Health impacts of air pollution:

Modelling the health impact of air pollution in Lambeth and Southwark

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Commissioned by

Guy's and St Thomas' Charity

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Glossary

Terms	Meaning
Ambitious	A modelled scenario wherein NO_2 levels stay as low as during the COVID-19 lockdown period for the rest of 2020.
Attributable	Can be attributed to air pollution (NO_2 or $PM_{2.5}$). Attributable incidence and costs are calculated by subtracting the outcomes of a hypothetical 100% reduction in anthropogenic air pollution scenario from the outcomes of the baseline scenario.
Baseline	This refers to the 'steady state' of the risk factor assuming no change from current exposure levels. However, changes in the population (e.g. ageing) occur.
Conservative	A modelled scenario wherein NO_2 levels return to pre-lockdown levels after a month of the COVID-19 lockdown.
COMEAP	Committee on the Medical Effects of Air Pollutants. An expert committee that provides advice to the UK Government on the health effects of air pollutants.
Cumulative incidence	Successive additions of annual cases of a disease. For example, the cumulative incidence between 2016 and 2025 would be the sum of the all new disease cases in each of those years.
Distribution	The possible values for a variable and how frequently it occurs. In the current context, the frequency of outcomes (or diseases) in the sample population. The probability distribution describes all the possible values and likelihoods that a variable can take within a specified range.
Dose-response	Also referred to as exposure response. Describes the change in health effect on an individual caused by a change in levels of exposure to a stressor (in this case an air pollutant) after a certain exposure time.
$\mu g/m^3$	Microgramme per metres cubed. This is the unit used to measure concentration of a pollutant in the air. Microgramme is a unit of mass equal to one millionth (1×10^{-6}) of a gram.
Microsimulation	A computer model that replicates real life as closely as possible using national population and disease statistics. It can test the long-term impact of a range of different scenarios on future outcomes.
Incidence	The occurrence of new cases of the disease – not to be confused with prevalence.
NO_2	Nitrogen dioxide is a noxious gas. It is a local, primary traffic pollutant and a biologically relevant indicator of exposure to traffic-related air pollution with known health effects.
$PM_{2.5}$	Fine particulate matter. It is an urban background pollutant which often disperses over a large area. PM consists of finely divided solids or liquids such as dust, fly ash, soot, smoke, aerosols, fumes, mists, and condensing vapours that can be suspended in the air.
Prevalence	This is the total number of cases of a disease in a particular population. This indicates how widespread the disease is.
Probability	This is the chance of a disease occurring. Probability always lies within 0 and 1.

Regression	A statistical technique for estimating the relationships between variables.

Key Findings

This study estimated the long-term health impacts (excluding disease exacerbations) of exposure to air pollution in Lambeth and Southwark from 2020 to 2024. Between 2020 and 2024, the total number of new disease cases attributable to NO_2 and $PM_{2.5}$ in Lambeth for diseases with an established evidence base is estimated to be 2,125. If including diseases with an emerging evidence base, this would rise to 4,730 cases. In Southwark in this same time period, the estimated new number of diseases attributable to NO_2 and $PM_{2.5}$ is 1,620 among diseases in the established evidence base, and 5,130 new cases when combined with emerging evidence.

Key findings from this study include:

- For NO_2 the largest number of cumulative cases of new disease avoided by 2024 would be 1,106 under the borough-specific COVID-19 ambitious scenario where NO_2 is reduced by the same percentage as during the COVID lockdown for each borough. Of these cases, 155 are for child asthma, which has an established evidence base. The total health costs avoided by Lambeth and Southwark under this scenario would be £58,180 for child asthma alone and a total of £4,520,940 by 2024 when all evidence is included.

- If both Lambeth and Southwark met the World Health Organization targets for $PM_{2.5}$ (10 µg/m^3 annual mean) by 2024, an estimated total of 2,821 disease cases could be avoided, resulting in a reduction of £14,402,406 in cumulative healthcare costs (emerging and established evidence). For those diseases with an established evidence base only, we would see a reduction in 1,184 cases resulting in a reduction of £3,851,374 in cumulative healthcare costs across both boroughs.

- A savings to the NHS of £14,402,406 if both Lambeth and Southwark met the World Health Organization targets for $PM_{2.5}$, would be equivalent to annual salaries for 86 nurses over 5 years.[1]

- The total costs avoided if Lambeth and Southwark reduced their air pollution (for NO_2 and $PM_{2.5}$ combined) to that of Havering (lowest London levels of NO_2 and $PM_{2.5}$) would be £6,713,061. Of this, £917,739 would be from diseases with the most established evidence base.

[1] This based on the Royal College of Nursing's 2018 calculation of £33,384 average annual pay for nurses.

Executive Summary

Background

Air pollution has an adverse effect on people's health, both in the long- and short-term (1–7). The Guy's and St Thomas' Charity commissioned this project to quantify the impact of air pollution on the health of the populations of the London boroughs of Lambeth and Southwark. In these areas, the majority of air pollution comes from road traffic, but also from heating and construction emissions (8,9). A number of policies have been put in place London-wide to reduce air pollution emissions and therefore prevent related impacts (for example ULEZ and BreatheLondon), as well as locally in Lambeth and Southwark (8,9). The findings of this study build on the existing body of knowledge on this topic by quantifying the impact of specific scenarios on air-pollution related health burden (10–12).

Aims

- Quantify the current annual morbidity, including disease incidence and NHS costs, attributable to air pollution in Lambeth and Southwark.
- Quantify the long-term morbidity impacts, including reductions in disease incidence, NHS cost savings, and quality-adjusted life years (QALYs) gained, over the next 5 years' time if Southwark and Lambeth were to meet the limits set by the WHO for $PM_{2.5}$.
- Quantify the long-term morbidity impacts over the next 5 years' time in a 'best case scenario' where Lambeth and Southwark reach the NO_2 and $PM_{2.5}$ levels of the local authority with the lowest NO_2 and $PM_{2.5}$ levels in London (Havering).
- Quantify the long-term morbidity impacts over the next 5 years' time if Southwark and Lambeth reduce their NO_2 and $PM_{2.5}$ levels by the same percentage as it has been reduced in the COVID lockdown.

Key results

- This study found that between 2020 and 2024, the total number of new disease cases attributable to NO_2 and $PM_{2.5}$ in Lambeth for diseases with an established evidence base is estimated to be 2,125, out of a total 4,730 cases when combined with emerging evidence. In Southwark in this same time period the estimated new number of diseases attributable to NO_2 and $PM_{2.5}$ is 1,620 among diseases in the established evidence base, out of a total 5,130 new cases when combined with emerging evidence.
- For NO_2 the largest number of cumulative cases – established and emerging evidence – of new disease avoided by 2024 would be 1,106 under the borough specific COVID-19 ambitious scenario where NO_2 is reduced by the same percentage as during the COVID lockdown for the rest of 2020. Of these, 155 are for child asthma which has an established evidence base.

- For $PM_{2.5}$, if both boroughs met the WHO targets by 2024 an estimated 2,821 cases of disease could be avoided – 1,184 of those are from diseases with an established evidence base.

- The total costs avoided if Lambeth and Southwark reduced their air pollution to that of Havering would be £6,713,061 (for NO_2 and $PM_{2.5}$ combined) – £3,851,374 of which would be from diseases with an established evidence base.

- For maintaining NO_2 levels reached during the COVID-19 lockdown for the rest of 2020 (ambitious scenario), the total costs avoided by Lambeth and Southwark would be £58,180 for child asthma, for which there is an established evidence base, and £4,520,940 in total by 2024 when combined with emerging evidence.

- The total cost avoided if Lambeth and Southwark were to reach the WHO targets for $PM_{2.5}$ would be £14,402,406, £3,851,374 of which from those diseases with an established evidence base.

Conclusion

Borough-specific and pan-London actions are required alongside local and national legislation and policy if larger health benefits and cost savings are to be made. It is clear that measures to maintain levels of NO_2 emissions found during the COVID-19 lockdown and to meet the WHO levels for $PM_{2.5}$ would have significant health and cost benefits for both Lambeth and Southwark.

Introduction

Extensive evidence has demonstrated that short-term and long-term exposure to air pollution has an adverse effect on people's health (1–7). Short-term exposure to air pollutants have been linked to increased hospitalisations and exacerbations in diseases including for example, Chronic Obstructive Pulmonary Disease (COPD) and asthma. Long-term exposure to air pollutants are related to the development of diseases including coronary heart disease (CHD), lung cancer and stroke. The main pollutants that impact health are particulate matter (PM) and Nitrogen dioxide (NO_2).

In Lambeth and Southwark, the majority of air pollution comes from road traffic, but also from heating and construction emissions (13,14). The BreatheLondon resource tracks and maps the major hot spots and sources of air pollution within London boroughs, and allows for up-to-date information about the causes of air pollution in Lambeth and Southwark (15).

A number of policies and initiatives have been put in place in London at large to reduce air pollution emissions and therefore prevent related impacts (for example the Ultra Low Emissions Zone (ULEZ) and BreatheLondon). Lambeth's local plan includes the commitment to encourage walking and cycling to reduce car use through a sustainable travel development plan (8). Southwark's Core Strategy calls for improving opportunities for walking and cycling to reduce car usage and the borough plans to release their New Southwark Plan later this year (9). All of these policies are in line with the broader concept of Health in All Policies, which are policies - regardless of sector - that include health outcome measures (16).

Furthermore, the COVID-19 pandemic has introduced a new dynamic to the air pollution discourse. Evidence indicates that co-morbidities – having more than one disease at a time – in particular those which affect the heart, lungs and metabolic system, increase the risk associated with COVID-19. All of these co-morbidities have been demonstrated to be attributable to air pollution (17–21). Lockdown measures in the UK and elsewhere in the world have seen a marked decrease in NO_2 in particular and with this has come some evidence to suggest that individuals are rethinking their transportation options (i.e. staying away from private vehicle use now that they have spent a period only walking and cycling), which may shape the policy landscape going forward (22).

NO_2 is a local, primary traffic pollutant which can act as a biologically relevant indicator of exposure to air pollution with known health effects. Fine particulate matter, $PM_{2.5}$, is largely an urban pollutant that originates from vehicle exhaust, tyre and brake wear, road abrasion, and construction. Additionally, $PM_{2.5}$ can come from heat and power sources such as wood burning stoves. $PM_{2.5}$ comprises a mixture of primary and secondary particles, which disperse over a large area. In this study each pollutant has been simulated independently. Adjustments have been made to account for the overlap between each pollutant, in line with recommendations from the Committee on the Medical Effects of Air Pollutants (COMEAP).

NO_2 and $PM_{2.5}$ are named as an attributing factor for a number of non-communicable diseases (NCDs). There is established evidence that air pollution is a factor in the causation of a number of diseases including coronary heart disease (CHD), stroke, asthma, and lung cancer. Further to the established evidence base, there is an emerging evidence base where the association with air pollution exposure and the onset of disease is weaker, for example Chronic Obstructive Pulmonary Disease (COPD). In addition to COPD, there is also an emerging evidence base on the relationship between air pollution and the onset of diabetes, dementia and low birth-weight among other NCDs. These along with COPD are all considered in the emerging or weaker evidence category for this study, as explained further in the results. There is a separate evidence base on the impacts of air quality on exacerbations of pre-existing cardiovascular and respiratory disease, however this study did not model impacts from disease exacerbation.

This study uses a mathematical model to quantify the health and economic impacts of both NO_2 and $PM_{2.5}$ under different scenarios. The findings of this study build on the existing body of knowledge on this topic, including Public Health England's 'Estimation of costs to the NHS and social care due to the health impacts of air pollution' (2018); Walton et al. (2019) 'Health impact assessment of air pollution on asthma in London'; and Webber et al. (2020) 'Modelling the long-term health impacts of changing exposure to NO_2 and $PM_{2.5}$ in London' (6,23,24).

HealthLumen's computer simulation model (25) was utilised to evaluate the following scenarios:

1. Where Lambeth and Southwark meet the WHO limits for $PM_{2.5}$ (10 µg/m^3 annual mean).
2. Where Lambeth and Southwark reach the NO_2 and $PM_{2.5}$ levels of those in Havering: the local London authority with the lowest NO_2 and $PM_{2.5}$ levels. This is referred to as the 'low pollution 'or 'best case' scenario.
3. Where Lambeth and Southwark reduce their NO_2 levels by the same percentage as they have been reduced during the COVID lockdown. This group of scenarios comprises the 'COVID-19 what-if' scenarios.

Methods

The detailed statistical methods used for this study have been described previously (23,25) and are provided in **Appendix 1**. A summary is provided below.

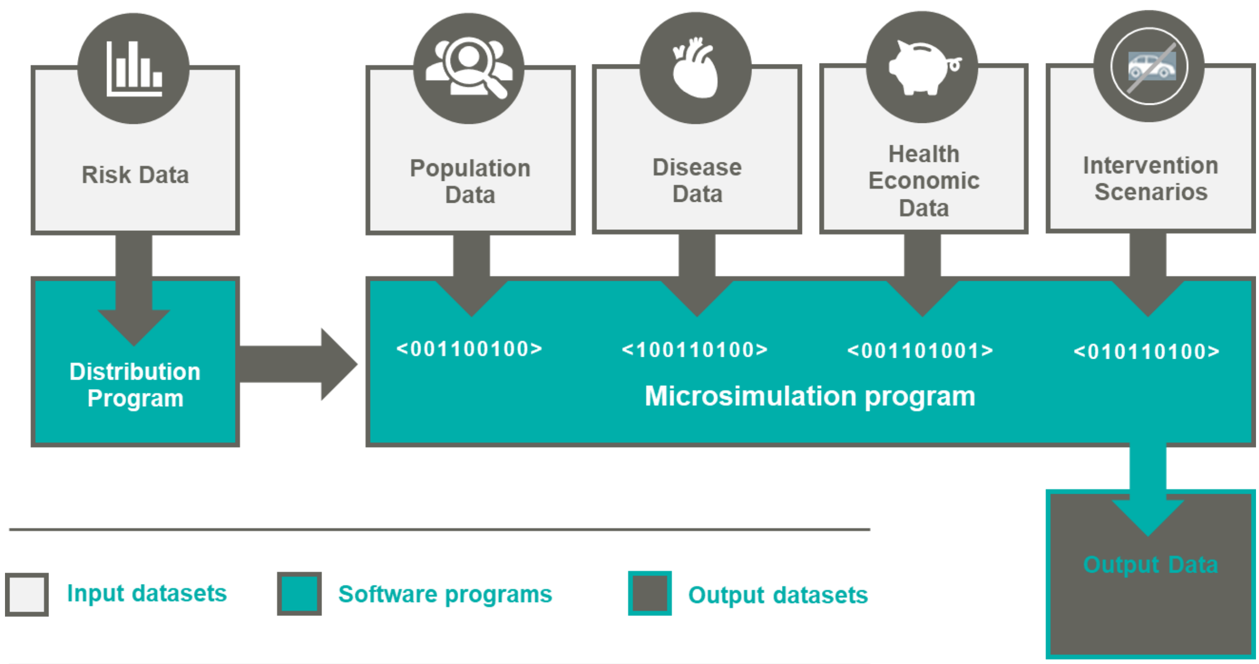
Microsimulation model

HealthLumen's microsimulation model simulates a virtual Lambeth and Southwark population based on known population statistics, births, and deaths. Each individual has an age, sex and air pollution exposure value (NO_2 or $PM_{2.5}$). This exposure gives each individual a particular risk of contracting, dying from or surviving related NCDs.

This simulation utilises geography-specific data on air pollution exposure extrapolated by age and sex, making use of disease data from the literature and population data collected from the Greater London Authority (GLA), a publicly available database. The microsimulation method is an advanced method for modelling NCDs because of its capacity to simulate entire populations at an individual level over time. Further technical detail can be found in previous reports (23).

Figure 1 provides a schematic illustration of the microsimulation model used.

Figure 1. Schematic illustration of the microsimulation model used in the analyses



Data inputs

The model requires data inputs relating to population and air pollution exposure. **Table 1** summarises the data sources included in the model.

Table 1. References used for the study

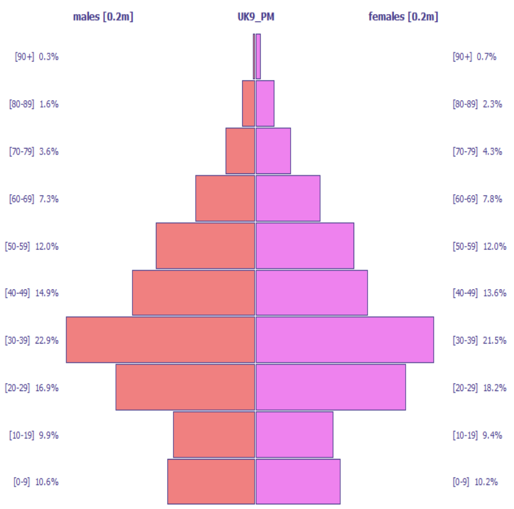
Parameter	Reference/source
Population data	Greater London Authority
NO_2 or $PM_{2.5}$ exposure	Transport for London
Epidemiological data	Literature review. National level disease data by age and sex.
NHS costs	Literature review. Annual cost per disease case
Utility weights	Literature review

Population data

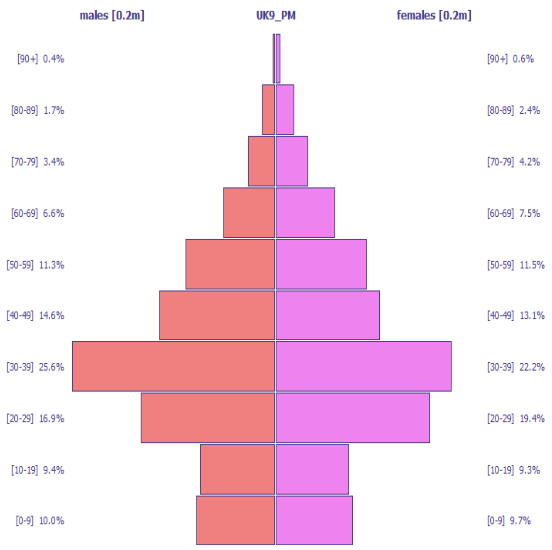
Population projections by age and sex are provided by the GLA and are publicly available (https://data.london.gov.uk/dataset/projections). Births by mother's age and total fertility rate by London borough were taken from the Office of National Statistics database 2018. The age-sex population distribution for Lambeth and Southwark are illustrated in **Figure 2**.

Figure 2. Population distributions by age and sex in Lambeth and Southwark respectively for year 2020

Lambeth



Southwark



Concentration data

NO_2 and $PM_{2.5}$ concentration data for the baseline scenario was taken from 2016 concentrations across London, interpolated from the baseline 2013 and forecast base 2020 concentrations published by the GLA as part of the London Atmospheric Emissions Inventory (LAEI) 2013 update (26). The LAEI is a comprehensive inventory of all air pollutant emission sources across London, updated on a regular basis. It includes both total emissions by source type, as well as ground level concentrations based on detailed dispersion modelling of emissions.

All concentrations, originally available across London at a 20m resolution grid level, were averaged at Output Area (OA) level before being combined with population data to calculate population exposure at Borough level for each of the years required by the microsimulation model to determine health impacts.

Disease data

Asthma, Chronic Obstructive Pulmonary Disease (COPD), Coronary Heart Disease (CHD), stroke, type 2 diabetes, lung cancer, low birth weight, and dementia data were included in the model.

The strength of evidence for each disease varies as described in **Table 2**.

Incidence (or prevalence), survival, mortality, and relative risk data were extracted from the literature as well as cost data. With the exception of lung cancer, no data was found for survival, so this was computed using WHO DisMod II equations and the existing epidemiological data. Annual cost-per-case to the NHS were found from the literature for each disease, with the exception of low-birth weight. The impact of low birthweight is heterogeneous and as such is a risk factor for other diseases, making it too complex to cost with any accurately. Therefore, only epidemiological outputs are provided for this condition.

The data references can be found in **Appendix 2**. Dose-response estimates for NO_2 were adjusted and reduced by 60% to take account of overlaps between risks based on COMEAP recommendations for mortality (27).

Table 2. Summary table of established and emerging evidence for the health impacts of $PM_{2.5}$ and NO_2

	Long term exposure to $PM_{2.5}$	Long term exposure to NO_2
Established evidence for an association	Coronary heart disease Stroke Lung cancer Asthma (children)	Asthma (children)
Evidence less certain or emerging evidence of associations	Chronic Obstructive Pulmonary Disease (as chronic bronchitis)[2] Diabetes Low birth weight	Asthma (adults) Diabetes Lung cancer Low birth weight Dementia COPD

Costs and Utility weights

A literature review was carried out to find an annual NHS cost per case for each of the diseases of interest. Sensitivity analysis was carried out around the costs by running the models with a 1.5% discount rate and without. Discounted costs are presented in **Appendix 3**.

Utility weights were also collected from the literature for each disease. These were used to calculate Quality Adjusted Life Years (QALYs).

Scenarios

A number of scenarios were run in the model. These are described below:

- Baseline – a static (flat) trend from the current 2016 data point was run as the 'current status quo'.

[2] All input data are for COPD as a whole, except for PM2.5 relative risks which are available for chronic bronchitis only.

- Attributable cases – the number of cases attributable to air pollution was calculated by subtracting the number of cases under a 100% reduction in anthropogenic air pollution from the number of cases as a result of baseline that are caused by exposure.

- Meeting WHO limits for $PM_{2.5}$ (10 µg/m^3 annual mean).

- A low pollution / 'best case' scenario where Lambeth and Southwark reach the NO_2 and $PM_{2.5}$ levels of the local authority with the lowest NO_2 and $PM_{2.5}$ levels in London (Havering was chosen).

- A 'COVID-19 what-if' scenario in which Lambeth and Southwark reduce their NO_2 levels by the same percentage as it has been reduced during the COVID lockdown. There are different ways that this has been implemented (see **Appendix 1** for additional information):

  a. **Conservative assumption:** the NO_2 levels return to pre-lockdown levels after a month of lockdown: an annual **4% reduction** in NO_2 level in Lambeth for the year of 2020 was modelled. Similarly, for Southwark, a **2% reduction** in NO_2 for the year of 2020 was modelled. This was deemed conservative given that lockdown was in place for longer than a month.

  b. **Ambitious assumption**: the NO_2 levels stay as low as during the lockdown period for the rest of the year: a **34% reduction** in NO_2 level in both Lambeth for the year 2020 was assumed. Similarly, for Southwark, a **18% reduction** in NO_2 for the year of 2020 was assumed.

  c. **London scenarios:** an implementation of the conservative and ambitious scenarios, where instead of using borough-specific reductions, the average reduction in NO_2 in London during lockdown was assumed to be the reduction for both Lambeth and Southwark.

A summary of the COVID-19 scenarios modelled are presented in **Table 3**.

Table 3. COVID-19 scenarios modelled

Assumption	Local authority	Reduction by time period
Conservative Assumption(borough-specific)	Lambeth	NO_2 level reduced by 4% in 2020 using Lambeth reduction in NO_2 level
	Southwark	NO_2 level reduced by 2% in 2020 using Southwark reduction in NO_2 level
More ambitious Assumption (borough-specific)	Lambeth	NO_2 level reduced by 34% in 2020 using Lambeth reduction in NO_2 level
	Southwark	NO_2 level reduced by 18% in 2020 using Southwark reduction in NO_2 level
Conservative Assumption (London-wide)	Lambeth	NO_2 level reduced by 2% in 2020 using London reduction in NO_2 level
	Southwark	NO_2 level reduced by 2% in 2020 using London reduction in NO_2 level
	Lambeth	NO_2 level reduced by 21.5% in 2020 using London reduction in NO_2 level

More ambitious Assumption (London-wide)	Southwark	NO_2 level reduced by 21.5[3]% in 2020 using London reduction in NO_2 level

Note that studies have shown that levels of $PM_{2.5}$ increased during lockdown due to easterly winds, pollutants from northern Europe and more time spent cooking indoors (28), therefore $PM_{2.5}$ was not included in this scenario.

Outputs

Appendix 1 provides a detailed methodology of how each output is generated. In summary, the outputs are defined in the following ways:

Epidemiological outputs

Annual attributable incidence per total population over the simulation period/ New cases of disease attributable to air pollution: The number of new cases each year of disease attributable to air pollution per population. This reflects the difference in cases between baseline and if air pollution was reduced to non-anthropogenic levels.

Cumulative attributable incidence per total population over the simulation period/New cases of disease attributable to air pollution: The total number of new cases of disease attributable to air pollution per population.

Cumulative incidence per population over the simulation period / New cases of disease: The total number of new cases of disease, divided by the total number of people in the population in a given year, and accumulated over a specified period of the simulation from year 2020. Therefore, the cumulative number of incident cases represents a sum of all of the incident cases from the start of the simulation as a rate per population, by scenario.

Annual incidence avoided per population over the simulation period / New cases of disease avoided: The number of cases of disease avoided each year since the start year 2020.

Cumulative incidence avoided per population over the simulation period / New cases of disease avoided: The total number of incident cases of disease avoided since the start year 2020 as compared to baseline “no-change” scenario. A positive value represents the number of cases avoided.

Economic outputs

Cumulative NHS costs avoided: The total NHS cots avoided since the start of 2020 as compared to baseline “no-change” scenario.

Annual QALYs gained: The total QALYs gained each year since the start of 2020.

The confidence limits that accompany the sets of output data represent the accuracy of the microsimulation (stochastic or aleatoric uncertainty) as opposed to the confidence of the input data itself (parameter uncertainty). Errors around the input data were not available.

'Disease cases' refers to the diseases listed above only, not total of all possible disease cases. There are other diseases with emerging evidence of association with air pollution exposure that have not been included in this study including pneumonia, depression and neurological development in children. As a result, this may be a conservative estimate.

Note that costs are not included for low birth weight since the costs are frequently related to other diseases later in the child's life.

Results

This report presents the results for Lambeth and Southwark. Results from the microsimulation have been scaled to the respective population of each borough for that year, using projection estimates from the Greater London Authority. Note that unless otherwise stated, the results presented here are for disease where there is both established or emerging evidence available for NO_2 and $PM_{2.5}$. Additional analysis is presented in appendix 4.

Lambeth

NO_2 results for Lambeth

Lambeth disease cases attributable to air pollution

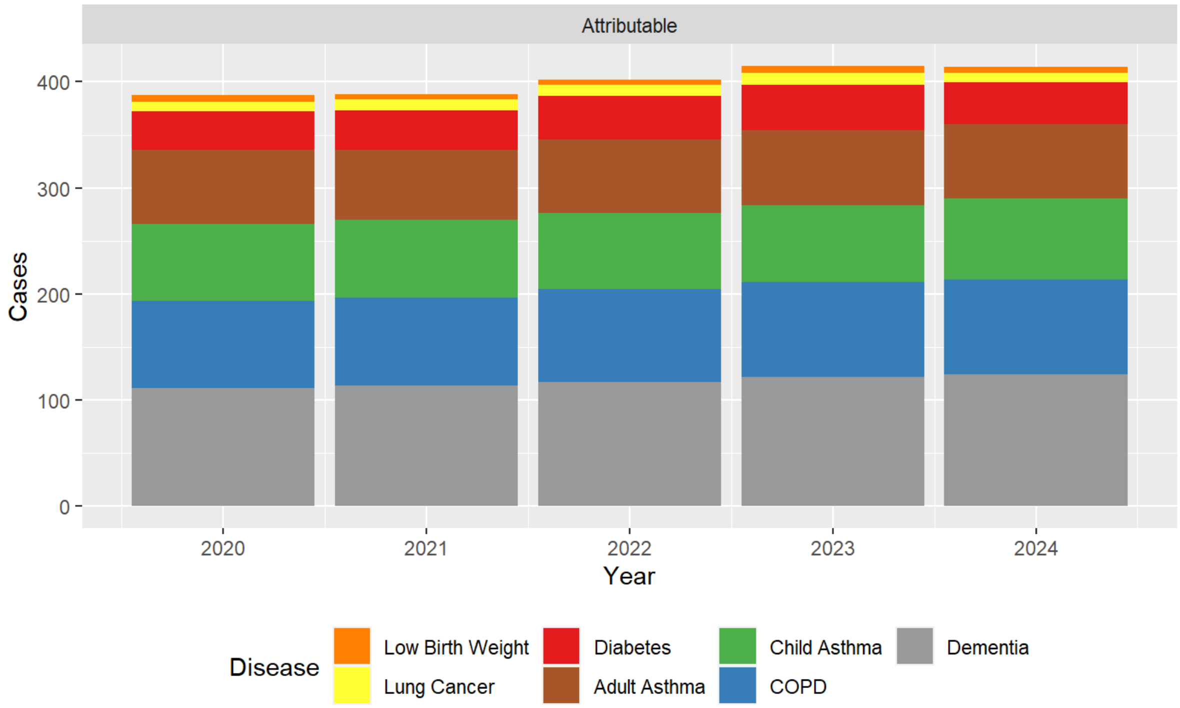
Annual incidence disease cases attributable

Table 4 and **Figure 3** show the total incidence of diseases related to NO_2. Between 2020 and 2024, the annual incidence of disease attributable to NO_2 in Lambeth is projected to be between 387 and 414, with dementia being the largest contributor with 111-124 new cases each year.

Table 4. Lambeth annual disease incidence attributable to NO_2

Year	Adult Asthma	Child Asthma	COPD	Dementia	Diabetes	Low Birth Weight	Lung Cancer	Total
2020	70 ± [5]	72 ± [4]	83 ± [4]	111 ± [5]	37 ± [7]	6 ± [3]	9 ± [3]	387 ± [12]
2021	67 ± [5]	73 ± [4]	83 ± [4]	114 ± [5]	36 ± [8]	5 ± [3]	11 ± [3]	388 ± [12]
2022	69 ± [5]	72 ± [4]	88 ± [4]	117 ± [5]	41 ± [7]	5 ± [3]	10 ± [3]	402 ± [12]
2023	71 ± [5]	73 ± [4]	89 ± [5]	121 ± [5]	43 ± [8]	6 ± [3]	11 ± [3]	415 ± [12]
2024	70 ± [5]	76 ± [4]	89 ± [5]	124 ± [5]	40 ± [8]	6 ± [3]	9 ± [3]	414 ± [12]

Figure 3. Annual disease incidence attributable to NO_2 by year in Lambeth



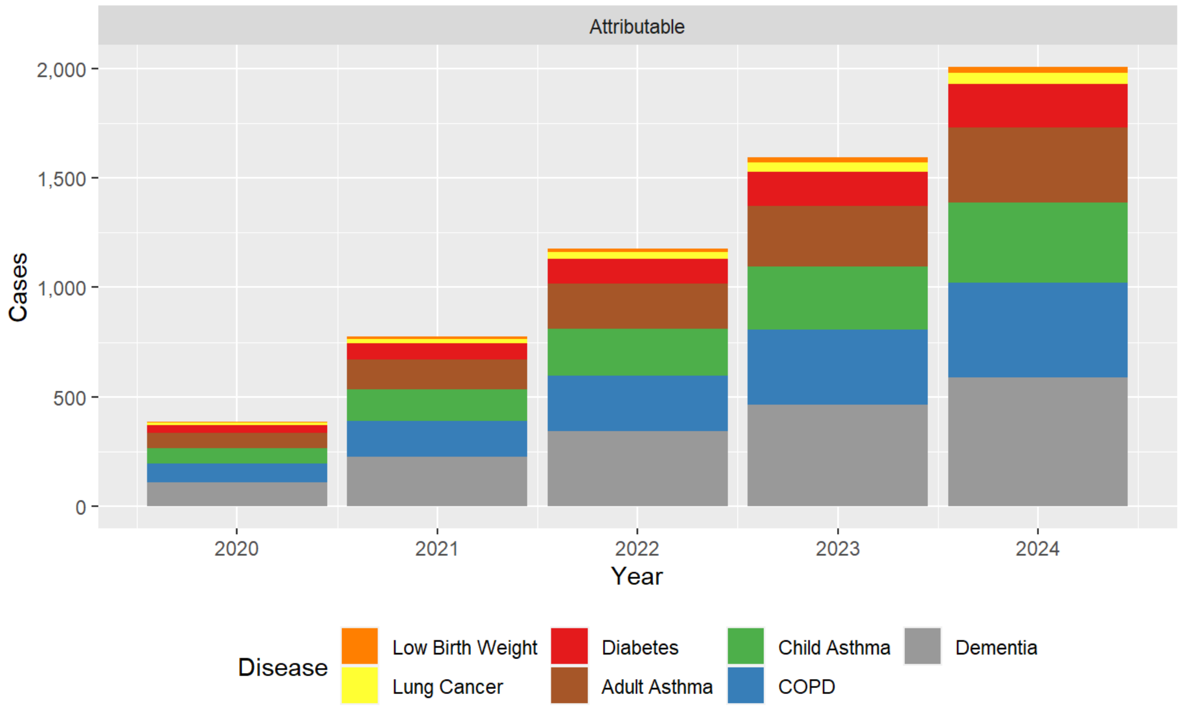
Cumulative incidence attributable

Table 5 and **Figure 4** show the total new cumulative cases of disease attributable to NO_2. By 2024 it is predicted there will be approximately 2,000 new disease cases attributable to NO_2 in Lambeth. Dementia is the largest contributor with 588 cumulative incidence cases expected by 2024.

Table 5. Lambeth cumulative disease incidence attributable to NO_2

Year	Adult Asthma	Child Asthma	COPD	Dementia	Diabetes	Low Birth Weight	Lung Cancer	Total
2020	70 ± [5]	72 ± [4]	83 ± [4]	111 ± [5]	37 ± [7]	6 ± [3]	9 ± [3]	387 ± [12]
2021	136 ± [7]	145 ± [6]	165 ± [6]	225 ± [6]	73 ± [11]	11 ± [4]	20 ± [4]	776 ± [18]
2022	206 ± [9]	217 ± [7]	253 ± [8]	342 ± [8]	114 ± [13]	16 ± [5]	30 ± [5]	1,178 ± [21]
2023	277 ± [10]	290 ± [8]	342 ± [9]	463 ± [9]	157 ± [15]	22 ± [5]	41 ± [5]	1,592 ± [25]
2024	346 ± [11]	366 ± [9]	432 ± [10]	588 ± [11]	196 ± [17]	28 ± [6]	50 ± [6]	2,006 ± [28]

Figure 4. Cumulative disease incidence attributable to NO_2 by year in Lambeth



Cumulative NHS costs attributable

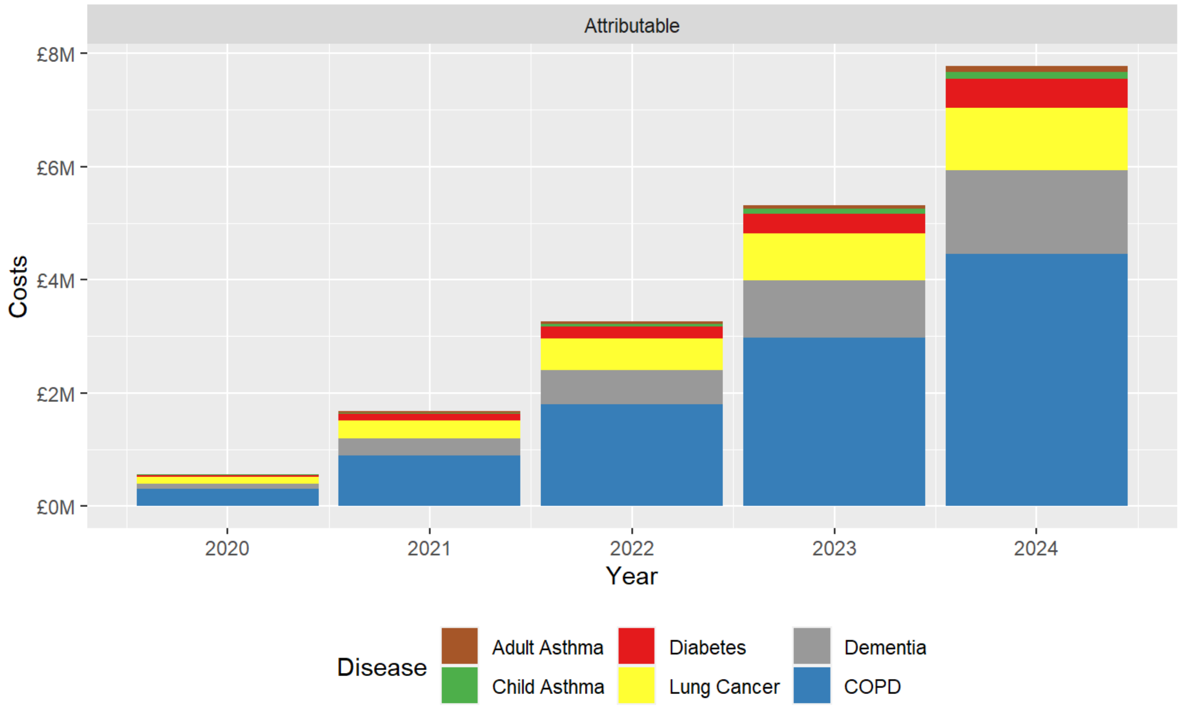
Table 6 and

Figure 5 show the total new cumulative NHS costs attributable to NO_2. By 2024 it is predicted that £7,771,414 NHS costs will be attributable to NO_2 in Lambeth. COPD is the largest contributor to this with a cost of £4,450,979 expected by 2024.

Table 6. Lambeth cumulative NHS costs attributable to NO_2

Year	Adult Asthma	Child Asthma	COPD	Dementia	Diabetes	Lung Cancer	Total
2020	£8,542 ± [£3,609]	£8,111 ± [£1,694]	£297,800 ± [£62,873]	£102,137 ± [£11,861]	£35,850 ± [£33,507]	£112,049 ± [£40,875]	£564,489 ± [£83,084]
2021	£23,802 ± [£5,083]	£24,762 ± [£2,383]	£893,411 ± [£89,523]	£305,337 ± [£17,002]	£105,871 ± [£47,585]	£319,380 ± [£60,158]	£1,672,564 ± [£119,240]
2022	£44,235 ± [£6,205]	£49,123 ± [£2,904]	£1,791,400 ± [£110,381]	£605,322 ± [£21,096]	£211,368 ± [£58,524]	£563,349 ± [£75,793]	£3,264,798 ± [£147,802]
2023	£70,787 ± [£7,143]	£81,185 ± [£3,337]	£2,982,235 ± [£128,325]	£999,840 ± [£24,679]	£351,254 ± [£67,867]	£832,344 ± [£89,463]	£5,317,647 ± [£172,476]
2024	£102,469 ± [£7,964]	£120,469 ± [£3,714]	£4,450,979 ± [£144,439]	£1,485,005 ± [£27,943]	£517,513 ± [£76,205]	£1,094,980 ± [£101,849]	£7,771,414 ± [£194,682]

Figure 5. Cumulative NHS costs attributable to NO_2 by year in Lambeth



Lambeth scenario assessment

This section estimates the impact of the scenarios on the new cases of disease, cases avoided, NHS costs, and QALYs as a result of changes in NO_2 to the year 2024 in Lambeth.

Annual disease incidence

Table 7 and

Figure 6 present the annual incidence of disease in Lambeth between 2020 and 2024 across baseline and the five scenarios for NO_2.

For the baseline scenario – a static/flat trend – the model projects 3,059 incidence cases in 2024 in Lambeth. Diabetes is the largest contributor at 1,057 incidence cases, followed by dementia (498) and adult asthma (456).

For the low pollution or ‘best case’ scenario where Lambeth has the same level of NO_2 as the London borough with the lowest reported levels (Havering), the model projects a disease incidence of 2,984 in 2024. Diabetes is the largest contributor at 1,051 cases, followed again by dementia (475) and adult asthma (442).

COVID-19 scenarios for Lambeth:

- The London-wide COVID-19 conservative scenario projection is a disease incidence of 3,051 in 2024. Diabetes incidence, the largest contributor, is 1,057.

- The London-wide COVID-19 ambitious scenario projection for Lambeth for total disease incidence is 2,976 in 2024. Diabetes incidence, the largest contributor, is 1,049.

- The Lambeth conservative COVID-19 reduction scenario of a 4% annual NO_2 reduction projects 3,043 disease incidence in 2024. Diabetes incidence, the largest contributor, is 1,056.

