Llywodraeth Cymru
Welsh Government

Number: WG52778

Welsh Government

Consultation Document

Cleaner and healthier air:

Consultation on draft regulations to implement fine particulate matter ($PM_{2.5}$) air quality targets.

Date of issue: 17 November 2025

Action required: Responses by 16 February 2026

Overview

Our *Clean Air Plan for Wales: Healthy Air, Healthy Wales* set out a commitment to develop and enact a new target for fine particulate matter ($PM_{2.5}$), taking account of the World Health Organisation (WHO) guidelines on air quality.

The Environment (Air Quality and Soundscapes) (Wales) Act 2024 places a duty on Welsh Ministers to make regulations setting a long- or short-term air quality target for $PM_{2.5}$ by January 2027

This consultation seeks your views on draft regulations required to implement $PM_{2.5}$ air quality targets.

How to respond

Insert text to explain how to respond to the consultation. This **should** include by post, email and online form (contact your Departmental Web Manager for a link to the online form).

The closing date for responses is 16 February 2025. Please either respond using the online form or complete the enclosed consultation response form and send it to any of the following:

Email: airqualitypolicy@gov.wales
(please include 'Consultation on draft regulations to implement fine particulate matter air quality targets' in the subject line)

Post:
Air Quality Evidence, Monitoring and Assessment Branch
Environmental Protection Division
Welsh Government
Cathays Park
Cardiff
CF10 3NQ

Further information and related documents

Large print, Braille and alternative language versions of this document are available on request.

Contact details

For further information:

Environmental Protection Division
Welsh Government
Cathays Park
Cardiff
CF10 3NQ
Email: airqualitypolicy@gov.wales
This document is also available in Welsh

UK General Data Protection Regulation (UK GDPR)

The Welsh Government will be data controller for Welsh Government consultations and for any personal data you provide as part of your response to the consultation.

Welsh Ministers have statutory powers they will rely on to process this personal data which will enable them to make informed decisions about how they exercise their public functions. The lawful basis for processing information in this data collection exercise is our public task; that is, exercising our official authority to undertake the core role and functions of the Welsh Government. (Art 6(1)(e))

Any response you send us will be seen in full by Welsh Government staff dealing with the issues which this consultation is about or planning future consultations. In the case of joint consultations this may also include other public authorities. Where the Welsh Government undertakes further analysis of consultation responses then this work may be commissioned to be carried out by an accredited third party (e.g. a research organisation or a consultancy company). Any such work will only be undertaken under contract. Welsh Government's standard terms and conditions for such contracts set out strict requirements for the processing and safekeeping of personal data.

In order to show that the consultation was carried out properly, the Welsh Government intends to publish a summary of the responses to this document. We may also publish responses in full. Normally, the name and address (or part of the address) of the person or organisation who sent the response are published with the response. If you do not want your name or address published, please tell us this in writing when you send your response. We will then redact them before publishing.

You should also be aware of our responsibilities under Freedom of Information legislation and that the Welsh Government may be under a legal obligation to disclose some information.

If your details are published as part of the consultation response then these published reports will be retained indefinitely. Any of your data held otherwise by Welsh Government will be kept for no more than three years.

Your rights

Under the data protection legislation, you have the right:

- to be informed of the personal data held about you and to access itto require us to rectify inaccuracies in that data
- to (in certain circumstances) object to or restrict processing
- for (in certain circumstances) your data to be 'erased'
- to (in certain circumstances) data portability
- to lodge a complaint with the Information Commissioner's Office (ICO) who is our independent regulator for data protection

For further details about the information the Welsh Government holds and its use, or if you want to exercise your rights under the UK GDPR, please see contact details below:

Data Protection Officer:
Welsh Government
Cathays Park
CARDIFF
CF10 3NQ
e-mail: dataprotectionofficer@gov.wales

The contact details for the Information Commissioner's Office are:

Wycliffe House
Water Lane
Wilmslow
Cheshire SK9 5AF
Tel: 0303 123 1113
Website: https://ico.org.uk/

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Consultation Response Form

Your name:

Organisation (if applicable):

email / telephone number:

Your address:

Questions

We are seeking views to the following questions. Responses may be submitted through our online form or by downloading a Word version of the response form for completion. Completed response forms may be emailed to: airqualitypolicy@gov.wales.

Question 1a: To what extent do you agree with the level of ambition proposed for the Annual Mean Concentration Target (AMCT)?

☐ Strongly agree

☐ Agree

☐ Neither agree nor disagree

☐ Disagree

☐ Strongly disagree

Question 1b: Please explain your answer.

Question 2a: To what extent do you agree with the level of ambition proposed for the Population Exposure Reduction Target (PERT)?

☐ Strongly agree

☐ Agree

☐ Neither agree nor disagree

☐ Disagree

☐ Strongly disagree

Question 2b: Please explain your answer.

Question 3a: To what extent do you agree with the proposed arrangements for assessing $PM_{2.5}$ levels and achievement of the targets?

☐ Strongly agree

☐ Agree

☐ Neither agree nor disagree

☐ Disagree

☐ Strongly disagree

Question 3b: Please explain your answer.

Question 4a: To what extent do you agree with the provision in the draft regulations to allow the subtraction of the 'natural contribution' to particulate matter where exceedances of a target are due in whole or in part to these natural contributions?

☐ Strongly agree

☐ Agree

☐ Neither agree nor disagree

☐ Disagree

☐ Strongly disagree

Question 4b: Please explain your answer.

Question 5: We have asked some specific questions. If you have any other relevant thoughts or comments on our proposals, please provide them here. Responses to consultations are likely to be made public, on the internet or in a report. If you would prefer your response to remain anonymous, please tick here:

Please provide a part post code, eg. CF10

Ministerial Foreword

Our air is generally cleaner than at any time since the industrial revolution. This has largely been achieved through controls on emissions of pollutants from power stations, industry, agriculture, transport and domestic sources. Air pollutants may now be largely invisible, but exposure to atmospheric pollution is one of the biggest environmental public health challenges we face today. It is shortening lifespans and damaging the quality of life of many, including the most vulnerable in our society, like the elderly, young children, and those with existing health issues. Air pollution also impacts wildlife, changing where many species are found and the quality of sensitive habitats.

The National Air Quality Strategy (the Clean Air Plan for Wales) sets out our ambitions and the actions we will take to improve air quality and reduce the impacts of air pollution on human health, biodiversity, the natural environment and the economy. The enactment of the Environment (Air Quality and Soundscapes) (Wales) Act 2024 achieved a key commitment in both the Clean Air Plan for Wales and the Programme for Government to introduce a Clean Air Act for Wales. The national air quality target setting framework is a cornerstone of the Act, including powers and duties for Welsh Ministers to set new air quality targets. It is important we are able to set the right targets to drive action needed to achieve cleaner air and reduce the impacts of air pollution in Wales.

The duty to achieve targets rests with national government, but delivery will require action across society for the benefit of current and future generations. New legally binding targets will provide long-term certainty and direction, including for business and industry.

We are now consulting on new targets for fine particulate matter ($PM_{2.5}$), the most harmful pollutant to public health. The proposed targets cut the allowed annual mean level for $PM_{2.5}$ by more than half, aligning more closely with World Health Organisation recommendations. Stricter targets will help reduce levels across the country, in locations where levels are highest, and help reduce exposure for all. It is an important step towards achieving cleaner air, protecting everyone's health for current and future generations.

Whilst setting targets that are both ambitious but achievable, we can all play our part for the benefit of everyone in Wales. I look forward to hearing your views.

Huw Irranca-Davies MS,
Deputy First Minister and Cabinet Secretary for Climate Change and Rural Affairs

Introduction

Our air is cleaner in general terms than at any time since the industrial revolution, largely achieved through tighter controls on emissions of pollutants from industry, transport and domestic sources. Despite these significant improvements, exposure to air pollution remains the leading environmental risk to public health - especially affecting vulnerable groups like the elderly, young children, and those with existing health issues. It also harms natural habitats, disrupts essential ecosystem services, and can influence climate systems. Despite notable improvements in air quality across Wales over recent decades, further efforts are needed to achieve cleaner, healthier air for all.

Exposure to airborne pollutants including fine particulate matter can cause some health problems and make others worse. Breathing in these pollutants over several years can increase health risks from heart and lung diseases, including lung cancer. There is also evidence other body organs may be affected, with possible effects on dementia, low birth weight and diabetes.

The Welsh Government's national air quality strategy, the Clean Air Plan for Wales, was published in 2020 and sets out our ambitions and actions to be taken to improve air quality and reduce the impacts of air pollution on human health, biodiversity, the natural environment and the economy.

The enactment of the Environment (Air Quality and Soundscapes) (Wales) Act 2024 ("the Act") achieved a key commitment in both the Clean Air Plan for Wales and the Programme for Government (for 2021 to 2026) to introduce a Clean Air Act for Wales, consistent with World Health Organisation ("WHO") guidance and extend the provision of air quality monitoring. The Act is part of a broader approach within the Clean Air Plan for Wales to improve air quality in Wales, which is consistent with wider environmental objectives and builds on a suite of existing legislation.

National air quality improvements to date have been driven by both international agreements and European Union directives, as well as UK and Welsh legislation. This includes legislation which set limits on ambient concentrations, UK pollutant emission reductions and concentrations of pollutants from specific sources, such as cars and industry. Under separate national legislation, local authorities tackle air quality issues at a local level through a Local Air Quality Management (LAQM) process. In order to drive the action needed to go further and make sustained improvements to the air we breathe, it is important that we now set targets and make sure we have the right set of targets and standards in place.

The national air quality target setting framework is a cornerstone of the Act, which includes duties for Welsh Ministers to set new air quality targets for Wales. The new framework strengthens Welsh Ministers' powers and enables the introduction of long-term targets for identified pollutant risks. The Act also requires Welsh Ministers to set a target for fine particulate matter ($PM_{2.5}$) by February 2027. We are proposing national $PM_{2.5}$ targets that we consider will lead to action in areas that drive public and environmental health outcomes where we face some of the greatest pressures.

The purpose of this consultation is to seek views on the draft regulations, including the proposed $PM_{2.5}$ air quality target levels and dates and the associated target compliance assessment arrangements.

Why new air quality targets are needed

Clean air is essential to human health and sustaining the environment. The WHO has described air pollution as the world's largest single environmental health risk.

Breathing polluted air over the long-term can reduce life expectancy and lead to respiratory diseases, heart conditions, and lung cancer. Air pollution affects everyone and can particularly affect some individuals who are more vulnerable to harm - including children, the elderly, and those with pre-existing health conditions.

Air pollution is a complex mix of particles and gases of both natural and human origin. It is a local, regional and international problem caused by the emission of pollutants which, either directly or through chemical reactions in the atmosphere, lead to negative impacts on human health, ecosystems and the economy.

Air pollution is a cause of both chronic and acute diseases. The burden of long-term air pollution exposure in Wales is estimated to be equivalent to between 1,000 to 1,400 deaths (at typical ages) each year[1,2]. Air pollution also adversely affects wildlife. It causes widespread changes to species distribution and to the quality of habitats in the UK and is a threat to the conservation status of many sensitive habitat sites. Although air quality in Wales is generally good, more needs to be done to reduce the harmful effects of air pollution in areas where it remains an issue.

