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Technical Annex:

Methodology, Data & Analytical Approach

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Contents

1. Purpose and scope

This technical annex provides a detailed account of the methodology, data sources and key assumptions underpinning the analysis presented in the main report. It explains how modelled changes in $PM_{2.5}$ and NO_2 exposure are converted into health impacts and then valued through productivity, healthcare and welfare channels.

The annex should be read alongside the main report. It does not reproduce every underlying dataset, model input or intermediate calculation, but instead explains the analytical framework, source data, modelling assumptions and areas of uncertainty that shape the results. Detailed outputs are reported in the main report, while this annex provides the technical basis for interpreting those outputs.

Readers should note that the estimates represent selected quantifiable air quality co-benefits, not the full social value of cleaner air. The analysis focuses on pollutants, health outcomes and valuation channels where there is sufficient evidence to support modelling. Wider impacts, including black carbon-specific health effects, educational impacts, building damage and ecosystem effects, are discussed qualitatively in the main report and not in this annex.

The results should therefore be interpreted as estimates of selected quantifiable air quality co-benefits, not as a complete measure of the full social value of cleaner air. The methodological choices set out in this annex are intended to provide a basis for interpreting the analysis, while recognising that the findings are assumption-sensitive and wider benefits of reduced air pollution may extend beyond the impacts quantified here.

2. Detailed Methodology

This section provides a detailed description of the methodology from pollutant exposure changes to health impacts and economic valuations.

2.1 Air quality modelling methodology

The first stage of the analysis was to construct a set of emissions scenarios and model the resulting changes in pollutant concentrations. This stage was undertaken by WSP and provides the exposure inputs used in the health impact assessment described in **Section 2.2.** The air quality modelling estimates how selected CCC-aligned decarbonisation pathways affect annual average concentrations of NO_2 and $PM_{2.5}$ across the UK, and how these concentration changes translate into population-weighted exposure changes.

2.1.1 Baseline emissions data

The emissions baseline for the air quality modelling was based on the UK National Atmospheric Emissions Inventory (NAEI). The NAEI provides gridded emissions maps at 1 km resolution and splits emissions into relevant source sectors, including road transport, domestic and commercial combustion, industrial combustion and power generation. It also includes point sources, which were allocated to relevant sector categories where appropriate.

The most recent available NAEI gridded emissions data at the time of modelling were for 2023, which was therefore selected as the baseline year. The baseline scenario is representative of emissions and concentrations in the UK in 2023, with no further emissions changes applied. This provides the counterfactual against which each decarbonisation scenario is compared.

2.1.2 Scenario construction

Using the 2023 NAEI emissions baseline, WSP developed three sectoral scenarios and one combined scenario aligned with relevant elements of the CCC's Balanced Pathway. The scenarios focus on the electrification and decarbonisation of key emitting sectors, including surface transport, residential and non-residential combustion, industrial combustion and power generation.

Activity data and assumptions from the CCC's Seventh Carbon Budget (Balanced Pathway) were used to scale emissions to 2050. The scenarios are designed to isolate the air quality effects of selected net zero pathways relative to the 2023 baseline. This means that, for each individual sector scenario, emissions changes are applied only to the relevant modelled sectors, rather than across the full economy. Each individual sector scenario includes power generation, reflecting its role in enabling wider decarbonisation through electrification.

The modelled scenarios are summarised below.

Scenario	Sectors adjusted	Summary of modelling approach
Baseline	None	Represents 2023 emissions and concentrations, with no changes applied.
Scenario 1: Surface transport + power generation	Road transport, rail transport and power generation	Road transport emissions were scaled to reflect projected electric vehicle uptake to 2050. The Emissions Factors Toolkit was used to model EV uptake assumptions for cars, vans, HGVs and buses and develop scaling factors for NOx and $PM_{2.5}$ across exhaust and non-exhaust emissions. A modal shift component was also applied to cars. Rail transport emissions were scaled to reflect electrification assumptions. Power generation emissions were scaled to reflect the transition to low-carbon electricity generation.

Scenario	Sectors adjusted	Summary of modelling approach
Scenario 2: Residential and non-residential combustion (buildings) + power generation	Domestic combustion, commercial/public sector combustion and power generation	Domestic combustion was used to represent residential combustion. Relevant commercial and public sector combustion sources were used to represent non-residential combustion. Emissions were scaled using CCC assumptions on the transition to electrified and low-carbon heating in homes, commercial buildings and public sector buildings. Power generation emissions were scaled to reflect the transition to low-carbon electricity generation.
Scenario 3: Industrial combustion + power generation	Industrial combustion, associated point sources and power generation	Industrial combustion emissions and associated point sources were scaled using CCC assumptions on the increasing share of industrial energy demand supplied by electricity. Power generation emissions were scaled to reflect the transition to low-carbon electricity generation.
Scenario 4: Combined scenario	Surface transport, residential and non-residential combustion, industrial combustion and power generation	Applies the same sector-specific assumptions as Scenarios 1 to 3 in parallel. The combined scenario is modelled separately to avoid triple counting power generation, which is included in each individual sector scenario.