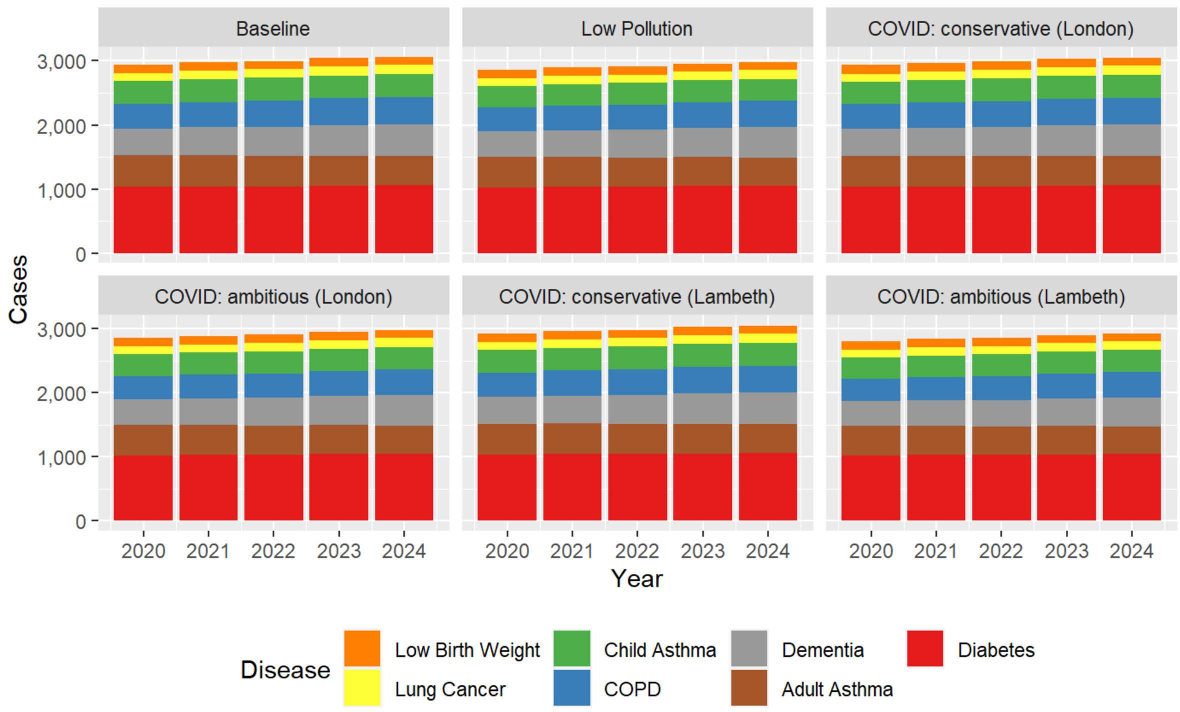
- The Lambeth ambitious COVID-19 reduction scenario of a 34% in annual NO_2 reduction projects 2,928 disease incidence in 2024. Diabetes incidence, the largest contributor, is 1,044.

Table 7. Annual disease incidence by NO_2 scenario for Lambeth

Scenario	Year	Adult Asthma	Child Asthma	COPD	Dementia	Diabetes	Low Birth Weight	Lung Cancer	Total
Baseline	2020	492 ± [4]	355 ± [3]	386 ± [3]	420 ± [3]	1,030 ± [5]	138 ± [2]	123 ± [2]	2,944 ± [9]
	2021	481 ± [4]	356 ± [3]	395 ± [3]	441 ± [3]	1,040 ± [5]	135 ± [2]	129 ± [2]	2,978 ± [9]
	2022	472 ± [4]	357 ± [3]	405 ± [3]	459 ± [4]	1,040 ± [5]	131 ± [2]	133 ± [2]	2,998 ± [9]
	2023	465 ± [4]	358 ± [3]	416 ± [3]	482 ± [4]	1,051 ± [5]	128 ± [2]	139 ± [2]	3,040 ± [9]
	2024	456 ± [4]	359 ± [3]	423 ± [3]	498 ± [4]	1,057 ± [5]	125 ± [2]	141 ± [2]	3,059 ± [9]
Low Pollution (Havering)	2020	477 ± [4]	341 ± [3]	370 ± [3]	396 ± [3]	1,024 ± [5]	137 ± [2]	121 ± [2]	2,866 ± [9]
	2021	470 ± [4]	341 ± [3]	377 ± [3]	416 ± [3]	1,032 ± [5]	133 ± [2]	127 ± [2]	2,896 ± [9]
	2022	459 ± [4]	342 ± [3]	387 ± [3]	435 ± [3]	1,032 ± [5]	130 ± [2]	130 ± [2]	2,914 ± [9]
	2023	452 ± [4]	344 ± [3]	398 ± [3]	456 ± [4]	1,044 ± [5]	126 ± [2]	138 ± [2]	2,958 ± [9]
	2024	442 ± [3]	345 ± [3]	406 ± [3]	475 ± [4]	1,051 ± [5]	124 ± [2]	140 ± [2]	2,984 ± [9]
COVID: Conservative (London)	2020	490 ± [4]	354 ± [3]	385 ± [3]	418 ± [3]	1,028 ± [5]	138 ± [2]	123 ± [2]	2,936 ± [9]
	2021	480 ± [4]	355 ± [3]	393 ± [3]	439 ± [3]	1,038 ± [5]	135 ± [2]	129 ± [2]	2,969 ± [9]
	2022	471 ± [4]	356 ± [3]	403 ± [3]	456 ± [4]	1,040 ± [5]	131 ± [2]	133 ± [2]	2,991 ± [9]

Scenario	Year	Adult Asthma	Child Asthma	COPD	Dementia	Diabetes	Low Birth Weight	Lung Cancer	Total
	2023	464 ± [4]	357 ± [3]	414 ± [3]	479 ± [4]	1,051 ± [5]	128 ± [2]	139 ± [2]	3,032 ± [9]
	2024	454 ± [4]	358 ± [3]	420 ± [3]	495 ± [4]	1,057 ± [5]	125 ± [2]	141 ± [2]	3,051 ± [9]
COVID: Ambitious (London)	2020	476 ± [4]	338 ± [3]	368 ± [3]	393 ± [3]	1,021 ± [5]	136 ± [2]	122 ± [2]	2,854 ± [9]
	2021	467 ± [4]	341 ± [3]	375 ± [3]	413 ± [3]	1,031 ± [5]	132 ± [2]	127 ± [2]	2,886 ± [9]
	2022	457 ± [4]	345 ± [3]	384 ± [3]	431 ± [3]	1,031 ± [5]	129 ± [2]	131 ± [2]	2,907 ± [9]
	2023	450 ± [4]	348 ± [3]	394 ± [3]	452 ± [4]	1,041 ± [5]	126 ± [2]	136 ± [2]	2,947 ± [9]
	2024	440 ± [3]	352 ± [3]	401 ± [3]	470 ± [4]	1,049 ± [5]	124 ± [2]	140 ± [2]	2,976 ± [9]
COVID: Conservative (Lambeth)	2020	489 ± [4]	352 ± [3]	383 ± [3]	415 ± [3]	1,027 ± [5]	138 ± [2]	123 ± [2]	2,926 ± [9]
	2021	480 ± [4]	353 ± [3]	391 ± [3]	436 ± [3]	1,038 ± [5]	134 ± [2]	129 ± [2]	2,961 ± [9]
	2022	469 ± [4]	355 ± [3]	401 ± [3]	453 ± [4]	1,039 ± [5]	131 ± [2]	133 ± [2]	2,981 ± [9]
	2023	462 ± [4]	356 ± [3]	412 ± [3]	476 ± [4]	1,050 ± [5]	128 ± [2]	139 ± [2]	3,022 ± [9]
	2024	453 ± [4]	357 ± [3]	418 ± [3]	493 ± [4]	1,056 ± [5]	125 ± [2]	141 ± [2]	3,043 ± [9]
COVID: Ambitious (Lambeth)	2020	467 ± [4]	328 ± [3]	357 ± [3]	378 ± [3]	1,018 ± [5]	134 ± [2]	120 ± [2]	2,804 ± [9]
	2021	458 ± [4]	333 ± [3]	364 ± [3]	398 ± [3]	1,027 ± [5]	132 ± [2]	125 ± [2]	2,837 ± [9]
	2022	449 ± [4]	338 ± [3]	372 ± [3]	415 ± [3]	1,024 ± [5]	129 ± [2]	129 ± [2]	2,855 ± [9]
	2023	441 ± [3]	343 ± [3]	382 ± [3]	437 ± [3]	1,036 ± [5]	126 ± [2]	135 ± [2]	2,899 ± [9]
	2024	432 ± [3]	348 ± [3]	389 ± [3]	453 ± [4]	1,044 ± [5]	124 ± [2]	138 ± [2]	2,928 ± [9]

Figure 6. Annual incidence by year and NO_2 scenario for Lambeth



Cumulative disease incidence

Table 8 and **Figure 7** show the cumulative incidence of disease in Lambeth from 2020-2024 across baseline and the five scenarios for NO_2.

For the baseline scenario – a static/flat trend – the model projects a cumulative incidence of 15,019 cases by 2024 in Lambeth. Diabetes is the largest contributor at 5,219 cases, followed by adult asthma (2,366) and dementia (2,301).

For the low pollution or 'best case' scenario where Lambeth has the same level of NO_2 as the London borough with the lowest reported levels (Havering), the model projects 14,619 cumulative incidence of disease by 2024. Diabetes is the largest contributor at 5,182 incidence, followed again by adult asthma (2,300) and dementia (2,178).

COVID-19 scenarios for Lambeth:

- The London-wide COVID-19 conservative scenario projection is 14,979 cumulative disease incidence by 2024. Diabetes cumulative incidence, the largest contributor, is 5,215.

- The London-wide COVID-19 ambitious scenario projection for Lambeth is 14,570 cumulative incidence by 2024. Diabetes incidence, the largest contributor, is 5,173.

- The Lambeth conservative COVID-19 reduction scenario of a 4% annual NO_2 reduction projects 14,934 cumulative disease incidence by 2024. Diabetes incidence, the largest contributor, is 5,209.

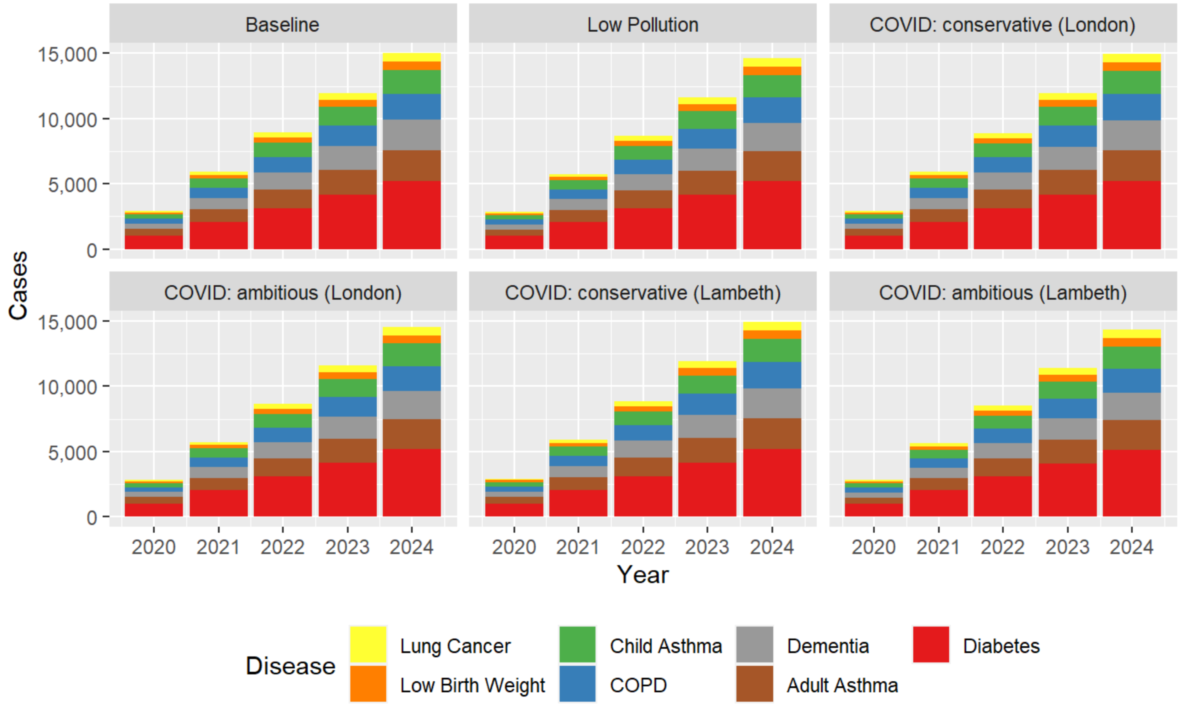
- The Lambeth ambitious COVID-19 reduction scenario of a 34% in annual NO_2 reduction projects 14,323 cumulative disease incidence by 2024. Diabetes incidence, the largest contributor, is 5,148.

Table 8. Cumulative disease incidence by NO_2 scenario for Lambeth

Scenario	Year	Adult Asthma	Child Asthma	COPD	Dementia	Diabetes	Low Birth Weight	Lung Cancer	Total
Baseline	2020	492 ± [4]	355 ± [3]	386 ± [3]	420 ± [3]	1,030 ± [5]	138 ± [2]	123 ± [2]	2,944 ± [9]
	2021	973 ± [5]	711 ± [4]	782 ± [5]	862 ± [5]	2,069 ± [8]	272 ± [3]	252 ± [3]	5,922 ± [13]
	2022	1,446 ± [6]	1,068 ± [5]	1,186 ± [6]	1,321 ± [6]	3,110 ± [9]	403 ± [3]	385 ± [3]	8,920 ± [16]
	2023	1,911 ± [7]	1,426 ± [6]	1,602 ± [7]	1,803 ± [7]	4,161 ± [11]	532 ± [4]	525 ± [4]	11,960 ± [18]
	2024	2,366 ± [8]	1,785 ± [7]	2,025 ± [7]	2,301 ± [8]	5,219 ± [12]	657 ± [4]	666 ± [4]	15,019 ± [20]
Low Pollution	2020	477 ± [4]	341 ± [3]	370 ± [3]	396 ± [3]	1,024 ± [5]	137 ± [2]	121 ± [2]	2,866 ± [9]
	2021	947 ± [5]	682 ± [4]	747 ± [5]	812 ± [5]	2,055 ± [8]	270 ± [3]	249 ± [3]	5,762 ± [13]
	2022	1,406 ± [6]	1,024 ± [5]	1,134 ± [6]	1,247 ± [6]	3,087 ± [9]	400 ± [3]	379 ± [3]	8,676 ± [15]
	2023	1,858 ± [7]	1,368 ± [6]	1,532 ± [7]	1,703 ± [7]	4,131 ± [11]	526 ± [4]	516 ± [4]	11,635 ± [18]
	2024	2,300 ± [8]	1,713 ± [7]	1,938 ± [7]	2,178 ± [8]	5,182 ± [12]	650 ± [4]	657 ± [4]	14,619 ± [20]
COVID: Conservative (London)	2020	490 ± [4]	354 ± [3]	385 ± [3]	418 ± [3]	1,028 ± [5]	138 ± [2]	123 ± [2]	2,936 ± [9]
	2021	971 ± [5]	708 ± [4]	778 ± [5]	857 ± [5]	2,067 ± [8]	273 ± [3]	252 ± [3]	5,905 ± [13]
	2022	1,442 ± [6]	1,065 ± [5]	1,181 ± [6]	1,313 ± [6]	3,107 ± [9]	404 ± [3]	385 ± [3]	8,896 ± [16]
	2023	1,905 ± [7]	1,422 ± [6]	1,595 ± [7]	1,792 ± [7]	4,158 ± [11]	532 ± [4]	524 ± [4]	11,928 ± [18]
	2024	2,360 ± [8]	1,780 ± [7]	2,015 ± [7]	2,288 ± [8]	5,215 ± [12]	657 ± [4]	665 ± [4]	14,979 ± [20]
COVID: Ambitious (London)	2020	476 ± [4]	338 ± [3]	368 ± [3]	393 ± [3]	1,021 ± [5]	136 ± [2]	122 ± [2]	2,854 ± [9]
	2021	943 ± [5]	678 ± [4]	743 ± [5]	806 ± [5]	2,052 ± [8]	269 ± [3]	248 ± [3]	5,740 ± [13]
	2022	1,400 ± [6]	1,023 ± [5]	1,127 ± [6]	1,237 ± [6]	3,082 ± [9]	398 ± [3]	379 ± [3]	8,647 ± [15]

Scenario	Year	Adult Asthma	Child Asthma	COPD	Dementia	Diabetes	Low Birth Weight	Lung Cancer	Total
	2023	1,850 ± [7]	1,372 ± [6]	1,521 ± [6]	1,689 ± [7]	4,123 ± [11]	524 ± [4]	515 ± [4]	11,594 ± [18]
	2024	2,290 ± [8]	1,723 ± [7]	1,922 ± [7]	2,158 ± [8]	5,173 ± [12]	649 ± [4]	655 ± [4]	14,570 ± [20]
COVID: Conservative (Lambeth)	2020	489 ± [4]	352 ± [3]	383 ± [3]	415 ± [3]	1,027 ± [5]	138 ± [2]	123 ± [2]	2,926 ± [9]
	2021	968 ± [5]	705 ± [4]	775 ± [5]	851 ± [5]	2,065 ± [8]	272 ± [3]	251 ± [3]	5,888 ± [13]
	2022	1,438 ± [6]	1,060 ± [5]	1,175 ± [6]	1,304 ± [6]	3,104 ± [9]	403 ± [3]	384 ± [3]	8,868 ± [16]
	2023	1,899 ± [7]	1,416 ± [6]	1,587 ± [7]	1,780 ± [7]	4,153 ± [11]	531 ± [4]	523 ± [4]	11,890 ± [18]
	2024	2,352 ± [8]	1,773 ± [7]	2,005 ± [7]	2,273 ± [8]	5,209 ± [12]	656 ± [4]	664 ± [4]	14,934 ± [20]
COVID: Ambitious (Lambeth)	2020	467 ± [4]	328 ± [3]	357 ± [3]	378 ± [3]	1,018 ± [5]	134 ± [2]	120 ± [2]	2,804 ± [9]
	2021	925 ± [5]	662 ± [4]	720 ± [4]	776 ± [5]	2,045 ± [8]	267 ± [3]	246 ± [3]	5,641 ± [12]
	2022	1,374 ± [6]	999 ± [5]	1,092 ± [5]	1,191 ± [6]	3,069 ± [9]	396 ± [3]	375 ± [3]	8,496 ± [15]
	2023	1,815 ± [7]	1,342 ± [6]	1,474 ± [6]	1,628 ± [7]	4,104 ± [11]	522 ± [4]	510 ± [4]	11,395 ± [18]
	2024	2,247 ± [8]	1,690 ± [7]	1,863 ± [7]	2,081 ± [8]	5,148 ± [12]	645 ± [4]	648 ± [4]	14,323 ± [20]

Figure 7. Cumulative disease incidence by year and NO_2 scenario for Lambeth



Cumulative disease incidence avoided

Table 9 and **Figure 8** present the cumulative cases of disease avoided in Lambeth from 2020-2024 across the five scenarios for reductions in NO_2.

For the low pollution or 'best case' scenario where Lambeth has the same level of NO_2 as the London borough with the lowest reported levels (Havering), the model projects 401 cumulative incidence cases avoided by 2024. Dementia is the largest contributor at 123 cumulative incidence avoided, followed by COPD (87) and child asthma (72).

COVID-19 scenarios for Lambeth:

- The London-wide COVID-19 conservative scenario projection is 41 cumulative disease incidence cases avoided in disease by 2024. Dementia cumulative incidence cases avoided, the largest contributor, is 14.
- The London-wide COVID-19 ambitious scenario projection for Lambeth is 449 cumulative disease incidence cases avoided by 2024. Dementia incidence, the largest contributor, is 143.
- The Lambeth conservative COVID-19 reduction scenario of a 4% annual NO_2 reduction projects 86 cumulative disease incidence cases avoided by 2024. Dementia incidence, the largest contributor, is 28.

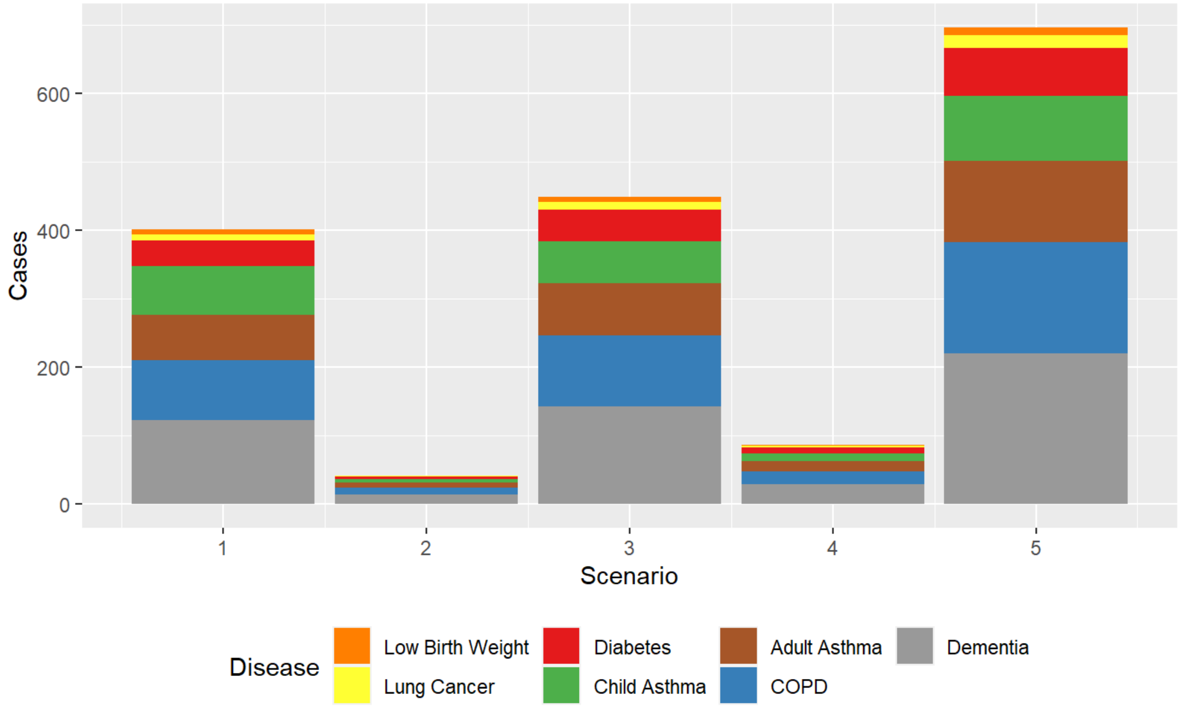
- The Lambeth ambitious COVID-19 reduction scenario of a 34% in annual NO_2 reduction projects 697 cumulative disease incidence cases avoided by 2024. Dementia incidence, the largest contributor, is 220.

Table 9. Cumulative disease incidence avoided by NO_2 scenario for Lambeth

Scenario	Year	Adult Asthma	Child Asthma	COPD	Dementia	Diabetes	Low Birth Weight	Lung Cancer	Total
Low Pollution	2020	14 ± [5]	14 ± [4]	17 ± [5]	24 ± [5]	6 ± [8]	1 ± [3]	1 ± [3]	78 ± [13]
	2021	26 ± [7]	30 ± [6]	35 ± [7]	49 ± [7]	14 ± [11]	3 ± [4]	3 ± [4]	160 ± [18]
	2022	40 ± [9]	44 ± [8]	53 ± [8]	74 ± [8]	23 ± [13]	4 ± [5]	6 ± [5]	244 ± [22]
	2023	53 ± [10]	58 ± [9]	70 ± [9]	100 ± [10]	30 ± [15]	6 ± [5]	8 ± [5]	325 ± [26]
	2024	66 ± [11]	72 ± [10]	87 ± [10]	123 ± [11]	37 ± [17]	7 ± [6]	9 ± [6]	401 ± [29]
COVID: Conservative (London)	2020	1 ± [5]	2 ± [4]	1 ± [5]	2 ± [5]	1 ± [8]	0 ± [3]	0 ± [3]	8 ± [13]
	2021	3 ± [7]	3 ± [6]	4 ± [7]	4 ± [7]	3 ± [11]	0 ± [4]	0 ± [4]	17 ± [18]
	2022	4 ± [9]	4 ± [8]	6 ± [8]	7 ± [9]	3 ± [13]	0 ± [5]	1 ± [5]	24 ± [22]
	2023	5 ± [10]	5 ± [9]	8 ± [9]	11 ± [10]	4 ± [15]	0 ± [5]	1 ± [5]	32 ± [26]
	2024	7 ± [11]	5 ± [10]	10 ± [11]	14 ± [11]	4 ± [17]	0 ± [6]	1 ± [6]	41 ± [29]
COVID: Ambitious (London)	2020	16 ± [5]	18 ± [4]	19 ± [5]	27 ± [5]	9 ± [8]	1 ± [3]	1 ± [3]	90 ± [13]
	2021	30 ± [7]	33 ± [6]	39 ± [6]	55 ± [7]	18 ± [11]	4 ± [4]	4 ± [4]	182 ± [18]
	2022	46 ± [9]	45 ± [8]	60 ± [8]	84 ± [8]	28 ± [13]	5 ± [5]	6 ± [5]	274 ± [22]
	2023	61 ± [10]	55 ± [9]	82 ± [9]	114 ± [10]	38 ± [15]	7 ± [5]	9 ± [5]	366 ± [25]
	2024	76 ± [11]	62 ± [10]	103 ± [10]	143 ± [11]	46 ± [17]	8 ± [6]	11 ± [6]	449 ± [29]
	2020	3 ± [5]	3 ± [4]	3 ± [5]	5 ± [5]	3 ± [8]	0 ± [3]	0 ± [3]	18 ± [13]

Scenario	Year	Adult Asthma	Child Asthma	COPD	Dementia	Diabetes	Low Birth Weight	Lung Cancer	Total
COVID: Conservative (Lambeth)	2021	5 ± [7]	6 ± [6]	7 ± [7]	10 ± [7]	5 ± [11]	0 ± [4]	1 ± [4]	34 ± [18]
	2022	8 ± [9]	8 ± [8]	11 ± [8]	17 ± [9]	6 ± [13]	0 ± [5]	1 ± [5]	52 ± [22]
	2023	11 ± [10]	10 ± [9]	15 ± [9]	23 ± [10]	8 ± [15]	1 ± [5]	2 ± [5]	69 ± [26]
	2024	14 ± [11]	12 ± [10]	20 ± [11]	28 ± [11]	9 ± [17]	1 ± [6]	2 ± [6]	86 ± [29]
COVID: Ambitious (Lambeth)	2020	25 ± [5]	27 ± [4]	30 ± [5]	42 ± [5]	11 ± [8]	3 ± [3]	2 ± [3]	140 ± [13]
	2021	48 ± [7]	50 ± [6]	61 ± [6]	85 ± [7]	25 ± [11]	5 ± [4]	6 ± [4]	281 ± [18]
	2022	72 ± [9]	69 ± [8]	94 ± [8]	130 ± [8]	41 ± [13]	7 ± [5]	10 ± [5]	424 ± [22]
	2023	95 ± [10]	84 ± [9]	129 ± [9]	175 ± [10]	57 ± [15]	10 ± [5]	15 ± [5]	565 ± [25]
	2024	119 ± [11]	95 ± [10]	162 ± [10]	220 ± [11]	71 ± [17]	11 ± [6]	18 ± [6]	697 ± [28]

Figure 8. Cumulative disease incidence avoided by NO_2 scenario for Lambeth



Scenarios: (1) Low pollution, (2) COVID: conservative (London), (3) COVID: ambitious (London), (4) COVID: conservative (Lambeth), (5) COVID: ambitious (Lambeth)

Cumulative NHS costs avoided

Table 10 and **Figure 9** show the cumulative NHS costs avoided in Lambeth from 2020-2024 across the five scenarios for reductions in NO_2.

For the low pollution or 'best case' scenario where Lambeth has the same level of NO_2 as the London borough with the lowest reported levels (Havering), the model projects £1,609,398 cumulative NHS costs avoided by 2024. COPD is the largest contributor at £913,805 cumulative NHS costs avoided, followed by dementia (£320,395) and lung cancer (£219,680).

COVID-19 scenarios for Lambeth:

- The London-wide COVID-19 conservative scenario projection is £203,121 cumulative NHS costs avoided by 2024. The COPD cumulative NHS costs avoided, the largest contributor, is £124,998.

- The London-wide COVID-19 ambitious scenario projection for Lambeth is £1,812,918 cumulative NHS costs avoided by 2024. COPD cumulative NHS costs avoided, the largest contributor, is £1,028,043.

- The Lambeth conservative COVID-19 reduction scenario of a 4% annual NO_2 reduction projects £388,277 cumulative NHS costs avoided by 2024. COPD cumulative NHS costs avoided, the largest contributor, is £232,520.

- The Lambeth ambitious COVID-19 reduction scenario of a 34% in annual NO_2 reduction projects £2,883,006 cumulative NHS costs avoided by 2024. COPD cumulative NHS costs avoided, the largest contributor, is £1,661,278.

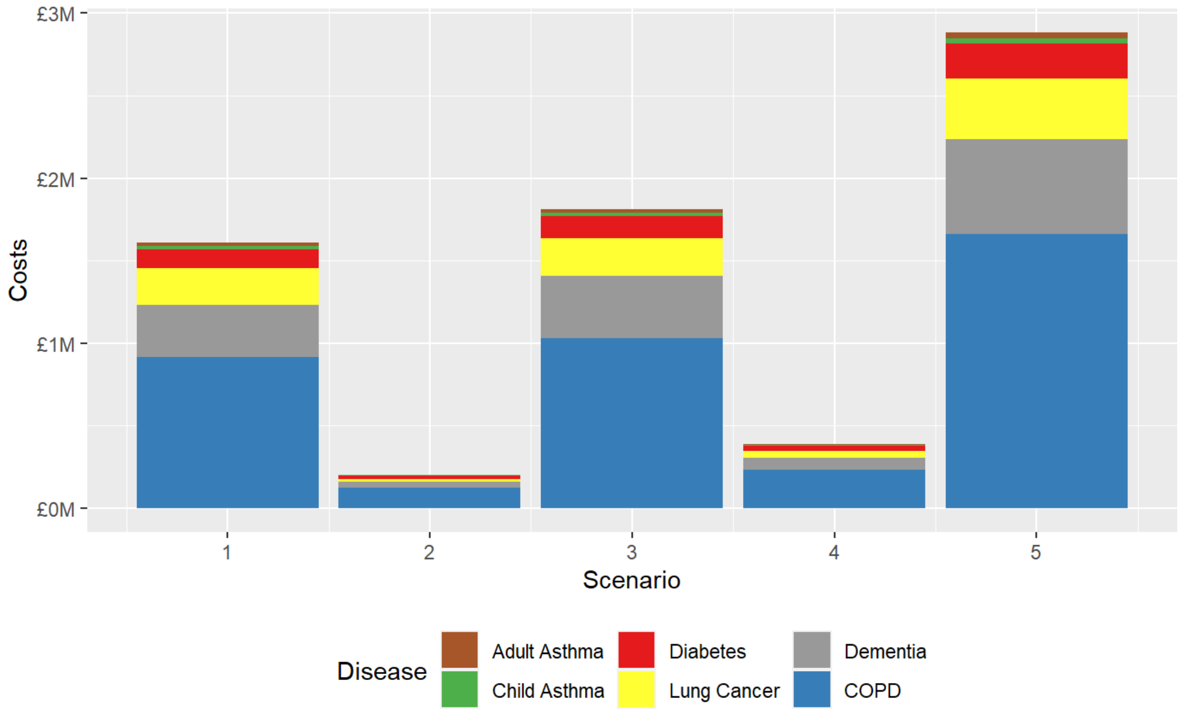
Table 10. Cumulative NHS costs avoided by NO_2 scenario for Lambeth

Scenario	Year	Adult Asthma	Child Asthma	COPD	Dementia	Diabetes	Lung Cancer	Total
Low Pollution	2020	£1,694 ± [£3,612]	£1,552 ± [£1,700]	£60,778 ± [£63,059]	£24,277 ± [£11,944]	£8,514 ± [£33,517]	£11,755 ± [£41,257]	£108,570 ± [£83,430]
	2021	£4,520 ± [£5,088]	£5,064 ± [£2,396]	£183,907 ± [£89,912]	£69,099 ± [£17,176]	£24,978 ± [£47,606]	£48,756 ± [£60,856]	£336,324 ± [£119,919]
	2022	£8,347 ± [£6,213]	£9,907 ± [£2,925]	£371,463 ± [£111,011]	£134,278 ± [£21,375]	£49,102 ± [£58,559]	£110,338 ± [£76,719]	£683,435 ± [£148,803]
	2023	£13,182 ± [£7,154]	£16,174 ± [£3,367]	£615,225 ± [£129,227]	£219,392 ± [£25,072]	£78,482 ± [£67,918]	£172,010 ± [£90,604]	£1,114,466 ± [£173,818]
	2024	£19,123 ± [£7,978]	£23,561 ± [£3,754]	£913,805 ± [£145,634]	£320,395 ± [£28,459]	£112,834 ± [£76,272]	£219,680 ± [£103,176]	£1,609,398 ± [£196,366]
COVID: Conservative (London)	2020	£659 ± [£3,612]	£81 ± [£1,702]	£11,146 ± [£63,098]	£2,255 ± [£11,967]	£2,711 ± [£33,519]	-£719 ± [£41,305]	£16,133 ± [£83,487]
	2021	£1,367 ± [£5,089]	£350 ± [£2,399]	£29,961 ± [£89,997]	£6,374 ± [£17,222]	£7,129 ± [£47,611]	£2,065 ± [£60,976]	£47,246 ± [£120,053]
	2022	£2,176 ± [£6,214]	£648 ± [£2,929]	£54,939 ± [£111,152]	£13,210 ± [£21,446]	£11,335 ± [£58,567]	£9,007 ± [£76,924]	£91,314 ± [£149,028]
	2023	£2,920 ± [£7,156]	£1,080 ± [£3,374]	£85,439 ± [£129,428]	£22,683 ± [£25,170]	£15,678 ± [£67,930]	£15,423 ± [£90,873]	£143,223 ± [£174,127]
	2024	£3,727 ± [£7,981]	£1,523 ± [£3,763]	£124,998 ± [£145,899]	£34,513 ± [£28,584]	£20,849 ± [£76,287]	£17,511 ± [£103,480]	£203,121 ± [£196,747]
	2020	£2,087 ± [£3,612]	£1,904 ± [£1,700]	£63,096 ± [£63,057]	£29,125 ± [£11,939]	£10,375 ± [£33,516]	£9,234 ± [£41,267]	£115,823 ± [£83,432]

Scenario	Year	Adult Asthma	Child Asthma	COPD	Dementia	Diabetes	Lung Cancer	Total
COVID: Ambitious (London)	2021	£5,242 ± [£5,088]	£5,806 ± [£2,395]	£195,744 ± [£89,906]	£82,296 ± [£17,166]	£30,071 ± [£47,605]	£43,530 ± [£60,870]	£362,689 ± [£119,920]
	2022	£9,379 ± [£6,213]	£10,647 ± [£2,924]	£402,793 ± [£110,998]	£158,292 ± [£21,361]	£57,877 ± [£58,557]	£101,878 ± [£76,736]	£740,867 ± [£148,800]
	2023	£14,805 ± [£7,154]	£16,536 ± [£3,367]	£681,494 ± [£129,203]	£257,889 ± [£25,053]	£93,968 ± [£67,915]	£170,314 ± [£90,608]	£1,235,005 ± [£173,798]
	2024	£21,600 ± [£7,978]	£22,707 ± [£3,754]	£1,028,043 ± [£145,596]	£377,274 ± [£28,434]	£135,726 ± [£76,268]	£227,568 ± [£103,165]	£1,812,918 ± [£196,327]
COVID: Conservative (Lambeth)	2020	£609 ± [£3,612]	£353 ± [£1,701]	£19,983 ± [£63,091]	£5,351 ± [£11,964]	£3,798 ± [£33,519]	£1,092 ± [£41,298]	£31,186 ± [£83,478]
	2021	£1,163 ± [£5,089]	£1,117 ± [£2,398]	£53,006 ± [£89,985]	£15,213 ± [£17,215]	£9,309 ± [£47,610]	£7,148 ± [£60,963]	£86,955 ± [£120,035]
	2022	£1,931 ± [£6,214]	£1,991 ± [£2,929]	£100,807 ± [£111,132]	£30,598 ± [£21,436]	£15,777 ± [£58,566]	£21,870 ± [£76,898]	£172,974 ± [£148,998]
	2023	£3,079 ± [£7,156]	£3,028 ± [£3,373]	£158,788 ± [£129,401]	£50,528 ± [£25,156]	£23,637 ± [£67,928]	£34,824 ± [£90,840]	£273,885 ± [£174,086]
	2024	£4,384 ± [£7,981]	£4,134 ± [£3,762]	£232,520 ± [£145,863]	£73,988 ± [£28,567]	£32,120 ± [£76,285]	£41,131 ± [£103,445]	£388,277 ± [£196,698]
COVID: Ambitious (Lambeth)	2020	£3,424 ± [£3,611]	£3,039 ± [£1,699]	£110,702 ± [£63,019]	£43,530 ± [£11,923]	£16,204 ± [£33,514]	£23,716 ± [£41,211]	£200,615 ± [£83,373]
	2021	£8,724 ± [£5,087]	£8,924 ± [£2,393]	£331,938 ± [£89,831]	£124,172 ± [£17,135]	£45,458 ± [£47,600]	£87,588 ± [£60,756]	£606,805 ± [£119,800]
	2022	£15,499 ± [£6,211]	£16,521 ± [£2,921]	£667,027 ± [£110,881]	£240,470 ± [£21,312]	£88,959 ± [£58,550]	£174,603 ± [£76,588]	£1,203,080 ± [£148,626]

Scenario	Year	Adult Asthma	Child Asthma	COPD	Dementia	Diabetes	Lung Cancer	Total
	2023	£23,995 ± [£7,152]	£25,666 ± [£3,363]	£1,112,539 ± [£129,038]	£392,197 ± [£24,986]	£144,250 ± [£67,906]	£274,276 ± [£90,429]	£1,972,922 ± [£173,569]
	2024	£34,228 ± [£7,976]	£35,425 ± [£3,749]	£1,661,278 ± [£145,383]	£575,340 ± [£28,347]	£208,193 ± [£76,256]	£368,542 ± [£102,952]	£2,883,006 ± [£196,040]

Figure 9. Cumulative NHS costs avoided by NO_2 scenario for Lambeth



Scenarios: (1) Low pollution, (2) COVID: conservative (London), (3) COVID: ambitious (London), (4) COVID: conservative (Lambeth), (5) COVID: ambitious (Lambeth)

Annual QALYs gained

Table 11 and **Figure 10** show the annual QALYs gained in Lambeth from 2020-2024 across the four scenarios as a result of reductions in NO_2.

For the low pollution or 'best case' scenario where Lambeth has the same level of NO_2 as the London borough with the lowest reported levels (Havering), the model projects 109 annual QALYs gained in 2024. Based on a projected 2024 Lambeth population of 327,570, this equates to around 33 QALYs per 100,000 individuals.

