a Scotland level but given the marine-dominant local geography and prevailing wind patterns of Scotland, it is expected that these aspects will be further amplified for Scotland compared to the UK. Notwithstanding specific pollution events beyond domestic control (such as a volcanic eruption or combustion event having transboundary impact), the UK's and Scotland's policymakers generally have greater control of their own air quality than most other European countries.²¹ This is due to relatively clean incoming air, and other factors influencing the emissions/concentration relationship, which are relatively favourable.

2.11 This has, along with some effective policy measures, enabled Scotland, as part of the UK, to set lower concentration objectives (under the Air Quality (Scotland) Regulations 2000) that are more stringent than the associated limit values (set under the Air Quality Standards (Scotland) Regulations 2010) to date, and to achieve better air quality with respect to PM, than many comparator countries. For example, in the WHO's most recent (2023) ambient air quality database, Scottish locations are amongst the lowest 10% on PM concentrations across sites in the WHO European zone, although comparisons need to be treated with caution.²² Exceedance of the WHO's Air Quality Guidelines (AQGs) and comparison with Europe is covered in section 5.

2.12 On a concentration basis, in 2021 (the most recent year for which validated statistics are available) all zones and agglomerations (as designated for reporting requirements under the Air Quality Standards (Scotland) Regulations 2010) in Scotland met the existing EU-transposed limit value for annual mean concentration of PM_{2.5} and PM₁₀.

3. World Health Organisation guidance recommends that targets for particulate matter need to be strengthened

3.1 The evidence base about the toxicity of PM to human health has expanded in recent decades.² As a result, in 2021, the WHO updated its 2005 Air Quality Guidelines (AQGs) for concentrations of key pollutants.² The updated AQGs significantly tighten all the annual and daily standards for both PM_{2.5} and PM₁₀, but the most significant and challenging change is the halving (from 10 to 5 micrograms per cubic metre ($\mu\text{g m}^{-3}$)) of the recommended allowable level of PM_{2.5} in the air as an annual average.

3.2 Updated AQGs are also provided for ozone, nitrogen dioxide, sulphur dioxide and carbon monoxide but were not within scope of this analysis. There continues to be no AQGs provided for forms or definitions of PM other than PM_{2.5} and PM₁₀. However, “good practice statements” of recommendations for suitable monitoring and management regimes for other PM definitions such as ultrafine particles (UFP (PM_{0.1})) are considered appropriate by the WHO at this time.

3.3 It is because of this strengthened evidence base about the human health impacts of PM that ESS finds that a revision to the statutory standards in Scotland is necessary. ESS considers that the appropriate mechanism for this is through a tightening of limit values currently contained in the Air Quality Standards (Scotland) Regulations 2010 (as amended). This should result in a clear statutory obligation to achieve new limit values and ensure that the legal framework is robust, enforceable and capable of delivering the necessary improvements to Scotland’s air quality.

3.4 ESS notes that the WHO AQGs are not legally binding and that governments in Scotland and elsewhere will need to consider whether to adopt them, taking into account a range of factors. This consideration will include policy choices and technical factors affecting the potential achievement of the AQGs such as the fact that transported and natural contributions to pollutant concentrations (particularly for PM_{2.5}) are, at times, close to both the limits suggested, and also the detection limits of most instruments.

3.5 The Scottish Government has committed to “keeping pace” with the EU on environmental standards, and in its current strategy document for air quality, Cleaner Air for Scotland 2 (CAFS2) sets out a vision “to have the best air quality in Europe”.²³

3.6 The EU has responded to the updated WHO AQGs by proposing changes to its limit values for air pollution, to be achieved in the coming decades.^{24,25} In November 2023 the Council of the European Union agreed proposals that are, in respect of the headline levels, very close to meeting the WHO AQGs by 2030 (notwithstanding further amendment).²⁵ This represents a significant elevation of ambition beyond current levels for PM.

3.7 However, there are a number of caveats in the EU proposals, including the ability to subtract the “natural” component of exceedances of PM levels under certain circumstances. The WHO AQGs do not distinguish between the harm caused by natural and anthropogenic PM and the natural contribution to pollution from PM could be significant,²⁶ especially at the concentrations recommended by the WHO.

3.8 As a result, the current EU proposal would not, in precise terms, meet the AQGs. The EU proposals have yet to be adopted, and so are not yet legally binding, but, as currently drafted, would significantly elevate ambition above current levels and are therefore likely to drive continuous improvement across Europe.

3.9 Figure 3-2 provides a schematic illustration of the key legislation concerning PM in Scotland. The Ambient Air Quality Directive 2008 (2008/50/EC) set legally binding limits for concentrations in ambient air of most major air pollutants that are known to have a significant impact on human health, including PM₁₀ and PM_{2.5}. These limits are identical across the UK and achievement was a mandatory requirement for what were the EU member states. This Directive was made law in Scotland through the Air Quality Standards (Scotland) Regulations 2010 (as amended) (“the 2010 Regulations”). These Regulations place legal responsibility for meeting limit values and ensuring air quality plans exist on Scottish Ministers.

3.10 In addition, there are separate obligations on local authorities in terms of local air quality management (LAQM) under the Air Quality (Scotland) Regulations 2000 (as amended by the Air Quality (Scotland) Amendment Regulations 2002 and the Air Quality (Scotland) Amendment Regulations 2016) (“the 2000 Regulations”). These Regulations set air quality objectives (including for PM₁₀ and PM_{2.5}) which local authorities must demonstrate that they are taking all reasonable steps to work toward. While this complements the wider action taken by central government in improving air quality, there is no legal obligation on local authorities to meet these objectives. It is important to recognise that although LAQM under the 2000

Regulations and the broader approach provided for under the 2010 Regulations have the shared aim of improving human and environmental health through reducing air pollution, they are distinct regimes with a different emphasis, rationale and approach.