Fine particulate matter ($PM_{2.5}$) is the air pollutant most strongly linked to serious health effects, including premature death and chronic illness. Scientific studies have shown that these associations are now widely recognised to be causal. In September 2021, the WHO published updated guidelines in relation to six pollutants, including for $PM_{2.5}$. The guideline for $PM_{2.5}$ was halved. Currently there is no clear evidence of a threshold concentration of $PM_{2.5}$ in ambient air below which there are no harmful effects on human health. Therefore, reductions in concentrations below the current limits (and even the recommended guideline) are likely to bring additional health benefits. Evidence on the effects of air pollutants is constantly emerging and so it is important we continue to have the ability to manage associated pressures and risks in the long term.

Existing air quality standards, which have their origins in EU law, continue to have effect in Wales, providing continuity and ensuring standards are maintained. However, it is important Welsh Ministers have their own mechanisms for setting new targets to drive the further actions needed to achieve cleaner air and reduce the impacts of air pollution in Wales.

Consequently, the Act introduced an air quality target setting framework which enables Welsh Ministers to tighten existing air quality targets and introduce long-term targets for newly identified pollutant risks. Targets set under the Act are required to be informed by evidence, including new evidence as it emerges, and

[1] (2020) Air Pollution and Health in Wales. Available at: https://phw.nhs.wales/services-and-teams/environmental-public-health/air-quality/air-pollution-and-health-fact-sheet/ (Accessed: 17 July 2024).
[2] Burden range does not reflect 'actual' deaths from air pollution exposure. It is an estimate of the 'equivalent' reduced life expectancy, when summed, which everyone experiences because of air pollution exposure.

supported by a clear process for setting, reporting on and reviewing targets. The Act includes a duty on the Welsh Ministers to make regulations in respect of the annual mean level of $PM_{2.5}$ in ambient air in Wales within three years of the Act receiving Royal Assent (i.e. by 14 February 2027).

The National Air Quality Target-setting Framework

The Senedd passed the Act on November 2023, with the Act receiving Royal Assent on 14 February 2024. The Act provides an air quality target setting framework. The framework provides the basis for any new targets set under the Act. Key points of the framework, which must be considered when setting targets, include:

- A broad power: enabling Welsh Ministers to make regulations setting long term targets in respect of any matter relating to air quality in Wales. A target is long term if it is required to be complied with at least 10 years after it is set.
- Duties on Welsh Ministers to:
    - Make draft regulations setting a long or short-term air quality target for $PM_{2.5}$ by February 2027.
    - Make draft regulations setting a long-term air quality target by February 2030 for one of the following pollutants: nitrogen dioxide, sulphur dioxide, ammonia, ground level ozone, PM10 or carbon monoxide.
    - Have regard to scientific knowledge, independent and expert advice and the most recent WHO Air Quality guidelines for a pollutant when setting or reviewing a target for that pollutant.
    - Before setting or amending a target, ensure the target can be met.
    - Make arrangements to obtain data about air quality in Wales to monitor progress being made towards meeting targets set in regulations under the Act.
    - Review targets which have been set, having regard to scientific knowledge, independent and expert advice and the most recent WHO Air Quality guidelines for a pollutant when setting or reviewing a target for that pollutant. Having reviewed targets, lay a statement in the Senedd within 5 years of the first target being set and every 5 years thereafter.
    - Maintain the target standards once the target level and date have been reached and put in place reporting arrangements.
    - Report on the consideration Ministers have given to setting targets for the pollutants listed in the Act, where no target has previously been set.

As recognised by WHO, air quality standard-setting processes need to aim to achieve the lowest concentrations possible in the context of national and local constraints, capabilities and public health priorities. The assessment of target feasibility and cost in the context of Wales, balanced with associated benefits, are therefore important factors in determining proposed target levels and dates.

The $PM_{2.5}$ target regulations need to be laid as draft Statutory Instruments by 14 February 2027 and will come into force once approved by Senedd Cymru. Legally binding long-term air quality targets will compel successive governments to safeguard and improve our natural environment. These targets enable transparent monitoring and hold governments accountable to the public. While Welsh Government holds the responsibility to meet these targets, achieving them will demand coordinated efforts across the whole of society.

Approach to developing targets

Setting targets for $PM_{2.5}$ is complex as $PM_{2.5}$ is emitted from many sources, both manmade and natural, as well as being formed in the atmosphere from emissions of other pollutants. It is also a transboundary pollutant impacting areas large distances away from where it was released.

The development of the target proposals has been informed by a number of sources of evidence including scientific data and models, historical datasets, and assessment of what is feasible from a socio-economic perspective. It has been an iterative process, relying on input, expertise and scrutiny from others. The main steps are as follows:

1. Determining the scope of targets to be set under the framework, drawing on international practice, WHO guidelines and expert opinion, to ensure targets will effectively incentivise desired outcomes.
2. Analysing target options to provide the evidence base underpinning the detail of the targets.

   We have analysed future air quality concentrations over given time periods and the potential improvements which could be achieved through the implementation of potential cross-sector measures and future policy choices. Socio-economic analysis has been used to assess the costs, benefits and distributional impacts of any such measures.

   These considerations help to demonstrate that targets proposals are achievable (a statutory duty) and are affordable, whilst also able to drive the ambitious changes needed to improve air quality and support wider government ambitions, such as for decarbonisation. Independent expert advice from CAAP and UK groups have been instrumental in informing the direction of the work. They have guided the evidence processes and informed considerations regarding the scope and achievability of target options. Their advice has been published alongside this consultation. See Annex A: Advice Note: Development of New PM2.5 Air Quality Targets for Wales, Clean Air Advisory Panel, November 2025**.**

   This step has provided objectively measurable target metrics and a range of ambitious and achievable proposals for target standards and dates to be achieved by. Further detail is provided below.
3. Engagement and public consultation on the target proposals.

   We have engaged with key stakeholders during the development of target options to understand views on the ambition, evidence and their feasibility. A summary impact assessment has been published to inform the public consultation, to help us ensure that relevant evidence is properly gathered and is open to scrutiny.
4. Drafting of the target regulations.

   The consultation feedback will be considered, and the Welsh Government's response will be published. Welsh Ministers will then determine the targets to be set and the regulations will be drafted in full.

The contribution of independent expert advice, scientific knowledge and WHO air quality guidelines were integral to informing the development of the target proposals, as described below.

Expert Advice

Welsh Government has considered independent expert advice from several groups of experts in developing the policy proposals. The Clean Air Advisory Panel (CAAP), -an independent committee which provides evidence-based advice and recommendations on air quality matters in Wales to Welsh Government, was the lead source of expert advice. CAAP liaised with other independent expert bodies that advise all UK governments in the development of its advice, including – AQEG (Air Quality Expert Group) and COMEAP (Committee on the Medical Effects of Air Pollutants). Members of CAAP consist of multi-disciplinary policy makers, academia and air quality and public health practitioners.

WHO air quality guidelines

The World Health Organisation (WHO) updated its Air Quality Guidelines in 2021[3]. The guidelines can be used to inform the setting of air quality standards based on the impacts five key air pollutants have on human health. The guidelines are not standards as no consideration is given to whether the levels can be reached in any country or region, or how levels could be achieved and at what cost. In 2021, WHO lowered its guideline level for $PM_{2.5}$ annual mean concentration from 10 $\mu g/m^3$ to 5 $\mu g/m^3$ (alongside changes to guidelines for a range of other pollutants).

As recognised by WHO, air quality standard-setting processes need to aim to achieve the lowest concentrations possible in the context of national and local constraints, capabilities and public health priorities. Assessment of target feasibility and cost in the context of Wales is therefore a major focus in the modelling of possible target levels and dates.

The changes to WHO guidelines for $PM_{2.5}$ further highlight the importance of air quality and demonstrates that there is evidence of health impacts at levels significantly lower than the existing legally binding limit value of 25$\mu g.m^3$ within the Air Quality Standards (Wales) Regulations 2010.

Scientific knowledge: developing the evidence base for target proposals

Predicting future emissions of pollution with complete certainty is impossible. Emissions of pollutants are determined by a range of factors, including technological, behavioural and legislative. Future emissions projections are, however, produced as part of the National Atmospheric Emissions Inventory (NAEI) on behalf of the UK governments using agreed international methods for determining compliance with international emission reduction agreements. The projections take account of what is

[3] WHO global air quality guidelines. Particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide. Geneva: World Health Organization; 2021.

known and planned for in future years based on current knowledge and understanding. They therefore provide a baseline of expected emissions.

Expert technical consultants (Ricardo) were commissioned to work with Welsh Government and independent expert groups to develop evidence-informed target proposals. The stages of the work are shown in Figure 1 and are described below.

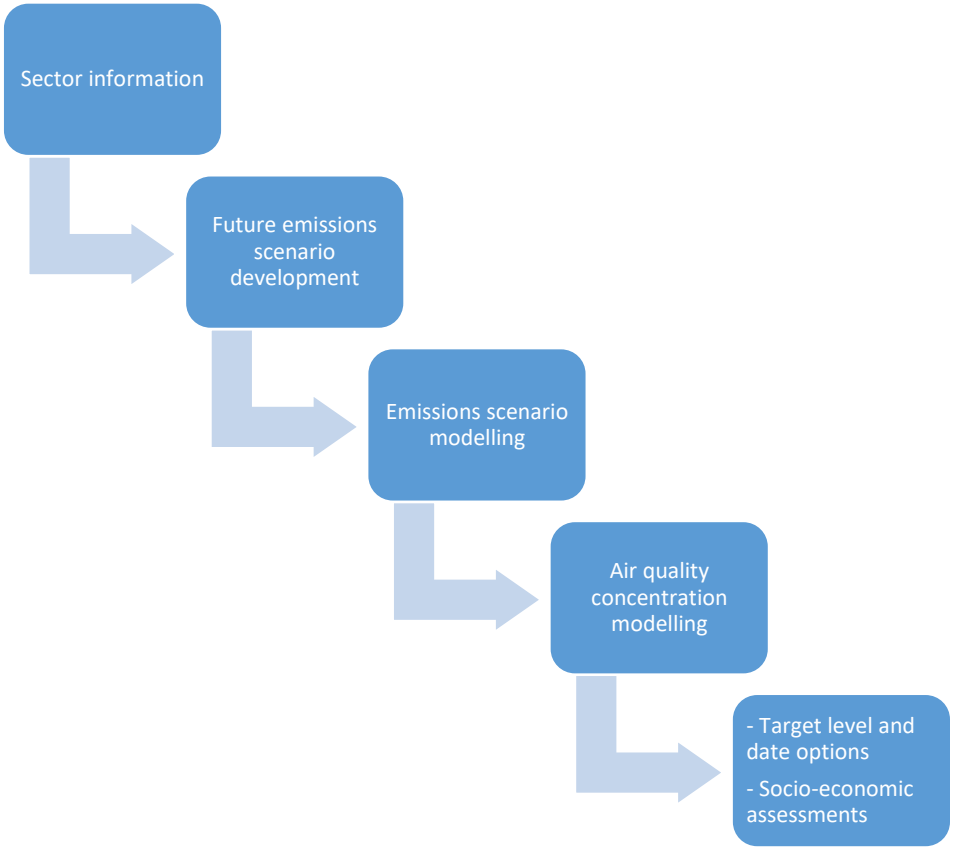

Figure 1: Stages in the development of air quality target proposals

- Sector emissions and future scenario development

  The consultants assessed possible technological, legislative and behavioural multi-pollutant (including $PM_{2.5}$) changes over and above the baseline across different sectors in five yearly intervals from the baseline year (2019) up to 2040. The assessment was used to produce lists of emission reduction 'measures', a mix of technologies, policies and behavioural changes. Working with a wide range of stakeholders, including regulators and industry sector leads, policies or changes to policy that may affect emissions of the pollutants of concern and that may be brought in by 2040 were identified and grouped into three ambition scenarios[4] based on the likelihood of the measures taking place. Feedback from the stakeholders along with the consultants' expert judgement were used to estimate likely uptake rates and timings of each measure and the associated implementation costs.