COVID-19 scenarios for Lambeth:

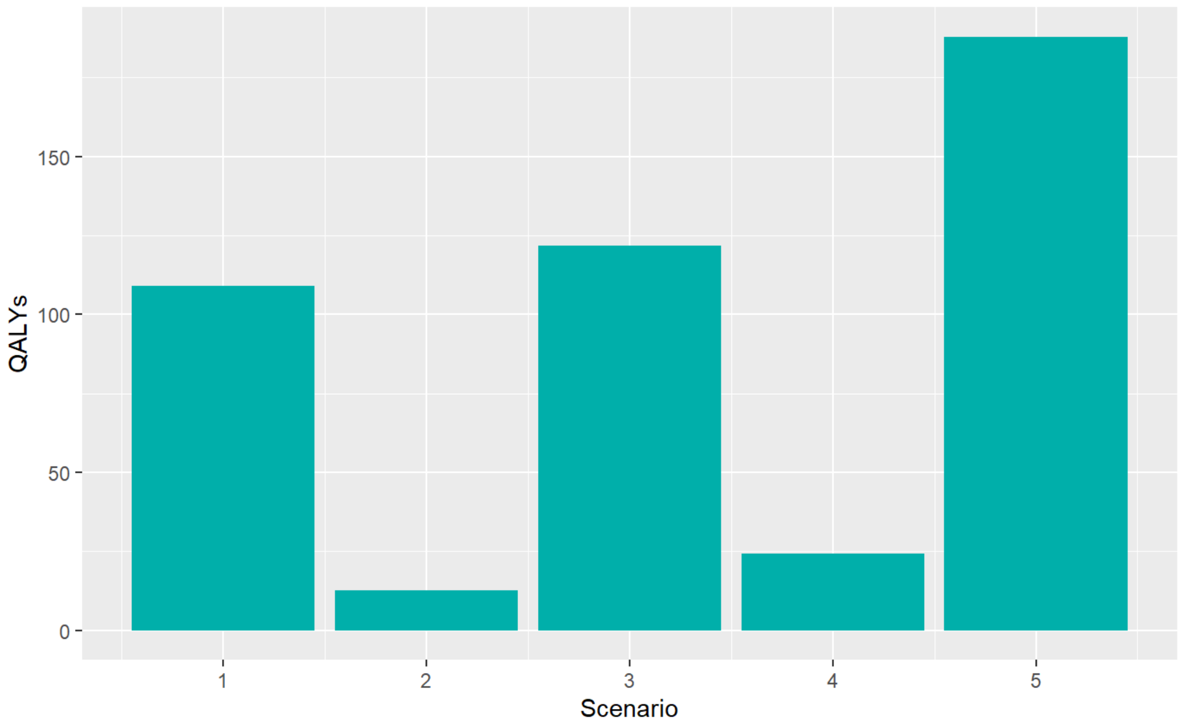
- The London-wide COVID-19 conservative scenario projection is 13 annual QALYs, or 4 QALYs per 100,000, gained in 2024.
- The London-wide COVID-19 ambitious scenario projection for Lambeth is 122 annual QALYs, or 37 QALYs per 100,000, gained in 2024.
- The Lambeth conservative COVID-19 reduction scenario of a 4% annual NO_2 reduction projects 24 annual QALYs, or 7 QALYs per 100,000, gained in 2024.

- The Lambeth ambitious COVID-19 reduction scenario of a 34% in annual NO_2 reduction projects 188 annual QALYs, or 57 QALYs per 100,000, gained in 2024.

Table 11. Annual QALYs gained by NO_2 scenario for Lambeth

Year	Low Pollution	COVID: Conservative (London)	COVID: Ambitious (London)	COVID: Conservative (Lambeth)	COVID: Ambitious (Lambeth)
2020	26 ± [29]	4 ± [29]	30 ± [29]	7 ± [29]	48 ± [29]
2021	50 ± [29]	7 ± [29]	57 ± [29]	12 ± [29]	89 ± [29]
2022	72 ± [29]	9 ± [29]	80 ± [29]	17 ± [29]	125 ± [29]
2023	92 ± [29]	11 ± [30]	103 ± [29]	21 ± [30]	159 ± [29]
2024	109 ± [30]	13 ± [30]	122 ± [30]	24 ± [30]	188 ± [30]

Figure 10. Annual QALYs gained by NO_2 scenario for Lambeth



Scenarios: (1) Low pollution, (2) COVID: conservative (London), (3) COVID: ambitious (London), (4) COVID: conservative (Lambeth), (5) COVID: ambitious (Lambeth)

PM$_{2.5}$ results for Lambeth

Lambeth disease incidence attributable to air pollution

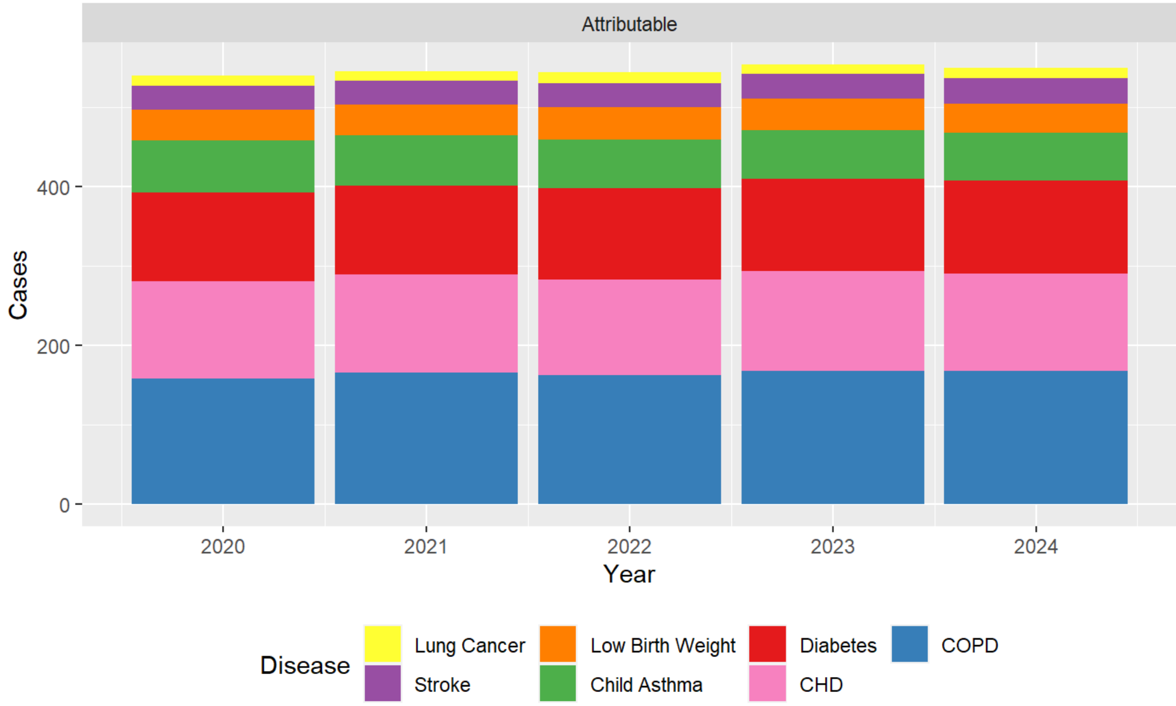
Annual disease incidence attributable

Table 12 and **Figure 11** shows the total new cases of diseases related to PM$_{2.5}$. In 2024, incidence attributable to PM$_{2.5}$ is projected to be 549, with COPD being the largest contributor with 167 new cases.

Table 12. Lambeth annual disease incidence attributable to PM$_{2.5}$

Year	CHD	Child Asthma	COPD	Diabetes	Low Birth Weight	Lung Cancer	Stroke	Total
2020	122 ± [4]	66 ± [4]	158 ± [4]	112 ± [7]	38 ± [3]	13 ± [3]	31 ± [3]	540 ± [12]
2021	123 ± [4]	64 ± [4]	166 ± [4]	111 ± [7]	39 ± [3]	12 ± [3]	30 ± [3]	545 ± [12]
2022	120 ± [4]	61 ± [4]	162 ± [4]	115 ± [7]	41 ± [3]	13 ± [3]	30 ± [3]	543 ± [12]
2023	126 ± [4]	62 ± [4]	167 ± [4]	116 ± [7]	40 ± [3]	12 ± [3]	31 ± [3]	553 ± [12]
2024	123 ± [4]	61 ± [4]	167 ± [4]	116 ± [7]	37 ± [3]	13 ± [3]	32 ± [4]	549 ± [12]

Figure 11. Annual disease incidence attributable to $PM_{2.5}$ by year in Lambeth



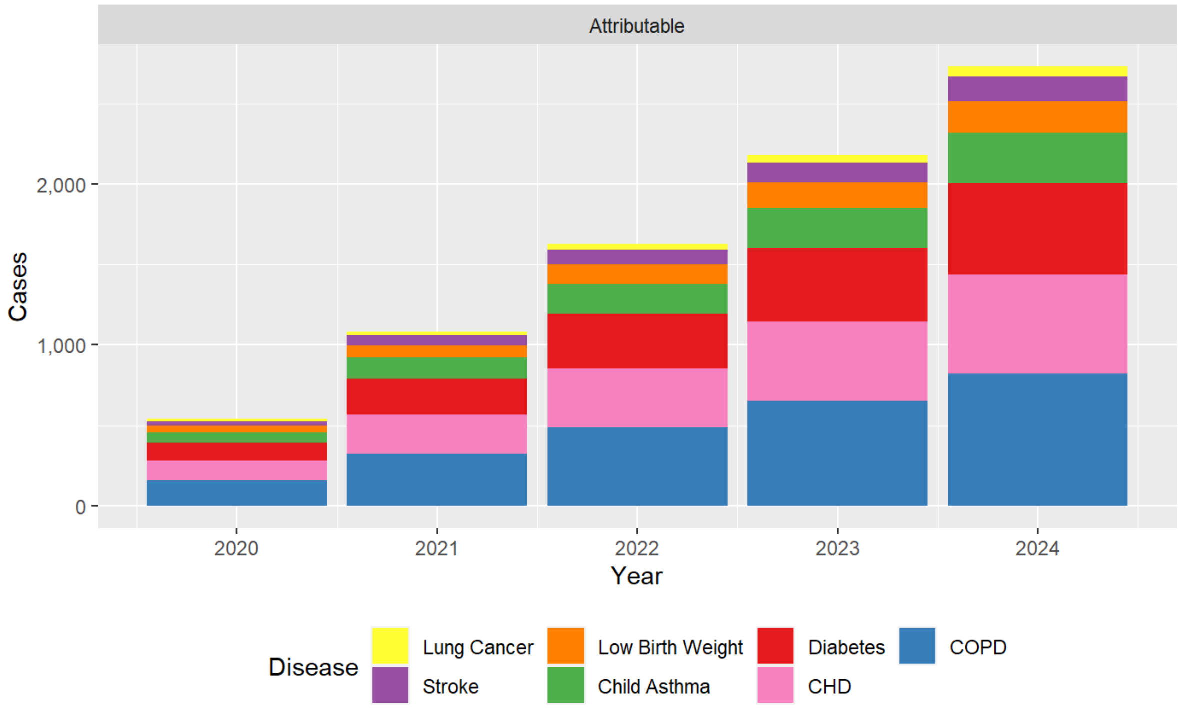
Cumulative disease incidence attributable

Table 13 and **Figure 12** show the total cumulative disease incidence attributable to $PM_{2.5}$. The model has calculated the cumulative incidence disease cases attributable to $PM_{2.5}$ in Lambeth to be 2,730 by 2024. COPD largest contributor with 821 cumulative incidence by 2024.

Table 13. Lambeth cumulative disease incidence attributable to $PM_{2.5}$

Year	CHD	Child Asthma	COPD	Diabetes	Low Birth Weight	Lung Cancer	Stroke	Total
2020	122 ± [4]	66 ± [4]	158 ± [4]	112 ± [7]	38 ± [3]	13 ± [3]	31 ± [3]	540 ± [12]
2021	246 ± [6]	129 ± [6]	324 ± [6]	223 ± [11]	77 ± [4]	24 ± [4]	61 ± [5]	1,085 ± [16]
2022	366 ± [7]	190 ± [7]	487 ± [8]	338 ± [13]	118 ± [5]	38 ± [5]	91 ± [6]	1,628 ± [20]
2023	492 ± [8]	252 ± [9]	654 ± [9]	454 ± [15]	157 ± [5]	50 ± [5]	122 ± [7]	2,181 ± [23]
2024	615 ± [9]	313 ± [10]	821 ± [10]	571 ± [17]	194 ± [6]	63 ± [6]	153 ± [8]	2,730 ± [26]

Figure 12. Cumulative disease incidence attributable to $PM_{2.5}$ by year in Lambeth



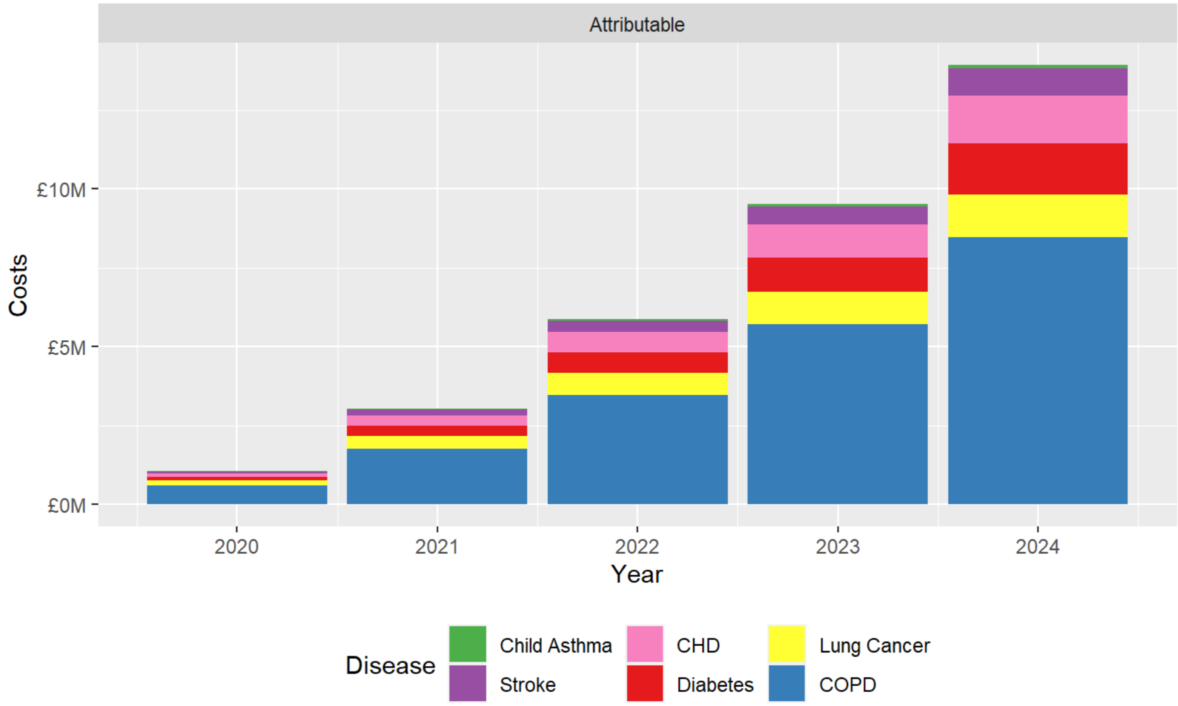
Cumulative NHS costs attributable

Table 14 and **Figure 13** show the total new cumulative NHS costs attributable to $PM_{2.5}$. By 2024 it is predicted that £13,914,091 NHS costs will be attributable to $PM_{2.5}$ in Lambeth. COPD is the largest contributor to this with a cost of £8,458,663 expected by 2024.

Table 14. Lambeth cumulative NHS costs attributable to $PM_{2.5}$

Year	CHD	Child Asthma	COPD	Diabetes	Lung Cancer	Stroke	Total
2020	£121,070 ± [£11,169]	£7,639 ± [£1,669]	£590,600 ± [£64,041]	£113,022 ± [£33,540]	£157,772 ± [£40,575]	£57,827 ± [£28,701]	£1,047,931 ± [£88,452]
2021	£340,555 ± [£15,830]	£22,492 ± [£2,353]	£1,759,860 ± [£90,670]	£332,627 ± [£47,523]	£393,080 ± [£59,420]	£178,043 ± [£40,661]	£3,026,658 ± [£126,173]
2022	£649,403 ± [£19,417]	£43,667 ± [£2,873]	£3,467,489 ± [£111,174]	£661,228 ± [£58,312]	£690,180 ± [£74,525]	£350,307 ± [£49,884]	£5,862,274 ± [£155,523]
2023	£1,049,628 ± [£22,460]	£70,119 ± [£3,308]	£5,709,356 ± [£128,560]	£1,096,556 ± [£67,472]	£1,012,452 ± [£87,579]	£578,668 ± [£57,721]	£9,516,778 ± [£180,547]
2024	£1,527,130 ± [£25,153]	£101,749 ± [£3,689]	£8,458,663 ± [£143,979]	£1,629,172 ± [£75,605]	£1,341,786 ± [£99,321]	£855,591 ± [£64,688]	£13,914,091 ± [£202,834]

Figure 13. Cumulative NHS costs attributable to $PM_{2.5}$ by year in Lambeth



Lambeth scenario assessment

This section estimates the impact of the scenarios on the new cases of disease, cases avoided, NHS costs avoided and QALYs gained to the year 2024 in Lambeth.

Annual incidence cases

Table 15 and **Figure 14** present the annual incidence of disease in Lambeth from 2020-2024 across baseline and the two scenarios for $PM_{2.5}$.

For the baseline scenario – a static/flat trend – the model projects a disease incidence of 2,735 in 2024 in Lambeth. Diabetes is the largest contributor at 1,067 incidence cases, followed by COPD (436) and CHD (364).

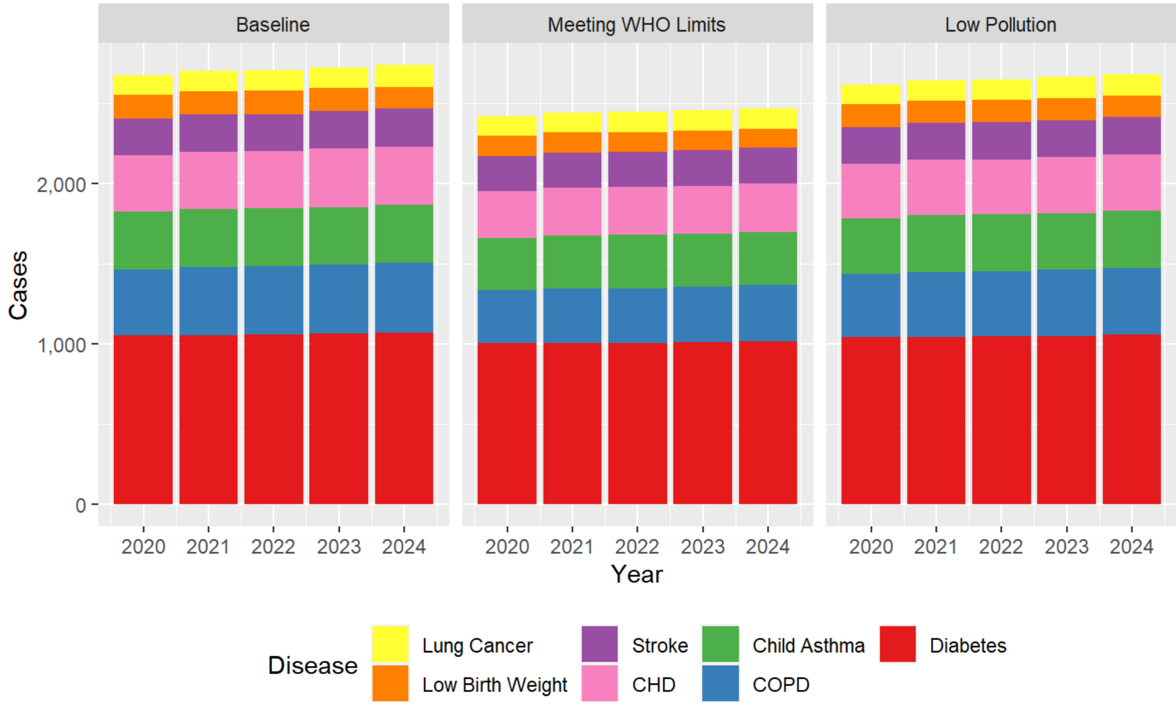
For the scenario where Lambeth meets the WHO limits for $PM_{2.5}$, the model projects 2,467 incidence of disease in 2024. Diabetes is the largest contributor with 1,013 disease incidence, followed by COPD (351) and child asthma (329).

For the low pollution or 'best case' scenario where Lambeth has the same level of $PM_{2.5}$ as the London borough with the lowest reported levels (Havering), the model projects 2,677 incidence of disease in 2024. Diabetes is the largest contributor with 1,056 incidence, followed by COPD (417), child asthma (354) and CHD (351).

Table 15. Annual disease incidence by $PM_{2.5}$ scenario for Lambeth

Scenario	Year	CHD	Child Asthma	COPD	Diabetes	Low Birth Weight	Lung Cancer	Stroke	Total
Baseline	2020	353 ± [3]	359 ± [3]	411 ± [3]	1,052 ± [5]	146 ± [2]	126 ± [2]	228 ± [3]	2,675 ± [9]
	2021	357 ± [3]	362 ± [3]	424 ± [3]	1,054 ± [5]	145 ± [2]	128 ± [2]	231 ± [3]	2,701 ± [9]
	2022	357 ± [3]	361 ± [3]	425 ± [3]	1,056 ± [5]	144 ± [2]	131 ± [2]	232 ± [3]	2,706 ± [9]
	2023	365 ± [3]	359 ± [3]	432 ± [3]	1,061 ± [5]	140 ± [2]	132 ± [2]	233 ± [3]	2,722 ± [9]
	2024	364 ± [3]	362 ± [3]	436 ± [3]	1,067 ± [5]	135 ± [2]	135 ± [2]	237 ± [3]	2,735 ± [9]
WHO Limits	2020	293 ± [3]	325 ± [3]	331 ± [3]	1,003 ± [5]	129 ± [2]	120 ± [2]	215 ± [2]	2,417 ± [8]
	2021	296 ± [3]	330 ± [3]	342 ± [3]	1,003 ± [5]	126 ± [2]	122 ± [2]	218 ± [2]	2,437 ± [8]
	2022	297 ± [3]	331 ± [3]	342 ± [3]	1,004 ± [5]	124 ± [2]	125 ± [2]	219 ± [2]	2,443 ± [8]
	2023	302 ± [3]	326 ± [3]	348 ± [3]	1,009 ± [5]	121 ± [2]	127 ± [2]	221 ± [2]	2,453 ± [8]
	2024	303 ± [3]	329 ± [3]	351 ± [3]	1,013 ± [5]	118 ± [2]	129 ± [2]	223 ± [2]	2,467 ± [8]
Low Pollution	2020	339 ± [3]	350 ± [3]	392 ± [3]	1,040 ± [5]	143 ± [2]	124 ± [2]	226 ± [3]	2,615 ± [9]
	2021	343 ± [3]	354 ± [3]	404 ± [3]	1,043 ± [5]	141 ± [2]	127 ± [2]	229 ± [3]	2,641 ± [9]
	2022	344 ± [3]	353 ± [3]	406 ± [3]	1,046 ± [5]	140 ± [2]	129 ± [2]	229 ± [3]	2,647 ± [9]
	2023	350 ± [3]	352 ± [3]	413 ± [3]	1,048 ± [5]	136 ± [2]	131 ± [2]	231 ± [3]	2,661 ± [9]
	2024	351 ± [3]	354 ± [3]	417 ± [3]	1,056 ± [5]	131 ± [2]	133 ± [2]	234 ± [3]	2,677 ± [9]

Figure 14. Annual incidence by year and $PM_{2.5}$ scenario for Lambeth



Cumulative incidence cases

Table 16 and

Figure 15 present the cumulative incidence of disease in Lambeth from 2020-2024 across baseline and the two scenarios for $PM_{2.5}$.

For the baseline scenario – a static/flat trend – the model projects 13,540 cumulative incidence cases by 2024 in Lambeth. Diabetes is the largest contributor at 5,291 cumulative incidence cases, followed by COPD (2,127) and child asthma (1,802).

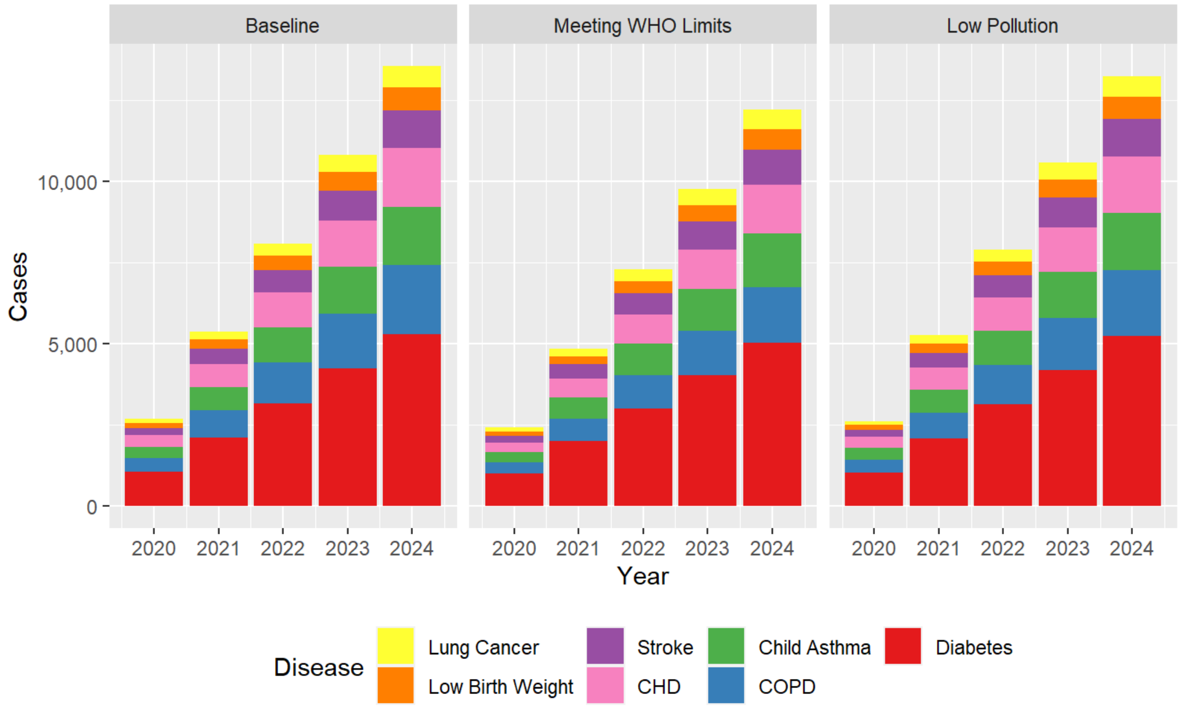
For the scenario where Lambeth meets the WHO limits for $PM_{2.5}$, the model projects 12,216 cumulative incidence of disease by 2024. Diabetes is the largest contributor at 5,032 incidence, followed by COPD (1,715) and child asthma (1,641).

For the low pollution or 'best case' scenario where Lambeth has the same level of $PM_{2.5}$ as the London borough with the lowest reported levels (Havering), the model projects 13,241 cumulative incidence of disease by 2024. Diabetes is the largest contributor at 5,233 incidence, followed by COPD (2,033), child asthma (1,763) and CHD (1,728).

Table 16. Cumulative disease incidence by $PM_{2.5}$ scenario for Lambeth

Scenario	Year	CHD	Child Asthma	COPD	Diabetes	Low Birth Weight	Lung Cancer	Stroke	Total
Baseline	2020	353 ± [3]	359 ± [3]	411 ± [3]	1,052 ± [5]	146 ± [2]	126 ± [2]	228 ± [3]	2,675 ± [9]
	2021	709 ± [4]	720 ± [4]	834 ± [5]	2,107 ± [8]	292 ± [3]	254 ± [3]	460 ± [4]	5,376 ± [12]
	2022	1,066 ± [5]	1,081 ± [5]	1,259 ± [6]	3,163 ± [9]	435 ± [3]	385 ± [3]	692 ± [4]	8,082 ± [15]
	2023	1,431 ± [6]	1,440 ± [6]	1,691 ± [7]	4,224 ± [11]	576 ± [4]	517 ± [4]	925 ± [5]	10,804 ± [17]
	2024	1,795 ± [7]	1,802 ± [7]	2,127 ± [8]	5,291 ± [12]	711 ± [4]	652 ± [4]	1,162 ± [6]	13,540 ± [19]
WHO Limits	2020	293 ± [3]	325 ± [3]	331 ± [3]	1,003 ± [5]	129 ± [2]	120 ± [2]	215 ± [2]	2,417 ± [8]
	2021	590 ± [4]	655 ± [4]	673 ± [4]	2,006 ± [7]	255 ± [3]	242 ± [3]	433 ± [3]	4,854 ± [12]
	2022	887 ± [5]	986 ± [5]	1,016 ± [5]	3,010 ± [9]	379 ± [3]	367 ± [3]	652 ± [4]	7,297 ± [14]
	2023	1,189 ± [6]	1,312 ± [6]	1,364 ± [6]	4,019 ± [11]	500 ± [4]	493 ± [4]	872 ± [5]	9,749 ± [16]
	2024	1,492 ± [6]	1,641 ± [7]	1,715 ± [7]	5,032 ± [12]	618 ± [4]	622 ± [4]	1,095 ± [6]	12,216 ± [18]
Low Pollution	2020	339 ± [3]	350 ± [3]	392 ± [3]	1,040 ± [5]	143 ± [2]	124 ± [2]	226 ± [3]	2,615 ± [9]
	2021	683 ± [4]	704 ± [4]	796 ± [5]	2,083 ± [8]	284 ± [3]	251 ± [3]	455 ± [4]	5,256 ± [12]
	2022	1,026 ± [5]	1,057 ± [5]	1,203 ± [6]	3,129 ± [9]	423 ± [3]	381 ± [3]	685 ± [4]	7,903 ± [15]
	2023	1,377 ± [6]	1,409 ± [6]	1,616 ± [7]	4,177 ± [11]	560 ± [4]	512 ± [4]	915 ± [5]	10,565 ± [17]
	2024	1,728 ± [7]	1,763 ± [7]	2,033 ± [8]	5,233 ± [12]	691 ± [4]	645 ± [4]	1,149 ± [6]	13,241 ± [19]

Figure 15. Cumulative disease incidence by year and $PM_{2.5}$ scenario for Lambeth



Cumulative incidence cases avoided

Table 17 and **Figure 16** present the cumulative cases of disease avoided in Lambeth from 2020-2024 across the two scenarios for reductions in $PM_{2.5}$.

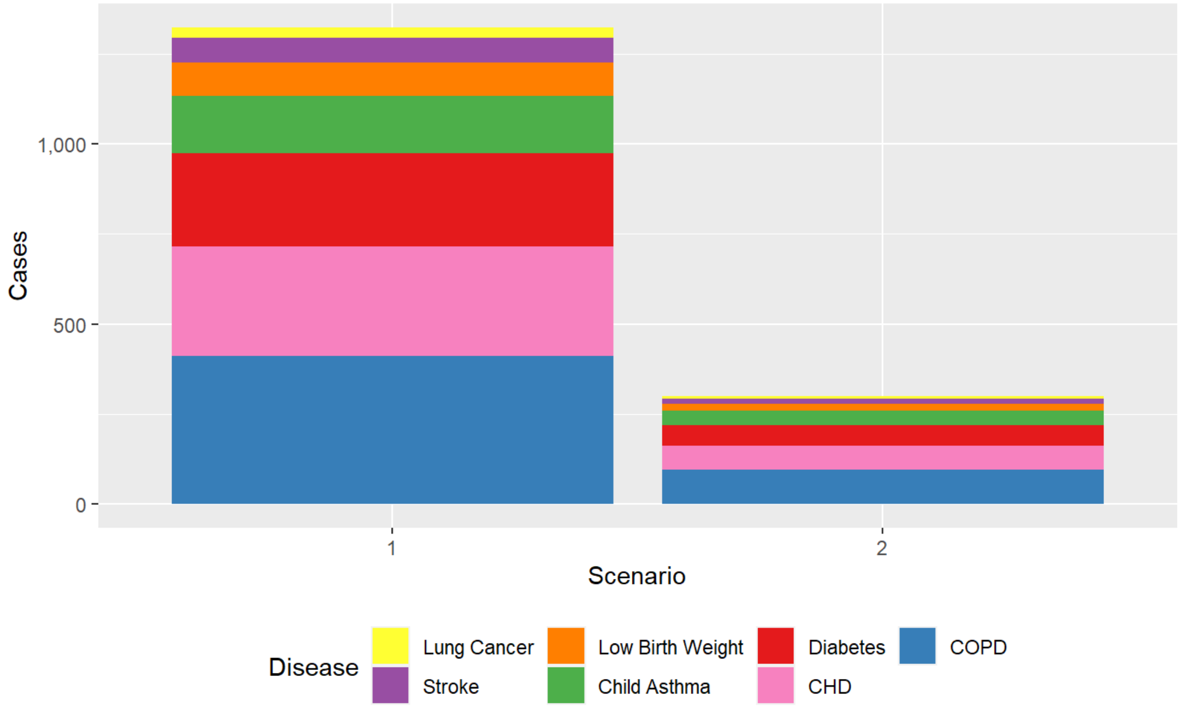
For the scenario where Lambeth meets the WHO limits for $PM_{2.5}$, the model projects 1,324 cumulative incidence of disease avoided by 2024. COPD is the largest contributor at 412 incidence, followed by CHD (303) and diabetes (259).

For the low pollution or ‘best case’ scenario where Lambeth has the same level of $PM_{2.5}$ as the London borough with the lowest reported levels (Havering), the model projects 298 cumulative incidence of disease avoided by 2024. COPD is the largest contributor at 94 incidence, followed by CHD (68) and diabetes (58).

Table 17. Cumulative disease incidence avoided by $PM_{2.5}$ scenario for Lambeth

Scenario	Year	CHD	Child Asthma	COPD	Diabetes	Low Birth Weight	Lung Cancer	Stroke	Total
WHO Limits	2020	59 ± [4]	33 ± [4]	79 ± [5]	50 ± [8]	17 ± [3]	6 ± [3]	13 ± [4]	258 ± [12]
	2021	119 ± [6]	66 ± [6]	161 ± [6]	100 ± [11]	36 ± [4]	13 ± [4]	27 ± [5]	522 ± [17]
	2022	179 ± [7]	95 ± [8]	244 ± [8]	153 ± [13]	56 ± [5]	19 ± [5]	40 ± [6]	785 ± [21]
	2023	242 ± [9]	128 ± [9]	327 ± [9]	205 ± [15]	75 ± [5]	24 ± [5]	53 ± [7]	1,055 ± [24]
	2024	303 ± [10]	161 ± [10]	412 ± [10]	259 ± [17]	93 ± [6]	30 ± [6]	67 ± [8]	1,324 ± [27]
Low Pollution	2020	13 ± [4]	9 ± [4]	18 ± [5]	13 ± [8]	4 ± [3]	2 ± [3]	2 ± [4]	60 ± [12]
	2021	27 ± [6]	16 ± [6]	38 ± [7]	23 ± [11]	8 ± [4]	3 ± [4]	4 ± [5]	119 ± [17]
	2022	40 ± [8]	24 ± [8]	57 ± [8]	34 ± [13]	12 ± [5]	5 ± [5]	7 ± [6]	178 ± [21]
	2023	54 ± [9]	31 ± [9]	75 ± [10]	47 ± [15]	16 ± [6]	6 ± [5]	10 ± [7]	240 ± [24]
	2024	68 ± [10]	39 ± [10]	94 ± [11]	58 ± [17]	20 ± [6]	7 ± [6]	13 ± [8]	298 ± [27]

Figure 16. Cumulative disease incidence avoided by $PM_{2.5}$ scenario for Lambeth



Scenarios: (1) Meeting WHO limits, (2) Low pollution

Cumulative NHS costs avoided

Table 18 and **Figure 17** show the cumulative NHS costs avoided in Lambeth from 2020-2024 across the two scenarios for reductions in $PM_{2.5}$.

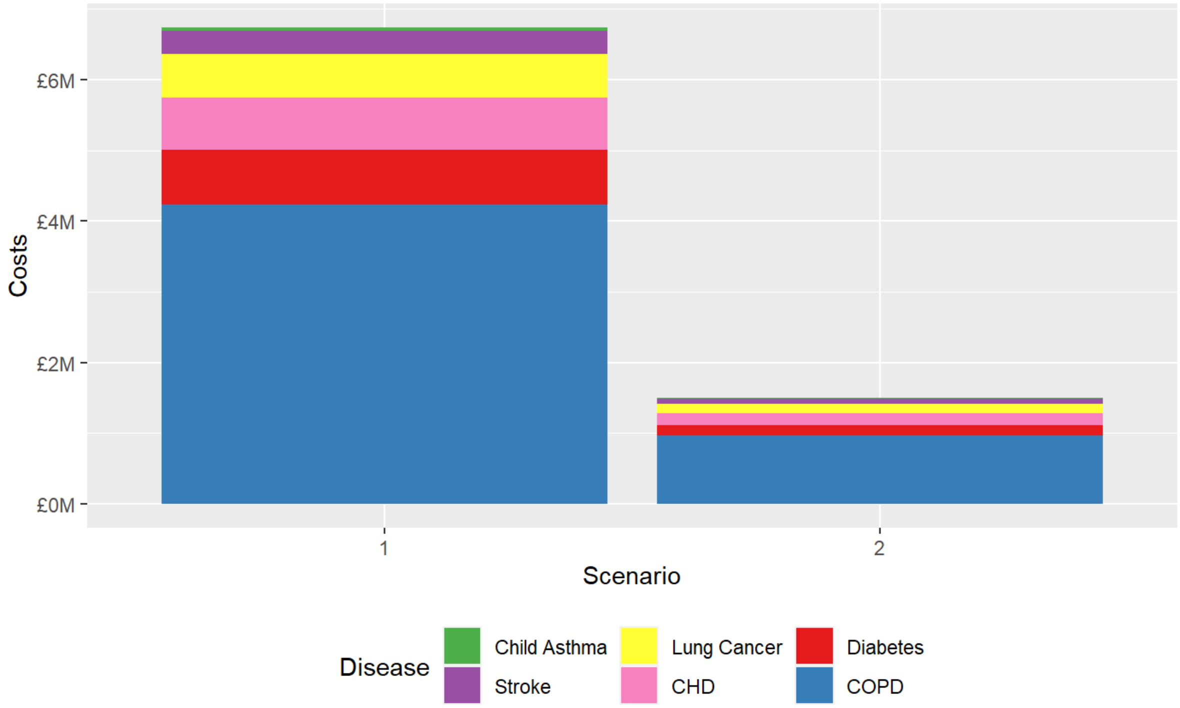
For the scenario where Lambeth meets the WHO limits for $PM_{2.5}$, the model projects £6,736,877 cumulative NHS costs avoided by 2024. COPD is the largest contributor at £4,234,572 costs avoided, followed by diabetes (£769,525) and CHD (£739,552).

For the low pollution or 'best case' scenario where Lambeth has the same level of $PM_{2.5}$ as the London borough with the lowest reported levels (Havering), the model projects £1,494,116 cumulative NHS costs avoided by 2024. COPD is the largest contributor at £971,417 costs avoided, followed by CHD (£162,605), diabetes (£144,187) and lung cancer (£139,211).

Table 18. Cumulative NHS costs avoided by $PM_{2.5}$ scenario for Lambeth

Scenario	Year	CHD	Child Asthma	COPD	Diabetes	Lung Cancer	Stroke	Total
WHO Limits	2020	£57,727 ± [£11,249]	£4,316 ± [£1,672]	£293,362 ± [£64,270]	£60,598 ± [£33,560]	£80,511 ± [£40,873]	£11,723 ± [£28,749]	£508,237 ± [£88,788]
	2021	£162,087 ± [£15,990]	£12,168 ± [£2,360]	£871,728 ± [£91,154]	£167,475 ± [£47,568]	£202,199 ± [£59,921]	£51,574 ± [£40,754]	£1,467,230 ± [£126,824]
	2022	£311,976 ± [£19,663]	£22,889 ± [£2,884]	£1,725,981 ± [£111,946]	£322,713 ± [£58,386]	£339,822 ± [£75,258]	£116,460 ± [£50,024]	£2,839,840 ± [£156,531]
	2023	£506,456 ± [£22,802]	£36,400 ± [£3,324]	£2,851,079 ± [£129,655]	£524,192 ± [£67,580]	£480,941 ± [£88,525]	£204,922 ± [£57,915]	£4,603,990 ± [£181,932]
	2024	£739,552 ± [£25,595]	£52,683 ± [£3,710]	£4,234,572 ± [£145,424]	£769,525 ± [£75,749]	£623,758 ± [£100,448]	£316,788 ± [£64,938]	£6,736,877 ± [£204,601]
Low Pollution	2020	£12,524 ± [£11,306]	£1,038 ± [£1,675]	£66,619 ± [£64,444]	£10,111 ± [£33,578]	£20,787 ± [£41,101]	£4,384 ± [£28,756]	£115,464 ± [£89,036]
	2021	£35,249 ± [£16,102]	£2,815 ± [£2,366]	£200,000 ± [£91,516]	£30,118 ± [£47,604]	£46,957 ± [£60,325]	£11,707 ± [£40,783]	£326,845 ± [£127,313]
	2022	£67,861 ± [£19,839]	£5,378 ± [£2,894]	£397,209 ± [£112,530]	£58,382 ± [£58,443]	£82,941 ± [£75,790]	£24,878 ± [£50,079]	£636,650 ± [£157,266]
	2023	£110,960 ± [£23,047]	£8,545 ± [£3,337]	£654,534 ± [£130,489]	£97,179 ± [£67,659]	£108,957 ± [£89,180]	£42,318 ± [£57,999]	£1,022,493 ± [£182,933]
	2024	£162,605 ± [£25,914]	£12,447 ± [£3,727]	£971,417 ± [£146,528]	£144,187 ± [£75,853]	£139,211 ± [£101,201]	£64,249 ± [£65,055]	£1,494,116 ± [£205,872]

Figure 17. Cumulative NHS costs avoided by $PM_{2.5}$ scenario for Lambeth



Scenarios: (1) Meeting WHO limits, (2) Low pollution

Annual QALYs gained

Table 19 and **Figure 18** present the annual QALYs gained in Lambeth from 2020-2024 across the two scenarios for reductions in $PM_{2.5}$.