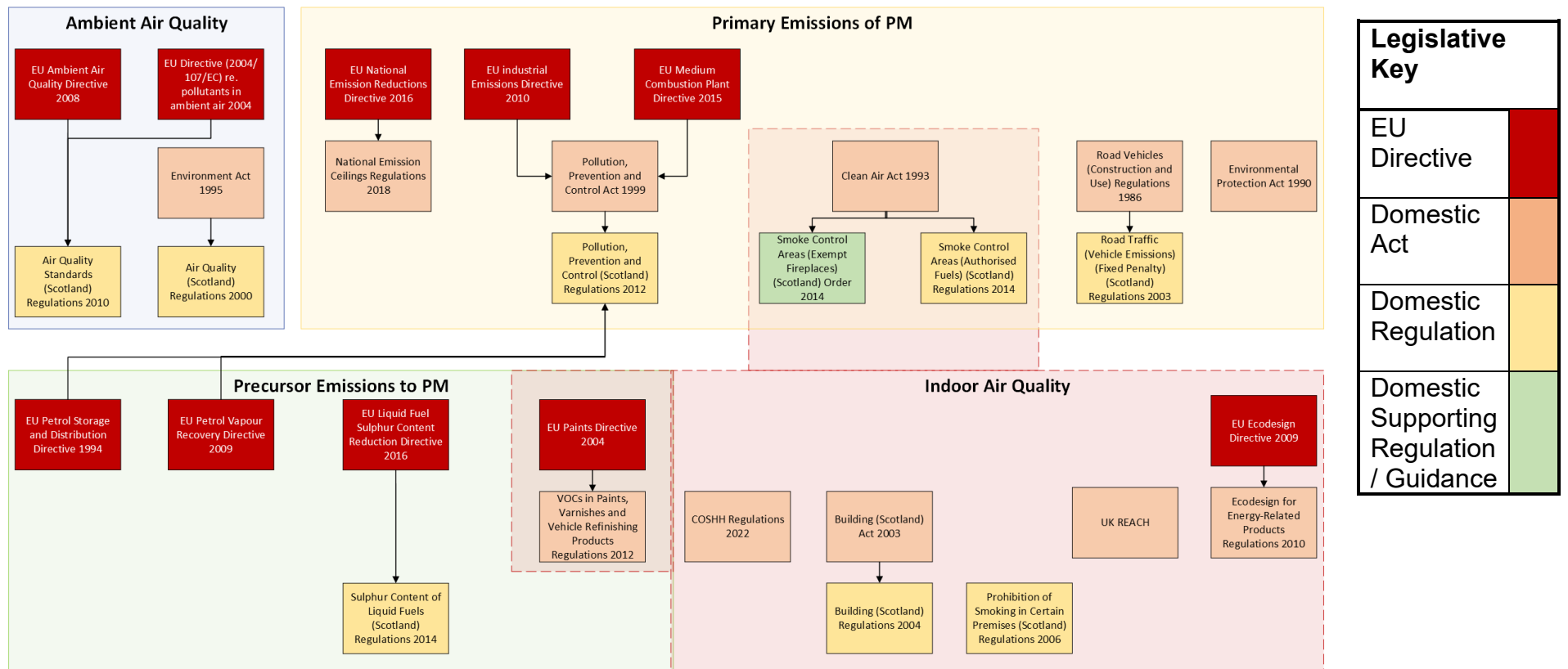


Figure 3-2 - Schematic illustration of the key legislative landscape around particulate matter emissions and indoor and ambient air quality in Scotland.

3.11 Figure 3-3 compares existing statutory standards that apply in Scotland, the UK and the EU, and the most recent EU proposals, against the WHO AQGs. This illustration does not compare direct equivalents and with consideration of the following:

- the EU proposals shown are not yet legally binding with EU trilogue negotiations ongoing (shown here are the latest proposals, as agreed by the Council of the European Union, 9 November 2023)
- the current concentration target for England by 2040 now applies at every monitoring station rather than a geographical average
- WHO AQGs are not legally binding
- the number of permitted exceedances is not shown here and do vary
- the EU proposals include the potential for exceedances of these standards to be excluded where certain criteria are met

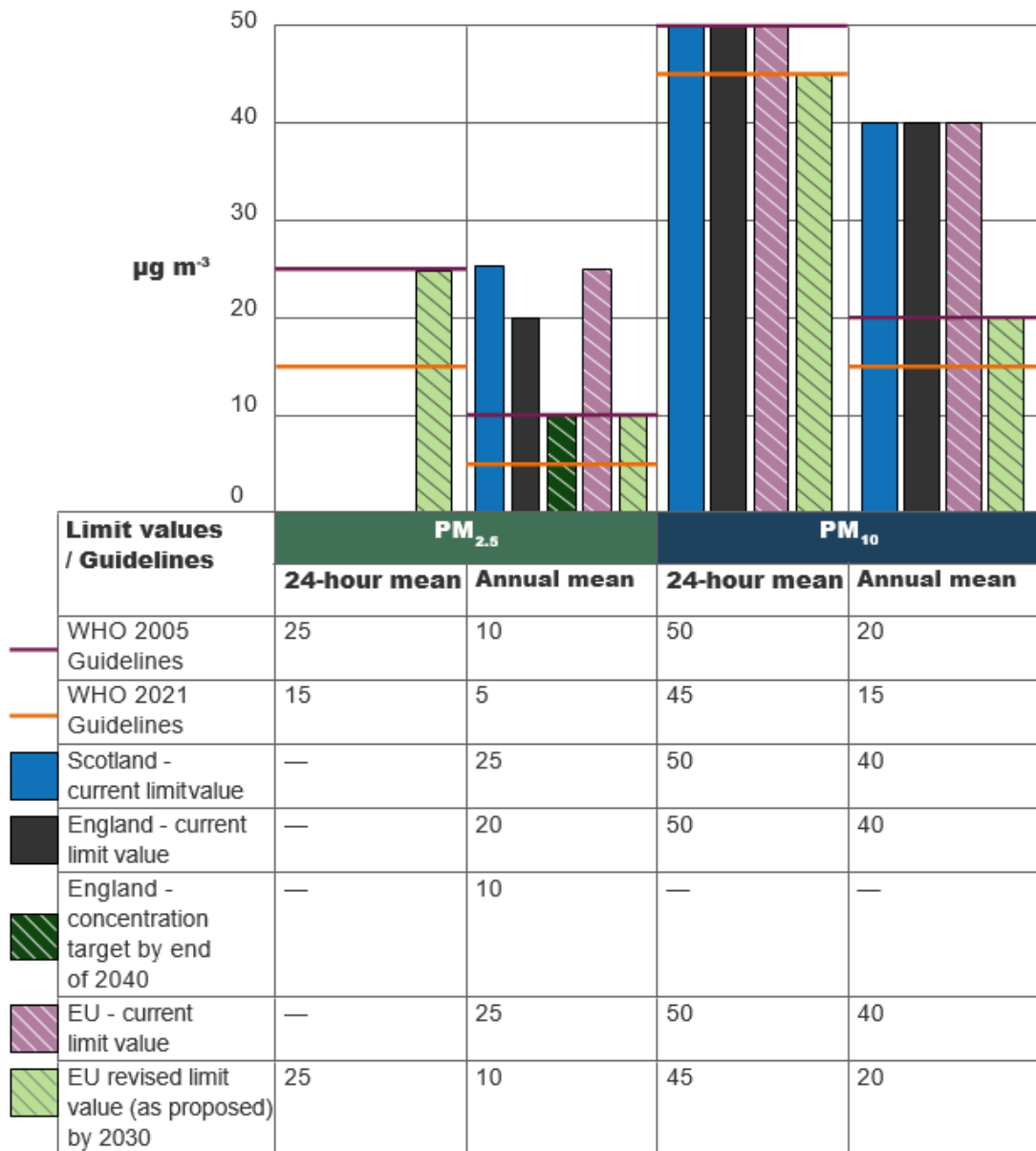


Figure 3-3 - Illustrative comparison of limit values and guidelines for PM_{2.5} and PM₁₀ for selected countries.