[4] High, medium and speculative emissions scenarios, as described in appendix A

The measures do not necessarily correspond with a particular potential government policy, and the scenarios developed should not be considered policy pathways. They illustrate the effect of possible future pathways for the purposes of determining ranges of feasible target levels and dates. The 'baseline' and 'speculative' scenarios set the boundaries of what is considered likely future emissions. The baseline provides the conservative view, with emissions unlikely to be above this, and the speculative the optimistic view, with emissions unlikely to be below this.

This provides important evidence to underpin Ministerial decisions on targets, as the Act requires Welsh Ministers to be satisfied that any targets set can be met.

- Emissions scenario modelling. The measure scenarios were modelled using an emissions modelling tool (the Scenario Modelling Tool (SMT)) by applying the associated measures to the baseline emissions, modifying the pollutant emission activity rates and factors over each five yearly time intervals up to 2040. The trajectories for primary $PM_{2.5}$ emissions produced by the SMT are shown in Figure 8, Appendix A – Scenario emissions modelling.
- Air quality concentration modelling.

  Air quality modelling has been used to predict how $PM_{2.5}$ concentrations may change in future years in response to both our best estimate of future conditions and emissions, as well as in response to additional measures (the emissions scenarios) that can be taken to meet future targets. A description of model performance and associated uncertainties is provided in Appendix B – Air dispersion model validation and calibration.

  The emissions scenarios for years 2019, 2025, 2030, 2035 and 2040 (the latest available year of projections data for Wales) were input into air dispersion models to predict the associated concentrations, where local models (AERMOD and RapidAir) were nested inside a regional model (CMAQ) to allow both regional effects and local dispersion to produce model concentrations for 2m grid squares across Wales[5]. This provides insight into spatial variation in concentrations for each scenario and year and also enables the backward apportionment of $PM_{2.5}$ to the key local and regional sources of $PM_{2.5}$.

  A combination of UK (NAEI) and European (European Monitoring and Evaluation Programme, EMEP) inventories were used as the basis for the emissions inputs. Including European emissions in the modelling enables the long-range transport of pollution impacting air quality in

[5] Model uncertainty was quantified through model verification, comparing measured concentrations of key pollutants at automatic analysers in the Automatic Urban and Rural Network and Welsh Air Quality Network with the total modelled concentrations from the model ensemble for 2019.

Wales to be accounted for. Biogenic emissions were accounted for using the Model of Emissions of Gases and Aerosols from Nature (MEGAN)[6]. The Weather Research and Forecasting model[7] (WRF) was used to generate meteorological inputs to the air quality models at 50 km, 10 km and 2 km resolution, representing the EU, UK and Wales respectively.

- Feasible target level and date options.

  The Act requires Welsh Ministers to be satisfied that targets set are achievable. The results of the concentration modelling provide an indicative estimate of the expected levels of pollutants associated with each scenario and modelled year.

  There are many uncertainties in modelling future $PM_{2.5}$ concentrations. For example, uncertainties include accounting for secondary $PM_{2.5}$ formation in the atmosphere, transboundary pollution and the complexity of emission sources and activities (see Table 6, Appendix B – Air dispersion model validation and calibration, for further detail). Therefore, uncertainties have been taken into account when evaluating achievable target levels by applying an average difference between modelled and measured concentrations to the central modelled predictions. For $PM_{2.5}$, this is an adjustment for overall uncertainty in annual mean concentration of 1.2 µg/m³. Further detail is provided in Appendix B – Air dispersion model validation and calibration.
- Socio-economic assessments were carried out on the modelling of outputs to understand the impact of the scenarios in terms of health benefits, economic costs, benefits and distributional impacts, disparities in exposure and ecosystems impacts. The outcomes are used to inform the impact assessments, summaries of which are published alongside the consultation. These considerations help ensure that proposed targets are achievable and affordable, whilst still driving the ambitious changes we need to the environment.

This evidence base provides an emulation of real-world implementation in order to help with prioritising our approach to tackling a variety of pollutants affecting public and environmental health as part of a coordinated policy approach. However, further work has been conducted into pollutant-specific cost benefit analysis beyond the above assessments - focussing on impacts of implementing specific $PM_{2.5}$ target levels in isolation[8].

[6] Ricardo-AEA. (2014). 'CMAQ Development for UK National Modelling'. Retrieved from https://uk-air.defra.gov.uk/assets/documents/reports/cat20/1511251727_AQ0701_CMAQ-UK_Phase_2_Final_Report_20151120.pdf

[7] https://www.mmm.ucar.edu/models/wrf

[8] Annex B: Evidence to support the development of PM2.5 target proposals in Wales, Ricardo, 2025

Spatial variation of $PM_{2.5}$ in Wales

The spatial distribution of annual mean $PM_{2.5}$ concentrations in the 2030 baseline scenario is presented in Figure 2. Although baseline emissions and concentrations are projected to reduce by 2030, concentrations exceed the 2021 WHO air quality guideline across south Wales and along the border with England in the northeast. As $PM_{2.5}$ is a regional pollutant, exceedances are predicted across wide areas of Wales rather than being restricted to the vicinity of local sources such as roads, ports, or industry. The maximum predicted concentrations are seen along the M4 in the vicinity of Cardiff and Newport, where regional and local contributions coincide to produce annual mean concentrations up to 16 µg/m^3.

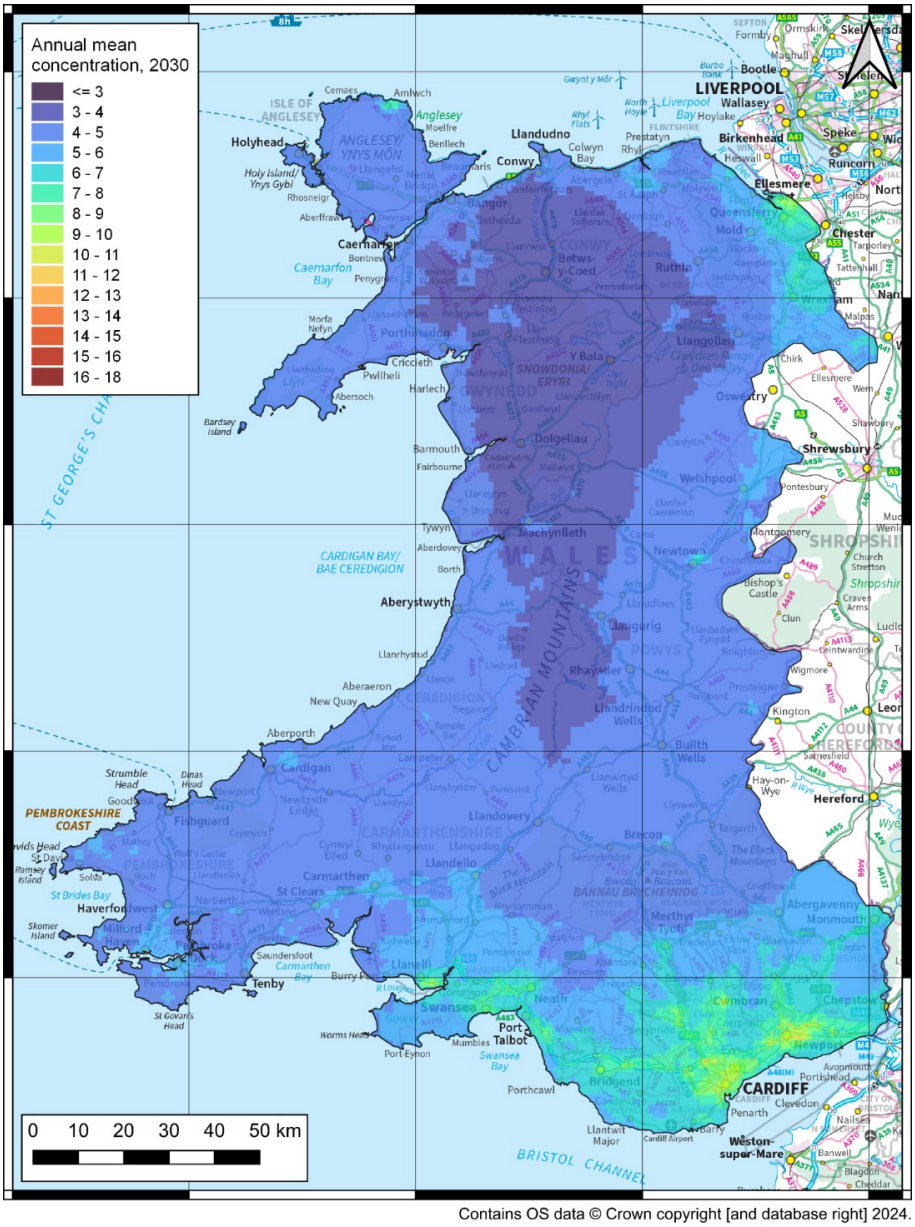

Figure 2: Modelled annual mean $PM_{2.5}$ concentration, 2030 base case, µg/m³.

Identifying the key components and sources of $PM_{2.5}$ concentrations

In addition to assessing the distribution of public exposure to pollution, the WHO air quality guidelines recommend that the origin of background air pollution, including long-range pollution transport and its contribution to ambient levels, should be evaluated when considering standards. Air quality concentration modelling enables the apportionment of $PM_{2.5}$ contributions to predicted concentrations back to their sources. Contributions from transboundary and natural sources, and Welsh and the rest of the UK manmade sources all vary across the country.

Figure 3 shows how primary contributions from natural and transboundary sources combine with Welsh and the rest of the UK manmade sources to produce the total $PM_{2.5}$ concentrations in typical rural and urban locations, along with the national average. The data were taken from the baseline scenario for 2030. With respect to the Wales average concentration, 22% of the annual mean concentration in 2030 is as a result of emissions in Wales. The majority (78%) of the concentration is therefore predicted to be outside of the control of measures taken in Wales - — either from natural sources or from pollution that travels into Wales from other parts of the UK or beyond.