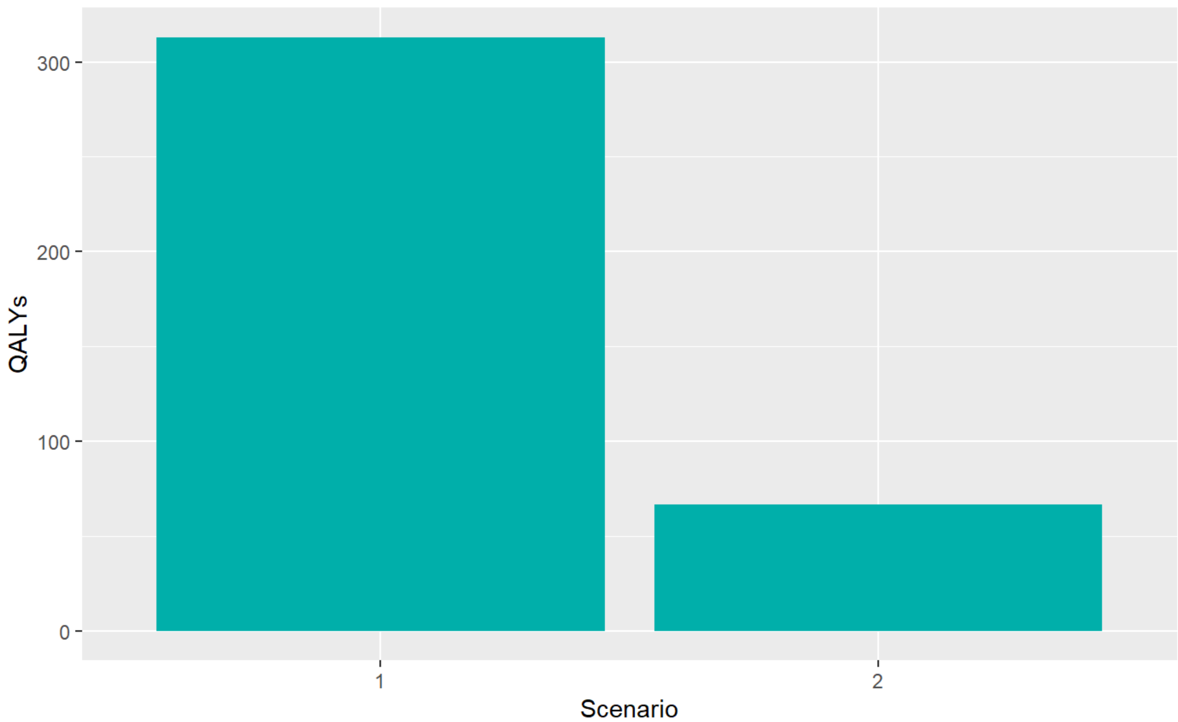
For the scenario where Lambeth meets the WHO limits for $PM_{2.5}$, the model projects 313 annual QALYs gained in 2024. Based on a projected 2024 Lambeth population of 327,570, this equates to around 96 QALYs per 100,000 individuals.

For the low pollution or 'best case' scenario where Lambeth has the same level of $PM_{2.5}$ as the London borough with the lowest reported levels (Havering), the model projects 66 annual QALYs, or 20 QALYs in 100,000, gained in 2024.

Table 19. Annual QALYs gained by $PM_{2.5}$ scenario for Lambeth

Year	WHO Limits	Low Pollution
2020	72 ± [30]	15 ± [30]
2021	136 ± [30]	29 ± [30]
2022	197 ± [30]	42 ± [30]
2023	257 ± [30]	55 ± [30]
2024	313 ± [30]	66 ± [30]

Figure 18. Annual QALYs gained by $PM_{2.5}$ scenario for Lambeth



Scenarios: (1) Meeting WHO limits, (2) Low pollution

Southwark

NO$_2$ results for Southwark

Southwark disease incidence attributable to air pollution

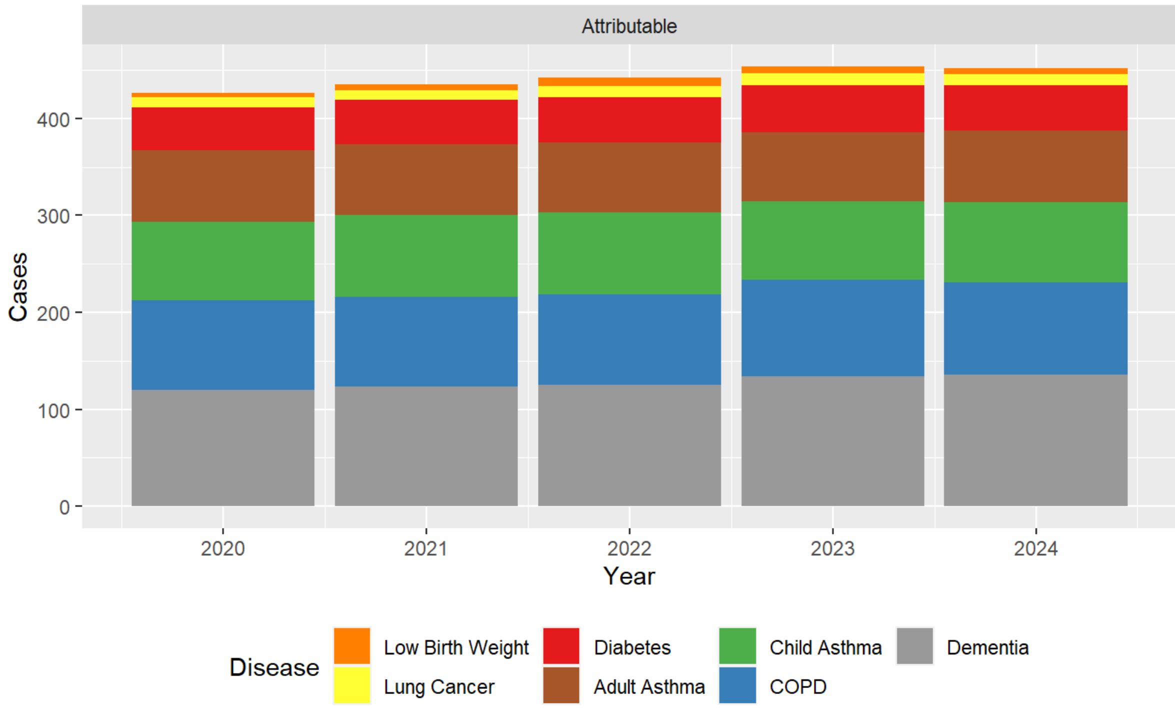
Annual disease incidence attributable
Table 20 and

Figure 19 show the total new cases of disease for the diseases related to NO_2. In 2024, the incidence of disease attributable to NO_2 in Southwark is projected to be 452 , with dementia being the largest contributor with 136 new cases.

Table 20. Southwark annual disease incidence attributable to NO_2

Year	Adult Asthma	Child Asthma	COPD	Dementia	Diabetes	Low Birth Weight	Lung Cancer	Total
2020	73 ± [5]	81 ± [4]	93 ± [4]	119 ± [5]	44 ± [7]	5 ± [3]	11 ± [3]	427 ± [12]
2021	73 ± [5]	84 ± [4]	93 ± [4]	123 ± [5]	46 ± [7]	6 ± [3]	9 ± [3]	435 ± [12]
2022	72 ± [5]	84 ± [4]	94 ± [4]	125 ± [5]	46 ± [7]	8 ± [3]	12 ± [3]	442 ± [12]
2023	72 ± [5]	81 ± [4]	99 ± [4]	134 ± [5]	48 ± [7]	7 ± [3]	12 ± [3]	453 ± [12]
2024	73 ± [5]	83 ± [4]	95 ± [4]	136 ± [5]	47 ± [7]	6 ± [3]	12 ± [3]	452 ± [12]

Figure 19. Annual disease incidence attributable to NO_2 by year in Southwark



Cumulative disease incidence attributable

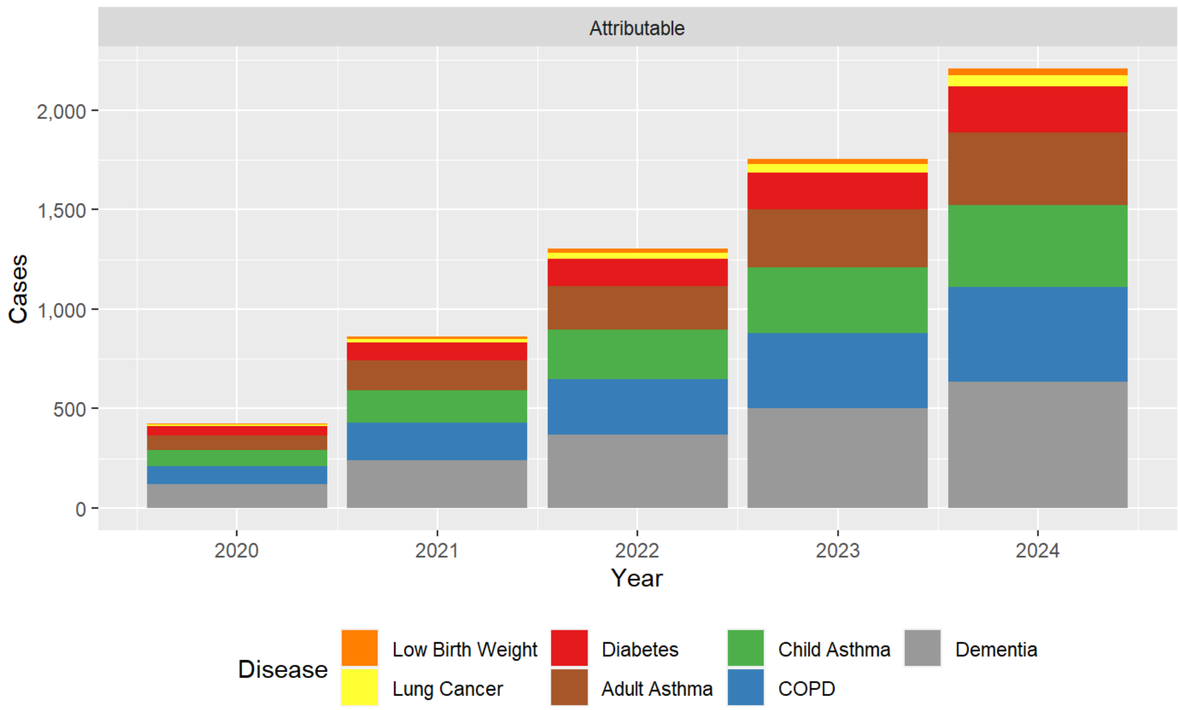
Table 21 and

Figure 20 show the cumulative incidence of disease attributable to NO_2. The model has calculated the cumulative incidence disease cases attributable to NO_2 in Southwark to be 2,208 by 2024. Dementia is the largest contributor with 637 cumulative incidence by 2024.

Table 21. Southwark cumulative disease incidence attributable to NO_2

Year	Adult Asthma	Child Asthma	COPD	Dementia	Diabetes	Low Birth Weight	Lung Cancer	Total
2020	73 ± [5]	81 ± [4]	93 ± [4]	119 ± [5]	44 ± [7]	5 ± [3]	11 ± [3]	427 ± [12]
2021	146 ± [7]	165 ± [6]	186 ± [6]	243 ± [7]	90 ± [10]	11 ± [4]	20 ± [4]	861 ± [18]
2022	219 ± [8]	250 ± [7]	280 ± [8]	367 ± [8]	136 ± [13]	20 ± [5]	32 ± [5]	1,303 ± [21]
2023	290 ± [10]	331 ± [8]	379 ± [9]	501 ± [10]	185 ± [15]	27 ± [6]	43 ± [5]	1,756 ± [25]
2024	364 ± [11]	413 ± [9]	474 ± [10]	637 ± [11]	231 ± [16]	33 ± [6]	55 ± [6]	2,208 ± [28]

Figure 20. Cumulative disease incidence attributable to NO_2 by year in Southwark



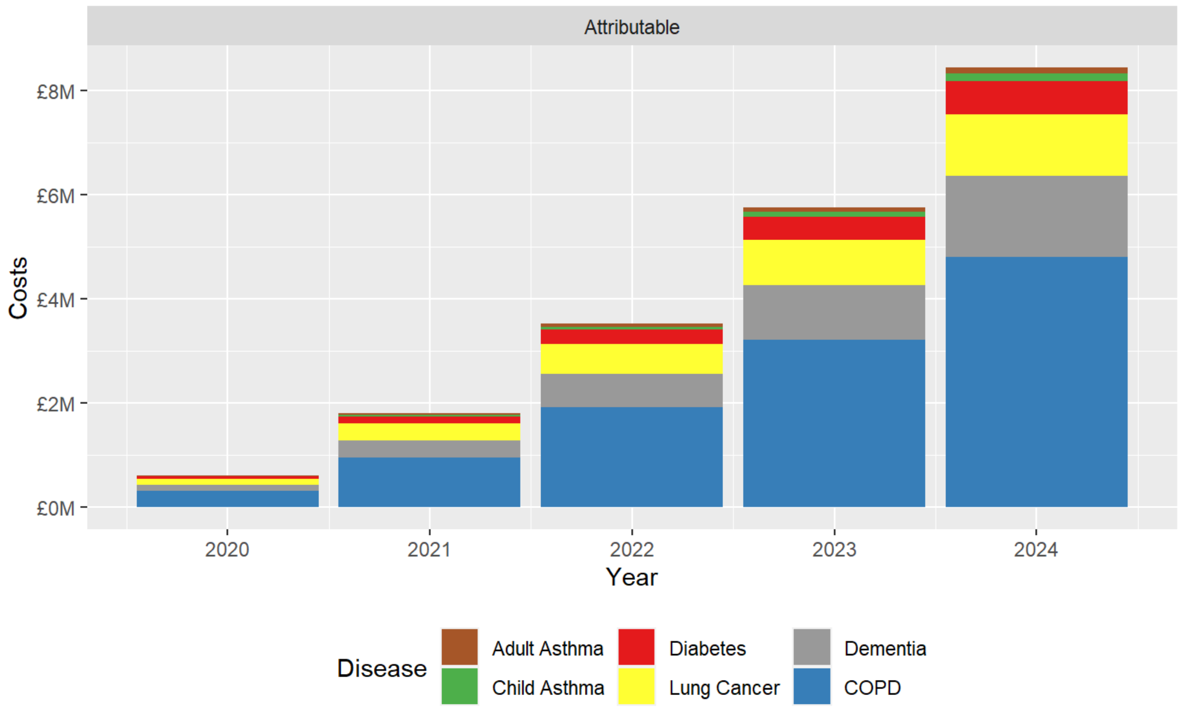
Cumulative NHS costs attributable

Table 22 and **Figure 21** show the cumulative NHS costs attributable to NO_2. By 2024 it is predicted that £8,435,292 NHS costs will be attributable to NO_2 in Southwark. COPD is the largest contributor to this with a cost of £4,794,428 expected by 2024.

Table 22. Southwark cumulative NHS costs attributable to NO_2

Year	Adult Asthma	Child Asthma	COPD	Dementia	Diabetes	Lung Cancer	Total
2020	£9,494 ± [£3,460]	£9,503 ± [£1,698]	£313,455 ± [£62,468]	£106,680 ± [£11,559]	£45,538 ± [£32,970]	£123,244 ± [£40,395]	£607,914 ± [£82,277]
2021	£27,358 ± [£4,865]	£28,536 ± [£2,379]	£959,665 ± [£88,895]	£320,327 ± [£16,787]	£138,869 ± [£46,738]	£326,804 ± [£59,235]	£1,801,560 ± [£117,927]
2022	£51,024 ± [£5,929]	£56,789 ± [£2,892]	£1,922,429 ± [£109,622]	£636,949 ± [£21,054]	£270,790 ± [£57,427]	£578,491 ± [£74,601]	£3,516,471 ± [£146,174]
2023	£79,904 ± [£6,817]	£93,048 ± [£3,315]	£3,210,858 ± [£127,423]	£1,053,855 ± [£24,833]	£441,414 ± [£66,535]	£867,631 ± [£88,004]	£5,746,711 ± [£170,536]
2024	£114,039 ± [£7,592]	£137,252 ± [£3,681]	£4,794,428 ± [£143,364]	£1,566,879 ± [£28,294]	£647,936 ± [£74,636]	£1,174,760 ± [£100,118]	£8,435,292 ± [£192,404]

Figure 21. Cumulative NHS costs attributable to NO_2 by year in Southwark



Southwark scenario assessment

This section estimates the impact of the scenarios on the new cases of disease, cases avoided, NHS costs avoided and QALYs gained due to changes in NO_2 to the year 2024 in Southwark.

Annual incidence cases

Table 23 and **Figure 22** present he annual incidence of disease in Southwark from 2020-2024 across baseline and the five scenarios for NO_2.

For the baseline scenario – a static/flat trend – the model projects a disease incidence of 3,123 in 2024 in Southwark. Diabetes is the largest contributor at 1,055 incidence cases, followed by dementia (522) and adult asthma (459).

For the low pollution or 'best case' scenario where Southwark has the same level of NO_2 as the London borough with the lowest reported levels (Havering), the model projects 3,035 incidence of disease in 2024. Diabetes is the largest contributor with 1,048 incidence, followed again by dementia (493) and adult asthma (445).

COVID-19 scenarios for Southwark:

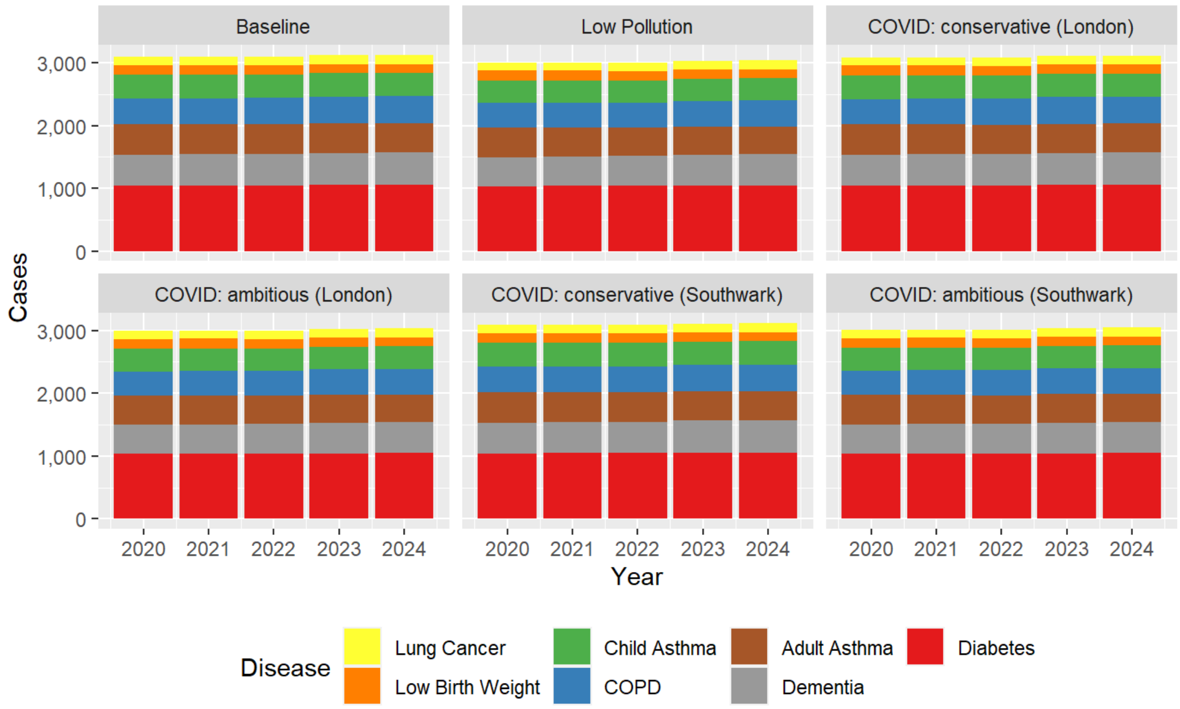
- The London-wide COVID-19 conservative scenario projection for Southwark is 3,115 disease incidence in 2024. Diabetes incidence, the largest contributor, is 1,054.
- The London-wide COVID-19 ambitious scenario projection for Southwark is 3,034 incidence in 2024. Diabetes incidence, the largest contributor, is 1,048.
- The Southwark conservative COVID-19 reduction scenario of a 2% annual NO_2 reduction projects 3,115 incidence in 2024. Diabetes incidence, the largest contributor, is 1,054.
- The Southwark ambitious COVID-19 reduction scenario of a 18% in annual NO_2 reduction projects 3,047 incidence in 2024. Diabetes incidence, the largest contributor, is 1,049.

Table 23. Annual disease incidence by NO_2 scenario for Southwark

Scenario	Year	Adult Asthma	Child Asthma	COPD	Dementia	Diabetes	Low Birth Weight	Lung Cancer	Total
Baseline	2020	485 ± [4]	381 ± [3]	408 ± [3]	493 ± [4]	1,042 ± [5]	155 ± [2]	131 ± [2]	3,094 ± [9]
	2021	478 ± [4]	376 ± [3]	415 ± [3]	497 ± [4]	1,046 ± [5]	153 ± [2]	133 ± [2]	3,097 ± [9]
	2022	468 ± [4]	372 ± [3]	422 ± [3]	501 ± [4]	1,048 ± [5]	148 ± [2]	139 ± [2]	3,097 ± [9]
	2023	466 ± [3]	370 ± [3]	429 ± [3]	513 ± [4]	1,052 ± [5]	146 ± [2]	140 ± [2]	3,117 ± [9]
	2024	459 ± [3]	370 ± [3]	432 ± [3]	522 ± [4]	1,055 ± [5]	143 ± [2]	144 ± [2]	3,123 ± [9]
Low Pollution	2020	471 ± [4]	364 ± [3]	386 ± [3]	465 ± [4]	1,033 ± [5]	154 ± [2]	128 ± [2]	3,001 ± [9]
	2021	464 ± [4]	356 ± [3]	395 ± [3]	470 ± [4]	1,037 ± [5]	153 ± [2]	132 ± [2]	3,007 ± [9]
	2022	454 ± [3]	354 ± [3]	402 ± [3]	473 ± [4]	1,039 ± [5]	146 ± [2]	136 ± [2]	3,004 ± [9]
	2023	453 ± [3]	352 ± [3]	407 ± [3]	486 ± [4]	1,045 ± [5]	145 ± [2]	138 ± [2]	3,025 ± [9]
	2024	445 ± [3]	353 ± [3]	412 ± [3]	493 ± [4]	1,048 ± [5]	141 ± [2]	142 ± [2]	3,035 ± [9]
COVID: Conservative (London)	2020	484 ± [4]	379 ± [3]	406 ± [3]	490 ± [4]	1,042 ± [5]	154 ± [2]	130 ± [2]	3,086 ± [9]
	2021	476 ± [4]	374 ± [3]	413 ± [3]	494 ± [4]	1,045 ± [5]	153 ± [2]	133 ± [2]	3,088 ± [9]
	2022	467 ± [4]	370 ± [3]	420 ± [3]	498 ± [4]	1,046 ± [5]	148 ± [2]	138 ± [2]	3,087 ± [9]
	2023	464 ± [3]	369 ± [3]	427 ± [3]	511 ± [4]	1,052 ± [5]	146 ± [2]	140 ± [2]	3,108 ± [9]
	2024	457 ± [3]	369 ± [3]	430 ± [3]	518 ± [4]	1,054 ± [5]	143 ± [2]	144 ± [2]	3,115 ± [9]

Scenario	Year	Adult Asthma	Child Asthma	COPD	Dementia	Diabetes	Low Birth Weight	Lung Cancer	Total
COVID: Ambitious (London)	2020	469 ± [4]	361 ± [3]	384 ± [3]	463 ± [4]	1,033 ± [5]	153 ± [2]	128 ± [2]	2,991 ± [9]
	2021	462 ± [4]	357 ± [3]	392 ± [3]	468 ± [4]	1,036 ± [5]	153 ± [2]	131 ± [2]	2,998 ± [9]
	2022	450 ± [3]	357 ± [3]	399 ± [3]	471 ± [4]	1,037 ± [5]	146 ± [2]	136 ± [2]	2,996 ± [9]
	2023	452 ± [3]	359 ± [3]	403 ± [3]	482 ± [4]	1,043 ± [5]	144 ± [2]	138 ± [2]	3,021 ± [9]
	2024	442 ± [3]	362 ± [3]	409 ± [3]	490 ± [4]	1,048 ± [5]	141 ± [2]	141 ± [2]	3,034 ± [9]
COVID: Conservative (Southwark)	2020	484 ± [4]	379 ± [3]	406 ± [3]	490 ± [4]	1,042 ± [5]	154 ± [2]	130 ± [2]	3,086 ± [9]
	2021	476 ± [4]	374 ± [3]	413 ± [3]	494 ± [4]	1,045 ± [5]	153 ± [2]	133 ± [2]	3,088 ± [9]
	2022	467 ± [4]	370 ± [3]	420 ± [3]	498 ± [4]	1,046 ± [5]	148 ± [2]	138 ± [2]	3,087 ± [9]
	2023	464 ± [3]	369 ± [3]	427 ± [3]	511 ± [4]	1,052 ± [5]	146 ± [2]	140 ± [2]	3,108 ± [9]
	2024	457 ± [3]	369 ± [3]	430 ± [3]	518 ± [4]	1,054 ± [5]	143 ± [2]	144 ± [2]	3,115 ± [9]
COVID: Ambitious (Southwark)	2020	472 ± [4]	365 ± [3]	387 ± [3]	467 ± [4]	1,035 ± [5]	154 ± [2]	128 ± [2]	3,008 ± [9]
	2021	464 ± [4]	360 ± [3]	396 ± [3]	472 ± [4]	1,037 ± [5]	152 ± [2]	132 ± [2]	3,015 ± [9]
	2022	454 ± [3]	360 ± [3]	403 ± [3]	475 ± [4]	1,039 ± [5]	147 ± [2]	137 ± [2]	3,014 ± [9]
	2023	454 ± [3]	360 ± [3]	407 ± [3]	487 ± [4]	1,045 ± [5]	144 ± [2]	138 ± [2]	3,036 ± [9]
	2024	445 ± [3]	364 ± [3]	412 ± [3]	494 ± [4]	1,049 ± [5]	142 ± [2]	142 ± [2]	3,047 ± [9]

Figure 22. Annual incidence by year and NO_2 scenario for Southwark



Cumulative incidence cases

Table 24 and **Figure 23** present the cumulative incidence of disease in Southwark from 2020-2024 across baseline and the five scenarios for NO_2.

For the baseline scenario – a static/flat trend – the model projects 15,529 cumulative incidence cases by 2024 in Southwark. Diabetes is the largest contributor at 5,243 cumulative incidence cases, followed by dementia (2,525) and adult asthma (2,357).

For the low pollution or 'best case' scenario where Southwark has the same level of NO_2 as the London borough with the lowest reported levels (Havering), the model projects 15,072 cumulative incidence of disease by 2024. Diabetes is the largest contributor at 5,201 incidence, followed again by dementia (2,387) and adult asthma (2,287).

COVID-19 scenarios for Southwark:

- The London-wide COVID-19 conservative scenario projection for Southwark is 15,483 cumulative incidence of disease by 2024. Diabetes cumulative incidence, the largest contributor, is 5,239.

- The London-wide COVID-19 ambitious scenario projection for Southwark is 15,041 cumulative incidence by 2024. Diabetes cumulative incidence, the largest contributor, is 5,197.

- The Southwark conservative COVID-19 reduction scenario of a 2% annual NO_2 reduction projects 15,483 cumulative incidence by 2024. Diabetes cumulative incidence, the largest contributor, is 5,239.

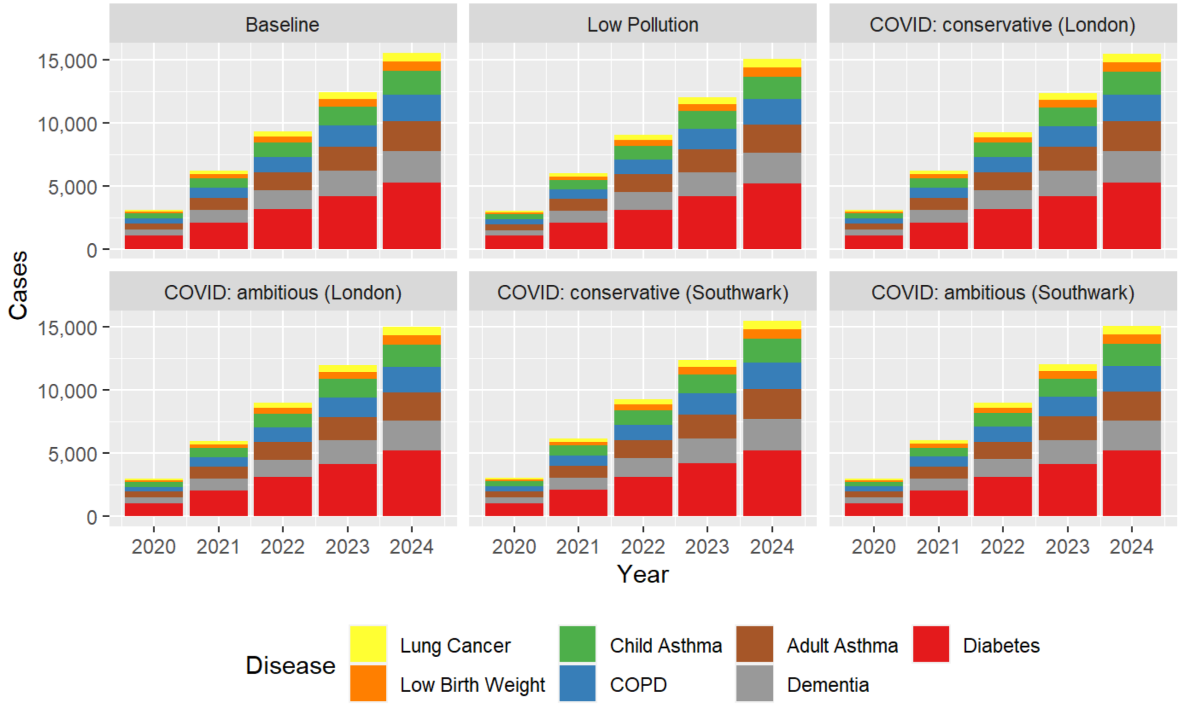
- The Southwark ambitious COVID-19 reduction scenario of a 18% in annual NO_2 reduction projects 15,119 cumulative incidence in 2024. Diabetes cumulative incidence, the largest contributor, is 5,205.

Table 24. Cumulative disease incidence by NO_2 scenario for Southwark

Scenario	Year	Adult Asthma	Child Asthma	COPD	Dementia	Diabetes	Low Birth Weight	Lung Cancer	Total
Baseline	2020	485 ± [4]	381 ± [3]	408 ± [3]	493 ± [4]	1,042 ± [5]	155 ± [2]	131 ± [2]	3,094 ± [9]
	2021	964 ± [5]	757 ± [5]	822 ± [5]	990 ± [5]	2,088 ± [7]	308 ± [3]	263 ± [3]	6,191 ± [13]
	2022	1,432 ± [6]	1,128 ± [5]	1,244 ± [6]	1,490 ± [6]	3,135 ± [9]	456 ± [3]	402 ± [3]	9,288 ± [16]
	2023	1,898 ± [7]	1,499 ± [6]	1,673 ± [7]	2,004 ± [7]	4,188 ± [11]	602 ± [4]	542 ± [4]	12,405 ± [18]
	2024	2,357 ± [8]	1,868 ± [7]	2,105 ± [7]	2,525 ± [8]	5,243 ± [12]	745 ± [4]	686 ± [4]	15,529 ± [20]
Low Pollution	2020	471 ± [4]	364 ± [3]	386 ± [3]	465 ± [4]	1,033 ± [5]	154 ± [2]	128 ± [2]	3,001 ± [9]
	2021	935 ± [5]	721 ± [4]	781 ± [5]	935 ± [5]	2,070 ± [7]	307 ± [3]	260 ± [3]	6,008 ± [13]
	2022	1,389 ± [6]	1,074 ± [5]	1,183 ± [6]	1,408 ± [6]	3,109 ± [9]	453 ± [3]	396 ± [3]	9,012 ± [15]
	2023	1,842 ± [7]	1,427 ± [6]	1,590 ± [6]	1,894 ± [7]	4,154 ± [10]	598 ± [4]	534 ± [4]	12,037 ± [18]
	2024	2,287 ± [8]	1,780 ± [7]	2,002 ± [7]	2,387 ± [8]	5,201 ± [12]	739 ± [4]	676 ± [4]	15,072 ± [20]
COVID: Conservative (London)	2020	484 ± [4]	379 ± [3]	406 ± [3]	490 ± [4]	1,042 ± [5]	154 ± [2]	130 ± [2]	3,086 ± [9]
	2021	960 ± [5]	753 ± [4]	818 ± [5]	985 ± [5]	2,087 ± [7]	308 ± [3]	263 ± [3]	6,174 ± [13]
	2022	1,427 ± [6]	1,123 ± [5]	1,238 ± [6]	1,483 ± [6]	3,133 ± [9]	455 ± [3]	401 ± [3]	9,261 ± [16]
	2023	1,891 ± [7]	1,492 ± [6]	1,665 ± [7]	1,993 ± [7]	4,185 ± [11]	601 ± [4]	541 ± [4]	12,369 ± [18]
	2024	2,348 ± [8]	1,861 ± [7]	2,094 ± [7]	2,512 ± [8]	5,239 ± [12]	744 ± [4]	685 ± [4]	15,483 ± [20]
	2020	469 ± [4]	361 ± [3]	384 ± [3]	463 ± [4]	1,033 ± [5]	153 ± [2]	128 ± [2]	2,991 ± [9]
	2021	931 ± [5]	718 ± [4]	776 ± [5]	931 ± [5]	2,069 ± [7]	306 ± [3]	259 ± [3]	5,989 ± [13]

Scenario	Year	Adult Asthma	Child Asthma	COPD	Dementia	Diabetes	Low Birth Weight	Lung Cancer	Total
COVID: Ambitious (London)	2022	1,381 ± [6]	1,075 ± [5]	1,175 ± [6]	1,401 ± [6]	3,106 ± [9]	452 ± [3]	395 ± [3]	8,986 ± [15]
	2023	1,833 ± [7]	1,434 ± [6]	1,578 ± [6]	1,884 ± [7]	4,149 ± [10]	596 ± [4]	533 ± [4]	12,007 ± [18]
	2024	2,275 ± [8]	1,796 ± [7]	1,987 ± [7]	2,374 ± [8]	5,197 ± [12]	737 ± [4]	675 ± [4]	15,041 ± [20]
COVID: Conservative (Southwark)	2020	484 ± [4]	379 ± [3]	406 ± [3]	490 ± [4]	1,042 ± [5]	154 ± [2]	130 ± [2]	3,086 ± [9]
	2021	960 ± [5]	753 ± [4]	818 ± [5]	985 ± [5]	2,087 ± [7]	308 ± [3]	263 ± [3]	6,174 ± [13]
	2022	1,427 ± [6]	1,123 ± [5]	1,238 ± [6]	1,483 ± [6]	3,133 ± [9]	455 ± [3]	401 ± [3]	9,261 ± [16]
	2023	1,891 ± [7]	1,492 ± [6]	1,665 ± [7]	1,993 ± [7]	4,185 ± [11]	601 ± [4]	541 ± [4]	12,369 ± [18]
	2024	2,348 ± [8]	1,861 ± [7]	2,094 ± [7]	2,512 ± [8]	5,239 ± [12]	744 ± [4]	685 ± [4]	15,483 ± [20]
COVID: Ambitious (Southwark)	2020	472 ± [4]	365 ± [3]	387 ± [3]	467 ± [4]	1,035 ± [5]	154 ± [2]	128 ± [2]	3,008 ± [9]
	2021	936 ± [5]	725 ± [4]	784 ± [5]	939 ± [5]	2,072 ± [7]	306 ± [3]	260 ± [3]	6,022 ± [13]
	2022	1,390 ± [6]	1,084 ± [5]	1,187 ± [6]	1,414 ± [6]	3,112 ± [9]	453 ± [3]	396 ± [3]	9,036 ± [16]
	2023	1,844 ± [7]	1,445 ± [6]	1,594 ± [6]	1,902 ± [7]	4,156 ± [10]	597 ± [4]	535 ± [4]	12,072 ± [18]
	2024	2,289 ± [8]	1,808 ± [7]	2,006 ± [7]	2,396 ± [8]	5,205 ± [12]	739 ± [4]	677 ± [4]	15,119 ± [20]

Figure 23. Cumulative disease incidence by year and NO_2 scenario for Southwark



Cumulative disease incidence avoided

Table 25 and **Figure 24** present the cumulative disease incidence avoided in Southwark from 2020-2024 across the five scenarios for reductions in NO_2.

For the low pollution or 'best case' scenario where Southwark has the same level of NO_2 as the London borough with the lowest reported levels (Havering), the model projects 457 cumulative incidence avoided by 2024. Dementia is the largest contributor at 139 cumulative incidence avoided, followed by COPD (103) and child asthma (88).

COVID-19 scenarios for Southwark:

- The London-wide COVID-19 conservative scenario projection is 45 cumulative incidence cases avoided in disease by 2024. Dementia cumulative incidence cases avoided, the largest contributor, is 14.

- The London-wide COVID-19 ambitious scenario projection for Southwark is 488 cumulative incidence cases avoided by 2024. Dementia incidence, the largest contributor, is 151.

- The Southwark conservative COVID-19 reduction scenario of a 2% annual NO_2 reduction projects 45 cumulative incidence cases avoided by 2024. Dementia incidence, the largest contributor, is 14.