3.12 If the EU proposals are confirmed, the Scottish Government will need to bring forward legislative proposals for a tightening of limits if it is to maintain alignment.

Specifically, this will need to include:

- introducing a new target for a 24-hour limit value for PM_{2.5}
- raising ambition on the current annual mean limit value for PM_{2.5}
- raising ambition on the 24-hour and annual mean limit value for PM₁₀ target
- introducing an exposure reduction target to replace the expired UK one

4. Progress has been made on reducing emissions but challenges remain

4.1 As well as ambient air quality concentrations, Scotland has also made significant progress in recent decades in reducing emissions (see Figure 4-5 at UK level and Figure 4-6 at Scotland level portioned by sector), but that progress appears to be stalling in some areas, except for the influence of the Covid-19 restrictions on recent data. By 2021, and including the impact of the pandemic, Scotland's national inventory of estimates of emissions,¹⁶ states emissions of PM_{2.5} and PM₁₀ have significantly reduced relative to 2005 (47% for PM_{2.5} and a 41% decrease for PM₁₀).²⁷

4.2 This was achieved predominantly through action on transport and energy generation, which historically were some of the most important sectors to tackle. The most recent data²⁷ suggests a significant post-Covid-19 pandemic increase in transport emissions (akin to other sectors returning to pre-pandemic activity levels). Therefore action such as that driven by low emission zones (LEZs) is still necessary in ESS' view.

4.3 Scotland's emissions contributed 8% to the relevant UK total for 2021 for both PM_{2.5} and PM₁₀²⁷ and this has been a stable proportion in recent years.²⁸ However, challenges remain. Figure 4-4 shows how UK total emissions have reduced over the last five decades and the failure to meet the emissions ceiling for PM_{2.5} in 2021.

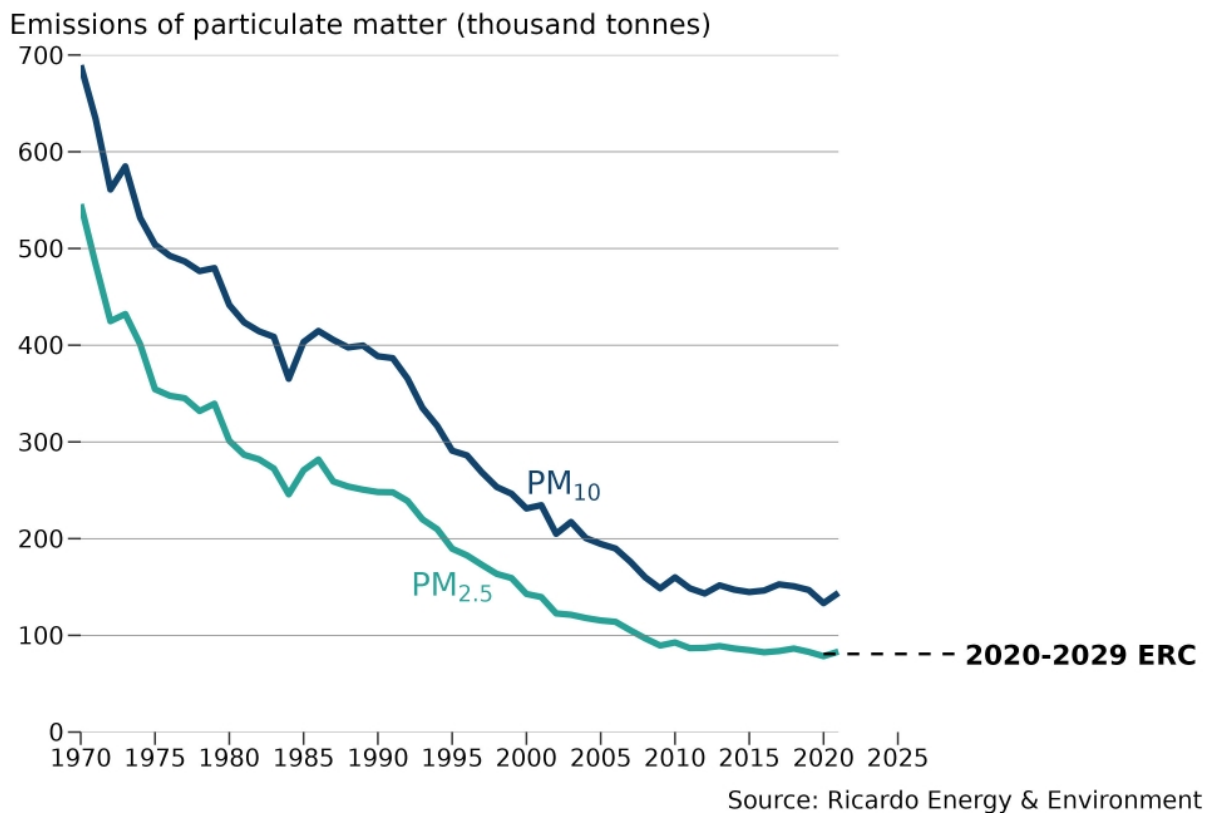


Figure 4-4 - UK Annual Emissions of Particulate Matter as PM₁₀ and PM_{2.5} for 2010-2021 and the National Emissions Ceiling Emissions Reductions Commitment (ERC) for PM_{2.5} for 2020 to 2030. Figure reproduced from National Statistics.²⁹

4.4 As Figure 4-4 shows, the 2020 PM_{2.5} emissions ceiling was met in 2020 (a year influenced by the Covid-19 pandemic restrictions) and in 2016 (prior to being a statutory legal requirement). However, 2021 data now shows a slight increase in emissions and the UK as a whole is now failing to comply with the emission reduction commitments (ERCs) under the National Emissions Ceiling Regulations 2018.³⁰ Furthermore, modelled projections to 2040, based on current policies, suggest the gap between attained emissions reductions and NECR commitments will widen by 2030 (see Figure 4-5).