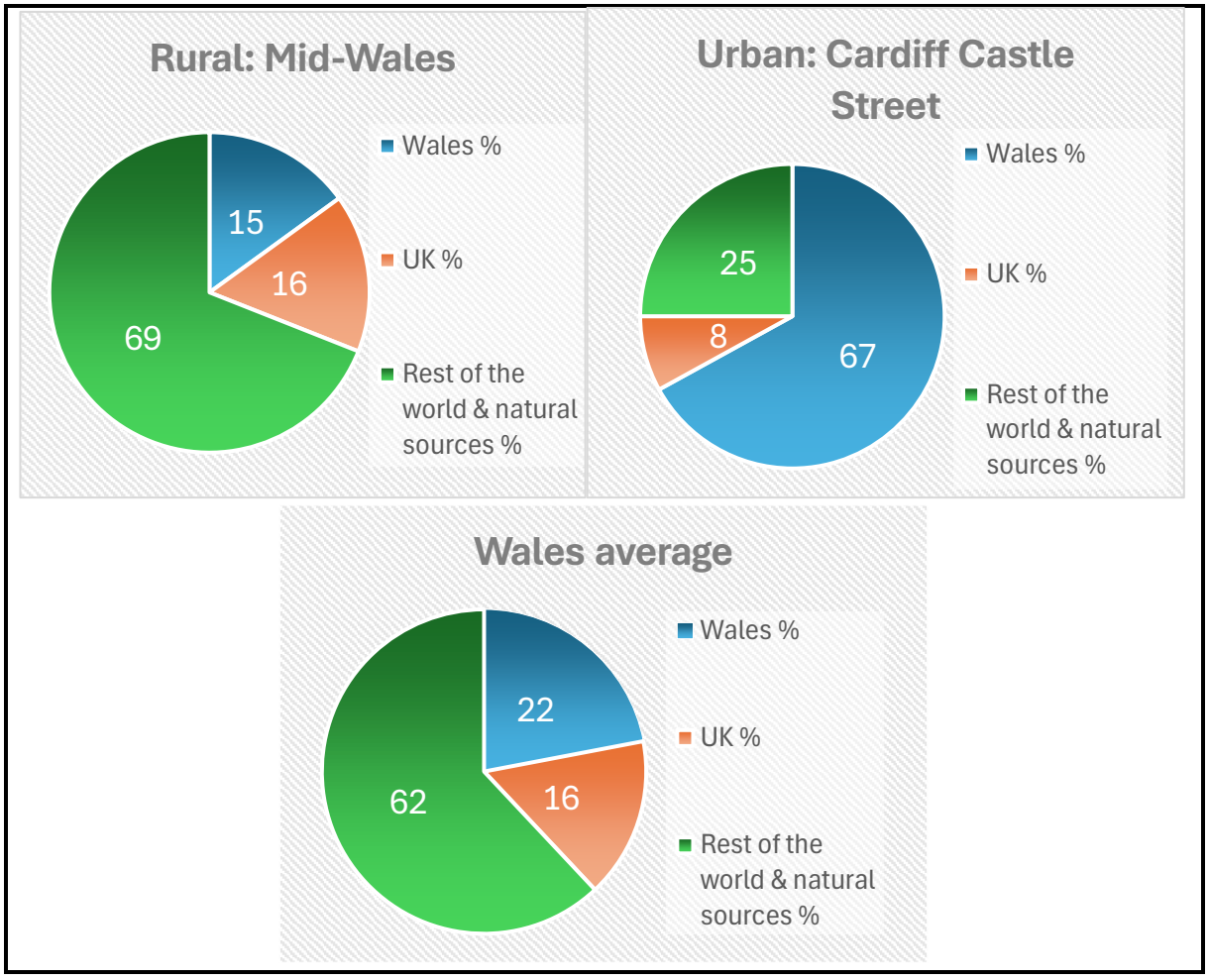

Figure 3: $PM_{2.5}$ annual mean concentration source apportionment as derived from primary emissions in each region, excluding secondary $PM_{2.5}$ (baseline scenario, 2030)

Figure 4 shows the average source contribution in Wales by sector as predicted in 2030 assuming baseline scenario emissions, accounting for primary and secondary sources of $PM_{2.5}$. Half of $PM_{2.5}$ comes from transboundary sources from outside Wales[9] (including from England, Europe and the North Atlantic) and up to a maximum of 23% from secondary $PM_{2.5}$[10].

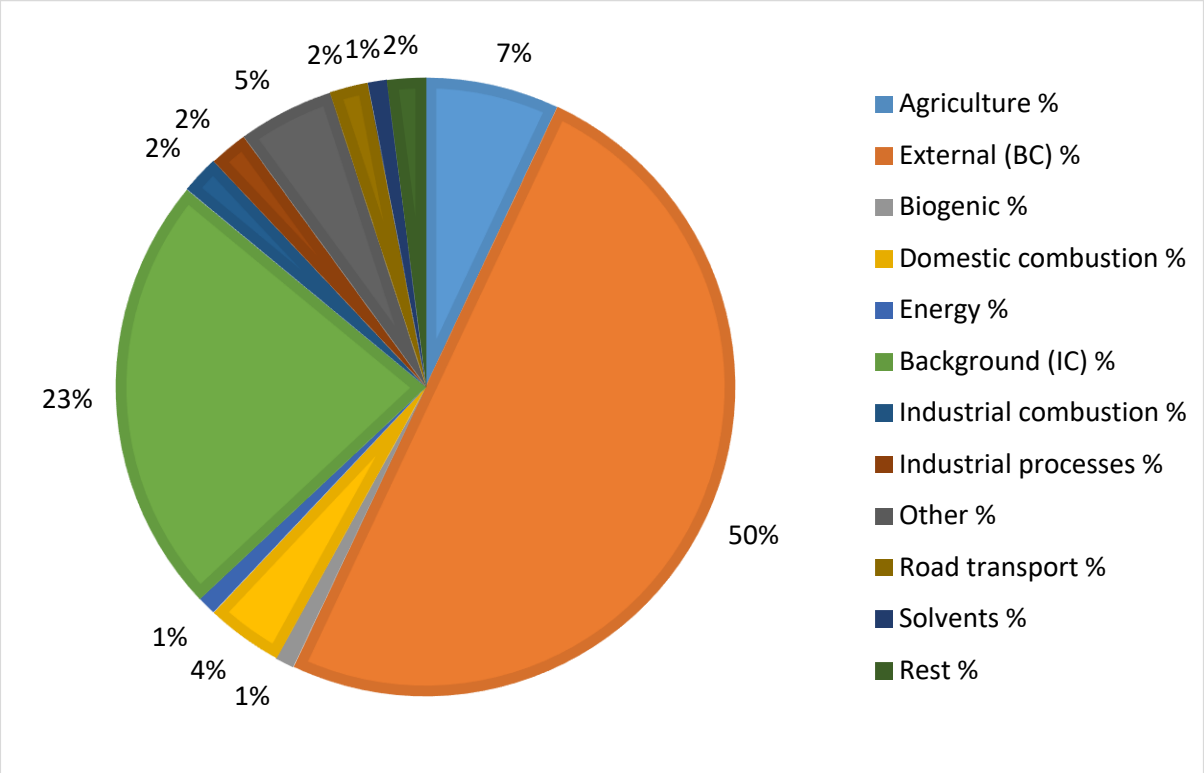

Figure 4: $PM_{2.5}$ annual mean concentration source apportionment in Wales by sector, accounting for primary and secondary $PM_{2.5}$ (baseline scenario, 2030)

Of the primary emissions in Wales, sector contributions include: agriculture, 7%; domestic combustion, 4%; energy, 1%; industrial processes, 2%; road transport, 2%; and the rest, 2% (shipping, offshore, accidental episodes and waste). To control long-range transboundary pollution, the amended Gothenburg Protocol to the UNECE Convention on Long-range Transboundary Air Pollution[11] set emission reduction targets for various pollutants. These international emission reduction commitments are implemented in the UK by the National Emission Ceilings Regulations 2018 which sets UK emission reduction targets for five key pollutants.

[9] External (BC) - all pollution from outside of Wales

[10] Background (IC) - resulting from former atmospheric chemical reactions with species linked to natural and anthropogenic sources

[11] The Convention and its achievements | UNECE, https://unece.org/environmental-policy/air/convention-and-its-achievements. Accessed 27 August 2025.

We are working together with the UK and other devolved governments to achieve them.

A useful way of using average concentration modelling data to represent population exposure to pollutant concentrations, is using population weighted mean concentrations (PWMC)[12]. This provides an estimate of the average concentration that the population living within that area would be exposed to. The PWMC apportionment in Figure 5, below, shows where the PWMC comes from. The apportionment is similar to the urban average apportionment illustrated in Figure 3, given that the majority of the population lives in urban areas.

The chart shows that domestic combustion (10.2%) and agriculture (6.4%) had the highest contributions to the PWMC out of manmade sources emitted from within Wales. However, when compared to all sectors, external (BC) contributed 40.8%, and background (IC) contributed 17.5% to PWMC; most of the $PM_{2.5}$ PWMC contributions are from external and background sources. The majority of the concentration is therefore predicted to be outside of the control of measures taken in Wales.

$PM_{2.5}$ levels across Wales at all location types are projected to reduce from the baseline year of 2019 onwards. At urban locations such as Cardiff Castle St, source apportionment of total $PM_{2.5}$ concentrations in 2030 shows that around 42% (greater than 4 µg/m³) came from sources outside of control in Wales. Therefore, even if there were no manmade emissions in Wales at all it would be extremely challenging, if at all possible, to meet the annual mean WHO air quality guideline for $PM_{2.5}$ of 5 µg/m³. These are important factors which must be considered in setting targets which are able to be met (a requirement of the Act) whilst able to drive the ambitious outcomes we would like to achieve.

The modelling of sources contributing to concentrations in Wales shows that exceedances are predicted across wide areas of Wales rather than being restricted to local hotspots, with levels tending to be highest in urban areas. Addressing pollutant concentrations requires coordinated action across multiple sectors — including domestic combustion, road transport, agriculture, and industrial processes — with responsibility shared among government, industry, and individuals.

[12] PWMC is calculated by taking the concentration of each modelling grid square and multiplying by the resident population within that grid square. The values are then summed for an area (for the whole of Wales, for example) and then divided by the total population of the area.

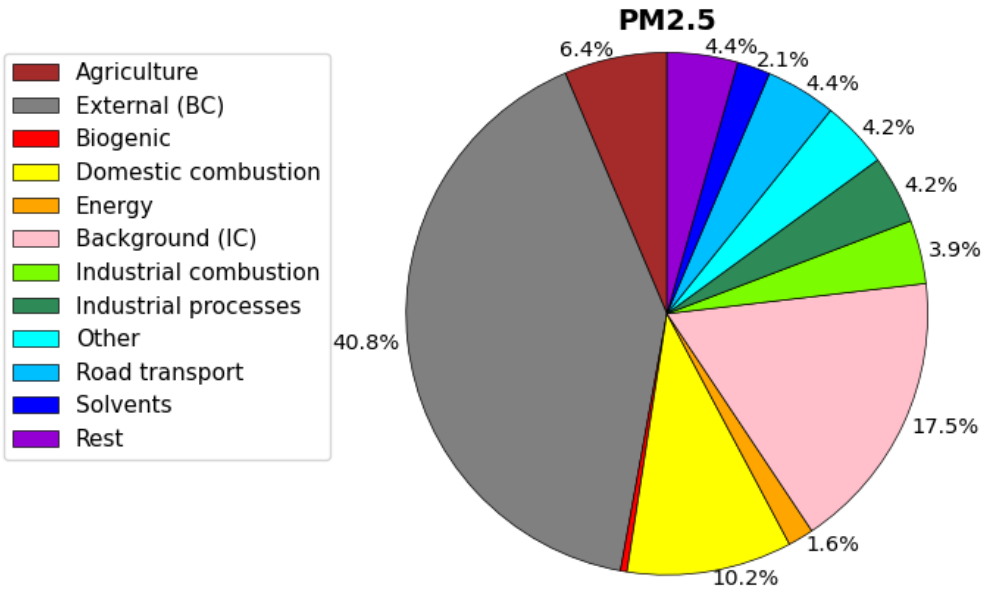

Figure 5: Sectoral source apportionment contribution to PWMC for $PM_{2.5}$

Target Proposals

Air quality targets require a concentration level (or standard) to be achieved and a date when that level must be met. Target metrics must be both measurable (an important requirement of the Act) and result in outcomes which align with the policy objectives.