The power generation methodology applies across all scenarios. Emissions from the power stations sub-sector of the NAEI's energy production sector, along with emissions from point sources for minor and major power generators, were scaled to represent an increase in low-carbon electricity generation to 2050. The reduction in power station emissions was based on the decreasing share of unabated gas generation in the CCC pathway.

For surface transport, road transport emissions were scaled using projected EV uptake according to the CCC's Balanced Pathway. Scaling factors were applied to exhaust emissions and non-exhaust emissions, including brake wear, tyre wear and road abrasion. Rail transport was treated as a sub-sector of other transport and scaled using electrification assumptions from the CCC's Balanced Pathway. Because the modelling uses gridded NAEI emissions, the road and rail scaling factors were applied across the relevant UK emissions grids rather than to specific individual road or rail links.

For residential and non-residential combustion (buildings), the domestic and commercial combustion NAEI sector was used to represent emissions from heating and other combustion sources in homes, commercial buildings and public sector buildings. Residential combustion was scaled using assumptions on the proportion of homes with electrified heating systems by 2050 according to the CCC's Balanced Pathway. Non-residential combustion was scaled using assumptions on the share of commercial and public sector heat delivered by low-carbon technology.

For industrial combustion, emissions from the NAEI industrial combustion sector and associated point sources were scaled using assumptions on the share of industrial energy use supplied by electricity by 2050 according to the CCC's Balanced Pathway. This reflects the role of electrification in reducing emissions from industrial heat and other combustion processes.

2.1.3 Air quality modelling approach

For each scenario, WSP applied its RapidAir® air quality modelling software to simulate annual average concentrations of primary $PM_{2.5}$ and NO_2 across the UK at 1 km resolution. This allowed the analysis to quantify changes in annual average concentrations under each scenario and identify the air quality improvements associated with the selected decarbonisation pathways.

The RapidAir® modelling used two principal inputs:

1. an emissions raster for the pollutant being modelled, assembled at 1 km resolution using emissions from relevant UK sectors in the NAEI and the scenario assumptions described above; and

2. meteorological data selected from UK monitoring sites to support the dispersion modelling.

The selected primary meteorological site was RAF Waddington in Lincolnshire, in line with a previous UK-wide modelling project for Defra. Data from Waddington were gap-filled using nearby meteorological stations at Cranwell and Coningsby to improve data coverage.

$PM_{2.5}$ concentrations were modelled directly using $PM_{2.5}$ emissions rasters. NO_2 concentration maps were derived from modelled NOx concentrations using a polynomial conversion approach. For each pollutant and scenario, the model produced UK-wide annual average concentration maps at 1 km resolution.

2.1.4 Population-weighted exposure outputs

The outputs of the air quality modelling were concentration maps for the 2023 baseline and each decarbonisation scenario. These maps were aggregated across UK local authority and country boundaries and combined with population estimates from the Office for National Statistics to derive population and age-weighted mean concentrations.

Population-weighted exposure estimates were produced for the UK, England, Scotland, Wales, Northern Ireland, Greater London and Inner London. These outputs indicate how pollutant exposure changes for the population, rather than how concentrations change across land area alone. This distinction is important because the health impact of a concentration change depends on how many people are exposed to it. A reduction in pollution in a densely populated area therefore has a larger health relevance than the same reduction in a less populated area.

The population-weighted exposure outputs for NO_2 and $PM_{2.5}$ form the direct input into the health impact assessment. In the health model, exposure change is defined as the difference between baseline exposure and scenario exposure:

$$\Delta\ \textit{concentration} = \textit{baseline exposure} - \textit{scenario exposure}$$

These exposure changes are then combined with baseline health burdens and concentration-response functions to estimate mortality and morbidity impacts.

2.1.5 Emissions trajectories and pollutant-specific patterns

The scenario modelling produces different emissions trajectories for NOx, $PM_{2.5}$ and black carbon because each pollutant has a different source profile. These differences are important for interpreting the exposure results in the main report.

For NOx, the surface transport scenario has the largest effect among the individual scenarios. This reflects the importance of road transport as a source of NOx emissions and the rapid reduction in tailpipe emissions under projected EV uptake. The combined scenario is estimated to reduce total UK NOx emissions by 46% between 2023 and 2050.

For $PM_{2.5}$, the residential and non-residential combustion (buildings) scenario has the largest effect among the individual scenarios. This reflects the importance of heating and other combustion sources for fine particulate emissions. Surface transport has a smaller impact on $PM_{2.5}$ emissions than on NOx emissions because road transport is a less dominant source of $PM_{2.5}$ and because non-exhaust emissions remain relevant. The combined scenario is estimated to reduce total UK $PM_{2.5}$ emissions by 36% between 2023 and 2050.

For black carbon, residential and non-residential combustion (buildings) also delivers the largest reduction among the individual scenarios. The combined scenario is estimated to reduce total UK black carbon emissions by 37% between 2023 and 2050. Black carbon emissions reductions are not translated into separate health or economic impacts in the core model, but they are discussed qualitatively in the main report as part of the wider air quality benefits of decarbonisation.