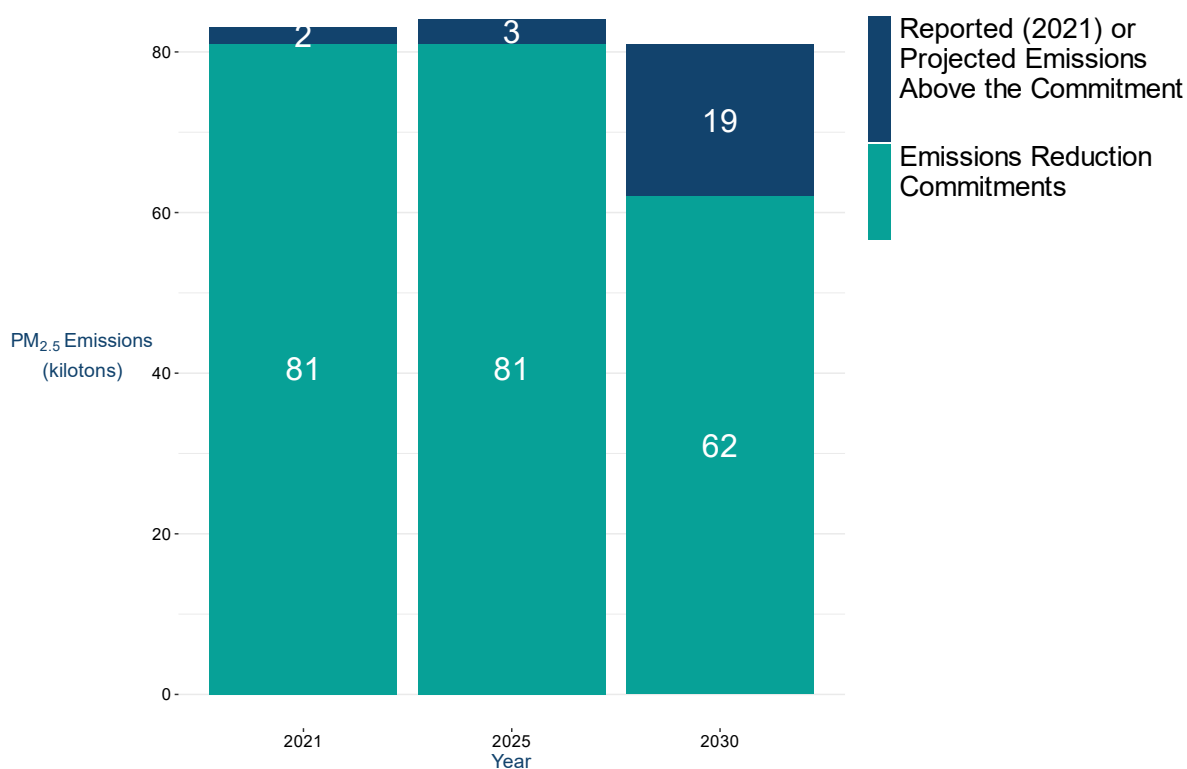


Figure 4-5 - UK national reported emissions of PM_{2.5} at 2021 and projected emissions above the committed reduction based on current policies at 2025 and 2030. Data extracted from UK Informative Inventory Report (1990 to 2021).³¹

4.5 The most recent data²⁷ (Figure 4-6) shows that transport no longer dominates emissions of either PM₁₀ or PM_{2.5} and that other sources are growing in relative importance. Transport is the third most contributing sector for PM_{2.5} and PM₁₀ emissions in Scotland in 2021 contributing 21% and 17% respectively.

4.6 Industrial processes are now the major source of PM₁₀ emissions in Scotland, accounting for roughly a third of the 2021 total (30%) and this sector's emissions have been highly variable in recent years. This sector ranks fourth for PM_{2.5} in Scotland at 10%.

4.7 With respect to PM_{2.5} in Scotland, industrial combustion is the second most polluting sector, accounting for 21% of the total. It ranks fifth at 12% for PM₁₀.

4.8 The residential commercial and public sector combustion was the greatest emitting sector of PM_{2.5} emissions in Scotland in 2021 (at 31%) and has achieved only modest reductions since 2005 – 27% reduction from 2005 to 2021 levels. This is a notably smaller decrease when compared to many other sectors over the same period – transport achieved a 71% reduction and energy industry an 83% reduction.

4.9 The agriculture sectoral contribution to PM₁₀ is the only sector in Scotland to have increased its reported PM emissions since 2005 (0.6% increase with large uncertainty) but remains low in the sectoral rankings. For PM_{2.5}, agricultural emissions have reduced very slightly from 0.39 to 0.36 kilotons from 2005 to 2021. Given that the NAEI figures reported here only include primary emissions, the role of the agriculture sector in PM emissions would be greater in absolute terms when secondary emissions are also considered. The relationship between primary agricultural emissions and PM generation is complex, with the exact contribution from secondary emissions uncertain³² and this is an area where further research is needed. Estimates across Europe have ranged from a few percent to up to 20%.^{48,33,34,35} One recent model study of cities in England (using some Covid-19 influenced data) suggested an overall ammonia contribution to total PM_{2.5} (primary and secondary) of up to 38%.³⁶ Tackling agricultural emissions will also have co-benefits beyond PM, for example, in reducing ammonia emissions and achieving more effective use of fertilisers.

4.10 The sectors summarised above are of growing concern and in need of further action – as set out in greater detail in Section 6