The independent expert advice from CAAP, in liaison with UK expert groups AQEG and COMEAP, proposed two metrics for $PM_{2.5}$. They are focused on long-term annual exposure with respect to ambient levels of $PM_{2.5}$, as it is the cumulative effect over many years which causes the most harm to the majority of people. Exposure to short-term peaks remains important for susceptible people, but as the two are interconnected, action to reduce long-term exposure would broadly be protective of short-term acute health impacts. CAAP's summary of collective advice therefore proposed that a focus on reducing long-term average concentrations of $PM_{2.5}$ is appropriate. The advice also concluded that reducing exposure of the whole population would achieve the greatest overall public health benefit. The target proposals include a twin-track target approach: an Annual Mean Concentration Target (AMCT) and a Population Exposure Reduction Target (PERT).

The AMCT sets a maximum concentration level to be reached by a future year. The AMCT will provide equity across Wales with a concentration limit, focusing attention on reducing concentrations where they are highest, thereby delivering a 'minimum' standard of air quality across the country. Alone, this target will not necessarily drive wider action and would not be most effective at delivering public health benefits, however it helps to protect the more vulnerable members of society living in the areas with the highest exposure.

The PERT sets a reduction in average population exposure to be obtained by a future year compared to a base year. The PERT will drive continuous improvement in areas of public exposure across the country to encourage action to deliver air quality improvements, even if levels are below the 'minimum' standard of air quality set by the AMCT - addressing the fact that there is no threshold below which exposure to $PM_{2.5}$ does not have an impact. This target will drive action that is the most beneficial for public health across the population.

The two targets are proposed to work in tandem to drive action across the country whilst ensuring improvements in the areas with the highest concentrations of $PM_{2.5}$. As any target set or amended must be able to be met, an assessment of potential target concentration levels and dates has been completed based on a range of feasible future emissions scenarios, as described in Appendix A – Scenario emissions modelling.

The three emissions scenarios were modelled to provide a range of plausible emissions reductions; however, this does not mean that a particular scenario needs to be followed to meet the proposed targets or that all measures within a scenario would need to be implemented. Policies to meet the targets will be developed and consulted on separately and could include measures from any scenario or none.

The range of AMCT options are shown below in Figure 6, with the annual mean WHO air quality guideline (AQG) level and interim targets for $PM_{2.5}$ are shown in Table 1, below, for comparison. In order to meet the AMCT target, all measured concentrations associated with the target must meet the target level by the target date. Given the inherent uncertainties in model predictions and monitor measurements (e.g. due to interannual variations in the weather which are difficult to account for), a model adjustment of 1.2 µg/m³ was applied to the central model estimate to account for the average difference between model predictions and measurements (as described under 'Feasible target level and date options', page 20).

Pollutant	Averaging time	Interim target				AQG level
		1	2	3	4	
$PM_{2.5}$ (µg.m-3)	Annual	35	25	15	10	5

Table 1: WHO annual mean air quality guideline levels and interim targets for $PM_{2.5}$

Figure 6: Matrix of AMCT options - percentage LSOA areas[13] compliant with WHO guideline and interim levels for annual mean $PM_{2.5}$ (adjusted for uncertainty)

The matrix of AMCT options in Figure 6 shows that it is not possible to achieve the WHO annual mean guideline level of 5 µg/m³ for any year or scenario, including the speculative scenario with highly ambitious, optimistic and untested measures. The WHO interim air quality target (interim target 3) of 15 µg/m³ can be achieved today. However, the predictions show that **the lowest level able to be achieved across the majority of the country is equivalent to the WHO interim target 4 (10 µg/m³)**.

The **earliest date the lowest level of 10 µg/m³ is feasible to achieve is in 2035**, with the likelihood of compliance with that level increasing with the implementation of

[13] Area as defined by lower super output areas (LSOAs) in Wales, geographical areas developed for census statistics

the most ambitious scenarios ('High' and 'Speculative'). This provides the basis for the proposed AMCT level and date. If the target date was set later at 2040 the likelihood of compliance with a level equivalent to WHO interim target 4 is increased across all measure scenarios, although a later date target set at the same level would be less ambitious.

In order to provide a summary of compliance with potential PERT percentage reductions (compared with levels in a baseline year of 2019) across all modelled years and scenarios, the achievement of potential PERTs based on population-weighted mean concentrations across Wales is represented in a compliance matrix (Figure 7). **The matrix shows that the most ambitious PERT option able to be achieved is a level of 25% by 2035**, without relying on the implementation of measures equivalent to those included in the speculative scenario. After this date the degree of improvement is subject to diminishing returns.

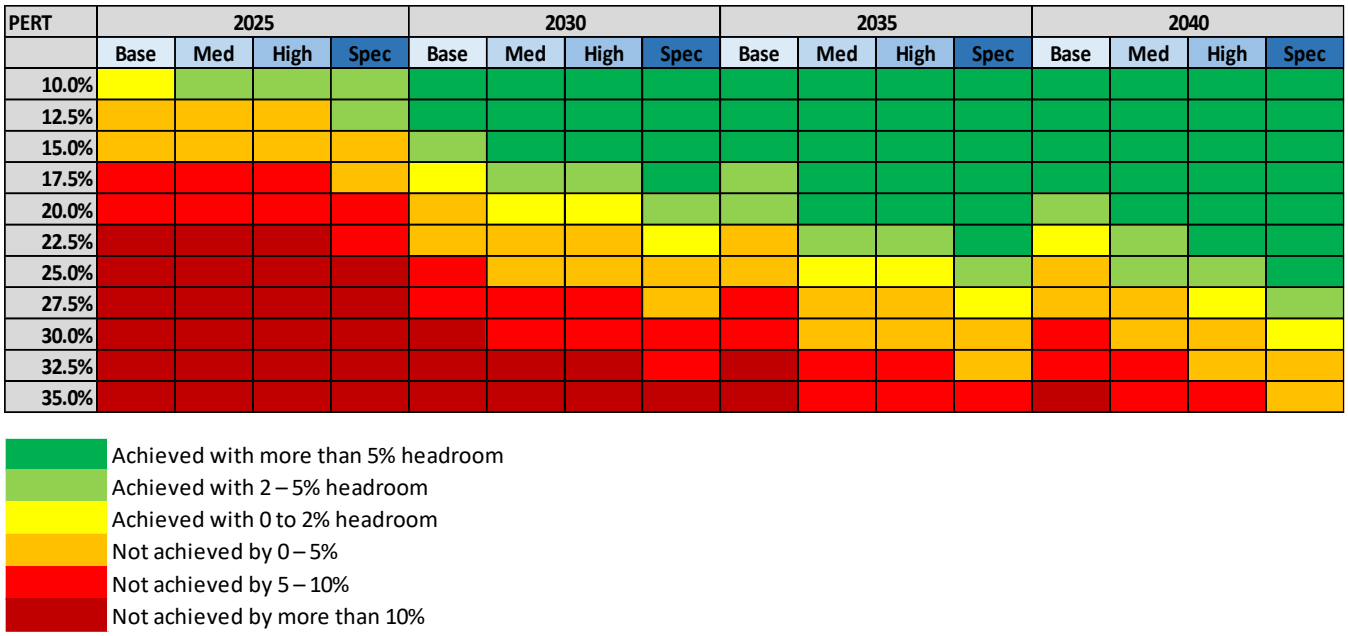

Figure 7: PERT compliance matrix for $PM_{2.5}$ concentrations

Having considered the assessment options alongside independent expert advice, the proposed targets are:

- an annual mean level of 10 µg/m³ to be achieved by 2035 (an Annual Mean Concentration Target, AMCT); and
- a 25% reduction in annual mean population exposure to be achieved by 2035 compared with a base year of 2019 (a Population Exposure Reduction Target, PERT).

The AMCT level of 10 µg/m³, the associated PERT percentage reduction (25%) and target date are estimated to be achievable under all additional measure pathway scenarios assessed. The World Health Organisation (WHO) has a guideline level of 5 µg/m³, although this is not currently considered a realistic target in Wales in light of

the assessment of feasible options up to 2040. We believe that the annual mean level of 10 µg/m³ is proportionate, realistic and achievable. The proposed AMCT reduces the permitted annual mean concentration of $PM_{2.5}$ in Wales by more than half, aligning more closely with the guidelines set by the World Health Organisation.

For comparison, a level of 10 µg/m³ has also been adopted for the setting of regulatory targets by the European Commission (2024) and by the UK Government in England (2023). The specified target date set in England is 2040. The European target date is 2030 but Member States can apply to extend the date up to 2040 (subject to conditions).

The strengthened AMCT and PERT targets are designed to operate in tandem, driving reductions in $PM_{2.5}$ levels nationwide, whilst ensuring improvements in areas with the highest concentrations. By lowering exposure across the population, the targets will deliver significant public health benefits and support long-term improvements in air quality. This approach reflects our commitment to protecting the health of current and future generations through evidence-informed, ambitious action.

The targets will apply nationally across Wales. Although there is no legislative objective which applies to local authorities in Wales with respect to $PM_{2.5}$ there is, however, a flexible role to reduce $PM_{2.5}$ which is set out in the Local Air Quality Management policy guidance. We will work together in exploring options to develop an appropriate role for local authorities to support the new targets.

Impact of the Target Proposals

A cost-benefit analysis was undertaken to assess the potential effect of the target proposals. The assessment includes estimates of the range of expected benefits for health, social inequalities, greenhouse gas emissions and the economy. A summary of the associated integrated impact assessment is provided as part of this consultation.

Since the targets serve as a catalyst for action rather than direct measures themselves, the analysis results provide an indicative basis for comparing various scenarios and guiding the establishment of targets. A more detailed evaluation would be necessary for any specific policy implemented to achieve these targets.

Table 2 below shows that, on average, there are significant health benefits, including deaths avoided, for major health issues of concern across all scenarios assessed. Under all scenarios (medium, high and speculative), the potential health benefits are estimated to increase, on average. These include improvements to individual and public health, quality of life, savings to the NHS and care sector and increased economic productivity from improved health outcomes

Table 2: Average annual health impact benefits across PM2.5 scenarios (compared to the baseline) over the period 2025-2035

Impact	Indicators and units	Medium Scenario: 10 µg/m3 by 2035	High Scenario: 10 µg/m3 by 2035	Speculative Scenario: 10 µg/m3 by 2035
Quality-Adjusted Life Years gained	LYs gained from deaths avoided	433	497	893
	QALY gained from morbidity avoided	279	320	576
	Total QALY gains	712	817	1,469
Deaths avoided (mortality)	Statistical deaths avoided	40	46	82
Illness prevented (morbidity)	Statistical cases avoided of asthma	12	14	25
	Statistical cases avoided of COPD	3	3	6
	Statistical cases avoided of Lung Cancer	4	5	9
	Statistical cases avoided of Stroke	9	10	18
	Statistical cases avoided of IHD	7	8	15
	Statistical cases avoided of Diabetes	34	39	70
Healthcare activity reduced	Respiratory and/or cardiovascular hospital admissions prevented	17	19	35

Economic Assessment of the Proposals

Air pollution impacts the economy as health issues diminish workers' capacity to be present in the workplace and to perform effectively. An economic appraisal of the modelled scenarios provided estimated costs and benefits and captured key impacts relating to the economy, human health and the environment. See Annex B: Evidence

to support the development of PM2.5 target proposals in Wales, Ricardo, 2025 for an explanation of the methodologies used for calculating costs and benefits.