The detailed emissions trajectories for NOx, $PM_{2.5}$ and black carbon are included in **Appendix B.**

2.1.6 Scope and limitations of the air quality modelling

The air quality modelling should be interpreted in light of several scope considerations.

First, the modelling is undertaken at 1 km resolution. This is suitable for national and regional analysis, but it may smooth over highly localised pollution gradients, particularly near busy roads, junctions and industrial sources. As a result, concentrations in street-level hotspots may differ from the grid-cell average represented in the model.

Second, the modelling focuses on annual average concentrations of NO_2 and $PM_{2.5}$. Other pollutants, including PM_{10}, ozone, sulphur dioxide and black carbon concentrations, are not modelled as separate concentration or health pathways in the core analysis. Black carbon emissions are modelled and discussed separately, but black carbon-specific concentration, health and economic impacts are not quantified.

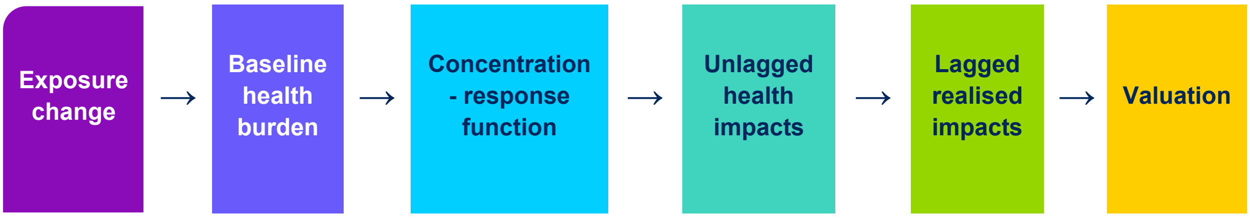
Third, the $PM_{2.5}$ modelling focuses on primary emissions from the selected UK sectors. It does not fully capture secondary particulate formation or transboundary $PM_{2.5}$ contributions from outside the UK. These can represent a meaningful share of measured $PM_{2.5}$ concentrations, so the $PM_{2.5}$ results should be interpreted as the modelled benefits from selected domestic sectoral pathways rather than the full potential change in ambient $PM_{2.5}$ under wider domestic and international decarbonisation.

Fourth, the scenarios cover selected CCC-aligned decarbonisation pathways rather than the full economy-wide transition to net zero. Sectors outside the modelled pathways, such as agriculture, waste, aviation and shipping, are not included. The results therefore estimate the air quality benefits associated with selected sectoral pathways, not all possible air quality changes under net zero.

Finally, the individual sector scenarios are designed to isolate the effects of selected decarbonisation pathways relative to the 2023 baseline. They should therefore be interpreted as illustrative scenario results rather than forecasts of total future ambient air quality. The combined scenario provides the most appropriate estimate of the aggregate impact across the selected sectors because it applies the sector assumptions in parallel and avoids triple counting the power generation pathway.

2.2 Health impact assessment methodology

The health impact assessment estimates how modelled changes in air pollution exposure affect mortality and morbidity health outcomes. The approach follows an impact-pathway structure:



The model calculates impacts by scenario, year, outcome, age band and pollutant.

1. Estimating exposure changes

WSP's outputs provide the starting point. This is the change in pollutant exposure between the baseline and each decarbonisation scenario. Exposure changes are estimated for $PM_{2.5}$ and NO_2 by year and age band.

The model defines the exposure change as:

$$\Delta\ \textit{concentration} = \textit{baseline exposure} - \textit{scenario exposure}$$

These exposure changes are population-weighted so that the model reflects the pollution reductions experienced by people, rather than average concentration changes across land area.

2. Compiling baseline rates

The next step is to compile baseline health rates for each health outcome and age-band included in the model. Age-specific baseline rates are estimated from literature and administrative data sources and **Table A2** in Section 4 of this Technical annex shows those sources and key assumptions for each health outcome. Baseline rates are held constant over time to avoid making strong assumptions about future changes in disease incidence, treatment, behaviour or healthcare quality.

3. Estimating the population at risk

For each health outcome, population projections are applied by year and age band. Population projections are sourced from ONS 2022-based UK population projections[1] and are applied consistently across the health impact model. Where relevant, the model estimates the population at risk by excluding people already living with the condition, using age-specific prevalence rates.

With prevalence rates being held constant, changes in the population at risk are driven by demographic change in the age-band population. It does not carry cohorts forward year by year and remove people who die from other causes before the lagged effect is realised. This means the model may overstate lagged impacts for older age bands compared with a full cohort life-table approach.

4. Calculating baseline health burden

For each health outcome, year and age band, the model calculates the baseline health burden before applying the air pollution effect. This is the expected number of deaths, incident cases, admissions or school days lost in the absence of the scenario-related exposure reduction for each year.

The calculation is:

Baseline health burden = population at risk × baseline rate

5. Applying concentration-response functions

Exposure changes by year and age-band are translated into health impacts using health outcome-specific concentration-response functions (CRFs) which are shown in **Table A1** In Section 3. CRFs are used to estimate how a given change in pollutant exposure affects the risk or frequency of each health outcome.