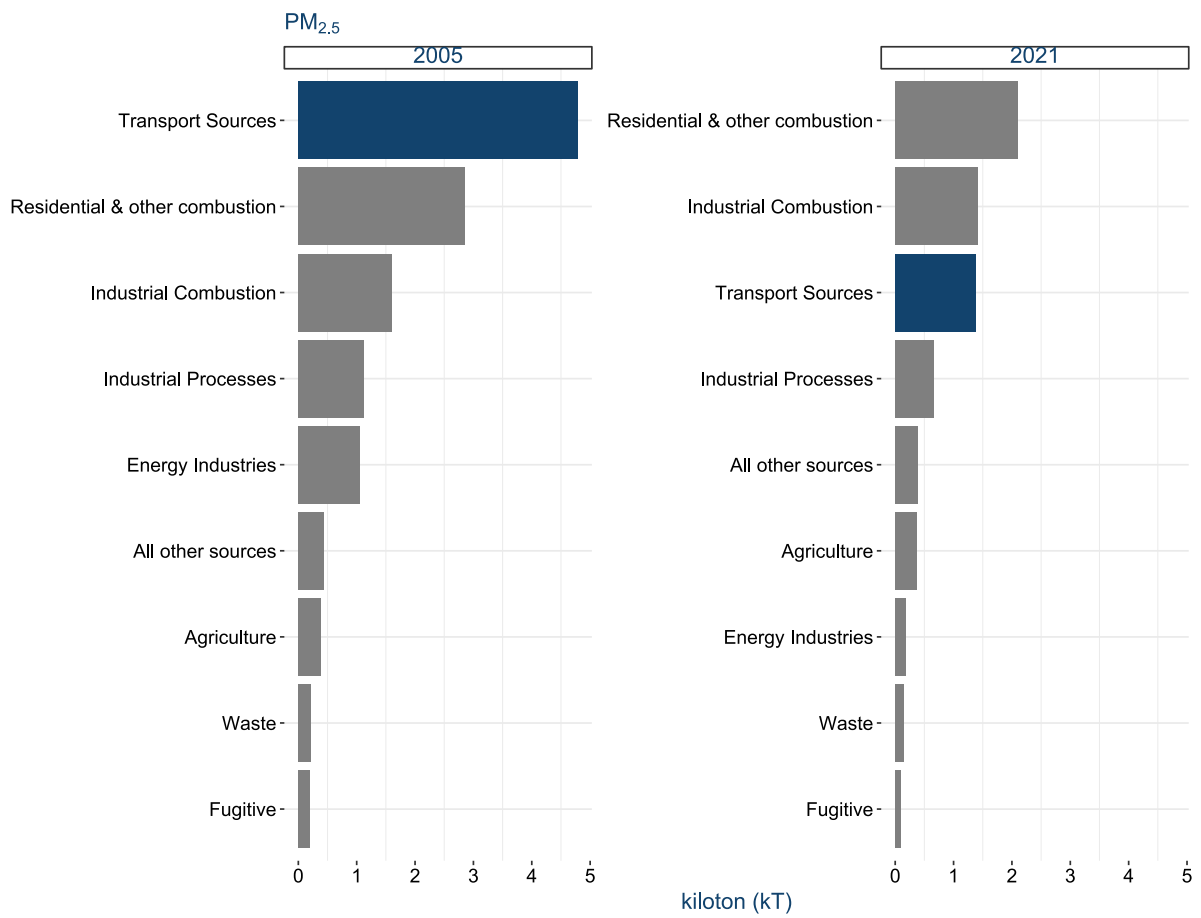
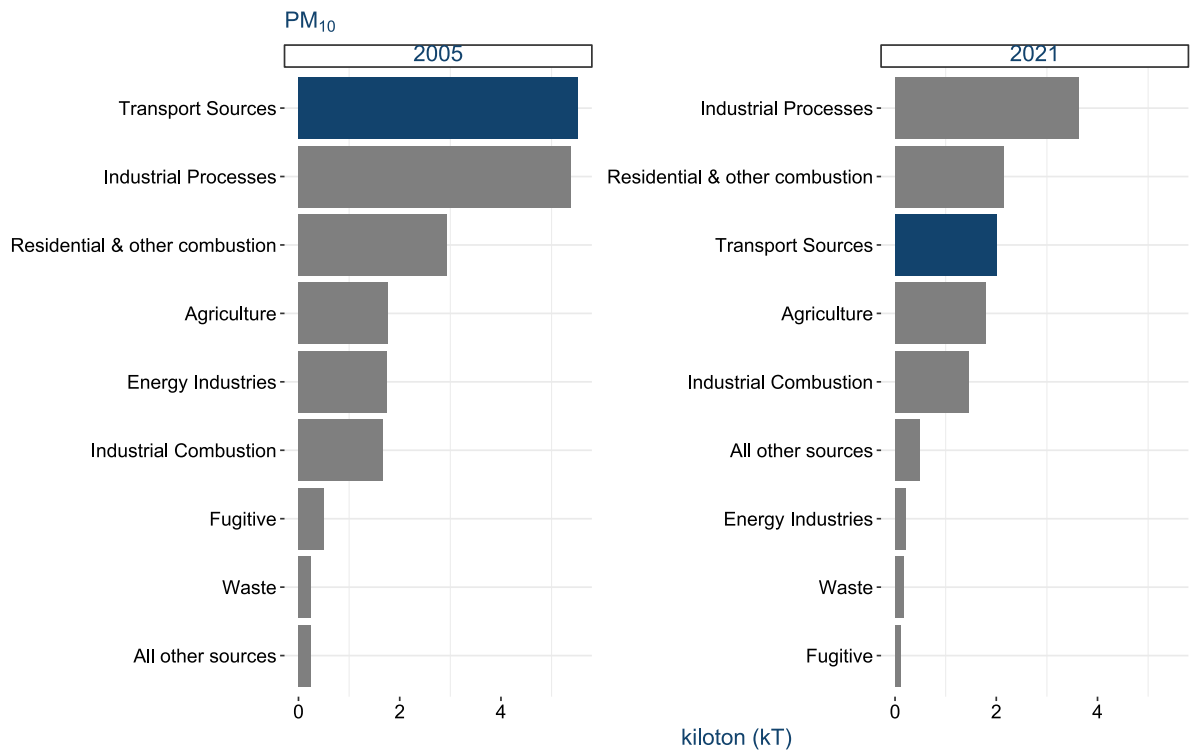


Figure 4-6 - Sectoral contributions to Scotland's PM₁₀ (top) and PM_{2.5} (bottom) emissions estimates for categories as reported by the National Atmospheric Emissions Inventory in 2005 (left) and 2021 (right)²⁷. In 2005, the "Transport" sector dominated PM emissions, but its influence has decreased along with the overall total emissions for both PM_{2.5} and PM₁₀. Figures reported here only include primary emissions – the role of some sectors (including agriculture) would be greater in absolute terms when secondary emissions are also considered. "Residential and other combustion" is shorthand for "Residential, Commercial & Public Sector Combustion."