The modelling indicates that the proposed reductions are technically feasible to achieve. However, feasibility is just one factor in determining the final targets. It is essential to balance the health benefits against the necessary actions and their economic implications. We consider the proposed targets to strike the optimal balance between maximising health outcomes and minimising impacts on people's daily lives.

The estimated costs and benefits arising from the implementation of each measure include (in 2025 prices):

- Capital costs – these relate to actions taken to reduce $PM_{2.5}$ emissions such as the cost of new equipment, machinery or technology.

- Operating costs or benefits – these include estimations of the costs or benefits arising from fuel consumption changes or ongoing costs and savings arising from non-fuel costs (such as maintenance costs).

- Time saving costs or benefits – these monetise changes in travel time and the associated costs or benefits of the implementation of a measure (such as the reduction of speed limits or greater use of public transport).
- Greenhouse gas (GHG) benefits – reducing $PM_{2.5}$ concentrations has co-benefits for greenhouse gas emissions are they often share the same sources. These benefits result from positive outcomes such as improved health and more equitable outcomes with the disproportionate burden of air pollution mortality reduced in deprived regions. The benefits are illustrated using the Social Cost of Carbon[14] which calculates the monetary value of the long-term damage an additional ton of carbon dioxide (CO_2) creates, such as the impacts on climate change, human health and the environment.
- Health benefits (non-market) – these benefits do not result from market transactions but are positive. They include improved human health; increased productivity from a healthier workforce; and improved quality of life which allows people to enjoy more leisure activities and lead happier lives.
- Healthcare benefits (from reduction in NHS costs) – these benefits include costs avoided from a reduction in primary and secondary care activity and medicine costs due to improvements in people's health and lower demand for healthcare services.

- Productivity benefits (from reductions in sickness absence - which covers the economic costs avoided due to reductions in sickness absence from improvements in people's health). With reductions in sickness absence across sectors of the economy, output per employee increases as do sales or the

[14] UK DESNZ (2023). Green Book supplementary guidance: valuation of energy use and greenhouse gas emissions for appraisal. Available at: https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal

number of socially responsible projects completed on time and which benefit wider society, including the environment.

Results for $PM_{2.5}$ target proposals

Table 3 below presents the Net Present Value (NPV) of the core costs and benefits of a pathway to achieving the $PM_{2.5}$ target proposals $PM_{2.5}$ for each scenario.

Estimation of NPV of costs and benefits - The total costs and benefits for each air quality target scenario were aggregated from the measure-level costs and benefits for the measures mapped to a scenario, for each year over the period 2025-2040. The NPV of these costs and benefits (or how much the investment in the proposals is worth discounted to 2025 values), was estimated over this appraisal period.

Estimation of Net Benefit and Benefit Cost Ratio (BCR) - The net benefits were calculated as the difference between total benefits and total costs associated with the scenario. The BCR was used to determine the financial viability of the proposals. The BCR was calculated by dividing the total present value of the expected benefits by the total present value of the costs. A BCR greater than 1 suggests that the benefits outweigh the costs, indicating the worthwhile quality of the proposals.

Table 3: Net Present Value of costs and benefits for each scenario in relation to the proposed targets: 10 µg/m^3 by 2035 and 25% reduction from 2019 concentrations (millions of GBP in 2025 prices, negative values representing costs)

Category	Specific cost or benefit	Medium scenario NPV **(£ millions)**	High scenario NPV **(£ millions)**	Speculative scenario NPV **(£ millions)**
Costs	Capital costs	-£5,100	-£7,100	-£9,800
	Operating costs	-£25	-£25	-£265
	Other capital or operating costs	-£300	-£300	-£300
	Time saving costs	-£1,200	-£2,500	-£5,700
Benefits	Operational benefits (fuel and non-fuel)	£13,900	£22,300	£34,200
	Time saving benefits	£4,100	£6,100	£8,100
	GHG benefits	£5,400	£8,400	£26,000
	Health benefits (non-market)	£600	£700	£1,300
	Healthcare benefits (from lower demand for healthcare)	£10	£10	£20
	Productivity benefits (from reduction in sickness absence)	£50	£60	£110

Analysis

The NPV of the total costs required to achieve the scenarios, in increasing order of ambition (medium, high and speculative), is estimated to range from £7-£16 billion, which includes capital investments with a NPV of around £5 billion. However, all associated scenario costs are outweighed by the potential benefits, estimated to range from £24-£70 billion. Overall, a net benefits ranging from £17-£54 billion are estimated . Associated **benefit-cost ratios range from 3.6-4.3.** This means that benefits from achieving all scenarios assessed outweigh the costs that could be born.

All scenarios relating to the target proposals illustrate a benefit-cost ratio greater than 1, indicating that the proposals are worthwhile and financially viable with respective returns of £3.60, £3.80 and £4.30 earned for every £1 spent.

The analysis of how the costs and benefits of the proposals are shared across different groups demonstrated that the distribution of benefits was similar across demographics, irrespective of the pathway of measures put into action.

The greatest benefits would be for business operations efficiencies (fuel and non-fuel operational savings), greenhouse gas benefits, travel time savings, health (a statistical equivalent of 40-82 deaths avoided per year, along with around a maximum of 140 statistical cases of illness prevented per year) and healthcare benefits (reduced hospital admissions per year i.e. between 17 and 35).

Public authorities would bear a large proportion of the costs – these costs were connected to conducting public awareness campaigns, incentivising transitions (such as the switch to renewable energy), investing in research and development to spur technological improvements. Costs would also be borne by private companies (such as those relating to capital expenditures to support transition towards renewable and cleaner energy sources and technologies etc.) and individual households (such as the indirect costs passed on by companies through higher prices, the cost of energy-efficient equipment and Electric Vehicles).

Distributional Analysis

While air pollution poses risks to everyone, some people experience greater impact due to living in areas with higher levels of pollution, encountering higher daily exposure, or having increased susceptibility to health issues triggered by pollution. A distributional assessment was undertaken to assess the effect of achieving the proposed targets across population demographics including levels of income deprivation and the proportion of children, elderly and Black, Asian and Minority Ethnic residents.

The modelling and technical analyses undertaken by technical consultants demonstrated that the proposals would impact concentration levels of $PM_{2.5}$ across Wales but would have no significant effect on how the benefits of the changes were distributed across the population. The biggest reduction in $PM_{2.5}$ will occur in the

most populous regions of Wales which includes areas of highest and lowest deprivation, and in areas with the highest proportion of children and Black, Asian and Minority Ethnic residents.

Overall, the economic assessment demonstrates that a substantial proportion of the financial benefits of the target proposals relate to the health sector, including the non-market health benefits. After detailed consideration of expert advice we believe that the proposed targets will provide a proportionate balance between overall feasibility and ambition, driving positive health outcomes and an overall positive cost-benefit analysis. Going further or faster with the targets, setting lower target levels or earlier target dates, would require much greater restrictions on society and increased costs for an increasingly smaller benefit.

Ecosystem impacts

In addition to the associated risks to public health, air pollution can also damage environmental health. Key pollutants such as ammonia, nitrogen oxides, and sulphur dioxide — which contribute to the formation of $PM_{2.5}$ — can affect ecosystems both through direct exposure in the air and through deposition onto soil and water. One of the most significant environmental impacts is the deposition of reactive nitrogen onto sensitive habitats, which can lead to eutrophication and a loss of biodiversity.

While this assessment does not include financial estimates for the benefits to ecosystem services, previous research suggests that any net gains are likely to be small. However, it is important to recognise that reducing emissions of pollutants such as nitrogen oxides (NO_x), sulphur dioxide (SO_2), and ammonia (NH_3) — which contribute to secondary inorganic aerosols — will bring additional environmental benefits, including improvements to ecosystem health.

Questions on the targets

Question 1a: To what extent do you agree with the level of ambition proposed for the Annual Mean Concentration Target (AMCT)?

Question 2a: To what extent do you agree with the level of ambition proposed Population Exposure Reduction Target (PERT)?

Assessing progress towards targets

This section explains how progress towards the $PM_{2.5}$ targets will be assessed, as informed by independent expert advice.

The Clean Air Advisory Panel (CAAP) recommended that the assessment of compliance with statutory $PM_{2.5}$ targets should be based on fixed monitoring using standard methods deployed at appropriate site locations, at a sufficient number of sites and be based on mass concentration. Such methods should be undertaken to at least the same standards as referred to by the Air Quality Standards (Wales) Regulations 2010, taking account of any subsequent changes to guidance or developments in best practice.

For the AMCT target, assessment should be carried out for individual calendar years, with no averaging over multiple years. The placement of new monitoring sites would need to ensure that an appropriate and representative cross-section of environments is covered, for example, residential areas near sources of $PM_{2.5}$.

For the PERT target, the use of a 3-year averaging period and rolling mean would provide a better estimate of the metric for comparison against a baseline. Population weighting for the PERT can be calculated using the average across monitoring stations that are strategically located in proportion to population distribution – and that exposure reduction targets should focus on background measurements.

In relation to both targets, assessment should not attempt to account for varying levels of population susceptibility. An assessment of a minimum number of monitors required to underpin the targets, as specified in the draft regulations, was considered by CAAP proportionate and fit for purpose. The assessment was based on a detailed analysis of population density, exposure gradients, and spatial representativeness.

This expert advice has been used as the basis for the compliance assessment approach, described below.

Target compliance assessment proposals

	Concentration Target (AMCT)	Exposure Reduction Target (PERT)
Target averaging period	Annual mean assessment (calendar year), at each monitoring location.	Three-year average (the average of three consecutive calendar years).
Assessment Locations	Appropriate locations where concentrations are likely to be highest and where there is appropriate public exposure. This will include all monitoring classifications (indicative of background and near-source levels).	Representative site locations indicative of average population exposure (predominantly urban background, not including near source locations).
Compliance assessment	Measurements at all monitoring sites will need to meet (report measurements at or below) the target concentration level by the target achievement date.	A national population exposure indicator based on the average of representative monitoring sites across the country. The indicator will need to meet the percentage reduction target by the target achievement date.

Minimum requirements for assessing the targets

To ensure consistent evaluation of targets nationwide, it is essential to employ a robust and reliable monitoring approach. When determining where to place instruments for measuring concentration levels, the main challenge lies in selecting locations likely to experience elevated pollutant levels and where there is significant public exposure. Although monitoring cannot cover every location, a minimum level of monitoring will be mandated and defined by the regulations .

Expert recommendations suggest that the PERT should be based on a network of monitoring sites spread across the country. These sites should be positioned to provide accurate estimates of $PM_{2.5}$ levels that represent the average exposure

experienced by the general population in those areas. This entails focusing primarily on urban and suburban background monitoring.