The model uses two main types of CRF with a detailed breakdown of how they are applied in Section 3. Once they are applied, we have unlagged impacts for each health outcome by year, age band and scenario.

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[1] ONS (2025) ***National population projections: 2022-based***
Note that 2024-based projections were not released when the analysis started.

6. Applying lag structures

Outcome-specific lag assumptions are applied to annual health impacts calculated using CRFs in step 5. This reflects the fact that some health benefits occur immediately, while others materialise over several years after exposure reductions.

Acute outcomes, such as hospital admissions and school days lost, are treated as same-year impacts. Other outcomes, including mortality and some chronic morbidity outcomes, are spread over later years using lag weights. Lags can be seen for each health outcome in **Table A3** in Section 4.

The model extends the time horizon beyond 2050 where lagged health benefits from exposure reductions during the modelling period will be realised. This is why some total health impacts extend to around 2070. These are not new post-2050 exposure reductions; they are further lagged benefits arising from exposure changes during the modelled pathway.

7. Health endpoints and inclusion approach

The health endpoints are divided into core and sensitivity outcomes. This split is based primarily on COMEAP's (2022)[2] recommendations for quantifying health effects associated with air pollutants and can be seen in Section 4 of the main report in **Table 1**.

This is a sensible but cautious split. Some sensitivity health outcomes are used in other studies but are either recommended for sensitivity analysis only or do not yet have a formal quantification recommendation from COMEAP (2022). They are therefore quantified separately and interpreted more cautiously than the core outcomes.

Lung cancer is not included as a separate endpoint. This is because lung cancer is commonly fatal within a relatively short period, meaning there is a material risk of double counting with the all-cause mortality endpoint. This approach is also taken by Dajnak et al (2022)[3].

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[2] COMEAP (2022) ***Summary of COMEAP recommendations for the quantification of health effects associated with air pollutants***

[3] Dajnak et al. (2022) ***Pathway to WHO: achieving clean air in the UK***

2.3 Economic valuation methodology

The economic valuation converts physical health impacts into monetary values. The model values benefits through three separate channels:

- Productivity valuation – additional labour market impact of healthier workforce
- Healthcare costs – avoided NHS resource use for hospital admissions
- Welfare valuation – improvements in health and quality of life

They are not treated as a single GDP or fiscal impact because they represent alternative valuation pathways and there may be conceptual overlap, particularly between welfare values and productivity or healthcare impacts.

2.3.1 Productivity valuation

The productivity model values avoided mortality and morbidity using the Human Capital Approach (HCA). This estimates the market output gained when cleaner air reduces illness, work absence, labour-market exit, caring-related productivity losses and premature mortality.

The model does not apply a single generic cost per case. Instead, each outcome is valued using the productivity channel judged most appropriate for that health outcome.

Mortality productivity

Avoided deaths generate future working-year streams. For each avoided death, the model estimates the number of remaining working years to retirement, applies the relevant employment rate[4], values each future working year using GVA per worker[5], and discounts the value back to the model base year.

This is repeated for each future working year until retirement. The retirement age is assumed to be 67. Working years remaining are based on age-band midpoints, which is a practical simplification but means the 65–69 age band currently has no remaining working years valued. GVA per worker is assumed to grow at 1% annually in line with the OBR's (2025) medium-term productivity growth assumption[6].

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[4] ONS (2024) *Annual population survey*

[5] London GVA/worker is adjusted compared to UK-wide GVA/worker estimates according to the ONS regional productivity parameters

[6] OBR (2025) *Briefing Paper No.9. Forecasting productivity*

Morbidity productivity

For morbidity outcomes, the valuation method differs by health outcome. **Table A4** in Section 4 outlines the productivity approach for each outcome alongside key assumptions and sources used.

Presenteeism is only partly captured. It is included explicitly for dementia caregiver impacts through an overall work impairment measure. For IHD, diabetes, asthma, COPD and stroke, the central model mainly captures absenteeism and labour-market exit effects. This means wider on-the-job productivity impacts may be understated.

2.3.2 Healthcare cost valuation

The healthcare cost model values avoided NHS resource costs from reduced hospital admissions. It focuses on respiratory and cardiovascular hospital admissions.

Unit costs are derived from the NHS England National Cost Collection admitted patient care data[7]. Average costs per finished consultant episode are calculated for relevant respiratory and cardiovascular HRG chapters.

Approximate unit costs are:

- **Respiratory admission**: £2,400 per admission
- **Cardiovascular admission**: £2,800 per admission

Avoided admissions in each year are multiplied by the unit cost and discounted using the standard discount factor, aligned with the Green Book[8].

The healthcare valuation is intentionally narrow. It does not include GP visits, medication, outpatient care, social care or long-term disease management. It also uses NHS England data as a proxy for UK-wide costs. Costs are based on finished consultant episodes rather than full admission spells. This is a practical data simplification and should be interpreted as an approximation to cost per admission.