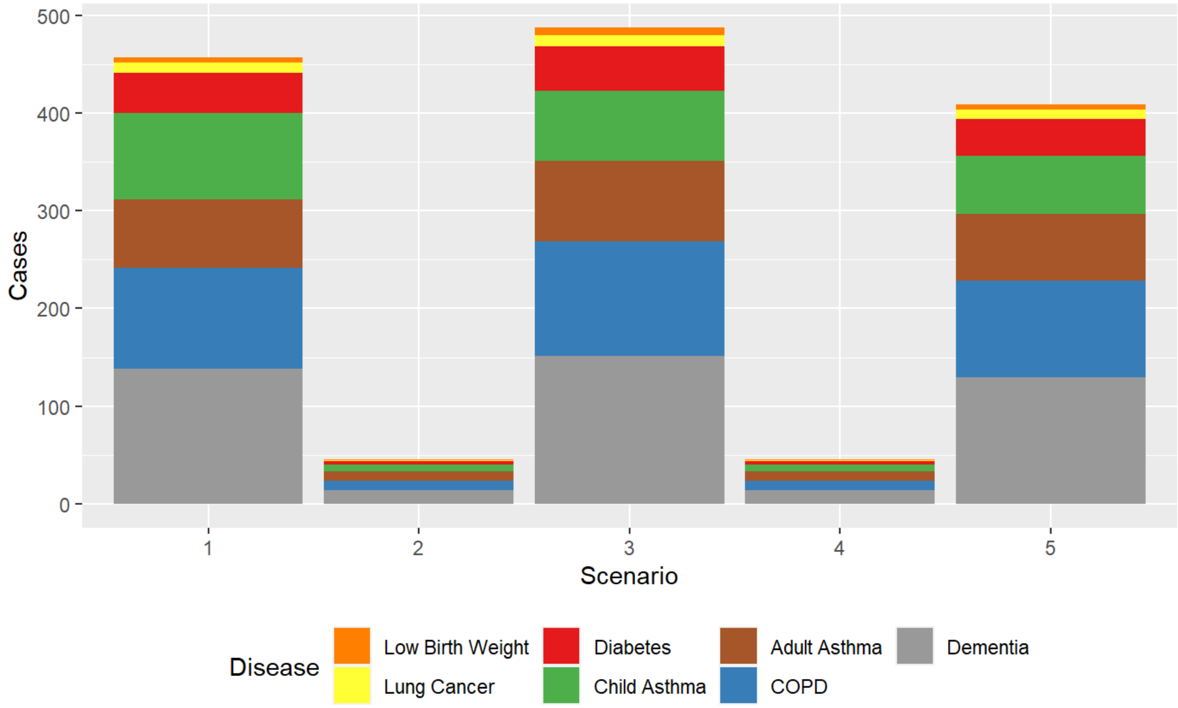
- The Southwark ambitious COVID-19 reduction scenario of a 18% in annual NO_2 reduction projects 409 cumulative incidence cases avoided by 2024. Dementia incidence, the largest contributor, is 129.

Table 25. Cumulative disease incidence avoided by NO_2 scenario for Southwark

Scenario	Year	Adult Asthma	Child Asthma	COPD	Dementia	Diabetes	Low Birth Weight	Lung Cancer	Total
Low Pollution	2020	15 ± [5]	17 ± [4]	22 ± [5]	28 ± [5]	9 ± [7]	1 ± [3]	3 ± [3]	93 ± [13]
	2021	28 ± [7]	36 ± [6]	41 ± [7]	55 ± [7]	18 ± [11]	1 ± [4]	4 ± [4]	183 ± [18]
	2022	43 ± [9]	54 ± [8]	61 ± [8]	82 ± [9]	26 ± [13]	3 ± [5]	6 ± [5]	276 ± [22]
	2023	56 ± [10]	72 ± [9]	83 ± [9]	110 ± [10]	34 ± [15]	4 ± [6]	9 ± [5]	368 ± [25]
	2024	70 ± [11]	88 ± [10]	103 ± [10]	139 ± [11]	41 ± [17]	6 ± [6]	10 ± [6]	457 ± [28]
COVID: Conservative (London)	2020	2 ± [5]	2 ± [5]	2 ± [5]	2 ± [5]	0 ± [7]	0 ± [3]	0 ± [3]	8 ± [13]
	2021	3 ± [7]	4 ± [6]	4 ± [7]	5 ± [7]	1 ± [11]	1 ± [4]	0 ± [4]	18 ± [18]
	2022	5 ± [9]	5 ± [8]	6 ± [8]	8 ± [9]	2 ± [13]	1 ± [5]	1 ± [5]	27 ± [22]
	2023	7 ± [10]	7 ± [9]	8 ± [9]	10 ± [10]	3 ± [15]	1 ± [6]	1 ± [5]	37 ± [26]
	2024	9 ± [11]	7 ± [10]	10 ± [11]	14 ± [12]	3 ± [17]	1 ± [6]	1 ± [6]	45 ± [29]
COVID: Ambitious (London)	2020	16 ± [5]	20 ± [4]	24 ± [5]	30 ± [5]	9 ± [7]	2 ± [3]	3 ± [3]	103 ± [13]
	2021	33 ± [7]	38 ± [6]	47 ± [7]	59 ± [7]	19 ± [11]	2 ± [4]	4 ± [4]	202 ± [18]
	2022	51 ± [9]	53 ± [8]	69 ± [8]	89 ± [9]	29 ± [13]	4 ± [5]	7 ± [5]	303 ± [22]
	2023	65 ± [10]	64 ± [9]	95 ± [9]	120 ± [10]	39 ± [15]	6 ± [6]	9 ± [5]	398 ± [25]
	2024	82 ± [11]	72 ± [10]	118 ± [10]	151 ± [11]	46 ± [17]	8 ± [6]	11 ± [6]	488 ± [28]
	2020	2 ± [5]	2 ± [5]	2 ± [5]	2 ± [5]	0 ± [7]	0 ± [3]	0 ± [3]	8 ± [13]
	2021	3 ± [7]	4 ± [6]	4 ± [7]	5 ± [7]	1 ± [11]	1 ± [4]	0 ± [4]	18 ± [18]

Scenario	Year	Adult Asthma	Child Asthma	COPD	Dementia	Diabetes	Low Birth Weight	Lung Cancer	Total
COVID: Conservative (Southwark)	2022	5 ± [9]	5 ± [8]	6 ± [8]	8 ± [9]	2 ± [13]	1 ± [5]	1 ± [5]	27 ± [22]
	2023	7 ± [10]	7 ± [9]	8 ± [9]	10 ± [10]	3 ± [15]	1 ± [6]	1 ± [5]	37 ± [26]
	2024	9 ± [11]	7 ± [10]	10 ± [11]	14 ± [12]	3 ± [17]	1 ± [6]	1 ± [6]	45 ± [29]
COVID: Ambitious (Southwark)	2020	14 ± [5]	16 ± [4]	20 ± [5]	26 ± [5]	7 ± [7]	1 ± [3]	2 ± [3]	87 ± [13]
	2021	27 ± [7]	32 ± [6]	39 ± [7]	50 ± [7]	16 ± [11]	2 ± [4]	4 ± [4]	169 ± [18]
	2022	42 ± [9]	44 ± [8]	57 ± [8]	76 ± [9]	24 ± [13]	3 ± [5]	5 ± [5]	252 ± [22]
	2023	54 ± [10]	54 ± [9]	80 ± [9]	102 ± [10]	31 ± [15]	5 ± [6]	7 ± [5]	333 ± [25]
	2024	68 ± [11]	60 ± [10]	99 ± [10]	129 ± [11]	37 ± [17]	6 ± [6]	10 ± [6]	409 ± [28]

Figure 24. Cumulative disease incidence avoided by NO_2 scenario for Southwark



Scenarios: (1) Low pollution, (2) COVID: conservative (London), (3) COVID: ambitious (London), (4) COVID: conservative (Southwark), (5) COVID: ambitious (Southwark)

Cumulative NHS costs avoided

Table 26 and **Figure 25** show the cumulative NHS costs avoided in Southwark from 2020-2024 across the five scenarios for reductions in NO_2.

For the low pollution or 'best case' scenario where Southwark has the same level of NO_2 as the London borough with the lowest reported levels (Havering), the model projects £1,743,093 cumulative NHS costs avoided by 2024. COPD is the largest contributor at £1,019,520 cumulative NHS costs avoided, followed by dementia (£378,855) and lung cancer (£205,875).

COVID-19 scenarios for Southwark:

- The London-wide COVID-19 conservative scenario projection is £130,231 cumulative NHS costs avoided by 2024. COPD cumulative NHS costs avoided, the largest contributor, is £62,779.

- The London-wide COVID-19 ambitious scenario projection for Southwark is £1,966,789 cumulative NHS costs avoided by 2024. COPD cumulative NHS costs avoided, the largest contributor, is £1,150,217.

- The Southwark conservative COVID-19 reduction scenario of a 2% annual NO_2 reduction projects £130,231 cumulative NHS costs avoided by 2024. COPD cumulative NHS costs avoided, the largest contributor, is £62,779.
- The Southwark ambitious COVID-19 reduction scenario of a 18% in annual NO_2 reduction projects £1,637,934 cumulative NHS costs avoided by 2024. COPD cumulative NHS costs avoided, the largest contributor, is £950,192.

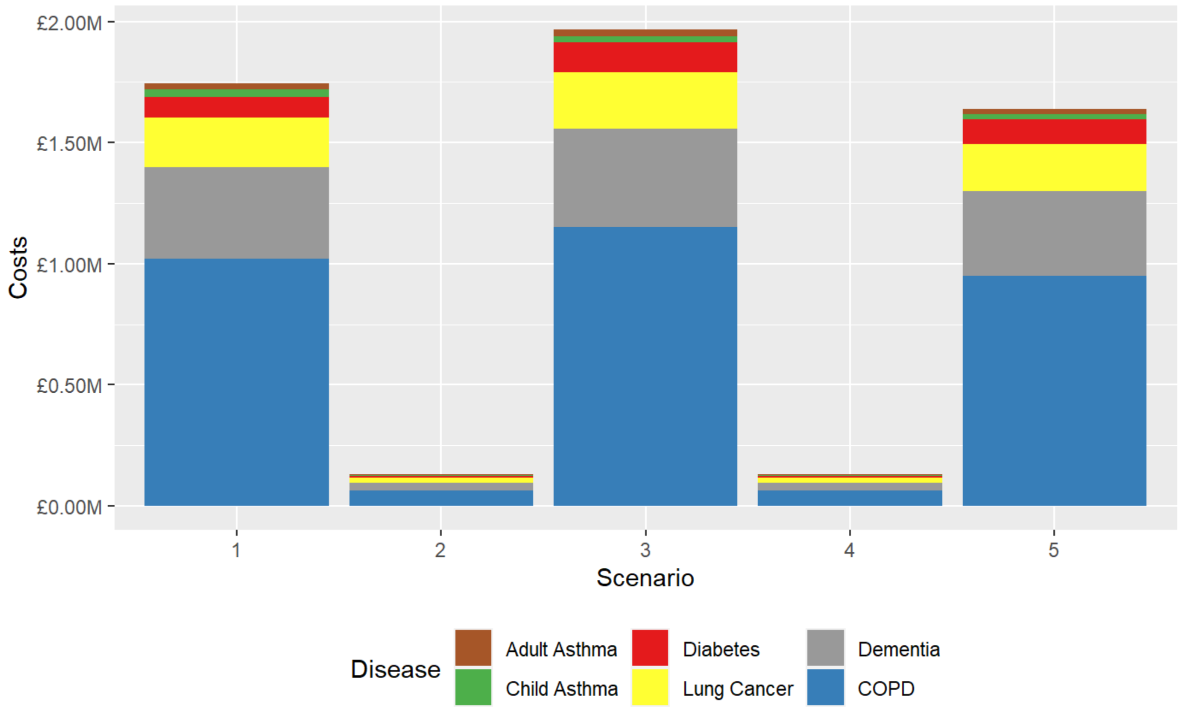
Table 26. Cumulative NHS costs avoided by NO_2 scenario for Southwark

Scenario	Year	Adult Asthma	Child Asthma	COPD	Dementia	Diabetes	Lung Cancer	Total
Low Pollution	2020	£2,412 ± [£3,463]	£1,943 ± [£1,705]	£65,055 ± [£62,659]	£30,469 ± [£11,640]	-£606 ± [£32,987]	£17,272 ± [£40,793]	£116,545 ± [£82,636]
	2021	£6,276 ± [£4,871]	£6,177 ± [£2,393]	£201,561 ± [£89,300]	£85,344 ± [£16,956]	£10,225 ± [£46,772]	£48,253 ± [£59,940]	£357,836 ± [£118,625]
	2022	£11,726 ± [£5,938]	£12,394 ± [£2,915]	£403,131 ± [£110,274]	£163,368 ± [£21,323]	£28,283 ± [£57,479]	£92,202 ± [£75,572]	£711,104 ± [£147,220]
	2023	£17,653 ± [£6,830]	£20,550 ± [£3,347]	£680,172 ± [£128,351]	£261,287 ± [£25,211]	£52,862 ± [£66,606]	£148,828 ± [£89,214]	£1,181,353 ± [£171,939]
	2024	£24,573 ± [£7,608]	£30,087 ± [£3,723]	£1,019,520 ± [£144,587]	£378,855 ± [£28,789]	£84,182 ± [£74,727]	£205,875 ± [£101,545]	£1,743,093 ± [£194,169]
COVID: Conservative (London)	2020	£329 ± [£3,464]	£249 ± [£1,706]	-£2,583 ± [£62,710]	£2,423 ± [£11,670]	£121 ± [£32,987]	-£428 ± [£40,859]	£111 ± [£82,712]
	2021	£745 ± [£4,872]	£737 ± [£2,397]	£2,804 ± [£89,406]	£6,869 ± [£17,012]	£472 ± [£46,775]	£4,401 ± [£60,051]	£16,028 ± [£118,770]
	2022	£1,363 ± [£5,941]	£1,362 ± [£2,920]	£14,314 ± [£110,441]	£13,651 ± [£21,408]	£2,157 ± [£57,484]	£12,671 ± [£75,730]	£45,519 ± [£147,441]
	2023	£2,120 ± [£6,833]	£2,109 ± [£3,355]	£35,068 ± [£128,587]	£22,239 ± [£25,324]	£3,790 ± [£66,615]	£16,470 ± [£89,435]	£81,797 ± [£172,250]
	2024	£2,996 ± [£7,611]	£2,875 ± [£3,734]	£62,779 ± [£144,895]	£33,378 ± [£28,931]	£7,174 ± [£74,740]	£21,030 ± [£101,814]	£130,231 ± [£194,565]

Scenario	Year	Adult Asthma	Child Asthma	COPD	Dementia	Diabetes	Lung Cancer	Total
COVID: Ambitious (London)	2020	£2,534 ± [£3,463]	£2,115 ± [£1,705]	£72,943 ± [£62,653]	£30,958 ± [£11,640]	£5,820 ± [£32,985]	£23,152 ± [£40,771]	£137,522 ± [£82,620]
	2021	£6,782 ± [£4,870]	£6,452 ± [£2,393]	£224,882 ± [£89,289]	£87,974 ± [£16,954]	£22,767 ± [£46,769]	£63,876 ± [£59,901]	£412,733 ± [£118,595]
	2022	£12,785 ± [£5,938]	£12,408 ± [£2,915]	£452,599 ± [£110,254]	£171,235 ± [£21,319]	£49,363 ± [£57,475]	£113,454 ± [£75,530]	£811,843 ± [£147,181]
	2023	£19,421 ± [£6,829]	£19,532 ± [£3,347]	£765,308 ± [£128,321]	£276,773 ± [£25,204]	£83,670 ± [£66,600]	£169,180 ± [£89,180]	£1,333,885 ± [£171,895]
	2024	£27,203 ± [£7,607]	£27,186 ± [£3,724]	£1,150,217 ± [£144,545]	£405,441 ± [£28,778]	£122,940 ± [£74,722]	£233,802 ± [£101,504]	£1,966,789 ± [£194,112]
COVID: Conservative (Southwark)	2020	£329 ± [£3,464]	£249 ± [£1,706]	-£2,583 ± [£62,710]	£2,423 ± [£11,670]	£121 ± [£32,987]	-£428 ± [£40,859]	£111 ± [£82,712]
	2021	£745 ± [£4,872]	£737 ± [£2,397]	£2,804 ± [£89,406]	£6,869 ± [£17,012]	£472 ± [£46,775]	£4,401 ± [£60,051]	£16,028 ± [£118,770]
	2022	£1,363 ± [£5,941]	£1,362 ± [£2,920]	£14,314 ± [£110,441]	£13,651 ± [£21,408]	£2,157 ± [£57,484]	£12,671 ± [£75,730]	£45,519 ± [£147,441]
	2023	£2,120 ± [£6,833]	£2,109 ± [£3,355]	£35,068 ± [£128,587]	£22,239 ± [£25,324]	£3,790 ± [£66,615]	£16,470 ± [£89,435]	£81,797 ± [£172,250]
	2024	£2,996 ± [£7,611]	£2,875 ± [£3,734]	£62,779 ± [£144,895]	£33,378 ± [£28,931]	£7,174 ± [£74,740]	£21,030 ± [£101,814]	£130,231 ± [£194,565]

COVID: Ambitious (Southwark)	2020	£1,850 ± [£3,463]	£1,778 ± [£1,705]	£58,966 ± [£62,663]	£27,201 ± [£11,643]	£4,408 ± [£32,985]	£18,350 ± [£40,789]	£112,553 ± [£82,637]
	2021	£5,133 ± [£4,871]	£5,425 ± [£2,394]	£181,974 ± [£89,311]	£76,288 ± [£16,963]	£18,113 ± [£46,770]	£51,144 ± [£59,933]	£338,077 ± [£118,630]
	2022	£9,833 ± [£5,939]	£10,380 ± [£2,916]	£368,586 ± [£110,289]	£148,007 ± [£21,332]	£39,541 ± [£57,476]	£92,321 ± [£75,572]	£668,668 ± [£147,232]
	2023	£14,899 ± [£6,830]	£16,394 ± [£3,349]	£627,449 ± [£128,371]	£238,432 ± [£25,222]	£67,201 ± [£66,603]	£140,489 ± [£89,228]	£1,104,863 ± [£171,961]
	2024	£20,940 ± [£7,608]	£22,755 ± [£3,726]	£950,192 ± [£144,609]	£349,391 ± [£28,801]	£99,804 ± [£74,725]	£194,851 ± [£101,560]	£1,637,934 ± [£194,194]

Figure 25. Cumulative NHS costs avoided by NO_2 scenario for Southwark



Scenarios: (1) Low pollution, (2) COVID: conservative (London), (3) COVID: ambitious (London), (4) COVID: conservative (Southwark), (5) COVID: ambitious (Southwark)

Annual QALYs gained

Table 27 and **Figure 26** show the annual QALYs gained in Southwark from 2020-2024 across the four scenarios for reductions in NO_2.

For the low pollution or 'best case' scenario where Southwark has the same level of NO_2 as the London borough with the lowest reported levels (Havering), the model projects 125 annual QALYs gained in 2024. Based on a projected 2024 Southwark population of 328,073, this equates to around 38 QALYs per 100,000 individuals.

COVID-19 scenarios for Southwark:

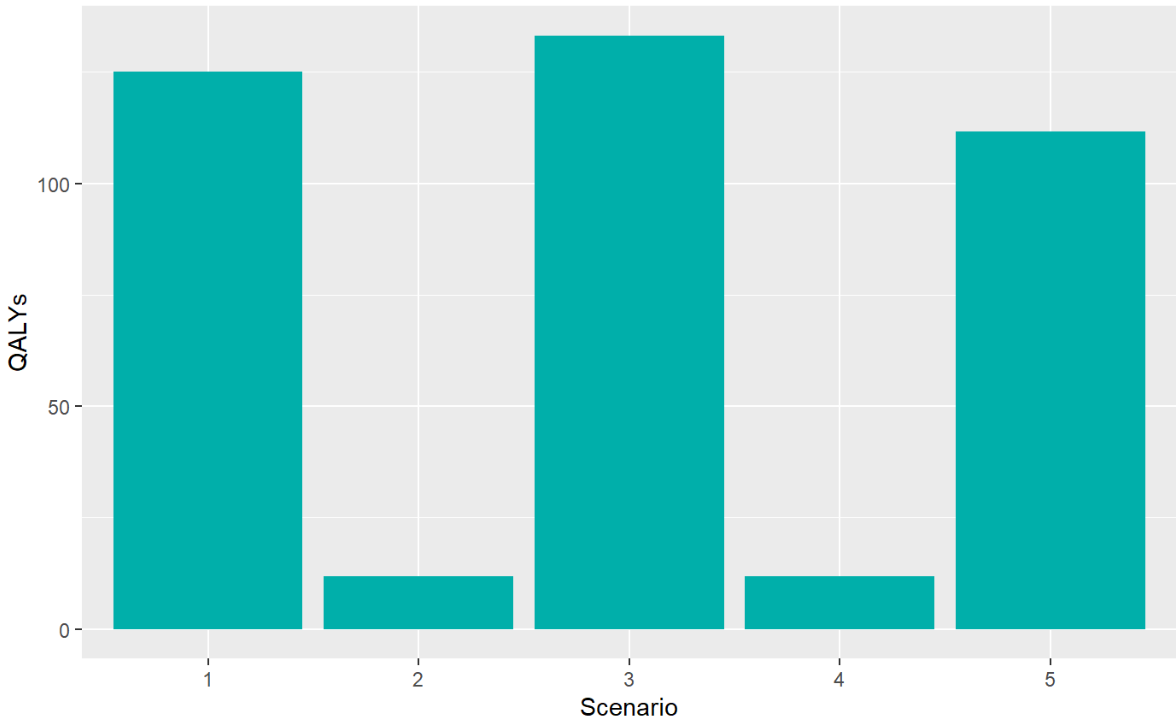
- The London-wide COVID-19 conservative scenario projection is 12 annual QALYs, or 4 QALYs per 100,000, gained in 2024.
- The London-wide COVID-19 ambitious scenario projection for Lambeth is 133 annual QALYs, or 41 QALYs per 100,000, gained in 2024.
- The Southwark conservative COVID-19 reduction scenario of a 2% annual NO_2 reduction projects 12 annual QALYs, or 4 QALYs per 100,000, gained in 2024.

- The Southwark ambitious COVID-19 reduction scenario of a 18% in annual NO_2 reduction projects 112 annual QALYs, or 34 QALYs per 100,000, gained in 2024.

Table 27. Annual QALYs gained by NO_2 scenario for Southwark

Year	Low Pollution	COVID: Conservative (London)	COVID: Ambitious (London)	COVID: Conservative (Southwark)	COVID: Ambitious (Southwark)
2020	28 ± [28]	2 ± [28]	32 ± [28]	2 ± [28]	26 ± [28]
2021	56 ± [28]	5 ± [28]	62 ± [28]	5 ± [28]	51 ± [28]
2022	83 ± [29]	8 ± [29]	90 ± [29]	8 ± [29]	75 ± [29]
2023	105 ± [29]	9 ± [29]	113 ± [29]	9 ± [29]	94 ± [29]
2024	125 ± [29]	12 ± [29]	133 ± [29]	12 ± [29]	112 ± [29]

Figure 26. Annual QALYs gained by NO_2 scenario for Southwark



Scenarios: (1) Low pollution, (2) COVID: conservative (London), (3) COVID: ambitious (London), (4) COVID: conservative (Southwark), (5) COVID: ambitious (Southwark)

PM$_{2.5}$ results for Southwark

Southwark disease incidence attributable to air pollution

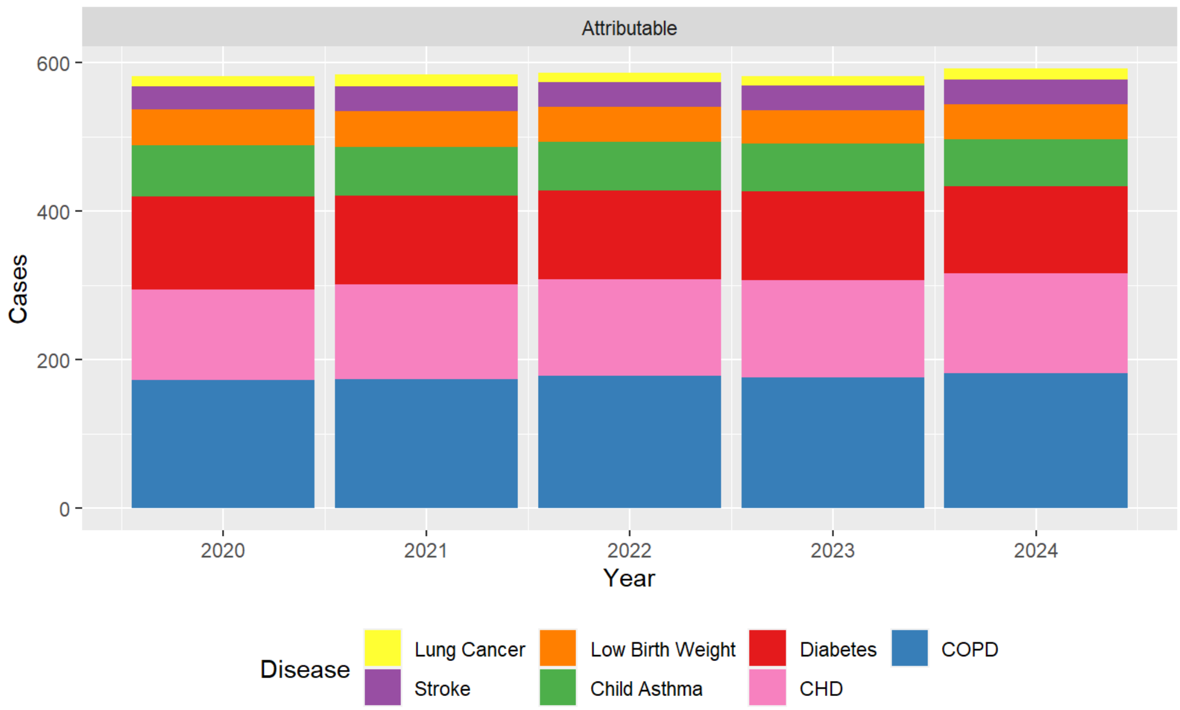
Annual disease incidence attributable
Table 28 and

Figure 27 show the total new cases of disease for the diseases related to PM$_{2.5}$. The annual incidence of disease attributable to PM$_{2.5}$ in Southwark is projected to be 591 between 2020 and 2024, with COPD being the largest contributor with 182 new incidence in 2024.

Table 28. Southwark annual disease incidence attributable to PM$_{2.5}$

Year	CHD	Child Asthma	COPD	Diabetes	Low Birth Weight	Lung Cancer	Stroke	Total
2020	122 ± [4]	70 ± [4]	172 ± [4]	125 ± [7]	48 ± [3]	14 ± [3]	32 ± [4]	582 ± [12]
2021	128 ± [4]	65 ± [4]	174 ± [4]	119 ± [7]	49 ± [3]	15 ± [3]	33 ± [3]	583 ± [12]
2022	130 ± [4]	66 ± [4]	178 ± [4]	120 ± [7]	46 ± [3]	12 ± [3]	34 ± [3]	585 ± [12]
2023	131 ± [4]	64 ± [4]	176 ± [4]	119 ± [7]	45 ± [3]	13 ± [3]	33 ± [3]	581 ± [11]
2024	135 ± [4]	63 ± [4]	182 ± [4]	116 ± [7]	47 ± [3]	14 ± [3]	34 ± [3]	591 ± [11]

Figure 27. Annual disease incidence attributable to $PM_{2.5}$ by year in Southwark



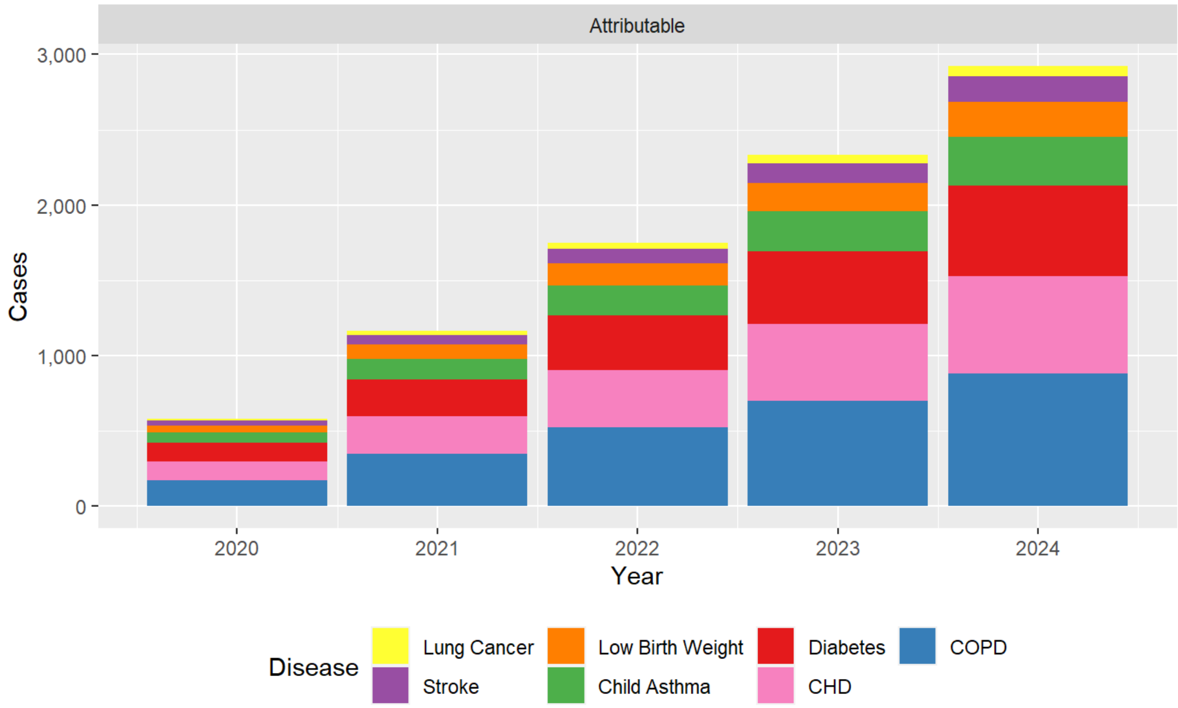
Cumulative disease incidence attributable

Table 29 and **Figure 28** show the total new cumulative cases of disease attributable to $PM_{2.5}$. The model has calculated the cumulative incidence of disease attributable to $PM_{2.5}$ in Southwark to be 2,922 by 2024. COPD largest contributor with 881 cumulative incidence by 2024.

Table 29. Southwark cumulative disease incidence attributable to $PM_{2.5}$

Year	CHD	Child Asthma	COPD	Diabetes	Low Birth Weight	Lung Cancer	Stroke	Total
2020	122 ± [4]	70 ± [4]	172 ± [4]	125 ± [7]	48 ± [3]	14 ± [3]	32 ± [4]	582 ± [12]
2021	250 ± [6]	134 ± [6]	346 ± [6]	244 ± [10]	96 ± [4]	29 ± [4]	65 ± [5]	1,165 ± [16]
2022	380 ± [7]	200 ± [7]	523 ± [8]	364 ± [13]	143 ± [5]	41 ± [5]	99 ± [6]	1,750 ± [20]
2023	511 ± [8]	264 ± [9]	699 ± [9]	483 ± [15]	187 ± [5]	54 ± [5]	132 ± [7]	2,331 ± [23]
2024	646 ± [9]	327 ± [10]	881 ± [10]	600 ± [16]	234 ± [6]	68 ± [6]	166 ± [8]	2,922 ± [26]

Figure 28. Cumulative cases of disease attributable to $PM_{2.5}$ by year in Southwark



Cumulative NHS costs attributable

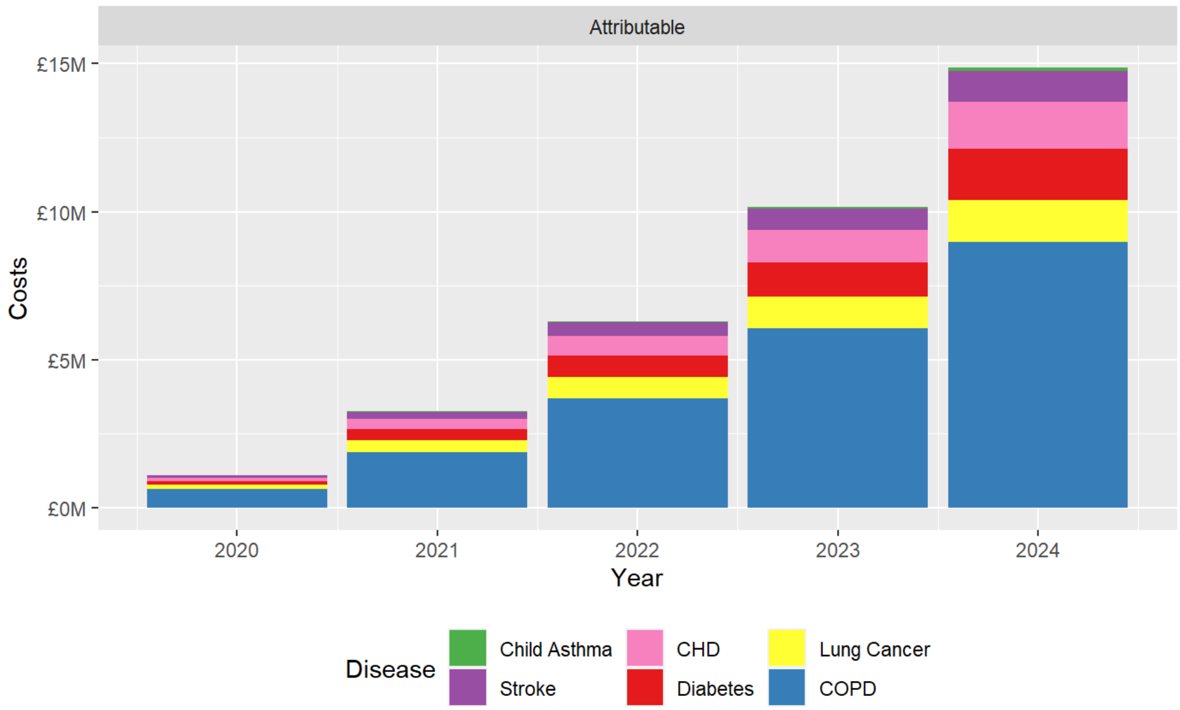
Table 30 and **Figure 29** show the total new cumulative NHS costs attributable to $PM_{2.5}$. By 2024 it is predicted that £14,855,486 NHS costs will be attributable to $PM_{2.5}$ in Southwark. COPD is the largest contributor to this with a cost of £8,977,323 expected by 2024.

Table 30. Southwark cumulative NHS costs attributable to $PM_{2.5}$

Year	CHD	Child Asthma	COPD	Diabetes	Lung Cancer	Stroke	Total
2020	£125,308 ± [£11,112]	£6,810 ± [£1,664]	£636,486 ± [£63,733]	£118,943 ± [£33,051]	£141,489 ± [£40,194]	£82,789 ± [£28,182]	£1,111,826 ± [£87,694]
2021	£354,964 ± [£15,745]	£20,710 ± [£2,337]	£1,868,596 ± [£90,193]	£355,679 ± [£46,750]	£427,254 ± [£58,628]	£230,849 ± [£40,010]	£3,258,053 ± [£124,947]
2022	£681,943 ± [£19,321]	£41,646 ± [£2,847]	£3,686,619 ± [£110,596]	£703,468 ± [£57,308]	£736,357 ± [£73,441]	£444,676 ± [£49,198]	£6,294,709 ± [£153,984]
2023	£1,098,760 ± [£22,349]	£68,675 ± [£3,270]	£6,056,321 ± [£127,873]	£1,158,642 ± [£66,246]	£1,069,183 ± [£86,303]	£714,266 ± [£57,019]	£10,165,847 ± [£178,744]

2024	£1,601,360 ± [£25,028]	£100,926 ± [£3,639]	£8,977,323 ± [£143,158]	£1,711,803 ± [£74,152]	£1,424,013 ± [£97,807]	£1,040,062 ± [£63,964]	£14,855,486 ± [£200,723]

Figure 29. Cumulative NHS costs attributable to $PM_{2.5}$ by year in Southwark



Southwark scenario assessment

This section estimates the impact of the scenarios on the new cases of disease, cases avoided, NHS costs avoided, and QALYs gained due to changes ino $PM_{2.5}$ to the year 2024 in Southwark.

Annual incidence cases

Table 31 and **Figure 30** present the annual incidence of disease in Southwark from 2020-2024 across baseline and the three scenarios for $PM_{2.5}$.

For the baseline scenario – a static/flat trend – the model projects a disease incidence of 2,803 in 2024 in Southwark. Diabetes is the largest contributor at 1,061 incidence cases, followed by COPD (456), CHD (379) and child asthma (369).

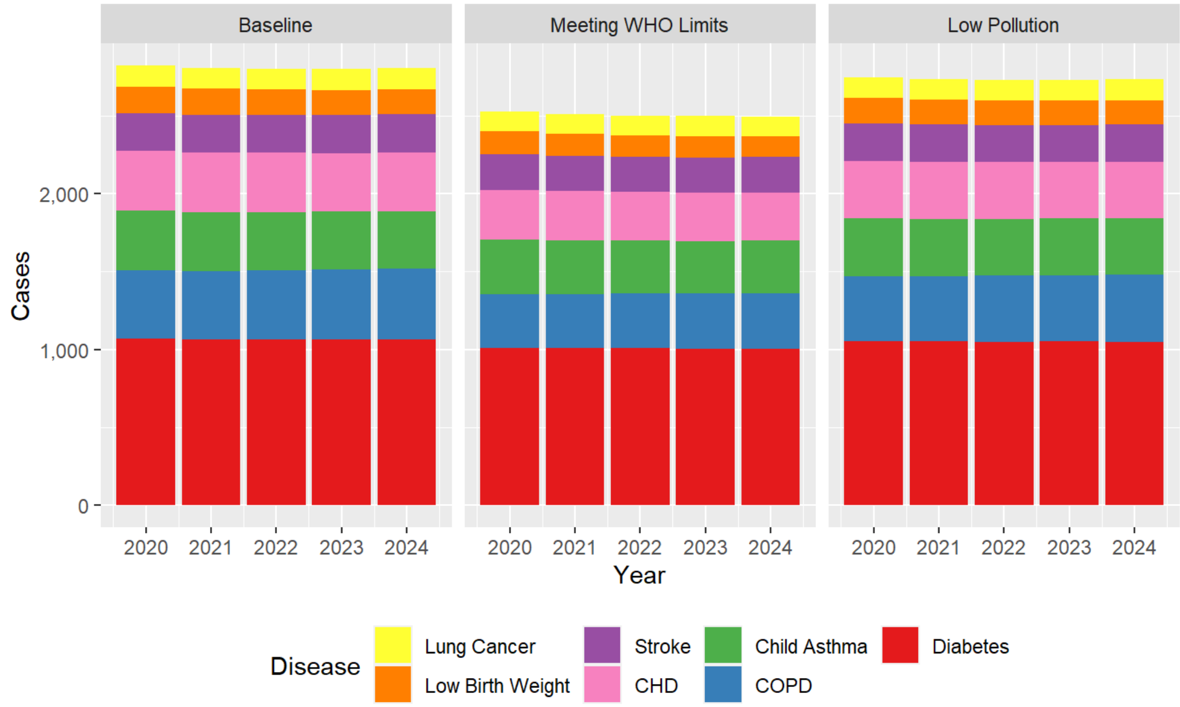
For the scenario where Southwark meets the WHO limits for $PM_{2.5}$, the model projects 2,495 incidence of disease in 2024. Diabetes is the largest contributor at 1,004 incidence, followed by COPD (355), child asthma (337) and CHD (310).

For the low pollution or ‘best case’ scenario where Lambeth has the same level of $PM_{2.5}$ as the London borough with the lowest reported levels (Havering), the model projects 2,731 incidence of disease in 2024. Diabetes is the largest contributor at 1,047 incidence, followed by COPD (433), child CHD (363) and CHD (361).