5. Scotland would not meet the World Health Organisation's new guidelines

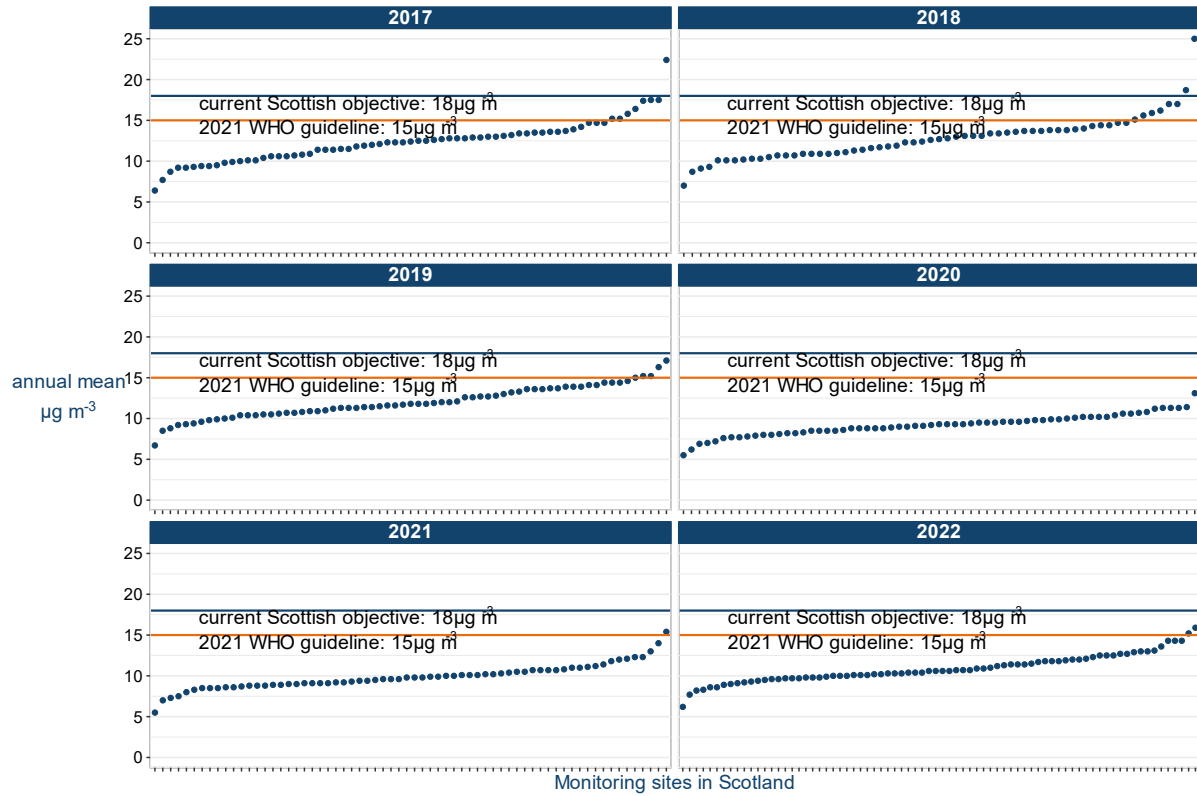
5.1 At present, Scotland would not meet the revised WHO AQGs (Figure 5-7). In 2022, the WHO assessed that 90% of the global population in assessed settlements were exposed to levels of PM_{2.5} or PM₁₀ above the latest AQGs.³⁷ In 2016, Scotland was the first country in Europe to adopt the 2005 WHO guideline of 10 µg m⁻³ for PM_{2.5} as an annual mean as a domestic objective, and to recognise the actions this would necessitate.

5.2 In April 2023, the Scottish Parliament's Net Zero, Energy and Transport (NZET) Committee proposed that the way to deal with such challenging new guidelines, in a backdrop of other pressures, was to create a policy and economic environment that drives continuous improvement in accordance with Scotland's Guiding Principles on the Environment.³⁸ ESS has considered whether Scotland's current domestic PM limit values are set at a level that does this, in recognition of the impact of PM on human health even at very low levels and the need for limit values to be part of a suite of tools to drive continuous improvement.

5.3 Apart from the years affected by the pandemic, progress in reducing Scotland's PM emissions has slowed. Following good progress in the mid-2000s (as "easier wins" were delivered), more recent trends suggest that continuous improvement requires new ambition.

5.4 While PM₁₀ concentrations in Scotland are close to the requirement of the WHO 2021 revised AQGs, there is a considerable challenge in meeting the revised AQGs for PM_{2.5}. Almost all current measuring sites (92.8% of the sites capturing data at least 75% of the time) exceeded the AQG for annual PM_{2.5} at least once in the six years shown (2017-22). In 2022, 89% of sites with data capture of at least 75% (67 of 75 sites) measured an average concentration in exceedance of the AQG of 5 µg m⁻³ for annual PM_{2.5}. Of those which exceeded it, they did so by an average of 18% (a mean of 5.88 µg m⁻³). Analysis by the European Environment Agency shows that on a concentration basis Scotland's sites are generally experiencing concentrations closer to the AQG for PM_{2.5} than most EU member states.³⁹

a-PM₁₀



b-PM_{2.5}

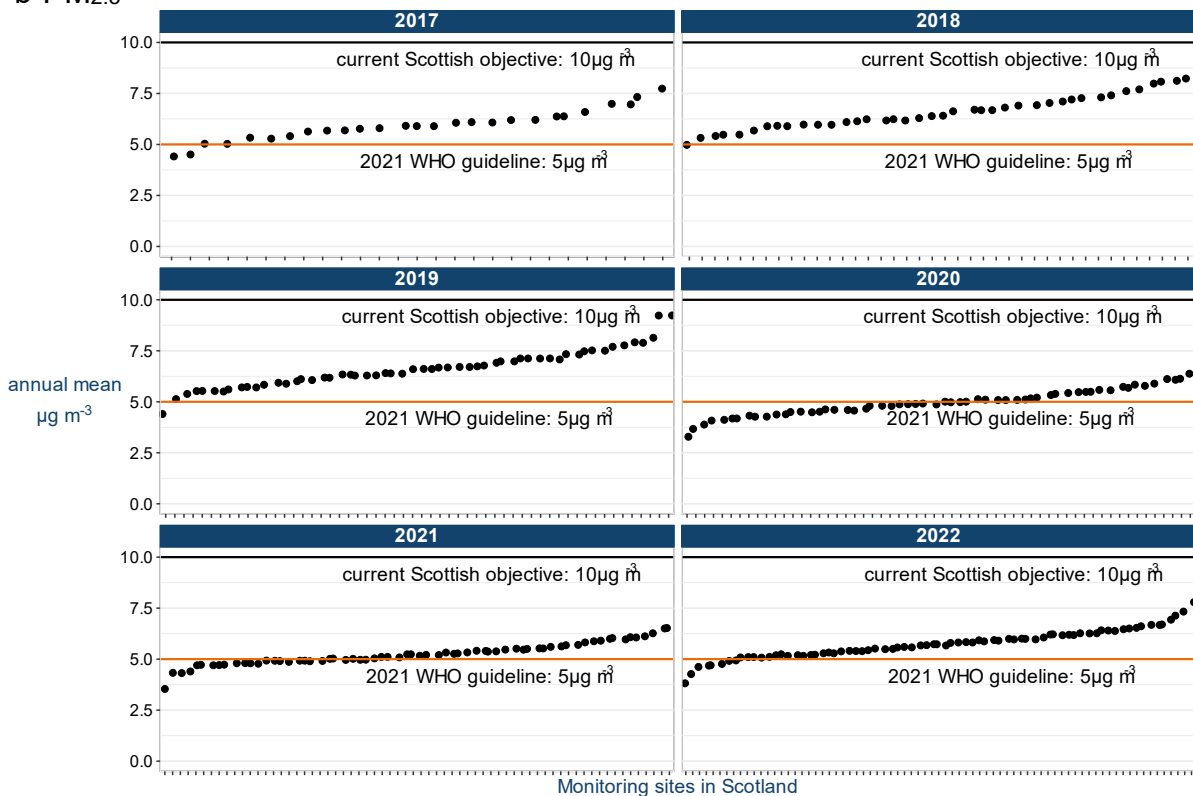


Figure 5-7 - Annual average concentrations ($\mu\text{g m}^{-3}$) of PM₁₀ (a, top) and PM_{2.5} (b, bottom) for all sites monitoring under the Scottish Air Quality Database in order of ranking for 2017 to 2022. Only sites with data capture >75% are included. Data used has not been subject to the FIDAS correction. The current Scotland objective for LAQMs (as set in the Air Quality (Scotland) Regulations 2000 (as amended)) is shown as a grey line, above the WHO 2021 guideline shown as an orange line.