The current specification includes all admitted patient care types, including day cases, elective inpatient, non-elective short stay and long stay, renal dialysis and regular day/night admissions. This provides a broad measure of healthcare resource use but may not fully align with pollution-related admissions.

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[7] NHS England (2025) ***National Cost Collection Data Publication***
[8] HM Treasury (2026) ***The Green Book: UK Government Guidance on Appraisal***

2.3.3 Welfare valuation

The welfare model values the wider social value of improved health and quality of life. It follows the approach used in Defra's Damage Costs[9] and HM Treasury Green Book principles.

Mortality benefits are valued using life years gained rather than avoided deaths. For each life year gained, the value of a life-year (VOLY) and health discount factor are applied by year, in the year where the additional life year gained is realised. The central VOLY, £59,200, is taken from Defra guidance in 2025 prices[10] and rebased to the model price year, 2023.

For morbidity endpoints, the model uses a QALY-based approach:
Morbidity welfare value = avoided cases × utility decrement × duration × value per QALY × health discount factor

Most utility decrement and duration assumptions are taken from Defra / WSP damage cost evidence[11] except for dementia which is not included in the standard morbidity damage cost assumptions. Therefore, alternative literature from Hvidberg and Alava (2023)[12] is used for dementia utility decrements with a duration of 6 years assumed[13,14]. COPD also requires an additional duration assumption because the Defra damage cost approach treats COPD differently from the incidence-based structure of this model.

Asthma welfare values are particularly sensitive to assumptions. Defra-style utility decrements and long durations can imply very large QALY losses per incident case. For this reason, asthma welfare valuation in the sensitivity health outcomes results should be interpreted cautiously. School days lost are not valued by welfare.

Hospital admissions are valued using fixed willingness-to-pay values per avoided admission. This captures the welfare value of avoiding a hospital admission, separate from the NHS resource cost captured in the healthcare cost model.

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[9] WSP (2025) ***Air Quality Damage Cost Update***

[10] Department for Environment, Food & Rural Affairs (2026) ***Air Quality Appraisal Impact Pathways Approach***

[11] WSP (2025) ibid.

[12] Hvidberg M.F. and Alava M.H. (2023) ***Catalogues of EQ-5D-3L Health-Related Quality of Life Scores for 199 Chronic Conditions and Health Risks for Use in the UK and the USA***

[13] Wolfson C. et al. (2001) ***A reevaluation of the duration of survival after the onset of dementia***

[14] Garre-Olmo J. et al. (2019) ***Survival, effect measures, and impact numbers after dementia diagnosis: a matched cohort study***

Compared with studies that use a cohort lifetable approach and a longer time horizon, our approach may result in life years gained being discounted less heavily on average, despite applying the same Green Book health discount rate. This is because our modelling captures a greater share of benefits in the nearer term, reflecting both the shorter study period and the concentration of life years gained among older age groups. As a result, a larger proportion of the total health benefits is realised earlier and therefore subject to less discounting.

2.3.4 Price base and discounting

All monetary outputs are reported in real £2023 present-value terms. This involves rebasing unit values into consistent 2023 prices and discounting to convert future benefits into present-value terms.

Discounting is applied in line with the suggested Green Book[15] approach. Productivity and healthcare values use the standard Green Book discount schedule because they represent economic output and resource costs. Welfare values use the Green Book health discount rate because they represent health and life effects. This distinction ensures that monetary values are comparable across time while respecting the different nature of the valuation channels.

2.4 Evidence hierarchy and uncertainty

The modelling in this report brings together evidence from air quality modelling, epidemiology, public health data and economic valuation. The strength of this evidence varies across pollutants, health endpoints and valuation channels. To reflect this, the analysis distinguishes between impacts that are quantified in the central model, impacts that are quantified but interpreted more cautiously, and wider impacts that are discussed qualitatively only.

This evidence hierarchy is important for interpreting the results. It allows the report to include a broad view of the potential benefits of cleaner air, while avoiding overclaiming where the evidence base is less mature or where robust valuation is not currently possible.

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[15] HM Treasury (2026) ***The Green Book: UK Government Guidance on Appraisal***

Quantified impacts

The central quantified impacts underpin this report's headline findings and are those where there is sufficient evidence to link changes in pollution exposure to health and economic co-benefits. This category includes the main modelled pathways from $PM_{2.5}$ and NO_2 exposure to physical health outcomes, such as avoided mortality, life years gained, selected morbidity endpoints and hospital admissions. These outcomes are then valued where a defensible productivity, healthcare or welfare valuation method is available. However, even within this category, the outputs should be interpreted as estimates rather than precise forecasts. Results depend on the chosen CRFs, baseline rates, lag assumptions, exposure modelling and valuation parameters.

Partially evidenced impacts

Some impacts have a credible evidence base but are subject to greater uncertainty. These may be included in sensitivity analysis, valued using additional assumptions, or interpreted more cautiously in the results. The rationale behind this decision is explained in step 7 of section 2.2. For these pathways, health impacts are estimated with economic benefits presented through sensitivity analysis in the appendix. These impacts are useful because they indicate the wider potential scale of air quality co-benefits. However, they should not be given the same interpretive weight as better-established core pathways.