Table 31. Annual disease incidence by $PM_{2.5}$ scenario for Southwark

Scenario	Year	CHD	Child Asthma	COPD	Diabetes	Low Birth Weight	Lung Cancer	Stroke	Total
Baseline	2020	382 ± [3]	384 ± [3]	437 ± [3]	1,069 ± [5]	170 ± [2]	134 ± [2]	245 ± [3]	2,820 ± [9]
	2021	383 ± [3]	375 ± [3]	441 ± [3]	1,062 ± [5]	167 ± [2]	133 ± [2]	244 ± [3]	2,804 ± [9]
	2022	381 ± [3]	373 ± [3]	446 ± [3]	1,061 ± [5]	163 ± [2]	133 ± [2]	242 ± [3]	2,798 ± [9]
	2023	377 ± [3]	372 ± [3]	448 ± [3]	1,063 ± [5]	161 ± [2]	136 ± [2]	244 ± [3]	2,800 ± [9]
	2024	379 ± [3]	369 ± [3]	456 ± [3]	1,061 ± [5]	156 ± [2]	136 ± [2]	245 ± [3]	2,803 ± [9]
WHO Limits	2020	319 ± [3]	349 ± [3]	348 ± [3]	1,007 ± [5]	147 ± [2]	127 ± [2]	230 ± [2]	2,526 ± [8]
	2021	318 ± [3]	340 ± [3]	350 ± [3]	1,006 ± [5]	142 ± [2]	125 ± [2]	227 ± [2]	2,508 ± [8]
	2022	312 ± [3]	338 ± [3]	353 ± [3]	1,007 ± [5]	139 ± [2]	126 ± [2]	225 ± [2]	2,501 ± [8]
	2023	308 ± [3]	338 ± [3]	355 ± [3]	1,003 ± [5]	138 ± [2]	129 ± [2]	228 ± [2]	2,499 ± [8]
	2024	310 ± [3]	337 ± [3]	355 ± [3]	1,004 ± [5]	132 ± [2]	130 ± [2]	228 ± [2]	2,495 ± [8]
Low Pollution	2020	364 ± [3]	375 ± [3]	415 ± [3]	1,053 ± [5]	165 ± [2]	133 ± [2]	241 ± [3]	2,745 ± [9]
	2021	367 ± [3]	367 ± [3]	418 ± [3]	1,049 ± [5]	160 ± [2]	131 ± [2]	240 ± [3]	2,732 ± [9]
	2022	364 ± [3]	364 ± [3]	424 ± [3]	1,049 ± [5]	158 ± [2]	131 ± [2]	239 ± [3]	2,728 ± [8]
	2023	361 ± [3]	364 ± [3]	426 ± [3]	1,050 ± [5]	155 ± [2]	134 ± [2]	240 ± [3]	2,729 ± [8]
	2024	363 ± [3]	361 ± [3]	433 ± [3]	1,047 ± [5]	151 ± [2]	135 ± [2]	240 ± [3]	2,731 ± [8]

Figure 30. Annual incidence by year and $PM_{2.5}$ scenario for Southwark



Cumulative incidence cases

Table 32 and

Figure 31 present the cumulative incidence of disease in Southwark from 2020-2024 across baseline and the two scenarios for $PM_{2.5}$.

For the baseline scenario – a static/flat trend – the model projects 14,025 cumulative incidence cases by 2024 in Southwark. Diabetes is the largest contributor at 5,316 cumulative incidence cases, followed by COPD (2,228), CHD (1,901) and child asthma (1,873).

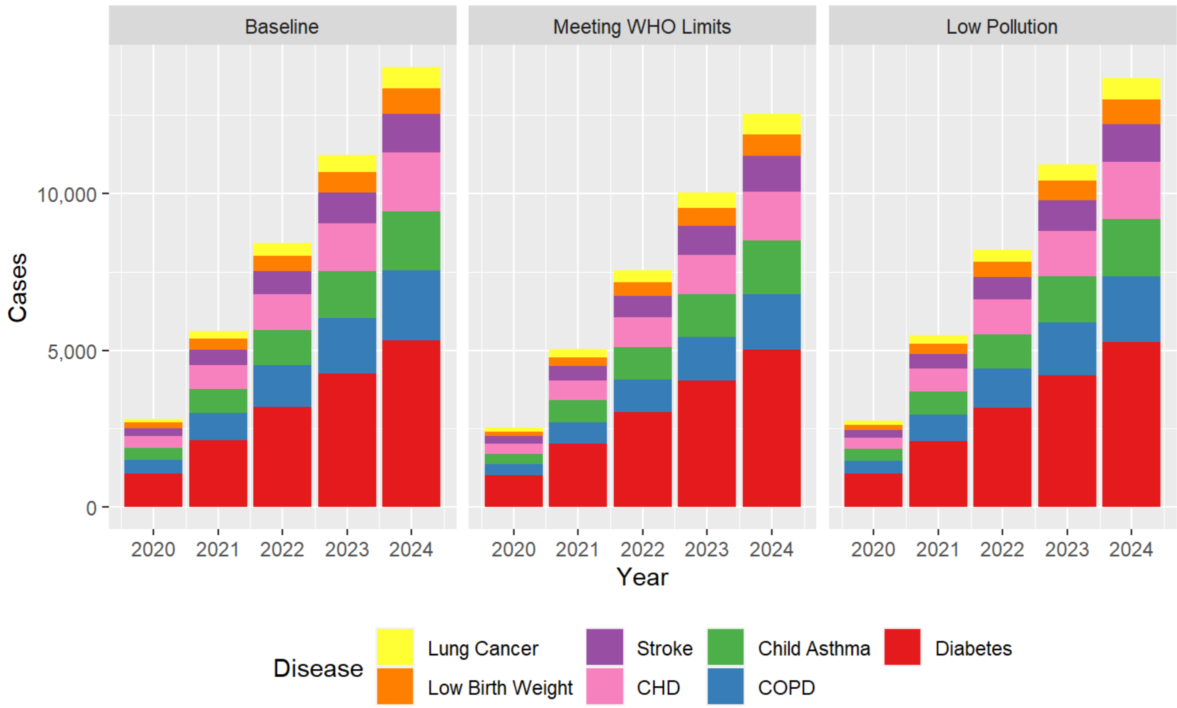
For the scenario where Southwark meets the WHO limits for $PM_{2.5}$, the model projects 12,529 cumulative incidence of disease by 2024. Diabetes is the largest contributor at 5,027 incidence, followed by COPD (1,760) and child asthma (1,702).

For the low pollution or 'best case' scenario where Southwark has the same level of $PM_{2.5}$ as the London borough with the lowest reported levels (Havering), the model projects 13,666 cumulative incidence of disease by 2024. Diabetes is the largest contributor at 5,248 incidence, followed by COPD (2,117), child asthma (1,831) and CHD (1,819).

Table 32. Cumulative disease incidence by $PM_{2.5}$ scenario for Southwark

Scenario	Year	CHD	Child Asthma	COPD	Diabetes	Low Birth Weight	Lung Cancer	Stroke	Total
Baseline	2020	382 ± [3]	384 ± [3]	437 ± [3]	1,069 ± [5]	170 ± [2]	134 ± [2]	245 ± [3]	2,820 ± [9]
	2021	765 ± [5]	758 ± [5]	878 ± [5]	2,131 ± [8]	337 ± [3]	267 ± [3]	489 ± [4]	5,624 ± [12]
	2022	1,145 ± [6]	1,131 ± [5]	1,324 ± [6]	3,192 ± [9]	500 ± [4]	400 ± [3]	731 ± [4]	8,423 ± [15]
	2023	1,522 ± [6]	1,504 ± [6]	1,772 ± [7]	4,255 ± [11]	660 ± [4]	535 ± [4]	975 ± [5]	11,223 ± [17]
	2024	1,901 ± [7]	1,873 ± [7]	2,228 ± [8]	5,316 ± [12]	817 ± [5]	672 ± [4]	1,220 ± [6]	14,025 ± [19]
WHO Limits	2020	319 ± [3]	349 ± [3]	348 ± [3]	1,007 ± [5]	147 ± [2]	127 ± [2]	230 ± [2]	2,526 ± [8]
	2021	636 ± [4]	689 ± [4]	698 ± [4]	2,013 ± [7]	290 ± [3]	252 ± [3]	457 ± [4]	5,035 ± [12]
	2022	949 ± [5]	1,027 ± [5]	1,051 ± [5]	3,020 ± [9]	429 ± [3]	377 ± [3]	683 ± [4]	7,535 ± [14]
	2023	1,256 ± [6]	1,365 ± [6]	1,405 ± [6]	4,023 ± [10]	567 ± [4]	507 ± [4]	911 ± [5]	10,034 ± [16]
	2024	1,566 ± [6]	1,702 ± [7]	1,760 ± [7]	5,027 ± [12]	699 ± [4]	637 ± [4]	1,138 ± [5]	12,529 ± [18]
Low Pollution	2020	364 ± [3]	375 ± [3]	415 ± [3]	1,053 ± [5]	165 ± [2]	133 ± [2]	241 ± [3]	2,745 ± [9]
	2021	731 ± [4]	742 ± [4]	834 ± [5]	2,102 ± [8]	324 ± [3]	263 ± [3]	481 ± [4]	5,477 ± [12]
	2022	1,095 ± [5]	1,106 ± [5]	1,257 ± [6]	3,151 ± [9]	482 ± [4]	394 ± [3]	720 ± [4]	8,206 ± [15]
	2023	1,456 ± [6]	1,470 ± [6]	1,683 ± [7]	4,200 ± [11]	637 ± [4]	529 ± [4]	960 ± [5]	10,935 ± [17]
	2024	1,819 ± [7]	1,831 ± [7]	2,117 ± [7]	5,248 ± [12]	788 ± [5]	664 ± [4]	1,200 ± [6]	13,666 ± [19]

Figure 31. Cumulative disease incidence by year and $PM_{2.5}$ scenario for Southwark



Cumulative incidence cases avoided

Table 33 and

Figure 32 present the cumulative cases of disease avoided in Southwark from 2020-2024 across the two scenarios for reductions in $PM_{2.5}$.

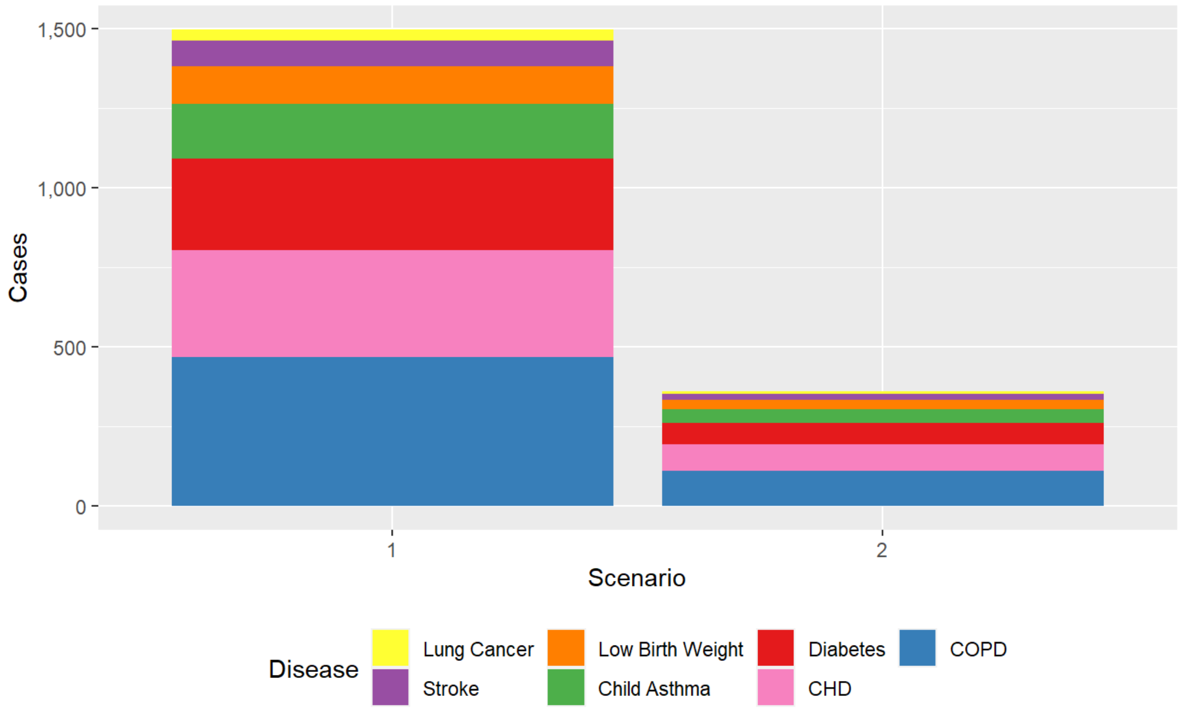
For the scenario where Southwark meets the WHO limits for $PM_{2.5}$, the model projects 1,497 cumulative incidence of disease avoided by 2024. COPD is the largest contributor at 467 incidence, followed by CHD (335) and diabetes (289).

For the low pollution or ‘best case’ scenario where Southwark has the same level of $PM_{2.5}$ as the London borough with the lowest reported levels (Havering), the model projects 360 cumulative incidence of disease avoided by 2024. COPD is the largest contributor at 111 incidence, followed by CHD (82) and diabetes (68).

Table 33. Cumulative disease incidence avoided by $PM_{2.5}$ scenario for Southwark

Scenario	Year	CHD	Child Asthma	COPD	Diabetes	Low Birth Weight	Lung Cancer	Stroke	Total
WHO Limits	2020	63 ± [4]	35 ± [4]	89 ± [5]	62 ± [7]	23 ± [3]	7 ± [3]	15 ± [4]	294 ± [12]
	2021	128 ± [6]	69 ± [6]	180 ± [7]	118 ± [11]	47 ± [4]	15 ± [4]	31 ± [5]	589 ± [17]
	2022	197 ± [7]	105 ± [8]	274 ± [8]	171 ± [13]	71 ± [5]	22 ± [5]	48 ± [6]	887 ± [21]
	2023	266 ± [9]	139 ± [9]	367 ± [9]	231 ± [15]	93 ± [6]	28 ± [5]	64 ± [7]	1,189 ± [24]
	2024	335 ± [10]	171 ± [10]	467 ± [10]	289 ± [17]	118 ± [6]	35 ± [6]	82 ± [8]	1,497 ± [27]
Low Pollution	2020	17 ± [4]	9 ± [5]	22 ± [5]	16 ± [8]	5 ± [3]	1 ± [3]	4 ± [4]	75 ± [12]
	2021	33 ± [6]	17 ± [6]	44 ± [7]	29 ± [11]	12 ± [4]	4 ± [4]	7 ± [5]	147 ± [17]
	2022	50 ± [8]	25 ± [8]	67 ± [8]	41 ± [13]	18 ± [5]	5 ± [5]	11 ± [6]	217 ± [21]
	2023	66 ± [9]	34 ± [9]	89 ± [10]	54 ± [15]	23 ± [6]	7 ± [5]	15 ± [7]	288 ± [24]
	2024	82 ± [10]	42 ± [10]	111 ± [11]	68 ± [17]	29 ± [7]	8 ± [6]	20 ± [8]	360 ± [27]

Figure 32. Cumulative disease incidence avoided by $PM_{2.5}$ scenario for Southwark



Scenarios: (1) Meeting WHO limits, (2) Low pollution

Cumulative NHS costs avoided

Table 34 and **Figure 33** show he cumulative NHS costs avoided in Southwark from 2020-2024 across the two scenarios for reductions in $PM_{2.5}$.

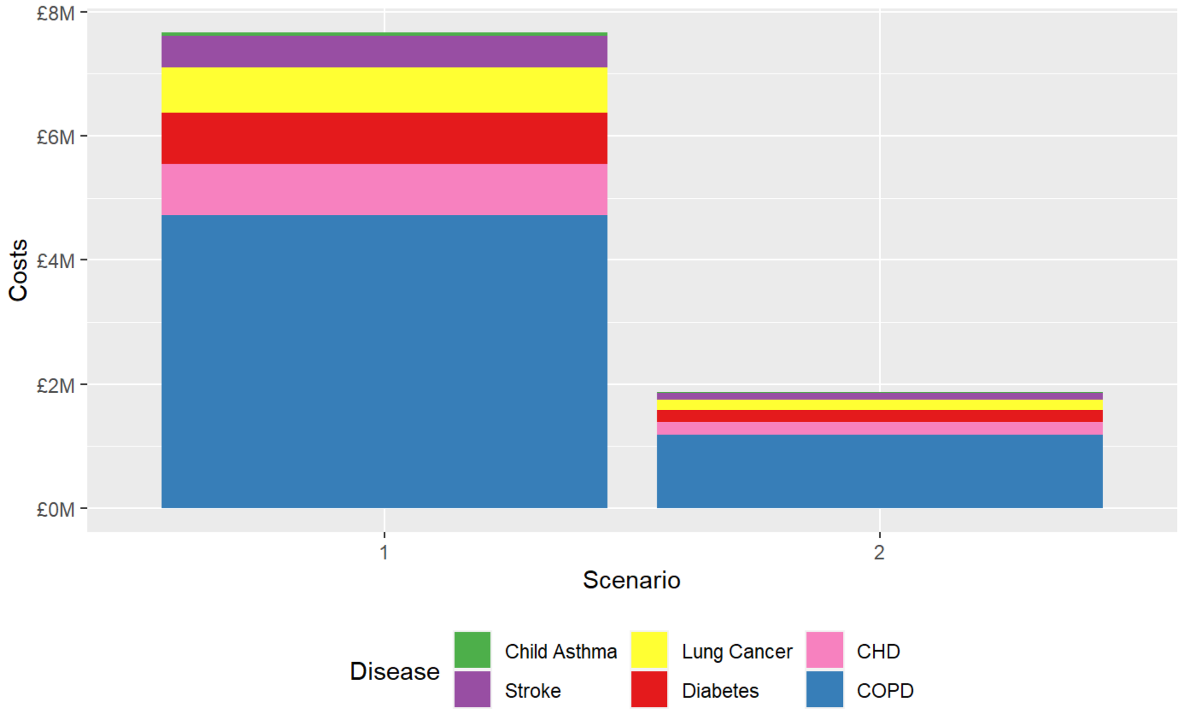
For the scenario where Southwark meets the WHO limits for $PM_{2.5}$, the model projects £7,665,529 cumulative NHS costs avoided by 2024. COPD is the largest contributor at £4,725,189 costs avoided, followed by CHD (£821,989) and diabetes (£821,747).

For the low pollution or 'best case' scenario where Southwark has the same level of $PM_{2.5}$ as the London borough with the lowest reported levels (Havering), the model projects £1,866,454 cumulative NHS costs avoided by 2024. COPD is the largest contributor at £1,180,196 costs avoided, followed by CHD (£204,280) and diabetes (£200,679).

Table 34. Cumulative NHS costs avoided by $PM_{2.5}$ scenario for Southwark

Scenario	Year	CHD	Child Asthma	COPD	Diabetes	Lung Cancer	Stroke	Total
WHO Limits	2020	£62,061 ± [£11,190]	£3,616 ± [£1,666]	£331,399 ± [£63,962]	£59,301 ± [£33,073]	£73,242 ± [£40,451]	£42,007 ± [£28,224]	£571,625 ± [£88,011]
	2021	£178,479 ± [£15,899]	£11,027 ± [£2,343]	£972,802 ± [£90,665]	£173,693 ± [£46,798]	£222,430 ± [£59,154]	£113,792 ± [£40,095]	£1,672,223 ± [£125,599]
	2022	£347,169 ± [£19,557]	£22,242 ± [£2,857]	£1,924,192 ± [£111,348]	£337,473 ± [£57,385]	£396,266 ± [£74,134]	£218,919 ± [£49,329]	£3,246,262 ± [£154,956]
	2023	£562,451 ± [£22,673]	£36,683 ± [£3,285]	£3,168,699 ± [£128,934]	£554,654 ± [£66,355]	£562,062 ± [£87,180]	£348,269 ± [£57,202]	£5,232,817 ± [£180,067]
	2024	£821,989 ± [£25,447]	£53,679 ± [£3,658]	£4,725,189 ± [£144,547]	£821,747 ± [£74,295]	£738,082 ± [£98,850]	£504,843 ± [£64,202]	£7,665,529 ± [£202,405]
Low Pollution	2020	£17,486 ± [£11,245]	£1,375 ± [£1,669]	£86,813 ± [£64,145]	£16,280 ± [£33,089]	£18,539 ± [£40,656]	£6,719 ± [£28,260]	£147,213 ± [£88,262]
	2021	£47,236 ± [£16,012]	£3,480 ± [£2,348]	£253,451 ± [£91,041]	£45,734 ± [£46,831]	£55,597 ± [£59,578]	£20,301 ± [£40,162]	£425,798 ± [£126,119]
	2022	£90,078 ± [£19,735]	£6,514 ± [£2,865]	£493,368 ± [£111,955]	£85,693 ± [£57,437]	£94,090 ± [£74,745]	£39,942 ± [£49,433]	£809,686 ± [£155,759]
	2023	£142,816 ± [£22,923]	£10,302 ± [£3,297]	£803,021 ± [£129,795]	£137,348 ± [£66,430]	£129,156 ± [£87,921]	£65,829 ± [£57,343]	£1,288,472 ± [£181,148]
	2024	£204,280 ± [£25,774]	£14,747 ± [£3,674]	£1,180,196 ± [£145,694]	£200,679 ± [£74,395]	£166,895 ± [£99,710]	£99,657 ± [£64,382]	£1,866,454 ± [£203,780]

Figure 33. Cumulative NHS costs avoided by $PM_{2.5}$ scenario for Southwark



Scenarios: (1) Meeting WHO limits, (2) Low pollution

Annual QALYs gained

Table 35 and

Figure 34 show the annual QALYs gained in Southwark from 2020-2024 across the two scenarios for reductions in $PM_{2.5}$.

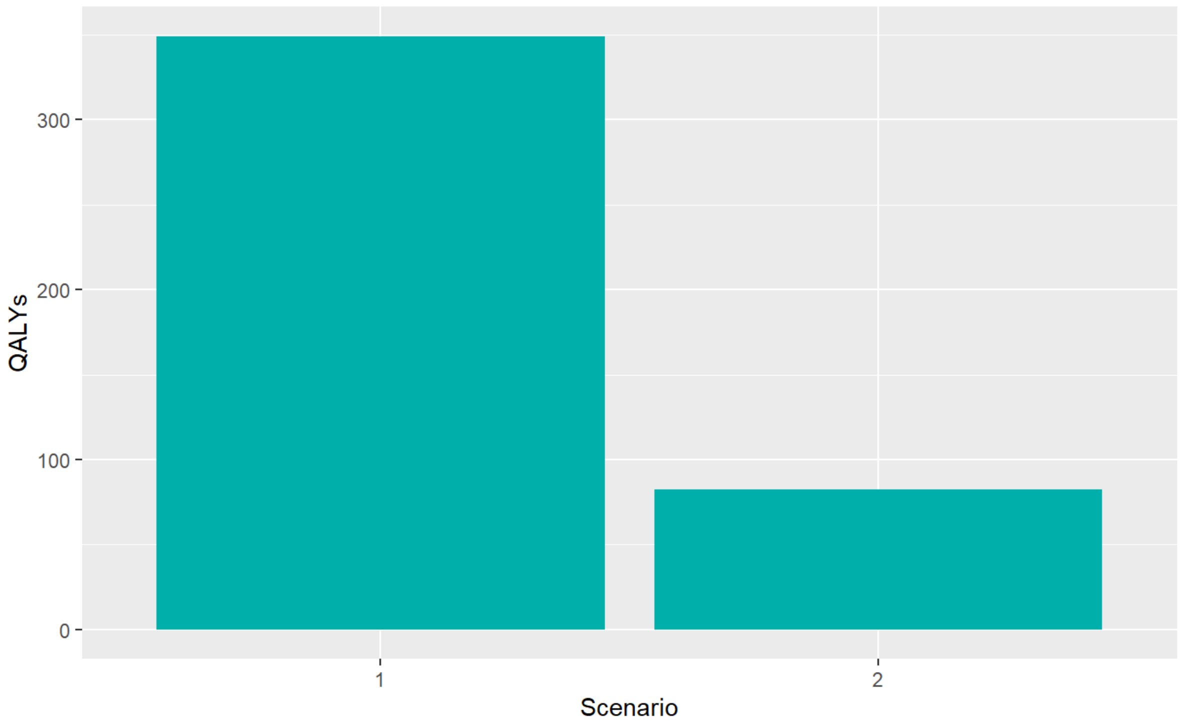
For the scenario where Southwark meets the WHO limits for $PM_{2.5}$, the model projects 349 annual QALYs gained in 2024. Based on a projected 2024 Southwark population of 328,073, this equates to around 106 QALYs per 100,000 individuals.

For the low pollution or 'best case' scenario where Southwark has the same level of $PM_{2.5}$ as the London borough with the lowest reported levels (Havering), the model projects 82 annual QALYs, or 25 QALYs per 100,000, gained in 2024.

Table 35. Annual QALYs gained by $PM_{2.5}$ scenario for Southwark

Year	WHO Limits	Low Pollution
2020	76 ± [29]	19 ± [29]
2021	150 ± [29]	36 ± [29]
2022	220 ± [29]	52 ± [29]
2023	285 ± [29]	68 ± [29]
2024	349 ± [29]	82 ± [29]

Figure 34. Annual QALYs gained by $PM_{2.5}$ scenario for Southwark



Scenarios: (1) Meeting WHO limits, (2) Low pollution

Discussion

What this study shows

This study quantified the attributable burden of air pollution-related diseases in Lambeth and Southwark and simulated the mid-term (2020-2024) health and economic impacts of reductions in NO_2 and $PM_{2.5}$ for both boroughs under a range of different scenarios.

Between 2020 and 2024, the total number of new disease cases attributable to NO_2 and $PM_{2.5}$ in Lambeth is estimated to be 4,730 (2,000 for NO_2 and 2,730 for $PM_{2.5}$) and in Southwark is 5,130 (2,208 for NO_2 and 2,922 for $PM_{2.5}$). The resulting combined cost to the NHS by 2024 in Lambeth and Southwark would be £44.8 million. Therefore, finding ways to reduce this attributable burden is important. This study explored different scenarios to illustrate the extent to which this burden could be reduced.

For example, the NO_2 low pollution or 'best case' scenario assessment found a total of 858 disease incidence cases would be avoided in Lambeth (401 cases) and Southwark (457 cases) combined by 2024, equating to 20% of the diseases attributable to NO_2. This highlights the importance of, and impact that ambitious policies can have on health. Preventing disease has a knock-on effect on quality of life, while also resulting in savings to the health systems (£1.6 million and over £1.7 million for Lambeth and Southwark by 2024).

Furthermore, the COVID-19 lockdown period, for example, reduced NO_2 dramatically across London due to reduced traffic. Modelling this reduction on health had a small but important long-term effect, for example – under the conservative assumption – 86 new air-pollution related diseases were avoided for Lambeth (41) and Southwark (45) by 2024. While relatively small numbers, this highlights the potential benefit of the 'new normal' with regards to the impact that new working practices and traffic pollution levels could have on these London boroughs, and more ambitious assumptions modelled suggests that the gains could be much larger. The lockdown had obvious economic and social downsides; however these results suggest re-imagining a 'new normal' of working patterns and transportation into the future could have beneficial health impacts, and knock-on cost savings to the NHS.

Finally, with regards to the $PM_{2.5}$ scenario assessments the savings to the NHS (£14.4 million across both boroughs) by reducing $PM_{2.5}$ to the WHO recommended levels (2,821 disease cases avoided across both boroughs), would enable salaries for 86 nurses to be paid for 5 years. These targets provide an important guide for reducing the attributable disease burden due to $PM_{2.5}$. In this example, however, only 50% of the attributable burden would be depleted. While Lambeth and Southwark have much higher pollution exposure than some other London boroughs, reducing $PM_{2.5}$ to the levels of a lower pollution area such as Havering resulted in the avoidance of 658 cases by 2024 (12% of the attributable cases). Therefore, an important impact, but reaching the WHO targets would have a substantially larger impact on disease cases avoided and cost savings than even the 'cleanest air' borough in London. This illustrates the importance of London-wide policies to combat air pollution.

It is important to note that children are also particularly vulnerable to the impacts of poor air quality, however many diseases will not manifest until later in life, and so a longer simulation period would be required in order for high-levels of disease to manifest in areas with a younger population structure. Therefore, continued work to reduce air pollution in these inner boroughs is required since exposure to pollutants is much higher and thus burden of related disease likely to rise the most.

How does this report complement other research?

This study complements previous work that has quantified disease incidence impacts attributable to air pollution for London (29). This analysis also builds on previous work using this model that was carried out in collaboration with Imperial College London and Public Health England, and the Greater London Authority and Transport for London (23,25).

This study also complements the work conducted by Webber et al. (2020) 'Modelling the long-term health impacts of changing exposure to NO_2 and $PM_{2.5}$ in London' by looking at the impact of borough or local authority level changes to levels of NO_2 and $PM_{2.5}$ on attributable disease outcomes and NHS costs avoided (24). However, these results are not directly comparable since those models were run from 2016, while the models in the current study were run from 2020.

What further research can be done?

While this report clearly presents a case for action for measures to more drastically reduce NO_2 and $PM_{2.5}$ in London boroughs, additional research could provide further evidence of policy impacts. In the present study we focussed on incidence avoided and NHS costs avoided, however further work might add to this by quantifying the impact of borough specific policies on mortality or hospitalisations.

This study does not include differential impacts by social groups. The impact of poor air quality and social inequality are well documented (30,31). This will be an important addition to this work since those who live in more deprived areas are more exposed to air pollution. In a recent study of social inequality and air pollution exposure in London, it was shown that the average concentration of NO_2 in the most deprived deciles is 24% higher than the least deprived (30). Quantifying the impact of different policies across different social groups would add to this body of work – this could include, for example, the impact of motor vehicle use reduction schemes and policies (i.e. ULEZ or borough active travel plan) across socio-economic groups or deprivation areas.

Strengths and limitations

This study has both strengths and limitations. The microsimulation is a robust tool for modelling population level interventions in detail because it models every individual within the population many years into the future. Individuals are randomly generated (age, sex, exposure) to reproduce exposure and population statistics. However, due to the five-year length of the simulation, it may underestimate the impact on diseases which take many years to accumulate.

It was not possible to include short-term effects of air pollution within the model since it focuses on long-term predictions using annual estimates. Therefore, including short-term peaks was not possible. This is largely due to short-term peaks in air pollution being unpredictable, both temporally and geospatially.

Short-term peaks may lead to increased hospitalisations and therefore greater NHS costs. However, the project would require a much longer time scale to develop ways of incorporating both short and long-term effects. Further, it is unclear how short-term and long-term risk overlap. The microsimulation structure quantifies disease incidence/prevalence on an annual basis.

Due to data availability, it was not possible to take account of other factors such as socio-economic status. Deprived sub-populations are more susceptible to the negative health effects of air pollution and at the same time are more likely to be exposed to higher air pollution levels (30). The microsimulation, however, assumes that the dose-response of exposure to disease varies only by age and sex, but not by socioeconomic status group. Such data could be incorporated into the model in future work.

Dose-response estimates for NO_2 and morbidity outcomes were adjusted and reduced by 60% to take account of overlaps between risks based on COMEAP recommendations for mortality (27). While COMEAP guidance for adjusting NO_2 on $PM_{2.5}$ dose-response metrics exists, however, there is still some uncertainty amongst the scientific community about the most appropriate level of adjustment. COMEAP have reviewed and quantified a number of dose-response relationships, however, others are available in published literature. Some evidence is emerging, for example that for dementia and low birthweight, so results should be interpreted with this in mind.

Policy implications and future work

This project has a number of implications for policy and future work.

- This study provides useful data for making the case to ensure uptake and enforcement of policies designed to reduce private vehicle use and the full implementation of the Lambeth and Southwark plans, and Health in All Policies more broadly (13,14,16).

- However, further policy measures are needed, especially those tackling $PM_{2.5}$ specifically, if air pollution-related diseases are to be eliminated and London is to meet World Health Organization limits.

- This study provides important evidence for understanding the mid-term (for example a 5-year period) effect of air pollution exposure across these boroughs, which is useful when considering additional potential policy measures into the future (e.g. population transport mode shift or significant change in vehicle type).

- Unique to the timing of this study, the COVID-19 scenarios provide a lens into the impact of rapid and drastic changes to working patterns and transportation modes . This has implications for policy development and planning in the future.

- Further work could replicate this study in other metropolitan areas or London boroughs, or across different social groups considering some of the same policies.

Modelling is a useful tool for quantifying the mid- and long-term impact of policy change that is not possible with randomised controlled trials. Further work could explore the differential impact of specific borough and London-wide policies on deprived sub-populations. As suggested above, this could include the impact of a specific borough policy to reduce vehicle use versus a London-wide policy (i.e. ULEZ) on deprived areas.

Conclusion

This study highlights that borough-specific and pan-London actions are required alongside local and national legislation and policy, if larger health benefits and cost savings are to be made to reduce the adverse effects of air pollution on people's health. It is clear that measures to maintain levels of NO_2 emissions found during the COVID-19 lockdown and to meet the WHO levels for $PM_{2.5}$ would have significant health and cost benefits for both Lambeth and Southwark.

References

1. Department for Environment F and RA (Defra) webmaster@defra. gsi. gov. u. Short-term effects of air pollution on health- Defra, UK.
2. COMEAP. The Effects of Long-Term Exposure to Ambient Air Pollution on Cardiovascular Morbidity : Mechanistic Evidence. Comm Med Eff air Pollut [Internet]. 2018;1--104. Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/749657/COMEAP_CV_Mechanisms_Report.pdf
3. Stockfelt L, Andersson EM, Molnár P, Gidhagen L, Segersson D, Rosengren A, et al. Long-term effects of total and source-specific particulate air pollution on incident cardiovascular disease in Gothenburg, Sweden. Environ Res. 2017;158:61–71.
4. Warburton DER, Bredin SSD, Shellington EM, Cole C, de Faye A, Harris J, et al. A Systematic Review of the Short-Term Health Effects of Air Pollution in Persons Living with Coronary Heart Disease. J Clin Med [Internet]. 2019;8(2):274. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6406357/
5. Beverland IJ, Cohen GR, Heal MR, Carder M, Yap C, Robertson C, et al. A comparison of short-term and long-term air pollution exposure associations with mortality in two cohorts in Scotland. Environ Health Perspect. 2012;120(9):1280–5.
6. Walton H, Dajnak D, Evangelopoulos D, Fecht D. Health Impact Assessment of Air Pollution on Asthma in London For: Greater London Authority. 2019.
7. Scheers H, Nawrot TS, Nemery B, Casas L. Changing places to study short-term effects of air pollution on cardiovascular health: a panel study. Environ Heal [Internet]. 2018;17(1):80. Available from: https://doi.org/10.1186/s12940-018-0425-7
8. Lambeth. Lambeth Local Plan [Internet]. Lambeth, London; 2015. Available from: https://www.lambeth.gov.uk/sites/default/files/pl-lambeth-local-plan-2015-web.pdf
9. Southwark. Local Development Plan. Southwark, London;
10. Lambeth. A guide to protect against air pollution [Internet]. 2016. Available from: https://www.lambeth.gov.uk/sites/default/files/cs-public-health-air-quality-leaflet_2.pdf
11. Southwark. Main causes of air pollution [Internet]. 2020. Available from: https://www.southwark.gov.uk/environment/air-quality/about-air-quality/main-causes-of-air-pollution
12. EDF Europe. BreathLondon [Internet]. 2020. Available from: https://www.breathelondon.org/
13. Webber L, Chalkidou K, Morrow S, Ferguson B, McPherson K. What are the best societal investments for improving people's health? BMJ. 2018;362.
14. Langford K. Learning from COVID-19 to find ways to build back cleaner air. Guy's and St Thomas' Charity Blog [Internet]. 2020; Available from: https://www.gsttcharity.org.uk/get-involved/news-and-opinion/views/learning-covid-19-find-ways-build-back-cleaner-air?utm_source=Master+mailing+list&utm_campaign=c525b5ab44-June+e-news&utm_medium=email&utm_term=0_4f6844026b-c525b5ab44-599166949
15. Estimation of costs to the NHS and social care due to the health impacts of air pollution [Internet]. 2018 [cited 2019 Oct 30]. Available from: www.gov.uk/phe
16. Webber L, Xu M, Graff H. Modelling the long-term health impacts of changing exposure to NO2 and PM2.5 in London [Internet]. London; 2020. Available from: https://www.london.gov.uk/sites/default/files/modelling_the_long-term_health_impacts_of_changing_exposure_to_no2_and_pm2.5_in_london_final_250220_-4.pdf

17. Pimpin L, Retat L, Fecht D, de Preux L, Sassi F, Gulliver J, et al. Estimating the costs of air pollution to the National Health Service and social care: An assessment and forecast up to 2035. Sheikh A, editor. PLOS Med [Internet]. 2018 Jul 10 [cited 2019 Aug 23];15(7):e1002602. Available from: https://dx.plos.org/10.1371/journal.pmed.1002602
18. London Atmospheric Emissions (LAEI) 2016 - London Datastore [Internet]. [cited 2019 Dec 9]. Available from: https://data.london.gov.uk/dataset/london-atmospheric-emissions-inventory--laei--2016
19. Associations of long-term average concentrations of nitrogen dioxide with mortality (2018): COMEAP summary - GOV.UK [Internet]. [cited 2019 Oct 25]. Available from: https://www.gov.uk/government/publications/nitrogen-dioxide-effects-on-mortality/associations-of-long-term-average-concentrations-of-nitrogen-dioxide-with-mortality-2018-comeap-summary
20. Environmental Research Group. The Effect of COVID-19 Lockdown Measures on Air Quality in Lodnon on 2020 [Internet]. London; 2020. Available from: https://assets.ctfassets.net/9qe8184l2nz4/2TM8WJUt2w1cHecdjkVIRQ/2e5a91667d676b3c63f1e748156b68c4/ERG_response_to_Defra.pdf
21. Atkinson RW, Analitis A, Samoli E, Fuller GW, Green DC, Mudway IS, et al. Short-term exposure to traffic-related air pollution and daily mortality in London, UK. J Expo Sci Environ Epidemiol [Internet]. 2016 Mar 14 [cited 2019 Oct 3];26(2):125–32. Available from: http://www.ncbi.nlm.nih.gov/pubmed/26464095
22. Fairburn J, Schüle SA, Dreger S, Karla Hilz L, Bolte G. Social Inequalities in Exposure to Ambient Air Pollution: A Systematic Review in the WHO European Region. Int J Environ Res Public Health [Internet]. 2019 Aug 28 [cited 2019 Dec 13];16(17):3127. Available from: https://www.mdpi.com/1660-4601/16/17/3127
23. London G, Recipient A, O'driscoll R, Williamson T, Brook R, German R, et al. Air Pollution Exposure in London: Impact of the London Environment Strategy I Title Air Pollution Exposure in London: Impact of the London Environment Strategy Customer Author(s) [Internet]. [cited 2019 Dec 13]. Available from: www.aether-uk.com

Appendix

Appendix 1. Detailed Methodology

Microsimulation framework

The microsimulation model employed for this project is modular. The first module calculates the predictions of risk factor trends over time based on data from rolling cross-sectional studies. The second module performs the microsimulation of a virtual population, generated with demographic characteristics matching those of the observed data. The health trajectory of each individual from the population is simulated over time allowing them to contract, survive or die from a set of diseases or injuries related to the analysed risk factors. The detailed description of the two modules is presented below.

Module one: Predictions of NO2 and PM2.5 over time

The concentration predictions are based on modelling undertaken by TfL, King's College London and the GLA. The 2016 baseline data comes from the London Atmospheric Emission Inventory (LAEI), full details of the data and methodology can be found here: https://data.london.gov.uk/air-quality/

NO_2 and $PM_{2.5}$ are analysed within the model as risk factors (RF), as described in **Table 36**.

Table 36. Description of the categories used for the risk factors NO_2 and $PM_{2.5}$

Risk factor (RF)	Number of categories (N)	Categories
Nitrogen dioxide (NO2)	3	NO_2 < 20.5 µg m-3 NO_2 from 20.5 to 28.5 µg m-3 NO_2 ≥ 28.5 µg m-3
Particulate matter (PM2.5)	3	$PM_{2.5}$ < 12.3 µg m-3 PM2.5 from 12.3 to 13.5 µg m-3 PM2.5 ≥ 13.5 µg m-3

Microsimulation methods considers the history of each individual from birth to death/ the end of the simulation. Therefore, an individual of age and sex in 2020 in the baseline will follow a different trajectory than the same individual with same age (a) and sex (s) in the other scenarios. The incident cases of diseases of interest are linked to the projections of:

i. air pollution exposures and associated risks to air pollution-related diseases,
ii. age and sex distributions of the population

Therefore, the quantified disease cases will be impacted.

Module two: Microsimulation model

Microsimulation initialisation: birth, disease and death models

Simulated people are generated with the correct demographic statistics in the simulation's start-year. In this year women are stochastically allocated the number and years of birth of their children – these are generated from known fertility and mother's age at birth statistics (valid in the start-year). If a woman has children then those children are generated as members of the simulation in the appropriate birth year.

The microsimulation is provided with a list of air pollution-related diseases. These diseases used the best available incidence, mortality, survival, relative risk and prevalence statistics (by age and gender). Individuals in the model are simulated from their year of birth (which may be before the start year of the simulation). In the course of their lives, simulated people can die from one of the diseases caused by an air pollutant that they might have acquired or from some other cause(s). The probability that a person of a given age and gender dies from a cause other than the disease are calculated in terms of known death and disease statistics valid in the start-year. It is constant over the course of the simulation.