Plans for future development include expanding the monitoring network in alignment with these guidelines. Additionally, the calculation of metrics and evaluation of both the AMCT and PERT will be conducted to standards at least equivalent to those established in the Air Quality Standards (Wales) Regulations 2010, whilst also integrating any updates in guidance or advancements in best practice.

Compliance assessment will rely on measurements from the existing Welsh and UK national networks operating in Wales to recognised international standards (at least the same standards as referred to by the Air Quality Standards (Wales) Regulations 2010), supplemented by any new sites installed to meet representativeness and coverage requirements set in regulations. The draft regulations set minimum number, siting and performance standards for $PM_{2.5}$ compliance assessment monitoring stations, together with quality assurance/quality control requirements.

There are currently 11 $PM_{2.5}$ monitoring stations located across Wales. Based on a technical assessment and expert advice from CAAP, the new targets for $PM_{2.5}$ will require an appropriate increase in $PM_{2.5}$ monitoring across the country to better assess exposure reduction and potential elevated levels (a minimum of an additional 9 monitors).

As required within the draft regulations, updated minimum number of monitoring criteria are required to be met from 1 January 2033. The existing network will be enhanced over time, consistent with the associated commitment in the Clean Air Plan for Wales and expert advice.

To ensure consistency and comparability with existing statutory air quality reporting in Wales (along with the rest of the UK), we propose to retain the same zones and agglomerations previously used in Wales for air quality assessment under the Air Quality Standards (Wales) Regulations 2010. These are:

Zone / Agglomeration	Type
North Wales	Zone
South Wales	Zone
Cardiff Urban Area	Agglomeration
Swansea Urban Area	Agglomeration

This approach aligns with the methodology established across the UK for assessing compliance with targets stemming from EU law, which uses zones and agglomerations as the basis for determining monitoring requirements and reporting. Retaining these boundaries will provide continuity, allow for efficient integration with existing monitoring infrastructure, and ensure that assessments and datasets remain robust and comparable over time.

Validated measurement data and annual compliance determinations will be published in line with Schedule 3 of the draft regulations.

Dealing with natural contribution

A significant share of $PM_{2.5}$ in Wales comes from sources beyond our direct control — either from natural sources or from pollution that travels into Wales from other parts of the UK or beyond.

Contributions from natural sources can be assessed but cannot be controlled. Natural sources include sea salt, material from volcanic eruptions and suspended soils and dusts. Therefore, where natural contributions to pollutants in ambient air can be determined with sufficient certainty, and where exceedances of a target are due in whole or in part to these natural contributions, we propose these should be able to be subtracted when assessing compliance with targets. Therefore, we have included a provision in the draft regulations to enable such subtraction. This is retaining the position set out in the current domestic legislation - Air Quality Standards (Wales) Regulations 2010. It is also consistent with the approach taken within the Ambient Air Quality Directive (Directive (EU) 2024/2881) and adopted by European Member States. However, this is only an option given to be exercised at the point of compliance assessment exceedance situations, and subject to there being a robust method of assessment and justification for subtraction.

We have sought expert advice from CAAP with regards to the subtraction of natural sources. CAAP's headline conclusions include:

- acknowledgement of the practical value of subtraction, given that natural contribution is not within the Welsh Government's control;
- if subtraction is not adopted then, as man-made sources are progressively mitigated, the natural component contribution will gain in significance;
- consideration needs to be given to the complexity of interactions between natural and man-made $PM_{2.5}$ sources;
- $PM_{2.5}$ will have a negative impact on health irrespective of source while highlighting the impact from natural sources alone is uncertain; and
- a robust method of assessment and justification for subtraction will be required.

Governance

Once targets have been set, the national air quality framework within the Act creates a cycle of monitoring, reporting and review, Welsh Ministers have a legal duty to:

- **Monitor** progress towards meeting the targets. Data must be collected and published to demonstrate progress towards the target.
- **Report** on targets. The target reporting date for both AMCT and PERT is 31 July 2036, which requires that a statement must be laid before the Senedd to report on whether the AMCT and PERT have been met. If, by the reporting date, it cannot be determined whether the target has been met, the reasons for that and the steps to be taken to determine whether the target has been met must be included in the statement with a further statement to report on compliance laid within 6 months. If the target hasn't been met, the Welsh Ministers must lay and publish a report before the Senedd within 12 months of the date on which the target statement was laid. The report must set out the reasons for non-compliance and the steps which have been (or which will be) taken to achieve the target as soon as possible.
- **Review** the targets. Targets must be reviewed within five years of the making of the regulations and, subsequently, at five yearly intervals. Following a review, a statement must be laid before the Senedd on the steps, if any, Welsh Ministers intend to take following the review process. This ensures progress towards air quality targets set under the framework would remain likely, based on current evidence, to drive the net air quality benefits anticipated when the targets were set whilst avoiding disproportionate costs.

Once the AMCT and PERT target dates have been reached and the target standards have been achieved (by the target date or later), the target standards assessment and reporting arrangements must be maintained to ensure on-going environmental protection.

Questions on target assessment

Question 3a: To what extent do you agree with the proposed arrangements for assessing $PM_{2.5}$ levels and achievement of the targets

Question 4a: To what extent do you agree with the provision in the draft regulations to allow the subtraction of the 'natural contribution' to particulate matter where exceedances of a target are due in whole or in part to these natural contributions?

Appendix A – Scenario emissions modelling

By modelling a range of scenarios, it is possible to gain insight into future emission reduction potential to inform associated target levels and dates. Three levels of ambition have been included to reflect different levels of emission reduction and subsequent concentrations, to provide evidence on which to base target setting. The baseline and speculative scenarios define the outer limits of projected future emissions. The baseline represents a conservative estimate, where emissions are unlikely to exceed this level. In contrast, the speculative scenario reflects a more optimistic outlook, where emissions are unlikely to fall below it. The medium and high scenarios serve as reference points within this range, illustrating the potential effects of different future developments. The levels of ambition are defined as:

Medium - Implementation of proven technology and likely government policy measures (informed by Welsh Government policy leads) and limited behaviour change, typical timescales and uptakes.
High - Technology considered likely to be implementable in the future and possible government policy measures (informed by WG policy leads), increased behaviour change, more rapid timescales and uptake levels.
Speculative - Ideas for all feasible measures that could have potential to reduce emissions, which could include largely/completely untested or unexamined measures at this point and ‘speculative’ potential government policy ideas (informed by WG policy leads), including emerging technology and significant behaviour change measures. Optimistic timescales and uptakes.

The measures identified in the literature review were discussed with industry experts and stakeholders through a series of one-to-one interviews and sector workshops. To make sure all future policies and potential technological advancements were included in the future scenarios a large amount of stakeholder engagement took place.

All scenarios see a significant reduction in emissions by 2040, from 11% in the medium scenario to 36% in the speculative scenario. The shape of the curve is determined by the implementation date and uptake profiles for the measures. For example, the changes in the processes at Port Talbot in the speculative scenario are responsible for the majority of emission savings starting in 2025.

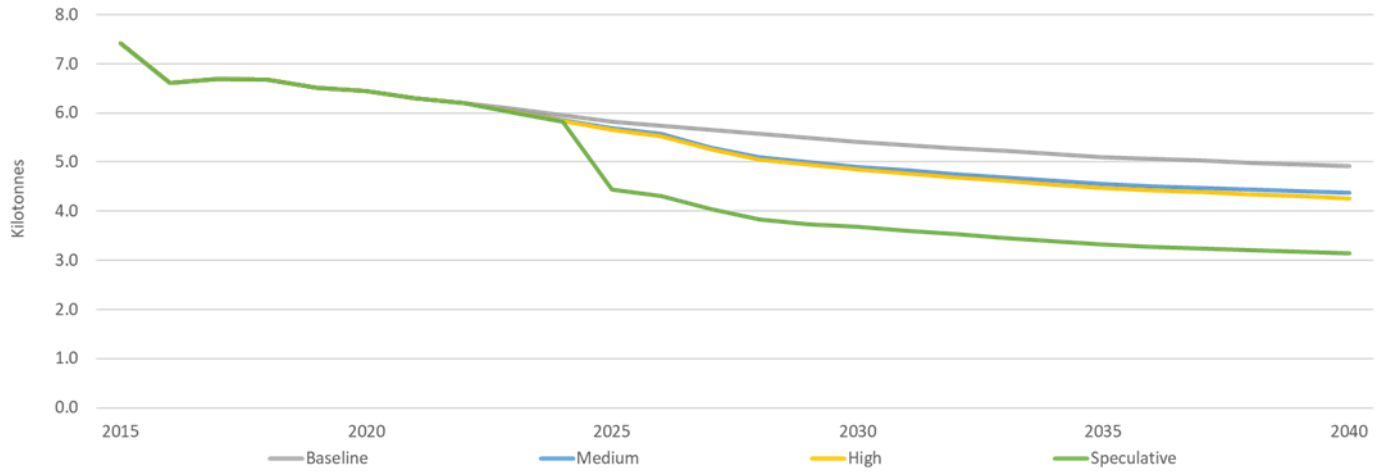

Figure 8: $PM_{2.5}$ emissions for the baseline and medium, high and speculative scenarios in 5 yearly intervals

The measures identified in the literature review were discussed with industry experts and stakeholders through a series of interviews and sector workshops. Prior to the first workshop, technical consultants acting on behalf of Welsh Government held a number of meetings with policy officials across Welsh Government departments including agriculture, domestic burning and industrial policy. The inputs from these colleagues helped to develop the first set of proposed measures that were presented to the cross-sector stakeholders at the first stakeholder workshop. Representation included academia, public sector regulators and public health bodies, industry and non-government organisations. Feedback from over 150 workshop consultees helped to refine dates and uptake rates for each of the scenarios. A follow up stakeholder workshop was held to present the projected emissions and costs and benefits associated with the scenarios, and to seek further feedback.

The measures do not necessarily correspond with a particular potential government policy, and the scenarios developed should not be considered policy pathways. They are possible futures for the purposes of mapping out which targets are feasible, and only provide an indication of the types of action and scale of intervention that would be needed to achieve different concentrations by different dates in the future. It should be noted that these future scenarios were developed using the information available at the time of undertaking the analysis it was not possible to take account of announcements related to changes in Policy after the scenarios had been developed.