Qualitative evidence only

A third category includes impacts where the evidence suggests there may be important benefits, but where the relationship cannot be robustly quantified or monetised within the scope of this study. This includes outcomes such as black carbon-specific health effects, long-term educational impacts from reduced school absence, ecosystem benefits, building and materials damage, some wider healthcare costs, some presenteeism effects and potential emerging impacts linked to future energy demand. These impacts are discussed qualitatively in Section 6 because they are relevant for policy and for understanding wider air quality co-benefits and risks. This evidence underlines how the headline figures in this study represent a significant but partial estimate of the air quality co-benefits associated with achieving the CCC's balanced pathway in our selected sectors.

Overall, the evidence hierarchy supports a cautious interpretation of the findings. The central results provide a transparent and evidence-based estimate of quantifiable air quality co-benefits. The partially evidenced and qualitative impacts indicate that the full benefits of cleaner air are likely to be wider than the central estimates alone.

3. Concentration-response functions

This section sets out the concentration-response functions (CRFs) that were used for each health outcome and how they are applied.

3.1 Selected CRFs

The CRFs were taken from existing literature using those recommended by COMEAP (2022)[16] or in alternative studies such as Walton et al. (2025)[17] or the CAF/Imperial report[18]. Where CRFs for association with both NO_2 and $PM_{2.5}$ were available, we estimate impacts using both and use the CRF which results in the largest impact. This is to avoid double counting. In Table A1, outcomes in bold are included in our core analysis with the rest included as sensitivity health outcomes as guided by COMEAP (2022).

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[16] COMEAP (2022**)** ***Summary of COMEAP recommendations for the quantification of health effects associated with air pollutants*** (2022)
[17] Walton et al (2025) ***Health and associated economic benefits of reduced air pollution and increased physical activity from climate change policies in the UK***
[18] Dajnak et al (2022) ***Pathway to WHO: achieving clean air in the UK***

Table A1: Concentration-response functions by health outcome

Health outcome	Pollutant	CRF (per 10 µg/m³ increase*)	Source
All-cause mortality	**NO_2**	**RR 1.023 (95% CI: 1.008, 1.037)**	**Chen and Hoek (2020)[19]**
IHD (coronary heart disease)	**$PM_{2.5}$**	**RR 1.07 (95% CI: 0.99, 1.16)**	**COMEAP (2021)[20]**
Stroke (Cerebrovascular disease)	**$PM_{2.5}$**	**RR 1.11 (95% CI: 0.99, 1.25)**	
Respiratory hospital admissions[21] – NO_2	**NO_2**	**0.57% (0.33%, 0.82%)**	**Mills et al (2015)[22]**
Cardiovascular hospital admissions – NO_2	**NO_2**	**0.66% (0.32%, 1.01%)**	
Adult asthma – NO_2	NO_2	RR 1.10 (95% CI: 1.01, 1.21)	Forastiere et al, 2024[23]
Child asthma – NO_2	NO_2	RR 1.10(95% CI: 1.05, 1.18)	
COPD – $PM_{2.5}$	$PM_{2.5}$	RR 1.18 (95% CI: 1.13, 1.23)	Park et al (2021)[24]
Dementia – $PM_{2.5}$	$PM_{2.5}$	RR 1.48 (95% CI: 1.23, 1.78)	Cheng et al (2022)[25] - adjusted by Forastiere et al (2024)
Diabetes – $PM_{2.5}$	$PM_{2.5}$	RR 1.1 (95% CI: 1.03, 1.18)	Yang et al (2020)[26] revised by Forastiere et al (2024)
School days – $PM_{2.5}$	$PM_{2.5}$	1.73% (95% CI: 0.56%, 2.9%)	Orellano et al (2023)**[27]

*Annual mean except for hospital admissions (24h mean)

** Implemented as a percentage following the way it is applied in Walton et al ((2025)

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[19] Chen, J. and Hoek, G. (2020) ***Long-term exposure to PM2.5 and mortality: a systematic review and meta-analysis***

[20] COMEAP (2021), ***Advice on health evidence relevant to setting PM2.5*** **targets**

[21] Hospital admissions CRFs are technically derived from short-term (24h mean) exposure data. We assume the annual mean concentration change data are a reasonable proxy for 24h mean concentrations.

[22] Mills, I. et al., (2015) ***Quantitative systematic review of the associations between short-term exposure to nitrogen dioxide and mortality and hospital admissions***

[23] Forastiere, F. et al. (2024) ***Choices of morbidity outcomes and concentration–response functions for health risk assessment of long-term exposure to air pollution***

[24] Park, J. et al. (2021) ***Impact of long-term exposure to ambient air pollution on the incidence of chronic obstructive pulmonary disease: A systematic review and meta-analysis***

[25] Cheng, S. et al., (2022) ***Long-term particulate matter 2.5 exposure and dementia: a systematic review and meta-analysis***

[26] Yang, B., et al. (2020) ***Ambient air pollution and diabetes: A systematic review and meta-analysis***

[27] Orellano, P. et al. (2023) ***Effects of air pollution on restricted activity days: systematic review and meta-analysis***

3.2 Application of CRFs

There are two types of CRFs in the above table. Those reported as relative risks (RR) and those reported as percentage changes. This refers to what the CRF value suggests the health impact for a given change in pollutant concentration is.