5.6 The WHO AQGs have driven statutory standards set in Scotland for PM and other pollutants. ESS finds that ambition can and should be raised if legislation is to be effective in driving further improvement and achieving better health outcomes. Existing annual mean PM concentration-based limits are now being met, but Scotland can and should elevate its ambition.

5.7 The Scottish Government has indicated that it plans to review statutory standards (limit values or objectives) in the context of the revised WHO AQGs during its review of CAFS2. The latest CAFS2 progress report, published in September 2023, suggests that this process will be delayed by at least a year.⁴⁰ Given the evidence of the effects of PM on human health, particularly of the most vulnerable, ESS finds this delay potentially harmful. The most recent two progress reports on CAFS2^{40,41} have not mentioned the updated evidence base assessed by the WHO.

6. Tackling a broader range of sources is necessary to reduce particulate matter further

6.1 To reduce the levels of PM further and make progress towards meeting the revised WHO AQGs, there needs to be consideration of all sources and “lifecycles” of PM pollutants. This means looking at:

- the sources of pollutants
- how their release can be prevented or slowed
- what happens to them in the atmosphere
- how they affect people and the environment

6.2 ESS has analysed where significant reductions have been achieved to date, where less progress has been made (Figure 4-6) and which sources the Scottish Government has the greatest potential to impact using devolved powers (Table 6-1).

Table 6-1 - Summary of ESS’ assessment of legislative competence for sectors as defined in the National Atmospheric Emissions Inventory.

Sector	Legislative competence
Agriculture	Largely devolved
Energy industries	Split
Fugitive ⁴²	Split
Industrial combustion	Largely devolved
Industrial processes	Split
Residential, commercial and public sector combustion	Split
Solvent processes	Split
Transport	Split
Waste	Largely devolved

6.3 The Scottish Government has varying levels of influence over emissions from different sources through its devolved powers. It has greatest control over emissions from activities within Scotland, but little influence over transboundary emissions

reaching Scotland, and aspects that affect what happens to pollution after it is released (meteorology, chemical transformation, transportation).

6.4 Analysis carried out by ESS (combining the sectoral contribution, the secondary contribution through key precursors and the legislative competence), suggests the Scottish Government needs to expand its focus to include further sectors (in addition to the transport sector) in tackling PM. Industrial processes would benefit from focus when considering PM₁₀ and residential and other combustion processes and industrial combustion would benefit from focus when considering PM_{2.5}, accounting for 31% and 21% respectively of Scotland's emissions in 2021.²⁷ Residential and other combustion was also the second largest contributor to PM₁₀ emissions estimates in 2021. Furthermore, agricultural emissions appear to be relatively unmitigated to date when considering both pollutants and may play a greater role (in absolute terms) than estimated in all PM emissions due to the secondary contribution being unaccounted for. All these sectors have significant devolved legal competence in ESS' assessment.

6.5 One sector which is growing in relative importance, where progress has largely stalled and where devolved legislative levers exists, is residential burning. In recent years, emissions of both PM_{2.5} and PM₁₀ from the residential, commercial and other combustion sector have slightly increased between 2020 and 2021. The increase for residential burning for PM₁₀ is attributed to an increasing quantity of wood fuel use, especially in the residential sector.²⁷

6.6 Smoke Controlled Areas (as defined in the Clean Air Act 1993) are the key tool for managing the effects of residential burning. In CAFS2, the Scottish Government has committed to considering revision of the Clean Air Act 1993 (with SEPA and local authorities). This should consider the effectiveness of Smoke Controlled Areas.

7. Monitoring and modelling of air quality must broaden its scope beyond a focus on vehicle emissions

7.1 Monitoring for compliance of air pollution has, to date, been dominated by understanding concentrations of PM and other pollutants close to the roadside. Major improvements have been made in reducing emissions from vehicle exhausts, though non-exhaust emissions, such as from tyre and brake wear, continue to be a challenge. This means that this sector is no longer the dominant contributing sector to either PM₁₀ or PM_{2.5} emissions in Scotland. Attention should now be broadened to give consideration to other polluting behaviours.

7.2 There is now more evidence about pathways from precursor emissions to PM, which are not yet accounted for in the NAEI.¹⁶ These include agricultural emissions of ammonia, and residential, commercial and public sector combustion forming primary PM and contributing to the formation of secondary pollutants (e.g. sulphur dioxide).

7.3 A reduction of pollution from a wider range of sources needs to take place, yet there are currently very few monitoring stations placed at locations to capture emissions from these sources. The Scottish Government and SEPA have recently reviewed guidance about the siting of monitoring stations in response to ESS' 2022 investigation on nitrogen dioxide (NO₂)⁴³, but were not asked to consider whether this monitoring adequately captures the variety of contributors to PM.

7.4 There is also now better understanding of where the most vulnerable and disproportionately affected people spend time. While local authorities are encouraged to make use of all available information on fine PM to inform "hotspot" monitoring, they do not have sufficiently detailed information available to them to inform this. Some local authorities have no measurements of PM_{2.5} and rely entirely on modelling. Modelling remains very coarse in resolution, constrained by measurements made at the roadside and unspecific to local needs.

7.5 ESS has seen no evidence that the Scottish Government or SEPA have started the process of modelling the policy measures that would be needed to meet the revised WHO AQGs. There is limited modelling information available at coarse resolution, and this is largely driven by the National Air Pollution Control Programme (see section 9).

7.6 Monitoring and modelling will need to continue to be internationally comparable but must also respond to emerging areas and sectors of concern, while considering the impact on the most vulnerable.

8. Coherent integration of policies is essential

8.1 CAFS2 recognises the need to “work in tandem with other key Scottish Government strategies”.²³ One of the guiding principles on the environment set out in the 2021 Act is the integration of environmental protection into the making of policies through the Strategic Environmental Assessment (SEA) process. However, ESS and others^{44,45,46,47, 48} have identified that there is potential for both co-benefits and tensions for different environmental impacts across a variety of policies including for fertiliser use in agriculture⁴⁸ and climate change.^{44,47}

8.2 The Scottish Government has commissioned work looking at policies to address climate change and the synergies and tensions with other areas.⁴⁷ This includes, amongst others, the co-benefits and tensions between vehicle electrification and PM emissions due to the significant reductions in tailpipe emissions that will be delivered on the one hand, but the increased wear on tyres and brakes from heavier vehicles on the other.

8.3 In order to be useful to the SEA process, such assessments of policy tensions need to be regularly updated, broadened to consider planning and nature recovery policies, and their outputs considered in line with continued policy developments.