A list of emissions measures by scenario are shown below:

Measures to address $PM_{2.5}$ air pollution, included under each Target Scenario	Medium Scenario: 10 µg/m³ by 2035	High scenario: 10 µg/m³ by 2035	Speculative scenario: 10 µg/m³ by 2035
All taxis and private hire fleet to zero emissions			X
Ban on domestic combustion of coal	X	X	X
Bespoke solid fuel appliance approval/certification			X
CAA for Wales	X	X	X
Combined effect of cavity wall insulation			X
Communication - Clean Air Day, guidance for good practise to encourage behaviour change, including benefit for indoor AQ	X	X	X
Communication - outdoor burning - guidance for good practise to encourage behaviour change	X	X	X
Electrification of railway lines (i.e. Phase out diesel-only trains)	X	X	X
Modal shift to active travel: all passenger cars	X	X	X
National Speed Limit (from 30 to 20 mph)			X
New renewables (non-thermal) instead of CCGT			X
Reduced carbon steelmaking			X
Regulating the sale of wet wood	X	X	X
Retrofitting active open fires to Ecodesign appliances			X
Sector 1A2a reduction (Blast Furnaces, Sinter production, Iron and steel combustion plant)	X	X	X
Sector 1A2b-e/gviii reduction (Non ferrous metal combustion, vehicle manufacture combustion, ammonia production combustion, chemical combustion, methanol production combustion, pulp, paper and print combustion, other industrial combustion, Food and drink, tobacco combustion, auto generators, mechanical engineering combustion)	X	X	X
Sector 1A2gvii reduction (Industrial off road mobile machinery, NRMM construction, NRMM generators, NRMM mining and quarrying, NRMM other industry, NRMM waste)	X	X	X
Sector 1A4a reduction (Miscellaneous industrial/ commercial combustion, public sector combustion, Railways stationary combustion, NRMM Forklifts)	X	X	X
Sector 1B1a reduction (Deep mined coal, open cast coal, coal storage and transport)	X	X	X
Sector 1B1b reduction (Coke production, Solid smokeless fuel production, iron and steel flaring, waste disposal benzole and tars, charcoal production)	X	X	X
Sector 2A3 reduction (Glass, general, lead crystal, glass wool, continuous filament glass fibre, frits, flat, container, domestic, special, ballotini)	X	X	X
Sector 2A5a reduction (Quarrying, dewatering of lead concentrates)	X	X	X
Sector 2A5b reduction (Construction of houses, apartment buildings, Roads and non-residential)	X	X	X
Sector 2B10a reduction (Chemical Industry)			X

Measures to address $PM_{2.5}$ air pollution, included under each Target Scenario	Medium Scenario: 10 µg/m³ by 2035	High scenario: 10 µg/m³ by 2035	Speculative scenario: 10 µg/m³ by 2035
Sector 2C7c reduction (Tin production, other non-ferrous metal processes, Foundries)	X	X	X
Sector 2D3b reduction (Road dressings, kerosene, bitumen, bitumen use, asphalt manufacture)		X	X
Sector 2H1 reduction (Paper production)	X	X	X
Sector 2H3 reduction (other industry – part B processes)	X	X	X
Sector 2I reduction (wood impregnation, Creosote use, wood products manufacture)	X	X	X
Solid fuel ban in designated areas - wood fuels			X
Test standards for new manufactured solid fuels entering the market by 2024	X	X	X
Transition to electric/ULEV Cars	X	X	X
Transition to electric/ULEV HGVs	X	X	X
Transition to electric/ULEV LGVs	X	X	X
Uptake of cleaner NRMM (i.e. Stage V)	X	X	X
Working from home	X	X	X

Appendix B – Air dispersion model validation and calibration

Model uncertainty due to model resolution and dispersion model approximations in the 2019 base year have been quantified through model verification, comparing measured concentrations of key pollutants at automatic analysers in the Automatic Urban and Rural Network and Welsh Air Quality Network with the total modelled concentrations from the model ensemble for 2019.

The model ensemble verification approach follows that used in the Pollution Climate Mapping (PCM) model run by Ricardo on behalf of Defra. The PCM model is a comparable (UK) regional scale model utilising chemistry models in combination with local modelling.

Some sites were excluded from the verification for the following reasons:

- Insufficient data capture (<75%).
- Particulate matter measurements collected using reference equivalent instruments.
- Sites classified as traffic sites which do not have a modelled road within a 50 m radius and kerbside sites.
- Roadside sites in areas that were modelled at 9m resolution, which is not sufficiently fine for verification. The other roadside sites have been verified at 3m resolution, which more precisely reflects how pollutant concentrations change at different distances from the road centre.

Following best practice guidance (LAQM.TG22), the relationship between measured and modelled concentrations has been identified. After iteratively reviewing and making changes to the model to improve agreement with measured concentrations, a linear adjustment factor based on this relationship has been derived for each pollutant. This adjustment factor has been applied to all modelled scenarios.

Statistics have been presented to describe the agreement between the modelled and measured pollutant concentrations. A summary of these statistics are presented in Table 4.

Table 4: Summary of model verification statistics

Pollutant	No. Sites	Observed Mean (µg/m³)	Modelled Mean (µg/m³)	FAC2	MB (µg/m³)	NMB (µg/m³)	RMSE (µg/m³)	r
$PM_{2.5}$	8	9.2	9.2	1.0	0.0	0.0	1.2	0.7

The adjusted nested model performs well for annual mean $PM_{2.5}$ concentrations across the model domain. The pollutant is emitted by a range of sources, and as a result are less sensitive to uncertainties in emissions and efflux characteristics from individual source types. The root mean square error (RMSE) for these pollutants is

relatively low relative to annual mean concentrations, and the spatial correlation between modelled and monitored concentrations is high.

The RMSE from model validation was used as uncertainty bounds for the results in this assessment. The calculated RMSE is included in the assessment and is presented in Table 5. The approach by which these uncertainty bounds have been incorporated into the compliance matrices presented in this report is described below.

Table 5: Calculated uncertainty bounds as a % of the modelled annual mean concentration for $PM_{2.5}$

Pollutant	Number of AURN stations	RMSE (µg/m³)	Annual mean (µg/m³)	Uncertainty bounds
$PM_{2.5}$	8	1.2	9.2	13%

Model limitations and uncertainty

Any modelling study is subject to uncertainty resulting from a number of factors including model inputs, intrinsic uncertainty in model parameterisation, uncertainties introduced by scales of the modelling and uncertainties in future conditions. In order to reduce and mitigate some of these uncertainties we have undertaken a number of steps including undertaking a model verification process and iterative model improvements were made to reduce uncertainties. The model verification processes are described in more detail below.

Key sources of uncertainty in this study, together with a description of how the uncertainty has been quantified or minimised where possible, are presented in Table 6.

Many of these sources of uncertainty cannot be robustly quantified as their impacts may vary significantly by sector, model scenario, and location. As such, the central model predictions have been presented as the main results in this report; there is therefore potential for real-world concentrations in future years to over or under-predict modelled concentrations.

Table 6: Key study limitations and sources of uncertainty

Category	Limitation / uncertainty	Description
Input data	Meteorological data.	Model predictions were compared with observed meteorological data in 2019; details are summarised in Appendix A1.
	Emissions inventory uncertainty for past years.	Uncertainty in the UK National Atmospheric Emissions Inventory is quantified in the UK Informative Inventory Report 2020 and summarised

Category	Limitation / uncertainty	Description
		in Appendix A2. Uncertainty is higher for particulate matter emissions compared to NO_X and SO_X emissions.
	Model resolution and spatial resolution of emissions data.	The spatial accuracy of model predictions and therefore the ability of the model to resolve concentrations at discrete locations is limited by the spatial resolution of the input emissions data. Emissions from all sources except for road transport and industry are calculated at 1km resolution as detailed in the Lot 1 report, and as a result disaggregation of more localised impacts from these sources is not possible. Emissions from large industrial sources and road transport were calculated at higher resolution using AERMOD and RapidAir respectively. Emissions from road transport were calculated for each PCM road link for use in the RapidAir model using average traffic flows and speeds across the entire link, as detailed in the Lot 1 report. As a result, variations in speeds near junctions or due to changes in road geometry are not accounted for in the model. As such, while the emissions used in this study are representative of average traffic conditions along each road link, emissions at individual receptor locations along each road may be over- or under-predicted. In particular, it is anticipated that the model will underpredict concentrations near road junctions or in areas of heavy congestion.
Model setup and calibration	Physical and chemical parametrisations and numerical approximations made in the dispersion models.	In order to quantify intrinsic model uncertainty, model verification has been carried out by comparing predictions against monitored concentrations in the baseline year (2019). This process and the associated model calibration are described in section 2.5. In order to assess the potential effect of intrinsic model uncertainty on future compliance against the

Category	Limitation / uncertainty	Description
		WHO guideline levels and interim target values, model compliance matrices were recalculated using guideline levels adjusted by the RMSE of modelled and measured concentrations. The results can be interpreted using a 'compliance band' approach where locations with concentrations within the RMSE of the proposed target are predicted to comply but remain at risk of exceeding; likewise, concentrations exceeding the target but which lie within the RMSE of the target are predicted to exceed but may comply.
	Uncertainty in model calibration factors where limited data is available.	For a number of pollutants, the number of automatic monitoring sites meeting data quality criteria is limited; as a result, the derivation of model calibration factors is subject to increased uncertainty for these pollutants. In light of this uncertainty, a conservative approach has been used to estimate calibration factors for pollutants with less than 5 monitoring stations available; when an adjustment factor below 1 is derived from the limited monitoring data available as is the case for SO_2, no adjustment factor has been applied.
	Uncertainties in PM_{10} and $PM_{2.5}$ predictions due to model underprediction at Port Talbot monitoring stations.	Analysis of model performance for PM_{10} and $PM_{2.5}$ indicates that the model systematically slightly underpredicts concentrations at Port Talbot monitoring stations (in the vicinity of the Port Talbot steelworks) compared to the rest of the model domain. Including these monitors in the model calibration process increases $PM_{2.5}$ concentrations by 4% and PM_{10} concentrations by 11% compared to results without these sites included. In the central model predictions presented in this report, these sites were included in the model calibration to provide a conservative estimate of overall PM_{10} and $PM_{2.5}$ concentrations.

Category	Limitation / uncertainty	Description
Uncertainty in future conditions	Uncertainty in emissions inventory projections and future scenarios.	The future scenarios represent a combination of technical, legislative, and behavioural measures based on best practice and current knowledge. Future policy and technology are inherently uncertain and as a result there is uncertainty in these projections.
	Potential impacts of climate change on future meteorology.	Not considered in this study.
	Interannual variability.	The ensemble model has been run using a single year of meteorological data (2019). In addition to long-term trends resulting from changes in emissions, concentrations are subject to interannual variability as a result of changes in meteorological data. To quantify this uncertainty, an analysis of long-term monitoring data from the Welsh Air Quality Network was carried out, as described in Appendix A2. This analysis indicates an average deviation of approximately 10% from long-term concentration trends for annual mean concentrations for the majority of pollutants.

In order to assess the potential effect of intrinsic model uncertainty on future compliance against the WHO guideline levels and interim target values, model compliance matrices were calculated using an adjusted guideline level. This adjusted guideline value was calculated for each pollutant using the formula

Guideline level accounting for uncertainty = WHO guideline level – RMSE.

The resulting matrices represent compliance should the model be underpredicting future concentrations across all sites by the RMSE. The results can be interpreted using a ‘compliance band’ approach where locations with concentrations within the RMSE of the proposed target are predicted to comply but remain at risk of exceeding; likewise, concentrations exceeding the target, but which lie within the RMSE of the target are predicted to exceed but may comply.

Note that this approach accounts for intrinsic model uncertainty due to spatial resolution and model assumptions but does not include sources of uncertainty such as uncertainty in future emissions as described in Table 6.

The results incorporate safety margins that reduce the risk of underestimating future pollutant levels or overestimating the effectiveness of mitigation measures into the target setting process.

Annexes

Annex A: Advice Note: Development of New PM2.5 Air Quality Targets for Wales, Clean Air Advisory Panel, November 2025

Annex B: Evidence to support the development of PM2.5 target proposals in Wales, Ricardo, 2025