For CRFs reported as relative risks (RR), the model first converts the published risk estimate into a log-linear coefficient:

$$\beta = \frac{\log\left(RR\ per\ 10\frac{\mu g}{m^3}\right)}{10}$$

The model then applies this coefficient to the concentration change compared to the baseline and converts the resulting risk change into an attributable fraction (AF):

$$AF = 1 - \frac{1}{\beta \times \Delta concentration}$$

The unlagged avoided cases for each year are then calculated as:

Unlagged avoided cases = baseline cases × attributable fraction

For endpoints reported as percentage changes, the model does not use the log transformation. Instead, the published percentage change is scaled directly to the modelled concentration change:

Unlagged avoided cases = baseline cases × percentage change × concentration change

This distinction is important because relative risks are multiplicative, while percentage-change CRFs are already expressed as a proportional change in the outcome per pollutant increment.

4. Key data sources and assumptions

This section outlines the key data sources, methods and assumptions for calculating the baseline rates and productivity valuation.

4.1 Baseline rates

Baseline rates include both incidence rates and prevalence rates used to calculate the baseline number of cases for each age band and year in the model. This calculation is set out in Section 2.2.4. Table A2 below outlines which health endpoints have mortality, incidence and prevalence rates as well as the sources used to derive these rates and key assumptions made.

Table A2: Baseline rate sources and assumptions by health outcome

Health outcome	Baseline rate types	Sources	Key assumptions
All-cause mortality	Age-specific mortality rate	ONS (2026[28])	Life-years gained estimated using age-band midpoints. England and Wales data used as a proxy for the UK
IHD (coronary heart disease)	Age-specific incidence rate and prevalence rate	Conrad et al. (2024)[29] British Heart Foundation (2026)[30]	UK prevalence distributed across age bands using the most recent England age profile; flat rates applied within wider bands. Same sources and methods are used for IHD and stroke baseline rates.
Stroke (cerebrovascular disease)			

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[28] ONS (2026) ***Mortality rates (qx), principal projection, England and Wales***

[29] Conrad, N. et al. (2024) ***Trends in cardiovascular disease incidence among 22 million people in the UK over 20 years: population based study***

[30] British Heart Foundation (2026) ***Cardiovascular Disease Statistics 2026***

Health outcome	**Baseline rate types**	**Sources**	**Key assumptions**
Respiratory hospital admissions	Age-specific hospital admission rate.	NHS England (2024)[31]	Derived from English NHS admissions data, using respiratory and cardiovascular ICD-10 codes, as a UK proxy, assuming the England age profile is broadly representative.
Cardiovascular hospital admissions			
Adult asthma	Age-specific incidence rate and prevalence rate.	Whittaker et al. (2025)[32]	UK country rates weighted by population. Total incidence distributed across age bands using the age profile of asthma hospital episodes as a proxy, which is uncertain as it reflects more severe/treated cases. The 15–19 band is apportioned 3/5 to child and 2/5 to adult.
Child asthma			
COPD	Age-specific incidence rate and prevalence rate.	Whittaker et al. (2025)[33] Stone et al. (2023)[34]	Incidence applied to the at-risk population aged 40+, with country rates weighted by population. England used as a UK proxy.; prevalence applied as flat rates across age bands.

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[31] NHS England (2024) ***Hospital Admitted Patient Care Activity, 2023-24***

[32] Whittaker et al. (2025) ***Incidence and prevalence of asthma, chronic obstructive pulmonary disease and interstitial lung disease between 2004 and 2023: harmonised analyses of longitudinal cohorts across England, Wales, South-East Scotland and Northern Ireland***

[33] Whittaker et al. (2025) ibid.

[34] Stone et al. (2023) ***Prevalence of Chronic Obstructive Pulmonary Disease in England from 2000 to 2019*** (2023)

Health outcome	Baseline rate types	Sources	Key assumptions
Dementia	Age-specific incidence rate and prevalence rate.	Matthews et al. (2016)[35] Matthews et al. (2013)[36]	Incidence and prevalence drawn from the same UK cohort study, in five-year bands from 65+.
Diabetes	Age-specific incidence rate and prevalence rate.	Pal et al. (2021)[37] ONS (2024)[38]	England used as a UK proxy. Prevalence based on a measure that includes undiagnosed cases, applied as flat rates within available age bands.
School days / school absences	Baseline school days lost per child (overall absence rate).	DfE (2026)[39] Welsh Government (2025)[40] Scottish Government (2025)[41] NISRA (2026)[42]	Population-weighted overall absence rate across the four UK nations, giving a baseline of about 13.4 days lost per child. Applied to the 5–9 and 10–14 age bands.