The microsimulation incorporates a sophisticated economic module. The module employs a Markov-type simulation of long-term health benefits and health care costs. It synthesises and estimates evidence on cost-utility analysis. The model is used to project the differences in quality-adjusted life years (QALYs), and direct lifetime health-care costs over a specified time scale. The direct healthcare costs are presented separately in terms of NHS costs and social care costs. Costs were calculated with and without discounting to provide some sensitivity analysis around the estimates. Since this is not a cost-benefit-analysis non-discounted costs are presented in the main body of the report and discounted costs in appendix 3.

This following section provides an overview of the main assumptions of the model.

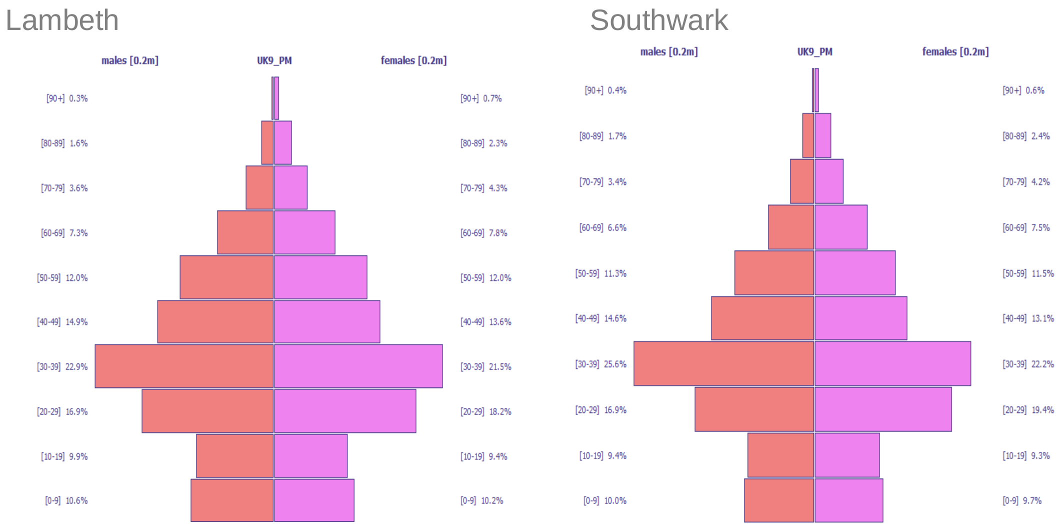
Population models

Populations are implemented as instances of the TPopulation C++ class. The TPopulation class is created from a population (*.ppl) file. Usually a simulation will use only one population but it can simultaneously process multiple populations (for example, different ethnicities within a national population).

Population Editor

The Population Editor Allows editing and testing of TPopulation objects. The population is created in the start-year and propagated forwards in time. An example population pyramid which can be used when initialising the model is shown in **Figure 35** shows the population distribution for Lambeth and Southwark respectively in 2020 which was used in the initialisation of the model.

Figure 35. Population pyramid for Lambeth and Southwark respectively in 2020



People within the model can die from specific diseases or from other causes. A disease file is created within the program to represent deaths from other causes. The following distributions are required by the population editor (**Table 37**).

Table 37. Summary of the parameters representing the distribution component

Distribution name	symbol	note
MalesByAgeByYear	$p_m(a)$	Input in year0 – probability of a male having age a
FemalesByAgeByYear	$p_f(a)$	Input in year0 – probability of a female having age a
BirthsByAgeofMother	$p_b(a)$	Input in year0 – conditional probability of a birth at age a| the mother gives birth.
NumberOfBirths	$p(n)$	$\lambda \equiv$TFR, Poisson distribution, probability of giving birth to n children

Birth model

Any female in the child-bearing years {AgeAtChild.lo, AgeAtChild.hi} is deemed capable of giving birth. The number of children, n, that she has in her life is dictated by the Poisson distribution p(n) where the mean of the Poisson distribution is the Total Fertility Rate (TFR) parameter.

The probability that a mother (who does give birth) gives birth to a child at age a is determined from the BirthsByAgeOfMother distribution as $p_b(a)$. For any particular mother the births of multiple children are treated as independent events, so that the probability that a mother who produces N children produces n of them at age a is given as the Binomially distributed variable,

$$p_b(\text{n at a} \mid N) = \frac{N!}{n!(N-n)!}\left(p_b(a)\right)^n\left(1-p_{bm}(a)\right)^{N-n} \quad (9)$$

The probability that the mother gives birth to n children at age a is

$$p_b(n\,at\,a) = e^{-\lambda}\sum_{N=n}^{\infty}\frac{\lambda^N}{N!}p_b(\text{n at a} \mid N) = e^{-\lambda}\sum_{N=n}^{\infty}\frac{\lambda^N}{n!(N-n)!}\left(p_b(a)\right)^n\left(1-p_b(a)\right)^{N-n}$$

(1.12)

Performing the summation in this equation gives the simplifying result that the probability pb(n at a) is itself Poisson distributed with mean parameter

$\lambda p_b(a)$

,

$$p_b(n\,at\,a) = e^{-\lambda p_b(a)}\frac{\left(\lambda p_b(a)\right)^n}{n!} = p_{\lambda p_b(a)}(n) \quad (10)$$

Thus, on average, a mother at age A will produce $\lambda p_b(a)$ children in that year.

The gender of the children is determined by the probability $p_{male}=1-p_{female}$. In the baseline model this is taken to be the probability $N_m/(N_m+N_f)$.

The Population editor' menu item Population Editor\Tools\Births\show random birthList creates an instance of the TPopulation class and uses it to generate and list a (selectable) sample of mothers and the years in which they give birth.

Deaths from modelled diseases

The simulation models any number of specified diseases some of which may be fatal. In the start year the simulation's death model uses the diseases' own mortality statistics to adjust the probabilities of death by age and gender. In the start year the net effect is to maintain the same probability of death by age and gender as before; in subsequent years, however, the rates at which people die from modelled diseases will change as modelled risk factors change.

The risk factor model

The distribution of risk factors (RF) in the population is estimated using regression analysis stratified by both sex *S* = {male, female} and age group *A* = {0-4, 5-9, ..., 70-74, 75+}. The fitted trends are extrapolated to forecast the distribution of each RF category in the future. For each sex-and-age-group stratum, the set of cross-sectional, time-dependent, discrete distributions is used to manufacture RF trends for individual members of the population. Each air pollutant (e.g. NO_2, $PM_{2.5}$) is modelled as a continuous risk factor.

Continuous risk factors

In the case of a continuous RF, for each discrete distribution D there is a continuous counterpart. Let β denote the RF value in the continuous scale and let f(β|A,S,t) be the probability density function of β for age group A and sex S at time t. Then

$$p_k(t|A,S) = \int_{\beta \in k} f(\beta|A,S,t)\, d\beta. \quad (11)$$

Equation (11) uses the definition of the probability density function to express the age-and-sex-specific percentage of individuals in RF category *k* at time *t*. The cumulative distribution function of β is

$$F(\beta|A,S,t) = \int_0^\beta f(\beta|A,S,t)\, d\beta. \quad (12)$$

At time *t*, a person with sex S belonging to the age group A is said to be on the p–th percentile of this distribution if Given the cross-sectional information from the set of distributions D, it is possible to simulate longitudinal trajectories by forming pseudo-cohorts within the population. A key requirement for these sets of longitudinal trajectories is that they reproduce the cross-sectional distribution of RF categories for any year with available data. The method adopted here and in our earlier work is based on the assumption that person's RF value changes throughout their lives in such a way that they always have the same associated percentile rank. As they age, individuals move from one age group to another and their RF value changes so that they have the same percentile rank but of a different RF distribution. Crucially it meets the important condition that the cross-sectional RF distributions obtained by simulation match the RF distributions of the observed data.

The above procedure can be explained using the example of the NO_2 distribution. The NO_2 distributions are known for the population stratified by sex and age for all years of the simulation (by extrapolation of fitted model, see equation (11). A person who is in age group A and who grows ten years older will at some time move into the next age group A' and will have an exposure that was described first by the distribution f(β|A,S,t) and then at the later time t' by the distribution f(β|A',S,t'). If the NO_2 exposure level of that individual is on the p-th percentile of the NO_2 distribution, their NO_2 exposure level will change from β to β' so that

$$\beta = F^{-1}\left(\frac{p}{100}|A,S,t\right) \quad (13)$$

$$\beta' = F^{-1}\left(\frac{p}{100}|A',S,t'\right) \Rightarrow \beta' = F^{-1}\left(F(\beta|A,S,t)|A',S,t'\right) \quad (14)$$

Where F^{-1} is the inverse of the cumulative distribution function of β, which we model with a continuous uniform distribution within the RF categories. Equation (15) guarantees that the transformation taking the random variable B to β'ensures the correct cross-sectional distribution at time t'.The microsimulation first generates individuals from the RF distributions of the set D and, once generated, grows the individual's RF in a way that is also determined by the set D. It is possible to implement equation (14) as a suitably fast algorithm.

Relative risks

Suppose that α is a risk factor state of some risk factor A and denote by $p_A(d|\alpha,a,s)$ the incidence probability for the disease d given the risk state, α, the person's age, a, and gender, s. The relative risk ρ_A is defined by equation (15).

$$\begin{aligned} p_{\mathrm{A}}(d|\alpha,a,s) &= \rho_{\mathrm{A}|d}(\alpha|a,s)\, p_{\mathrm{A}}(d|\alpha_0,a,s) \\ \rho_{\mathrm{A}|d}(\alpha_0|a,s) &\equiv 1 \end{aligned} \quad (15)$$

Where α_0 is the zero risk state.

The incidence probabilities, as reported, can be expressed in terms of the equation,

$$\begin{aligned} p(d|a,s) &= \sum_{\alpha} p_{\mathrm{A}}(d|\alpha,a,s)\pi_A(\alpha|a,s) \\ &= p_A(d|\alpha_0,a,s)\sum_{\alpha}\rho_{\mathrm{A}|d}(\alpha|a,s)\pi_A(\alpha|a,s) \end{aligned} \quad (16)$$

Combining these equations allows the conditional incidence probabilities to be written in terms of known quantities

$$p(d|\alpha,a,s) = \rho_{A|d}(\alpha|a,s)\frac{p(d|a,s)}{\sum_{\beta}\rho_{A|d}(\beta|a,s)\pi_A(\alpha|a,s)} \quad (17)$$

Previous to any series of Monte Carlo trials the microsimulation program pre-processes the set of diseases and stores the calibrated incidence statistics $p_A(d|\alpha_0, a, s)$. These incidence statistics are calibrated to national level data sets for both national level and local authority model simulations. In this project the risk factor distributions and incidence risks for England are used to calculate the calibrated risks.

Modelling diseases

Disease modelling relies heavily on the sets of incidence, mortality, survival, relative risk and prevalence statistics. In some cases where a data set is unavailable or not available is the specified form for the model, data has been approximated from the known sets of the data.

The microsimulation uses risk dependent incidence statistics and these are inferred from the relative risk statistics and the distribution of the risk factor within the population. In the simulation, individuals are assigned a risk factor trajectory giving their personal risk factor history for each year of their lives. Their probability of getting a particular risk factor related disease in a particular year will depend on their risk factor state in that year.

Once a person has a fatal disease (or diseases) their probability of survival will be controlled by a combination of the disease-survival statistics and the probabilities of dying from other causes. Disease survival statistics are modelled as age and gender dependent exponential distributions.

Mortality statistics

In any year, in some population, in a sample of N people who have the disease a subset N_ω will die from the disease.
Mortality statistics record the cross-sectional probabilities of death as a result of the disease – possibly stratifying by age

$$p_\omega = \frac{N_\omega}{N} \quad (18)$$

Within some such subset N_ω of people that die in that year from the disease, the distribution by year-of-disease is not usually recorded. This distribution would be most useful. Consider two important idealised, special cases.

Suppose the true probabilities of dying in the years after some age a_0 are $\{p_{\omega 0}, p_{\omega 1}, p_{\omega 2}, p_{\omega 3}, p_{\omega 4}\}$
The probability of being alive after N years is simply that you don't die in each year

$$p_{survive}(a_0 + N) = (1 - p_{\omega 0})(1 - p_{\omega 1})(1 - p_{\omega 2})..(1 - p_{\omega N-1}) \quad (19)$$

Survival rates

It is common practice to describe survival in terms of a survival rate R, supposing an exponential death-distribution. In this formulation the probability of surviving t years from some time t0 is given as

$$p_{survival}(t) = 1 - R\int_0^t due^{-Ru} = e^{-Rt} \quad (20)$$

For a time period of 1 year

$$p_{survival}(1) = e^{-R}$$

$$\Rightarrow$$

$$R = -1\ln\left(p_{survival}(1)\right) = -1\ln(1 - p_\omega)$$

(22)
For a time period of, for example, 4 years,

$$p_{survival}(t = 4) = 1 - R^{-1}\int_0^4 due^{-Ru} = e^{-4R} = (1 - p_\omega)^4$$

(23)
In short, the Rate is minus the natural log of the 1-year survival probability.

The survival models

For any potentially terminal disease the model can use any of the three survival models, numbered ((0, 1, 2)). The parameters describing these models are given below.

Survival model 0

A single probability of dying $\{p_{\omega 0}\}$, where $p_{\omega 0}$ is valid for all years. Given the 1-year survival probability $p_{survival}(1)$
The model uses 1 parameter ((R))

$$R = -\ln\left(p_{survival}(1)\right) \quad (24)$$

Survival model 1

Two different probabilities of dying $\{p_{\omega 0}, p_{\omega 1}\}$, where $p_{\omega 0}$ is valid for the first year; $p_{\omega 1}$ thereafter. The model uses two parameters ((p_1, R)). Given the 1-year survival probability $p_{survival}(1)$ and the 5-year survival probability $p_{survival}(5)$

$$p_1 = 1 - p_{survival}(1)$$
$$R = -\frac{1}{4}\ln\left(\frac{p_{survival}(5)}{p_{survival}(1)}\right)$$

$$(25)$$

Survival model 2

Three different probabilities of dying $\{p_{\omega 0}, p_{\omega 1}, p_{\omega 5}\}$, where $p_{\omega 0}$ is valid for the first year; $p_{\omega 1}$ for the second to the fifth year; $p_{\omega 5}$ thereafter. The model uses three parameters ((p_1, R, $R_{>5}$))

Given the 1-year survival probability $p_{survival}(1)$ and the 5-year survival probability $p_{survival}(5)$

$$p_1 = 1 - p_{survival}(1)$$
$$R = -\frac{1}{4}\ln\left(\frac{p_{survival}(5)}{p_{survival}(1)}\right)$$
$$R_{>5} = -\frac{1}{5}\ln\left(\frac{p_{survival}(10)}{p_{survival}(5)}\right) \quad (26)$$

Remember that different probabilities will apply to different age and gender groups. Typically the data might be divided into 10 year age groups.

Modelling low birth weight

The modelling method assumes that low birth weight (LBW) is a disease associated with a women who gives birth. The method also assumes that LBW is an acute disease; an incidence case in any year affects the prevalence rate in that year only. In the start year of the simulation the total of number of births associated to a woman and the year of each birth is computed. The probability of a newborn being LBW is calculated using the risk factor level (i.e., air pollution level) in the year of birth and the associated relative risk. This approach is used when modelling other diseases in the simulation.

There are two differences between modelling LBW and other diseases. Firstly, a mother can have multiple births in a given year which can result in multiple incident cases of LBW. In comparison other diseases can be contracted only once in a year. Secondly, it is possible that in some years of a mother's life she does not give birth. The probability of contracting a LBW in these years is therefore zero.

Limitations
The modelling method assumes that LBW is a disease per se. A limitation extending from this would be that we do not take account of subsequent diseases brought about by LBW, e.g., diabetes or CHD. The model therefore underestimates the long-term economic costs of LBW associated with air pollution. Another limitation is that we allow multiple births in the simulation (e.g. twins), but we do take account of the possible impact of multiple births on LBW. Multiple births are simulated as a list of independent births having the same probability of causing LBW.

Approximating missing disease statistics

A number of tools have been developed in the model in order to compute missing disease statistics data such as incidence or prevalence.

Approximating survival data from mortality and prevalence
An example is provided here with a standard life-table analysis for a disease *d*.
Consider the 4 following states:

state	Description
0	alive without disease d
1	alive with disease d
2	dead from disease d
3	dead from another disease

p_{ik} is the probability of disease d incidence, aged k
$p_{\omega k}$ is the probability of dying from the disease d, aged k

$p_{\omega - k}$ is the probability of dying other than from disease d, aged k

The state transition matrix is constructed as follows

$$\begin{bmatrix} p_0(k+1) \\ p_1(k+1) \\ p_2(k+1) \\ p_3(k+1) \end{bmatrix} = \begin{bmatrix} (1-p_{\bar{\omega}k})(1-p_{ik}) & (1-p_{\bar{\omega}k}-p_{\omega k})p_{\omega k} & 0 & 0 \\ (1-p_{\bar{\omega}k})p_{ik} & (1-p_{\bar{\omega}k}-p_{\omega k})(1-p_{\omega k}) & 0 & 0 \\ 0 & p_{\omega k} & 1 & 0 \\ p_{\bar{\omega}k} & p_{\bar{\omega}k} & 0 & 1 \end{bmatrix} \begin{bmatrix} p_0(k) \\ p_1(k) \\ p_2(k) \\ p_3(k) \end{bmatrix} \quad (27)$$

It is worth noting that the separate columns correctly sum to unity.

The disease mortality equation is that for state-2,

$$p_2(k+1) = p_{\omega k} p_1(k) + p_2(k) \quad (28)$$

The probability of dying from the disease in the age interval [k, k+1] is $p_{\omega k} p_1(k)$ - this is otherwise the (cross-sectional) disease mortality, $p_{mor}(k)$. $p_1(k)$ is otherwise known as the disease prevalence, $p_{pre}(k)$. Hence the relation

$$p_{\omega k} = \frac{p_{mor}(k)}{p_{pre}(k)} \quad (29)$$

For exponential survival probabilities the probability of dying from the disease in the age-interval [k, k+1] is denoted $p_{\Omega k}$ and is given by the formula

$$p_{\omega k} = 1 - e^{-R_k} \quad \Rightarrow \quad R_k = -\ln(1 - p_{\omega k}) \quad (30)$$

When, as is the case for most cancers, these survival probabilities are known the microsimulation will use them, when they are not known or are too old to be any longer of any use, the microsimulation uses survival statistics inferred from the prevalence and mortality statistics (equation). An alternative derivation equation (29) is as follows. Let Nk be the number of people in the population aged k and let nk be the number of people in the population aged k with the disease. Then, the number of deaths from the disease of people aged k can be given in two ways: as $p_{\omega k} n_k$ and, equivalently, as $p_{mor}(k) N_k$. Observing that the disease prevalence is n_k/N_k leads to the equation

$$p_{\Omega k} n_k = p_{mor}(k) N_k$$

$$p_{pre}(k) = \frac{n_k}{N_k}$$

$$\Rightarrow$$

$$p_{\Omega k} = \frac{p_{mor}(k)}{p_{pre}(k)} \quad (31)$$

Approximating disease incidence from prevalence

The algorithm estimates the probability of contracting a disease given age and sex, $\hat{p}(d \mid a, s)$ from prevalence rates, survival rates and mortality rates.

Step 1: State transition matrix of the algorithm

$$\begin{pmatrix} p_{\bar{d}}(a+1 \mid s) \\ p_{d1}(a+1 \mid s) \\ p_{d}(a+1 \mid s) \\ p_{dead}(a+1 \mid s) \end{pmatrix} = \begin{pmatrix} (1-p_{\pi}(a \mid s))(1-\hat{p}(d \mid a, s)) & 0 & 0 & 0 \\ (1-p_{\pi}(a \mid s))\hat{p}(d \mid a, s) & 0 & 0 & 0 \\ 0 & 1-p_{w1+\pi1}(a \mid s) & 1-p_{w+\pi}(a \mid s) & 0 \\ p_{\pi}(a \mid s) & p_{w1+\pi1}(a \mid s) & p_{w+\pi}(a \mid s) & 1 \end{pmatrix} \begin{pmatrix} p_{\bar{d}}(a \mid s) \\ p_{d1}(a \mid s) \\ p_{d}(a \mid s) \\ p_{dead}(a \mid s) \end{pmatrix}$$

(32)

The probability of being in a set of states:

S_0	$p_{\bar{d}}(a \mid s)$	**The probability of being alive without disease at age a**
S_1	$p_{d1}(a \mid s)$	The probability of being alive with new disease (contracting within a year) at age a
S_2	$p_{d}(a \mid s)$	The probability of being alive with old disease at age a

S_3	$p_{dead}(a\|s)$	The probability of being dead for any reason (from the disease or other reasons) at age a

$\hat{p}(d \mid a,s)$ The estimated incidence probability at age of a given sex type s.

$p_{\bar{w}}(a|s)$ The probability of dying from other causes at age a of given sex type s.

$p_{w1+\bar{w}1}(a|s)$ The probability of dying from any reason within the first years of contracting the disease at the age of a given sex type s.

$p_{w+\bar{w}}(a|s)$ The probability of dying from any reasons after the first years of contracting the disease at the age a given sex type s.

$p_{survival1st}(a|s)$ The probability of surviving the first year after contracting the disease at the age of a given sex type s.

$p_{survival1}(a|s)$ The probability of surviving the year at the age of a given sex type s.

Step 2: The prevalence for a particular age group

Estimated prevalence rate can be expressed by,

$$\hat{P}_{pre\_mean}(agegroup \mid s) = \frac{\sum_{min\_a}^{max\_a} \hat{P}_{pre}(a \mid s) \cdot \pi(a \mid s)}{\sum_{min\_a}^{max\_a} \pi(a \mid s)} \quad (33)$$

where

$$\hat{P}_{pre}(a \mid s) = \frac{p_d(a \mid s) + p_{d1}(a \mid s)}{p_d(a \mid s) + p_{d1}(a \mid s) + p_{\bar{d}}(a \mid s)} \quad (34)$$

where min_a is the youngest age in that age group and max_a the oldest. $\pi(a \mid s)$ is the population distribution stratified by age given sex.

Step 3: Regression

We have two algorithms to find the optimum value of $\hat{p}(d \mid a,s)$: simplex algorithm and cauchy algorithm. Simplex algorithm finds an optimum set of incidence rates of all age groups by minimising the distance between the estimated global prevalence rate and the actual global prevalence rate, shown in (35). We use simplex algorithm for most diseases as it is faster.

$$\underset{set(\hat{p}(d|a,s))}{\arg\min}\, S = \underset{set(\hat{p}(d|a,s))}{\arg\min}\, S\left(\sum_{age\_group} (P_{pre\_mean}(agegroup \mid s) - \hat{P}_{pre\_mean}(agegroup \mid s))\right) \quad (35)$$

Cauchy algorithm finds an optimum incidence rate for each individual age group by minimising the distance between the estimated prevalence rate and the actual prevalence rate of the age group, shown in (36). We use Cauchy algorithm for diseases which are associated to certain age groups, e.g., dementia which is only associated to people older than 60.

$$\underset{p(d|a,s)}{\arg\min}\, S = \underset{p(d|a,s)}{\arg\min}\, S\left(P_{pre\_mean}(agegroup \mid s) - \hat{P}_{pre\_mean}(agegroup \mid s)\right) \quad (36)$$

Model scenarios

The following protocol to derive the specifications for the COVID-19 scenarios for NO_2 was followed:

Step 1: use the daily NO_2 levels from Brixton Road, Lambeth and Elephant and Castle, Southwark [1] – (as per figure 1 and 2).

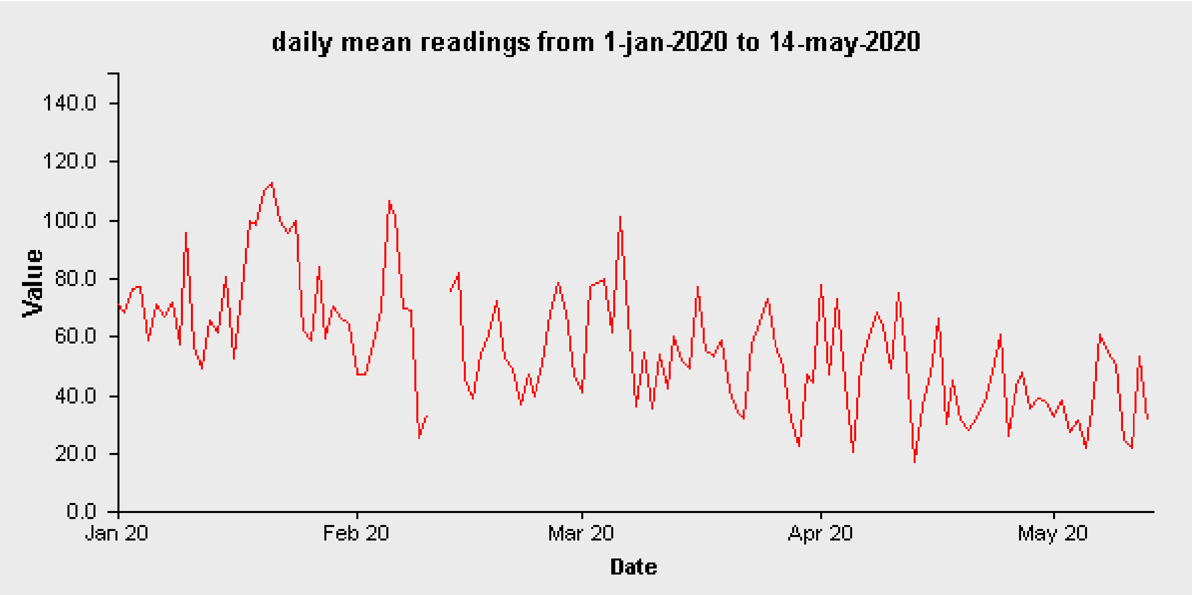


Figure 1. Illustrative figure of drop in NO2 exposure during lockdown in Lambeth – Brixton Road

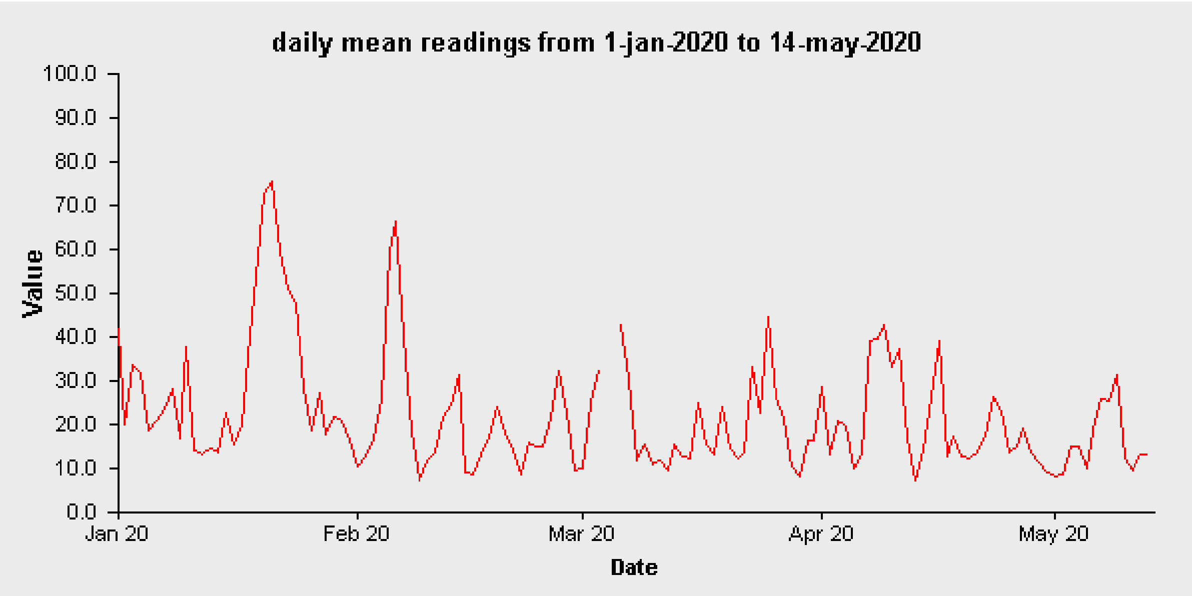


Figure 2. Illustrative figure of drop in NO2 exposure during lockdown in Southwark – Elephant and Castle

Step 2: Linear Regression to derive the impact of lockdown on NO_2 levels and the absolute drop in NO_2 over this period.

Step 3: Estimate the annual NO_2 reduction using the reduction during lockdown from the linear regression in step 2 (start date: 15/03/2020). This showed that there has been approximately 45% and 24% reduction in NO_2 level since the beginning of the lockdown period for Lambeth and Southwark respectively. This is aligned with published data.

Step 4: Implement this % drop. A 'COVID-19' what-if scenario, whereby Southwark and Lambeth reduce their NO_2 levels by the same percentage as it has been reduced in the COVID lockdown. There are different ways that this has been addressed:

a. **Conservative assumption:** the NO_2 levels come back to pre-lockdown levels after a month: an annual **4% reduction** in NO_2 level in Lambeth for the year of 2020 was modelled. Similarly, for Southwark, a **2% reduction** in NO_2 for the year of 2020 was modelled.
b. **Best-case/more ambitious assumption**: the NO_2 levels stay as low as during the lockdown period for the rest of the year: a **34% reduction** in NO_2 level in both Lambeth for the year 2020 was assumed. Similarly, for Southwark, a **18% reduction** in NO_2 for the year of 2020 was assumed.
c. **Additional London scenarios: running a COVID-19 scenario where the average reduction in** NO_2 **in London was assumed for both Lambeth and Southwark**

In a summary, the COVID-19 scenarios modelled are presented in **Table 38**:

Table 38. COVID-19 scenarios modelled

Assumption	Local authority	Reduction by time period
Conservative Assumption	**Lambeth**	NO_2 level reduced by 2% in 2020 **using London reduction in NO_2 level**
	Southwark	NO_2 level reduced by 2% in 2020 **using London reduction in NO_2 level**
More ambitious Assumption	**Lambeth**	NO_2 level reduced by 21.5% in 2020 **using London reduction in NO_2 level**
	Southwark	NO_2 level reduced by 21.5[2]% in 2020 using London reduction in NO_2 level
Conservative Assumption	**Lambeth**	**NO_2 level reduced by 4% in 2020 using Lambeth reduction in NO_2 level**
	Southwark	NO_2 level reduced by 2% in 2020 **using Southwark reduction in NO_2 level**
More ambitious Assumption	**Lambeth**	NO_2 level reduced by 34% in 2020 **using Lambeth reduction in NO_2 level**
	Southwark	NO_2 level reduced by 18% in 2020 **using Southwark reduction in NO_2 level**

Note that studies have shown that levels of $PM_{2.5}$ increased during lockdown due to easterly winds, pollutants from northern Europe and more time spent cooking indoors.

Direct costs

The cost model used in the simulation is part of the economics module and, here, simply scales the aggregated individual disease costs according to the relative disease prevalence in years after the start year for which the costs are known.

In any year, the total healthcare cost for the disease *D* is denoted $C_D(year)$. If the prevalence of the disease is denoted $P_D(year)$ we assume a simple relationship between the two of the form

$$C_D(year) = \kappa P_D(year) \quad (37)$$

for some constant κ.

For each of the trial years, the microsimulation records the prevalence of each disease call it $P_D(year|trial)$ and the trial population size for that year, $N_{pop}(year|trial)$. Further assume that the prevalence in the whole population $N_{pop}(year)$ is a simple scaling of the trial prevalence, then

$$C_D(year) = \kappa P_D(year) = \lambda \frac{N_{pop}(year) P_D(year|trial)}{N_{pop}(year|trial)} \quad (38)$$

for some constant λ.

By comparing any trial year to some initial year, *year0*, the total disease cost in any year is given as

$$\frac{C_D(year)}{C_D(year0)} = \frac{N_{pop}(year)}{N_{pop}(year0)} \frac{N_{pop}(year0 \mid trial)}{N_{pop}(year \mid trial)} \frac{P_D(year \mid trial)}{P_D(year0 \mid trial)}$$

Population data

Data on the total current population of Southwark and Lambeth, population projections, births by mothers age, total fertility rate and deaths by age and sex were extracted from Office for National Statistics and Greater London Authority estimates for both boroughs (**Table 39**).

Demographic characteristic	Source
Total population by age and sex	Office for National Statistics, NOMIS (2019) (32)
Population projection	Greater London Authority (2018) (33)
Births by mothers age	Office for National Statistics, NOMIS (2019) (34)
Total fertility rate	Office for National Statistics, NOMIS (2019) (34)
Deaths by age and sex	Office for National Statistics, NOMIS (2019) (35)

Disease data

Table 40. Summary of disease data inputs and data sources

Disease	Incidence	Prevalence	Mortality	Survival	Relative risk	Utility weight	Cost
Asthma	British Lung Foundation. Asthma Statistics 2015. (36)	NHS Digital, Health Survey for England 2018: Asthma. (37)	Office for National Statistics, NOMIS. Mortality statistics - underlying cause, sex and age, 2018. (35)	Computed	**NO_2:** Khreis et al. 2016 (21) In children =<6 years : OR 1.08 (1.04; 1.12) per 4 g/m3→Converted to OR 1.212 (1.103; 1.328) per 10 g/m3→REDUCED by 60% → **1.08 (1.01; 1.12) per 10 g/m3** In children >6 years: OR 1.03 (1.00; 1.06) per 4 g/m3→Converted to OR 1.08 (1.00; 1.16) per 10 g/m3→ REDUCED by 60% → **1.03 (1.00; 1.06) per 10 g/m3** Jacquemin et al. 2015 (38) In adults: OR 1.10 (0.99;1.21) per 10 g/m3 →REDUCED by 60% → **1.04 (0.996; 1.08) per 10 g/m3** **$PM_{2.5}$:** Khreis et al. 2016 (21) In children >6 years: OR 1.04 (1.02; 1.07) per 1 g/m3 →Converted **OR 1.48 (1.22 ; 1.97) per 10 g/m3**	0.722	Primary care (39): £17.6 Inpatient (40): £12.14 Outpatient (41): £12.21 Prescriptions (38): £72.41 **Total: £114.35**

Disease	Incidence	Prevalence	Mortality	Survival	Relative risk	Utility weight	Cost
COPD	British Lung Foundation. COPD Statistics 2015. (42)	British Lung Foundation. COPD Statistics 2015. (42)	Office for National Statistics, NOMIS. Mortality statistics - underlying cause, sex and age, 2018. (35)	Computed	**NO2** (per 10 µg/m3): Zhang et al. 2018 (19) RR: 1.170 (1.046-1.308) **PM2.5:** COMEAP 2016 (43) COMEAP recommend using PM 10 estimate based on Cai et al. 2014 estimate for chronic phlegm in never smokers in sensitivity analyses: OR 1.32 (1.02; 1.71) per 10µg/m3 of PM10 → scale to PM2.5 using the conversion factor of PM2.5-> PM10: 0.7 (or PM10 -> PM2.5:1.42) recently used in the air quality index, COMEAP: Converted to **1.49 (1.03; 2.14) per 10µg/m3 of PM2.5**	0.732	Collins et al. 2018 (44) A&E: £48.87 Admissions: £3070.42 Outpatient: £562.57 **Total: £3681.82**
CHD	Smolina K, Wright FL, Rayner M, Goldacre MJ. Determinants of the decline in mortality from acute myocardial infarction in England between 2002 and 2010: linked national database study. (45)	NHS Digital. Health Survey for England 2017. (46)	Office for National Statistics, NOMIS. Mortality statistics - underlying cause, sex and age, 2018. (35)	Computed	**PM2.5:** Cesaroni et al. 2014 (18) Estimate used in CAPTOR tool from subgroup analysis of participants with additional information on CVD risk factors: HR 1.19 (1.01; 1.42) per 5 g/m3→ Converted to **1.41 (1.00 - 2.01) per 10 g/m3**	0.605	Liu et al. 2006 (47) Primary care: £30.84 A&E: £10.45 Outpatient: £21.05 Inpatient: £579.61 Day case: £10.11 Rx: £352.71 Dispensing: £15.29 Rehab: £17.94 **Total: £1038.01**

Disease	Incidence	Prevalence	Mortality	Survival	Relative risk	Utility weight	Cost
Diabetes	Holden SH, Barnett AH, Peters JR, et al. The incidence of type 2 diabetes in the United Kingdom from 1991 to 2010. (48)	NHS Digital. National Diabetes Audit 2017/18. NHS Digital 2019. (49)	Office for National Statistics, NOMIS. Mortality statistics - underlying cause, sex and age, 2018. (35)	Computed	**NO2:** Liu et al. 2019 (50) HR=1.02 (0.99-1.05) per 10 g/m3 **PM2.5:** Liu et al. 2019 (50) HR=1.10 (1.04-1.16) per 10 g/m3	0.66 (51)	Primary care (52): £327.76 Inpatient(40): £66.71 Rx (52): £242 Outpatient (53): £399.23 **Total: £1035**
Stroke	British Heart Foundation. Stroke Statistics 2009. (54)	NHS Digital. Health Survey for England 2017. (46)	Office for National Statistics, NOMIS. Mortality statistics - underlying cause, sex and age, 2018. (35)	Computed	**PM2.5:** Scheers et al. 2015 (20) HR 1.064 (1.021; 1.109) per 5 g/m3 →Converted to **1.13 (1.04; 1.23) per 10 g/m3**	0.69 (55)	Luengo-Fernandez et al. 2020 (56) Primary care: £315.53 A&E: £97.27 Outpatient: £408.05 Inpatient: £1293.76 Rx: £79.87 **Total: £2194.48**
Dementia	Matthews FE, Stephan BC, Robinson L, et al. A two decade dementia incidence comparison from the Cognitive Function and Ageing Studies I and II. (57)	Dementia UK - second edition. Alzheimer's UK; 2014. (57)	Office for National Statistics, NOMIS. Mortality statistics - underlying cause, sex and age, 2018. (35)	Computed	**NO2:** Carey et al. 2018 (17) HR=1.15 (1.04-1.28) per 7.47 µg/m3 **PM2.5:** Carey et al. 2018 (27) HR=1.06 (1.01-1.13) per 0.95 µg/m3 →Converted to HR=**1.847 (1.110-3.620) per 10 µg/m3**	0.521 (51)	Primary care (58): £423.75 Outpatient (28): £73.57 Inpatient (40): £123.5 Rx ?(28): £305.29 **Total: £926**

Disease	Incidence	Prevalence	Mortality	Survival	Relative risk	Utility weight	Cost
Low birth weight	ONS. Birth characteristics in England and Wales. 2019. (59)	ONS. Birth characteristics in England and Wales. 2019. (59)	Non-terminal	N/A	**NO2:** Smith et al. 2017 OR: 1.03 (1.00-1.06) **PM2.5:** Smith et al. 2017 (60) OR: 1.06 (1.01-1.12) per 2.2 μg/m3 →Converted to OR=**1.303 (1.046-1.674) per 10 μg/m3**	N/A	N/A
Lung cancer	ONS. Cancer registration statistics 2017. (61)	Estimate from incidence	Office for National Statistics, NOMIS. Mortality statistics - underlying cause, sex and age, 2018. (35)	ONS. Cancer survival in England - adults diagnosed. 2019. (62)	**NO2:** Hamra et al. 2015 (63) RR 1.04 (1.01; 1.08) per 10 g/m3→REDUCED by 60% → **1.02 (1.00; 1.03) per 10 g/m3** **PM2.5:** Hamra et al. 2014 (64) RR=**1.09 (1.04; 1.14) per 10 g/m3**	**0.56** (51) Sullivan et al, 2011	Kennedy et al. 2016 (65) **Total: £11289.1**