9. The Retained European Union Law Act 2023 has implications for Scottish air quality policy and reporting

9.1 Air quality modelling and monitoring needs to support Scottish policy decisions and provide an internationally comparable benchmark. The main regulation driving understanding of how Scotland contributes to the larger international future air quality scenarios is the National Emissions Ceiling Regulations 2018 (NECR), originating from the EU National Emissions Ceiling Directive (as shown in Figure 3-2). The modelling this relies upon is coarse and considers the resulting emissions at a UK level from policy that often differs in all four nations of the UK.

9.2 The Retained EU Law (Revocation and Reform) Act 2023 revokes Regulations 9 and 10 of the NECR. These Regulations require the revision and public consultation on a National Air Pollution Control Programme (NAPCP),⁴⁹ if current or projected modelling suggests the current one is insufficient to meet international emissions targets. The UK Government's Department for Environment, Food and Rural Affairs (Defra) has reasoned that the Regulations can be revoked because they are duplicative in nature and resources may be better diverted elsewhere.

9.3 The process of revocation has not followed the Common Framework Agreement on Air Quality,⁵⁰ which was designed to represent the interests of all nations of the UK. The Scottish Government,⁵¹ Scottish Parliament⁵² and ESS⁵³ raised concerns about this during the passage of the Retained EU Law (Revocation and Reform) Act 2023. The revocation also leaves a gap in accountability in demonstrating how Scotland's policies will make a proportionate contribution to UK emissions targets.

9.4 While mechanisms for accountability in concentration-based objectives exist in Scotland, this gap exists both in the requirement to revise the NAPCP, when it proves inadequate in reducing emissions, and to consult on that revision. This gap presents an opportunity to design and support modelling that is both informative for international comparisons (such as the requirements under the Convention for Long Range Transboundary Air Pollution), domestic policy decisions, and supporting understanding about how Scotland best plans a proportionate contribution to UK emission reductions, as delivered by the NAPCP.

¹ [Environmental Standards Scotland Strategic Plan 2022-25](#)

² WHO global air quality guidelines: particulate matter (PM_{2.5} and PM₁₀), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide, Published 22 September 2021, [WHO global air quality guidelines: particulate matter \(PM_{2.5} and PM₁₀\), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide](#), Accessed 18 November 2022.

³ [Baseline Evidence Review – Air](#), Environmental Standards Scotland, 2022.

⁴ [New WHO Global Air Quality Guidelines aim to save millions of lives from air pollution](#), 22 September 2021.

⁵ [Air pollution and health briefing note: mortality associated with exposure to fine particulate matter \(PM_{2.5} attributable mortality\) in Scotland - Publications - Public Health Scotland](#), 18 June 2018; Accessed 2 November 2023.

⁶ [Frequently Asked Questions - Personal interventions and risks - Air Pollution - WHO](#) Accessed 12 December 2023.

⁷ [Ecological effects of particulate matter - ScienceDirect](#)

⁸ Rowe EC, Sawicka K, Tomlinson S, Levy P, Banin LF, Martín Hernandez C & Fitch A (2021) [Trends Report 2021: Trends in critical load and critical level exceedances in the UK](#). Report to Defra under Contract AQ0849, UKCEH project 07617.

⁹ [Air pollution, ecosystems and biodiversity](#), UNECE, Accessed 1 Feb 2023,

¹⁰ [Visibility and Regional Haze | US EPA](#), Accessed 31 August 2023.

¹¹ 1000 µm is 1 millimetre

¹² [Policy paper September 2021: Air quality factsheet](#).

¹³ [COMEAP statement: response to publication of the World Health Organization Air quality guidelines 2021 - GOV.UK \(www.gov.uk\)](#), 2022, Accessed 31 August 2023.

¹⁴ Air Quality Expert Group, Fine Particulate Matter (PM_{2.5}) in the United Kingdom [1212141150 AQEG Fine Particulate Matter in the UK.pdf \(defra.gov.uk\)](#)

¹⁵ [Modelling PM_{2.5} workshop summary 15_03_21 \(defra.gov.uk\)](#)

¹⁶ [NAEI, UK National Atmospheric Emissions Inventory - NAEI, UK \(beis.gov.uk\)](#)

¹⁷ [Population density \(people per sq. km of land area\) - European Union | Data \(worldbank.org\)](#)

¹⁸ [Scotland's Census 2022 - Rounded population estimates | Scotland's Census \(scotlandscensus.gov.uk\)](#)

¹⁹ Figure 5.25, Health risks of particulate matter from long-range transboundary air pollution, 2006, WHO. <https://www.who.int/publications-detail-redirect/E88189>

²⁰ Table 5.4, [Health risks of particulate matter from long-range transboundary air pollution](#), 2006, WHO.

²¹ As part of the UK. Figures 5.24 and 5.25, [Health risks of particulate matter from long-range transboundary air pollution \(who.int\)](#)

²² Data for Across all GBR sites, the 5 Scottish sites (Inverclyde, Aberdeen, Glasgow, Edinburgh and Highland) with measurements have the 5 lowest annual mean concentrations in 2020. Across all European sites, all Scottish sites are within the lowest 5% of records and lowest 10% by concentration for both PM10 and PM2.5. [WHO Ambient Air Quality Database](#)

²³ Cleaner Air for Scotland 2 (CAFS2) - Towards a Better Place for Everyone, Scottish Government, 2021. [Supporting documents - Cleaner Air for Scotland 2 - Towards a Better Place for Everyone - gov.scot \(www.gov.scot\)](#) Accessed 28 March 2023.

²⁴ [Clean Air \(Human Rights\) Bill \[HL\] - Parliamentary Bills - UK Parliament](#)

²⁵ [Amendments adopted by the European Parliament on 13 September 2023 on the proposal for a directive of the European Parliament and of the Council on ambient air quality and cleaner air for Europe \(recast\) \(COM\(2022\)0542 – C9-0364/2022 – 2022/0347\(COD\)\)1](#)

²⁶ [Particulate Matter in the United Kingdom, AQEG, 2005](#). Accessed 16 August 2023.

²⁷ [Air Pollutant Inventories for England, Scotland, Wales and Northern Ireland: 2005-2021](#), Accessed 2 November 2023.

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- ²⁹ National statistics, Emissions of air pollutants in the UK – Particulate matter (PM₁₀ and PM_{2.5}) 2023. [Emissions of air pollutants in the UK – Particulate matter \(PM₁₀ and PM_{2.5}\) - GOV.UK \(www.gov.uk\)](#)
- ³⁰ [The National Emission Ceilings Regulations 2018 \(legislation.gov.uk\)](#)
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- ³⁷ [WHO ambient air quality database, 2022 update: status report](#)
- ³⁸ [Meeting of the Parliament: NZET/18/04/2023 | Scottish Parliament Website](#)
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- ⁵¹ [Cabinet Secretary for Transport, Net Zero and Just Transition \(parliament.scot\)](#)
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