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[35] Matthews et al. (2016) ***A two decade dementia incidence comparison from the Cognitive Function and Ageing Studies I and II*** (2016). Available from: **https://pmc.ncbi.nlm.nih.gov/articles/PMC4838896/**

[36] Matthews et al. (2013) ***A two-decade comparison of prevalence of dementia in individuals aged 65 years and older from three geographical areas of England: results of the Cognitive Function and Ageing Study I and II***

[37] Pal et al. (2021) ***Time trends in the incidence of clinically diagnosed type 2 diabetes and pre-diabetes in the UK 2009–2018: a retrospective cohort study***

[38] ONS (2024) ***Risk factors for pre-diabetes and undiagnosed type 2 diabetes in England***

[39] Department for Education (2026) ***Pupil absence in schools in England***

[40] Welsh Government (2025) ***Attendance and absence from schools: September 2024 to August 2025***

[41] Scottish Government (2025) ***School attendance, absence and exclusions statistics 2024-25***

[42] NISRA (2026) ***Attendance at grant aided primary, post primary and special schools 2024/25***

4.2 Lag assumptions

Lag assumptions are sourced from supplementary material of Walton et al's (2024)[43] study.

Table A3: Lag structures by health outcome

Health outcome	Lag structure
All-cause mortality	US EPA Lag: 30% in year 0, 50% in years 1-4 and 20% in years 5-19
IHD (coronary heart disease)	EPA-style lag: 38% in first year and 15.5% from years two to 5
Stroke (Cerebrovascular disease)	EPA-style lag: 38% in first year and 15.5% from years two to 5
Respiratory hospital admissions	No long-term lag; treated as short-term / acute impact
Cardiovascular hospital admissions	No long-term lag; treated as short-term / acute impact
Adult asthma	No lag applied
Child asthma	No lag applied
COPD	Lag spread evenly over 5-10 years
Dementia	Lag spread over 4-8 years
Diabetes	Lag spread over 4-8 years
School days	No lag; treated as annual flow endpoint

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[43] Walton et al (2025) ***Health and associated economic benefits of reduced air pollution and increased physical activity from climate change policies in the UK***

4.3 Productivity valuation

The channel through which an avoided health impact results in a productivity uplift is dependent on the labour market impact. Since the labour market impact varies depending on the health outcome, we individually model the labour market impact to estimate the working days gained and multiply this by GVA per worker per day to estimate the additional GVA generated. For avoided mortality, this is a relatively simple calculation explained in Section 2.3.1. Table A4 sets out the productivity valuation method for each morbidity health outcome alongside the source(s) used to estimate the working days gained per avoided case.

Table A4: Productivity valuation method by morbidity health outcome

Health outcome	Productivity valuation method	Sources
IHD (coronary heart disease)	Time taken to return to work per case.	Stendardo et al. (2018)[44]
Stroke (Cerebrovascular disease)	Time taken to return to work / labour-force loss per case. Combines days lost for those returning early with the share who return later or not at all. Non-returners productivity loss capped at 5 years.	Radford et al. (2020)[45] Edward et al. (2017)[46]
Adult asthma	Annual work-loss stream per case (recurring absenteeism cost).	Dierick et al. (2021)[47]
Child asthma		

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[44] Stendardo et al. (2018) ***Predicting return to work after acute myocardial infarction: Socio-occupational factors overcome clinical conditions***

[45] Radford et al. (2020) ***Describing return to work after stroke: a feasibility trial of 12-month outcomes***

[46] Edwards et al. (2017) ***Return to work after young stroke: a systematic review***

[47] Dierick et al. (2021) ***Work absence in patients with asthma and/or COPD: a population-based study***

Health outcome	Productivity valuation method	Sources
COPD	Annual work-loss stream applied until retirement age with an early-retirement channel.	Erdal et al. (2022)[48] Fletcher et al (2011)[49]
Dementia – $PM_{2.5}$	Informal caregiver labour-market effects: as incident cases mostly fall beyond working age, loss is valued through employed carers' reduced output (~0.45 employed carers affected per case).	Goren et al. (2016)[50]
Diabetes – $PM_{2.5}$	Annual work-loss stream per case due to informal caregiving	Park et al. (2022)[51]
School days - $PM_{2.5}$	Parental labour-market effects: each avoided school day lost is valued as productive time recovered by a working parent/carer	ONS (2026)[52]

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[48] Erdal et al. (2022), ***Productivity losses in chronic obstructive pulmonary disease: a population-based survey*** (2022)

[49] Fletcher et al. (2011) ***COPD uncovered: an international survey on the impact of chronic obstructive pulmonary disease [COPD] on a working age population***

[50] Goren et al. (2016) ***Impact of caring for persons with Alzheimer’s disease or dementia on caregivers’ health outcomes: findings from a community based survey in Japan***

[51] Park et al. (2022) ***Productivity Loss and Medical Costs Associated With Type 2 Diabetes Among Employees Aged 18–64 Years With Large Employer-Sponsored Insurance***

[52] ONS (2026), ***Children in households by combined economic activity status of household members*** (2026)

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