Table 41. Dose-response estimates included in the model by disease and pollutant

Disease	Relative Risk	
	NO_2	$PM_{2.5}$
Asthma	*Khreis et al. 2016* (21) In children =<6 years: OR 1.08 (1.04; 1.12) per 4µg/m³à*Converted to OR 1.212 (1.103; 1.328)* per 10µg/m³à*REDUCED by 60%* à **1.08 (1.01; 1.12) per 10µg/m³** In children >6 years: OR 1.03 (1.00; 1.06) per 4µg/m³à*Converted to OR 1.08 (1.00; 1.16)* per 10µg/m³à *REDUCED by 60%* à **1.03 (1.00; 1.06) per 10µg/m³** *Jacquemin et al. 2015* (38) *In adults:* OR 1.10 (0.99;1.21) per 10µg/m³ à *REDUCED by 60%* à **1.04 (0.996; 1.08) per 10µg/m³**	*Khreis et al. 2016* (21) In children >6 years: OR 1.04 (1.02; 1.07) per 1µg/m³ à Converted OR **1.48 (1.22 ; 1.97) per 10µg/m³**
COPD	N/A	*COMEAP 2016* (43) COMEAP recommend using PM_{10} estimate based on Cai et al. 2014 estimate for chronic phlegm in never smokers in sensitivity analyses: OR 1.32 (1.02; 1.71) per 10µg/m³ of PM_{10} à scale to $PM_{2.5}$ using the conversion factor of $PM_{2.5}$-> PM_{10}: 0.7 (or PM_{10} -> $PM_{2.5}$:1.42) recently used in the air quality index, COMEAP: Converted to **1.49 (1.03; 2.14) per 10µg/m³ of $PM_{2.5}$**

CHD	N/A	*Cesaroni et al. 2014* (18) Estimate used in CAPTOR tool from subgroup analysis of participants with additional information on CVD risk factors: HR 1.19 (1.01; 1.42) per 5µg/m^3 à Converted to **1.41 (1.00 - 2.01) per 10µg/m^3**
Diabetes	Eze *et al.* 2015 (66) RR 1.12 (1.05; 1.19) per 10µg/m^3 à *REDUCED by 60%* à **1.05 (1.02; 1.07) per 10µg/m^3**	*Eze et al. 2015* (66) RR **1.10 (1.02; 1.18) per 10µg/m^3**
Stroke	NA	*Scheers et al. 2015* (67) HR 1.064 (1.021; 1.109) per 5µg/m^3 à Converted to **1.13 (1.04; 1.23) per 10µg/m^3**
Dementia	*Oudin et al. 2016* (68) HR 1.08 (1.00; 1.16) per 10µg/m^3 NOx. Scaling factor: NOx → NO2: 0.44 which was developed by Anderson et al. based on the ratio that fell midway between the average or roadside vs urban background monitoring sites in London for 2001 (see Online Supp 2) Converted from NOx to NO2:HR 1.03 (1.00; 1.07) à REDUCED by 60% à **1.01 (1.01; 1.03) per 10µg/m3 of NO2**	N/A
Low birth weight	*Pedersen et al. 2013* (69) OR 1.09 (1.00; 1.19) per 10µg/m^3 à *REDUCED by 60%* à **1.04 (1.00; 1.07) per 10µg/m^3**	*Pedersen et al. 2013* (69) OR 1.18 (1.06; 1.33) per 5µg/m^3 à Converted OR **1.39 (1.12; 1.77) per 10µg/m^3**
Lung cancer	*Hamra et al. 2015* (70) RR 1.04 (1.01; 1.08) per 10µg/m^3 à *REDUCED by 60%* à **1.02 (1.00; 1.03) per 10µg/m^3**	*Hamra et al. 2014* (71) **RR 1.09 (1.04; 1.14) per 10µg/m^3**

Appendix 3. Sensitivity Analysis around costs using discounting

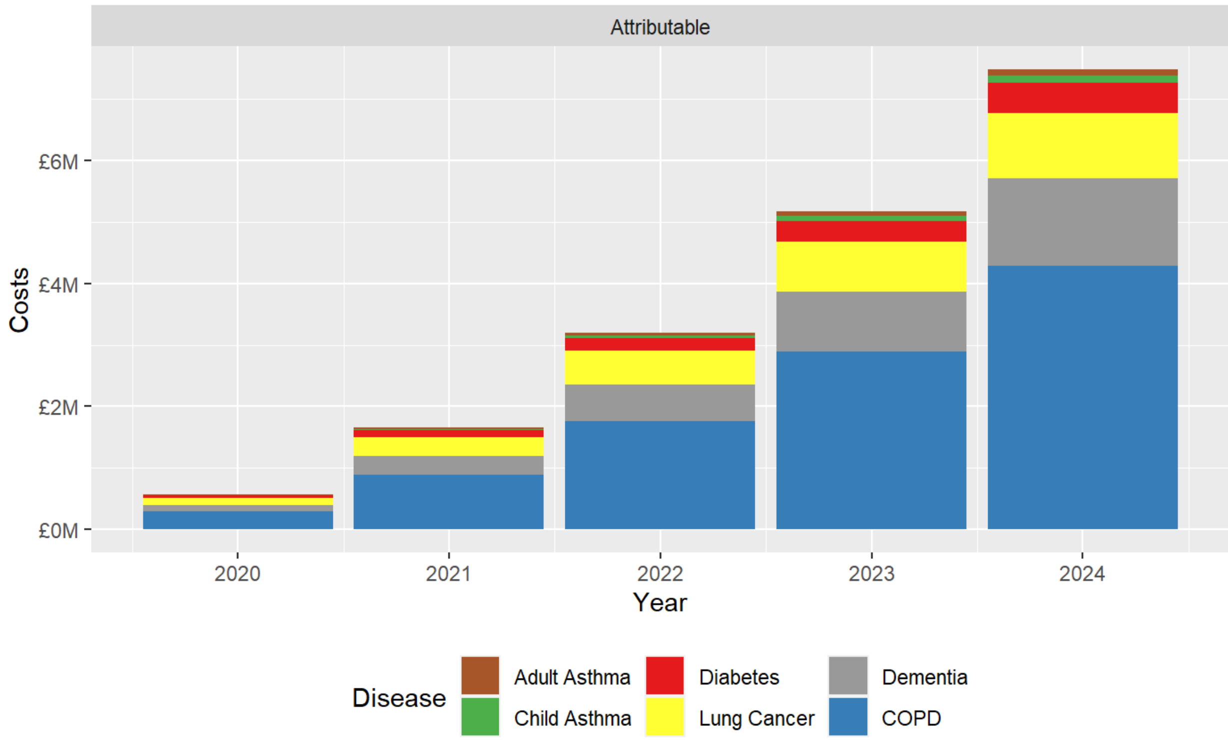
Costs were calculated with and without discounting. The discount rate of 1.5% was used.

Lambeth

NO_2

Cumulative NHS costs attributable to NO_2

Year	Adult Asthma	Child Asthma	COPD	Dementia	Diabetes	Lung Cancer	Total
2020	£8,542 ± [£3,609]	£8,111 ± [£1,694]	£297,800 ± [£62,873]	£102,137 ± [£11,861]	£35,850 ± [£33,507]	£112,049 ± [£40,875]	£564,489 ± [£83,084]
2021	£23,576 ± [£5,083]	£24,516 ± [£2,383]	£884,609 ± [£89,523]	£302,334 ± [£17,002]	£104,837 ± [£47,585]	£316,316 ± [£60,158]	£1,656,188 ± [£119,240]
2022	£43,410 ± [£6,205]	£48,162 ± [£2,904]	£1,756,253 ± [£110,381]	£593,518 ± [£21,096]	£207,238 ± [£58,524]	£553,128 ± [£75,793]	£3,201,709 ± [£147,802]
2023	£68,803 ± [£7,143]	£78,824 ± [£3,337]	£2,895,068 ± [£128,325]	£970,803 ± [£24,679]	£341,013 ± [£67,867]	£810,372 ± [£89,463]	£5,164,883 ± [£172,476]
2024	£98,652 ± [£7,964]	£115,836 ± [£3,714]	£4,278,896 ± [£144,439]	£1,427,917 ± [£27,943]	£497,660 ± [£76,205]	£1,057,823 ± [£101,849]	£7,476,784 ± [£194,682]

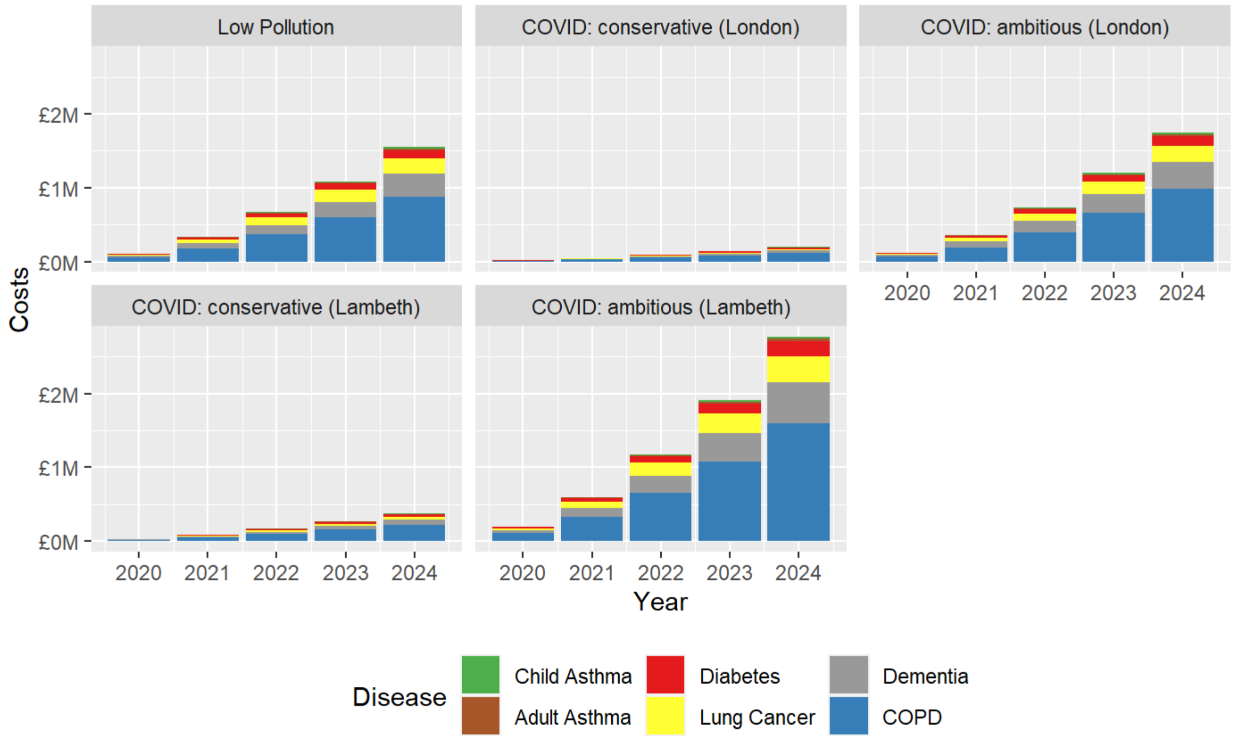

Attributable
Costs
£6M
£4M
£2M
£0M
2020
2021
2022
2023
2024
Year
Disease
Adult Asthma
Child Asthma
Diabetes
Lung Cancer
Dementia
COPD

Cumulative NHS costs avoided for NO_2

Scenario	Year	Adult Asthma	Child Asthma	COPD	Dementia	Diabetes	Lung Cancer	Total
Low Pollution	2020	£1,694 ± [£3,612]	£1,552 ± [£1,700]	£60,778 ± [£63,059]	£24,277 ± [£11,944]	£8,514 ± [£33,517]	£11,755 ± [£41,257]	£108,570 ± [£83,430]
	2021	£4,478 ± [£5,088]	£5,012 ± [£2,396]	£182,087 ± [£89,912]	£68,437 ± [£17,176]	£24,734 ± [£47,606]	£48,209 ± [£60,856]	£332,958 ± [£119,919]
	2022	£8,193 ± [£6,213]	£9,713 ± [£2,925]	£364,140 ± [£111,011]	£131,704 ± [£21,375]	£48,151 ± [£58,559]	£107,984 ± [£76,719]	£669,886 ± [£148,803]
	2023	£12,817 ± [£7,154]	£15,706 ± [£3,367]	£597,255 ± [£129,227]	£213,099 ± [£25,072]	£76,248 ± [£67,918]	£166,963 ± [£90,604]	£1,082,088 ± [£173,818]
	2024	£18,415 ± [£7,978]	£22,666 ± [£3,754]	£878,572 ± [£145,634]	£308,263 ± [£28,459]	£108,613 ± [£76,272]	£211,876 ± [£103,176]	£1,548,405 ± [£196,366]
COVID: Conservative (London)	2020	£659 ± [£3,612]	£81 ± [£1,702]	£11,146 ± [£63,098]	£2,255 ± [£11,967]	£2,711 ± [£33,519]	-£719 ± [£41,305]	£16,133 ± [£83,487]
	2021	£1,356 ± [£5,089]	£346 ± [£2,399]	£29,683 ± [£89,997]	£6,314 ± [£17,222]	£7,064 ± [£47,611]	£2,024 ± [£60,976]	£46,787 ± [£120,053]
	2022	£2,142 ± [£6,214]	£635 ± [£2,929]	£53,928 ± [£111,152]	£12,949 ± [£21,446]	£11,146 ± [£58,567]	£8,762 ± [£76,924]	£89,562 ± [£149,028]
	2023	£2,854 ± [£7,156]	£1,049 ± [£3,374]	£83,096 ± [£129,428]	£22,007 ± [£25,170]	£15,300 ± [£67,930]	£14,897 ± [£90,873]	£139,203 ± [£174,127]

Scenario	Year	Adult Asthma	Child Asthma	COPD	Dementia	Diabetes	Lung Cancer	Total
	2024	£3,613 ± [£7,981]	£1,466 ± [£3,763]	£120,368 ± [£145,899]	£33,153 ± [£28,584]	£20,172 ± [£76,287]	£16,866 ± [£103,480]	£195,638 ± [£196,747]
COVID: Ambitious (London)	2020	£2,087 ± [£3,612]	£1,904 ± [£1,700]	£63,096 ± [£63,057]	£29,125 ± [£11,939]	£10,375 ± [£33,516]	£9,234 ± [£41,267]	£115,823 ± [£83,432]
	2021	£5,195 ± [£5,088]	£5,748 ± [£2,395]	£193,784 ± [£89,906]	£81,510 ± [£17,166]	£29,780 ± [£47,605]	£43,023 ± [£60,870]	£359,040 ± [£119,920]
	2022	£9,211 ± [£6,213]	£10,447 ± [£2,924]	£394,758 ± [£110,998]	£155,277 ± [£21,361]	£56,771 ± [£58,557]	£99,659 ± [£76,736]	£726,123 ± [£148,800]
	2023	£14,400 ± [£7,154]	£16,079 ± [£3,367]	£661,284 ± [£129,203]	£250,523 ± [£25,053]	£91,284 ± [£67,915]	£165,106 ± [£90,608]	£1,198,676 ± [£173,798]
	2024	£20,802 ± [£7,978]	£21,893 ± [£3,754]	£987,798 ± [£145,596]	£363,006 ± [£28,434]	£130,629 ± [£76,268]	£219,050 ± [£103,165]	£1,743,177 ± [£196,327]
COVID: Conservative (Lambeth)	2020	£609 ± [£3,612]	£353 ± [£1,701]	£19,983 ± [£63,091]	£5,351 ± [£11,964]	£3,798 ± [£33,519]	£1,092 ± [£41,298]	£31,186 ± [£83,478]
	2021	£1,155 ± [£5,089]	£1,105 ± [£2,398]	£52,518 ± [£89,985]	£15,067 ± [£17,215]	£9,228 ± [£47,610]	£7,058 ± [£60,963]	£86,131 ± [£120,035]
	2022	£1,900 ± [£6,214]	£1,954 ± [£2,929]	£98,917 ± [£111,132]	£30,000 ± [£21,436]	£15,506 ± [£58,566]	£21,349 ± [£76,898]	£169,626 ± [£148,998]

Scenario	Year	Adult Asthma	Child Asthma	COPD	Dementia	Diabetes	Lung Cancer	Total
	2023	£2,998 ± [£7,156]	£2,946 ± [£3,373]	£154,365 ± [£129,401]	£49,061 ± [£25,156]	£23,023 ± [£67,928]	£33,737 ± [£90,840]	£266,129 ± [£174,086]
	2024	£4,228 ± [£7,981]	£3,988 ± [£3,762]	£223,834 ± [£145,863]	£71,164 ± [£28,567]	£31,015 ± [£76,285]	£39,679 ± [£103,445]	£373,907 ± [£196,698]
COVID: Ambitious (Lambeth)	2020	£3,424 ± [£3,611]	£3,039 ± [£1,699]	£110,702 ± [£63,019]	£43,530 ± [£11,923]	£16,204 ± [£33,514]	£23,716 ± [£41,211]	£200,615 ± [£83,373]
	2021	£8,646 ± [£5,087]	£8,837 ± [£2,393]	£328,669 ± [£89,831]	£122,980 ± [£17,135]	£45,026 ± [£47,600]	£86,644 ± [£60,756]	£600,802 ± [£119,800]
	2022	£15,222 ± [£6,211]	£16,211 ± [£2,921]	£653,927 ± [£110,881]	£235,866 ± [£21,312]	£87,251 ± [£58,550]	£171,106 ± [£76,588]	£1,179,583 ± [£148,626]
	2023	£23,347 ± [£7,152]	£24,957 ± [£3,363]	£1,079,977 ± [£129,038]	£380,965 ± [£24,986]	£140,126 ± [£67,906]	£266,425 ± [£90,429]	£1,915,797 ± [£173,569]
	2024	£32,988 ± [£7,976]	£34,151 ± [£3,749]	£1,596,991 ± [£145,383]	£553,520 ± [£28,347]	£200,372 ± [£76,256]	£355,241 ± [£102,952]	£2,773,263 ± [£196,040]

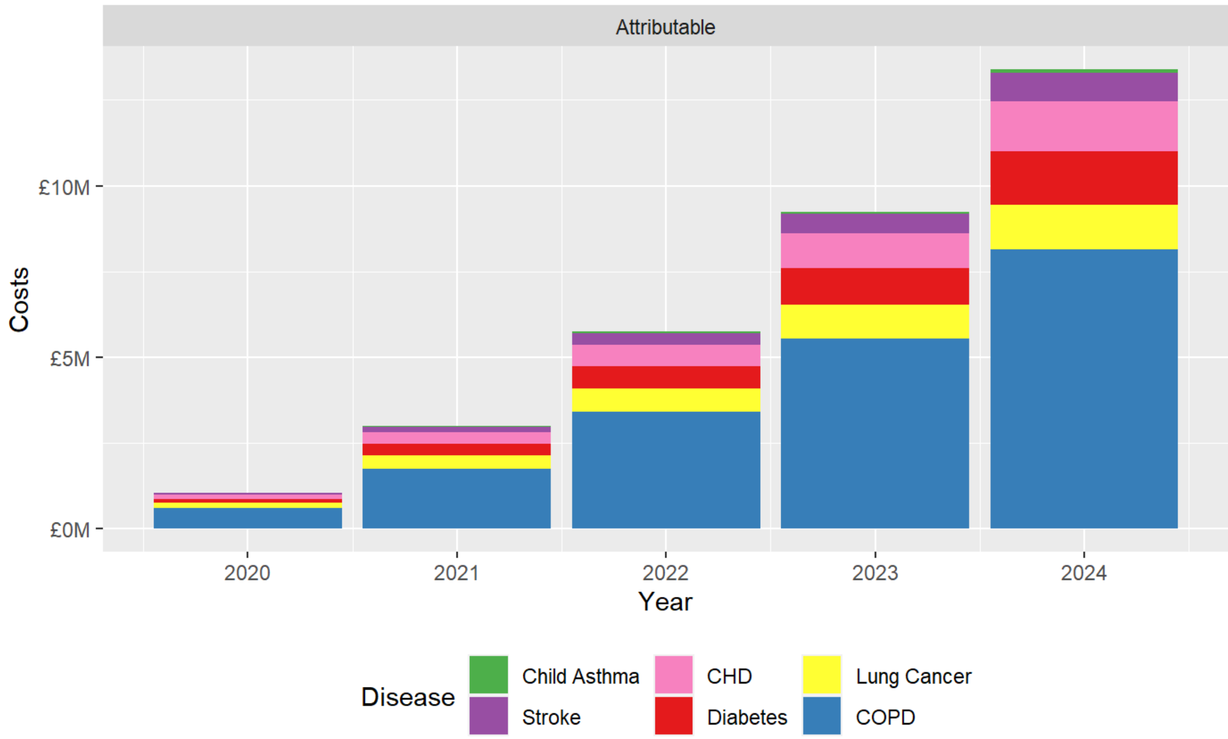


Low Pollution
COVID: conservative (London)
COVID: ambitious (London)
COVID: conservative (Lambeth)
COVID: ambitious (Lambeth)
Costs
£2M
£1M
£0M
2020
2021
2022
2023
2024
Year
Disease
Child Asthma
Adult Asthma
Diabetes
Lung Cancer
Dementia
COPD

$PM_{2.5}$

Cumulative NHS costs attributable to $PM_{2.5}$

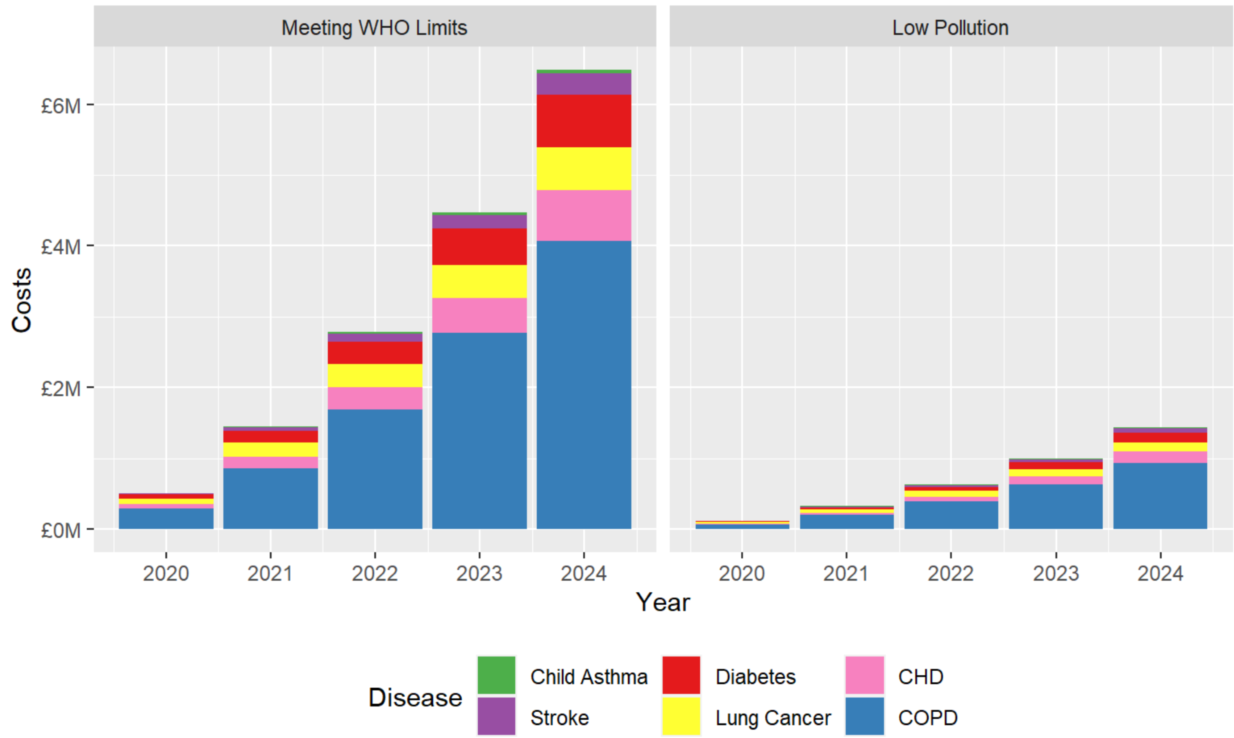
Year	CHD	Child Asthma	COPD	Diabetes	Lung Cancer	Stroke	Total
2020	£121,070 ± [£11,169]	£7,639 ± [£1,669]	£590,600 ± [£64,041]	£113,022 ± [£33,540]	£157,772 ± [£40,575]	£57,827 ± [£28,701]	£1,047,931 ± [£88,452]
2021	£337,311 ± [£15,830]	£22,273 ± [£2,353]	£1,742,581 ± [£90,670]	£329,382 ± [£47,523]	£389,603 ± [£59,420]	£176,267 ± [£40,661]	£2,997,415 ± [£126,173]
2022	£637,099 ± [£19,417]	£42,826 ± [£2,873]	£3,400,111 ± [£111,174]	£648,342 ± [£58,312]	£677,986 ± [£74,525]	£343,477 ± [£49,884]	£5,749,840 ± [£155,523]
2023	£1,019,841 ± [£22,460]	£68,122 ± [£3,308]	£5,544,046 ± [£128,560]	£1,064,653 ± [£67,472]	£986,181 ± [£87,579]	£561,862 ± [£57,721]	£9,244,704 ± [£180,547]
2024	£1,469,735 ± [£25,153]	£97,924 ± [£3,689]	£8,134,400 ± [£143,979]	£1,566,476 ± [£75,605]	£1,296,474 ± [£99,321]	£822,774 ± [£64,688]	£13,387,783 ± [£202,834]


Attributable
Costs
£10M
£5M
£0M
2020
2021
2022
2023
2024
Year
Disease
Child Asthma
Stroke
CHD
Diabetes
Lung Cancer
COPD

Cumulative NHS costs avoided for $PM_{2.5}$

Scenario	Year	CHD	Child Asthma	COPD	Diabetes	Lung Cancer	Stroke	Total
WHO Limits	2020	£57,727 ± [£11,249]	£4,316 ± [£1,672]	£293,362 ± [£64,270]	£60,598 ± [£33,560]	£80,511 ± [£40,873]	£11,723 ± [£28,749]	£508,237 ± [£88,788]
	2021	£160,545 ± [£15,990]	£12,052 ± [£2,360]	£863,181 ± [£91,154]	£165,895 ± [£47,568]	£200,401 ± [£59,921]	£50,985 ± [£40,754]	£1,453,058 ± [£126,824]
	2022	£306,036 ± [£19,663]	£22,458 ± [£2,884]	£1,692,371 ± [£111,946]	£316,579 ± [£58,386]	£333,986 ± [£75,258]	£113,968 ± [£50,024]	£2,785,398 ± [£156,531]
	2023	£492,020 ± [£22,802]	£35,379 ± [£3,324]	£2,768,322 ± [£129,655]	£509,257 ± [£67,580]	£468,941 ± [£88,525]	£198,565 ± [£57,915]	£4,472,484 ± [£181,932]
	2024	£711,640 ± [£25,595]	£50,721 ± [£3,710]	£4,071,827 ± [£145,424]	£740,405 ± [£75,749]	£603,500 ± [£100,448]	£303,964 ± [£64,938]	£6,482,057 ± [£204,601]
Low Pollution	2020	£12,524 ± [£11,306]	£1,038 ± [£1,675]	£66,619 ± [£64,444]	£10,111 ± [£33,578]	£20,787 ± [£41,101]	£4,384 ± [£28,756]	£115,464 ± [£89,036]
	2021	£34,914 ± [£16,102]	£2,788 ± [£2,366]	£198,028 ± [£91,516]	£29,822 ± [£47,604]	£46,570 ± [£60,325]	£11,598 ± [£40,783]	£323,721 ± [£127,313]
	2022	£66,569 ± [£19,839]	£5,277 ± [£2,894]	£389,452 ± [£112,530]	£57,258 ± [£58,443]	£81,499 ± [£75,790]	£24,384 ± [£50,079]	£624,437 ± [£157,266]
	2023	£107,785 ± [£23,047]	£8,305 ± [£3,337]	£635,536 ± [£130,489]	£94,359 ± [£67,659]	£106,378 ± [£89,180]	£41,062 ± [£57,999]	£993,425 ± [£182,933]

Scenario	Year	CHD	Child Asthma	COPD	Diabetes	Lung Cancer	Stroke	Total
	2024	£156,444 ± [£25,914]	£11,981 ± [£3,727]	£934,099 ± [£146,528]	£138,650 ± [£75,853]	£134,883 ± [£101,201]	£61,725 ± [£65,055]	£1,437,781 ± [£205,872]

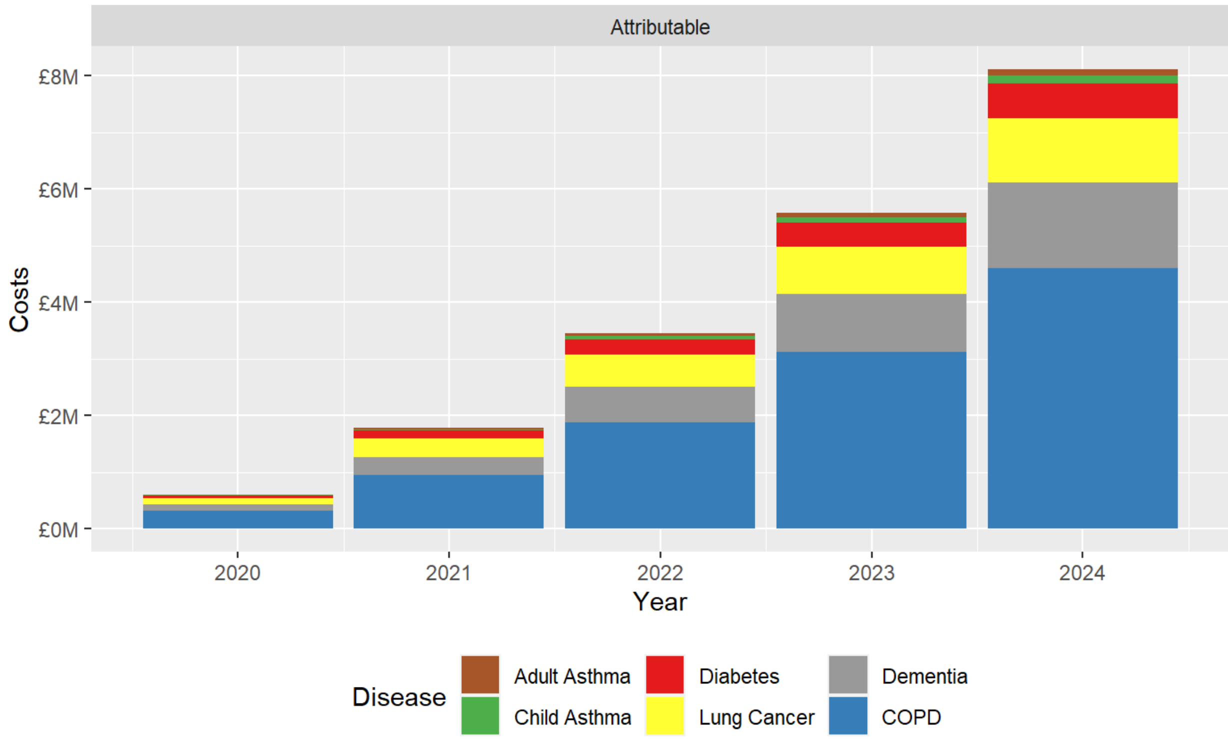


Southwark

NO_2

Cumulative NHS costs attributable to NO_2

Year	Adult Asthma	Child Asthma	COPD	Dementia	Diabetes	Lung Cancer	Total
2020	£9,494 ± [£3,460]	£9,503 ± [£1,698]	£313,455 ± [£62,468]	£106,680 ± [£11,559]	£45,538 ± [£32,970]	£123,244 ± [£40,395]	£607,914 ± [£82,277]
2021	£27,094 ± [£4,865]	£28,255 ± [£2,379]	£950,115 ± [£88,895]	£317,170 ± [£16,787]	£137,490 ± [£46,738]	£323,795 ± [£59,235]	£1,783,920 ± [£117,927]
2022	£50,066 ± [£5,929]	£55,679 ± [£2,892]	£1,884,633 ± [£109,622]	£624,502 ± [£21,054]	£265,540 ± [£57,427]	£568,099 ± [£74,601]	£3,448,519 ± [£146,174]
2023	£77,684 ± [£6,817]	£90,354 ± [£3,315]	£3,116,780 ± [£127,423]	£1,023,197 ± [£24,833]	£428,711 ± [£66,535]	£844,609 ± [£88,004]	£5,581,335 ± [£170,536]
2024	£109,846 ± [£7,592]	£132,002 ± [£3,681]	£4,608,794 ± [£143,364]	£1,506,560 ± [£28,294]	£623,292 ± [£74,636]	£1,133,980 ± [£100,118]	£8,114,474 ± [£192,404]

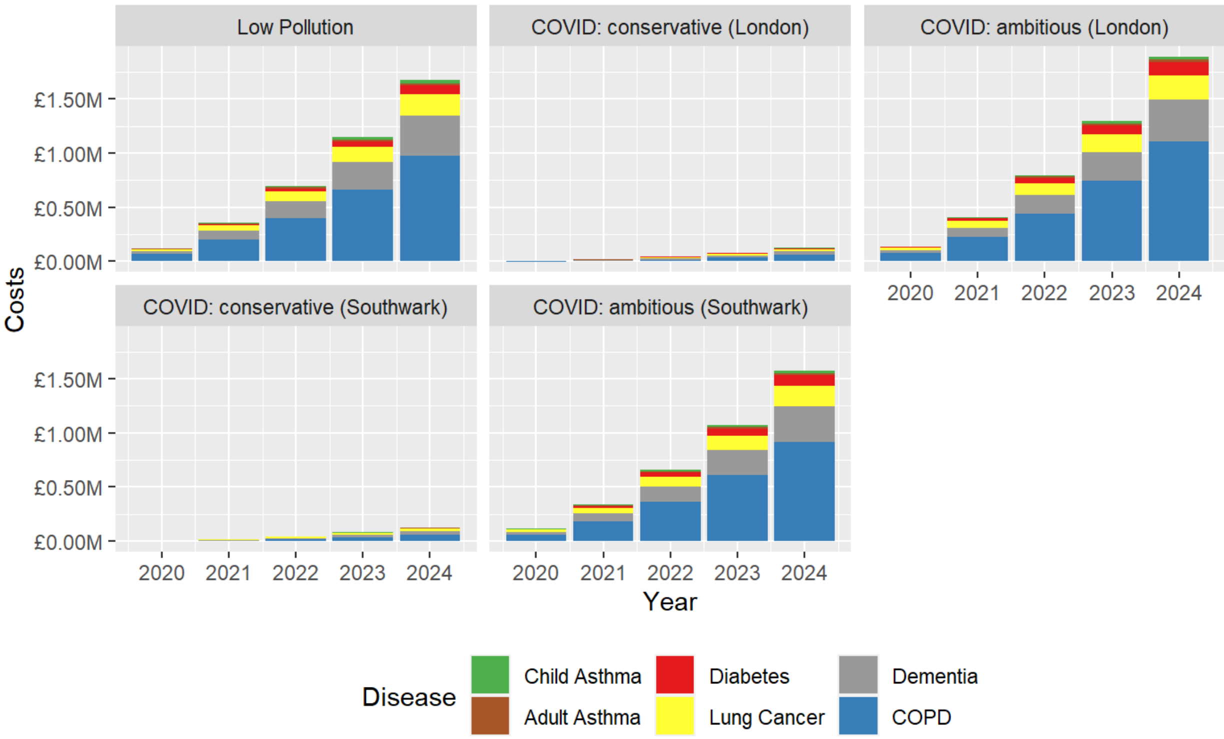

Attributable
£8M
£6M
£4M
£2M
£0M
Costs
2020
2021
2022
2023
2024
Year
Disease
Adult Asthma
Child Asthma
Diabetes
Lung Cancer
Dementia
COPD

Cumulative NHS costs avoided

Scenario	Year	Adult Asthma	Child Asthma	COPD	Dementia	Diabetes	Lung Cancer	Total
Low Pollution	2020	£2,412 ± [£3,463]	£1,943 ± [£1,705]	£65,055 ± [£62,659]	£30,469 ± [£11,640]	-£606 ± [£32,987]	£17,272 ± [£40,793]	£116,545 ± [£82,636]
	2021	£6,219 ± [£4,871]	£6,114 ± [£2,393]	£199,544 ± [£89,300]	£84,533 ± [£16,956]	£10,064 ± [£46,772]	£47,795 ± [£59,940]	£354,270 ± [£118,625]
	2022	£11,509 ± [£5,938]	£12,149 ± [£2,915]	£395,200 ± [£110,274]	£160,268 ± [£21,323]	£27,593 ± [£57,479]	£90,455 ± [£75,572]	£697,174 ± [£147,220]
	2023	£17,177 ± [£6,830]	£19,949 ± [£3,347]	£660,139 ± [£128,351]	£253,909 ± [£25,211]	£51,099 ± [£66,606]	£144,607 ± [£89,214]	£1,146,881 ± [£171,939]
	2024	£23,697 ± [£7,608]	£28,935 ± [£3,723]	£979,868 ± [£144,587]	£364,680 ± [£28,789]	£80,608 ± [£74,727]	£198,356 ± [£101,545]	£1,676,143 ± [£194,169]
COVID: Conservative (London)	2020	£329 ± [£3,464]	£249 ± [£1,706]	-£2,583 ± [£62,710]	£2,423 ± [£11,670]	£121 ± [£32,987]	-£428 ± [£40,859]	£111 ± [£82,712]
	2021	£739 ± [£4,872]	£730 ± [£2,397]	£2,724 ± [£89,406]	£6,803 ± [£17,012]	£467 ± [£46,775]	£4,330 ± [£60,051]	£15,793 ± [£118,770]
	2022	£1,339 ± [£5,941]	£1,337 ± [£2,920]	£13,897 ± [£110,441]	£13,386 ± [£21,408]	£2,102 ± [£57,484]	£12,357 ± [£75,730]	£44,418 ± [£147,441]
	2023	£2,063 ± [£6,833]	£2,051 ± [£3,355]	£33,744 ± [£128,587]	£21,599 ± [£25,324]	£3,664 ± [£66,615]	£15,990 ± [£89,435]	£79,112 ± [£172,250]

Scenario	Year	Adult Asthma	Child Asthma	COPD	Dementia	Diabetes	Lung Cancer	Total
	2024	£2,888 ± [£7,611]	£2,772 ± [£3,734]	£59,853 ± [£144,895]	£32,094 ± [£28,931]	£6,852 ± [£74,740]	£20,286 ± [£101,814]	£124,746 ± [£194,565]
COVID: Ambitious (London)	2020	£2,534 ± [£3,463]	£2,115 ± [£1,705]	£72,943 ± [£62,653]	£30,958 ± [£11,640]	£5,820 ± [£32,985]	£23,152 ± [£40,771]	£137,522 ± [£82,620]
	2021	£6,719 ± [£4,870]	£6,388 ± [£2,393]	£222,636 ± [£89,289]	£87,131 ± [£16,954]	£22,516 ± [£46,769]	£63,274 ± [£59,901]	£408,666 ± [£118,595]
	2022	£12,546 ± [£5,938]	£12,169 ± [£2,915]	£443,673 ± [£110,254]	£167,949 ± [£21,319]	£48,332 ± [£57,475]	£111,398 ± [£75,530]	£796,067 ± [£147,181]
	2023	£18,892 ± [£6,829]	£18,982 ± [£3,347]	£742,722 ± [£128,321]	£268,877 ± [£25,204]	£81,141 ± [£66,600]	£164,690 ± [£89,180]	£1,295,304 ± [£171,895]
	2024	£26,224 ± [£7,607]	£26,194 ± [£3,724]	£1,105,376 ± [£144,545]	£390,106 ± [£28,778]	£118,140 ± [£74,722]	£225,575 ± [£101,504]	£1,891,616 ± [£194,112]
COVID: Conservative (Southwark)	2020	£329 ± [£3,464]	£249 ± [£1,706]	-£2,583 ± [£62,710]	£2,423 ± [£11,670]	£121 ± [£32,987]	-£428 ± [£40,859]	£111 ± [£82,712]
	2021	£739 ± [£4,872]	£730 ± [£2,397]	£2,724 ± [£89,406]	£6,803 ± [£17,012]	£467 ± [£46,775]	£4,330 ± [£60,051]	£15,793 ± [£118,770]
	2022	£1,339 ± [£5,941]	£1,337 ± [£2,920]	£13,897 ± [£110,441]	£13,386 ± [£21,408]	£2,102 ± [£57,484]	£12,357 ± [£75,730]	£44,418 ± [£147,441]

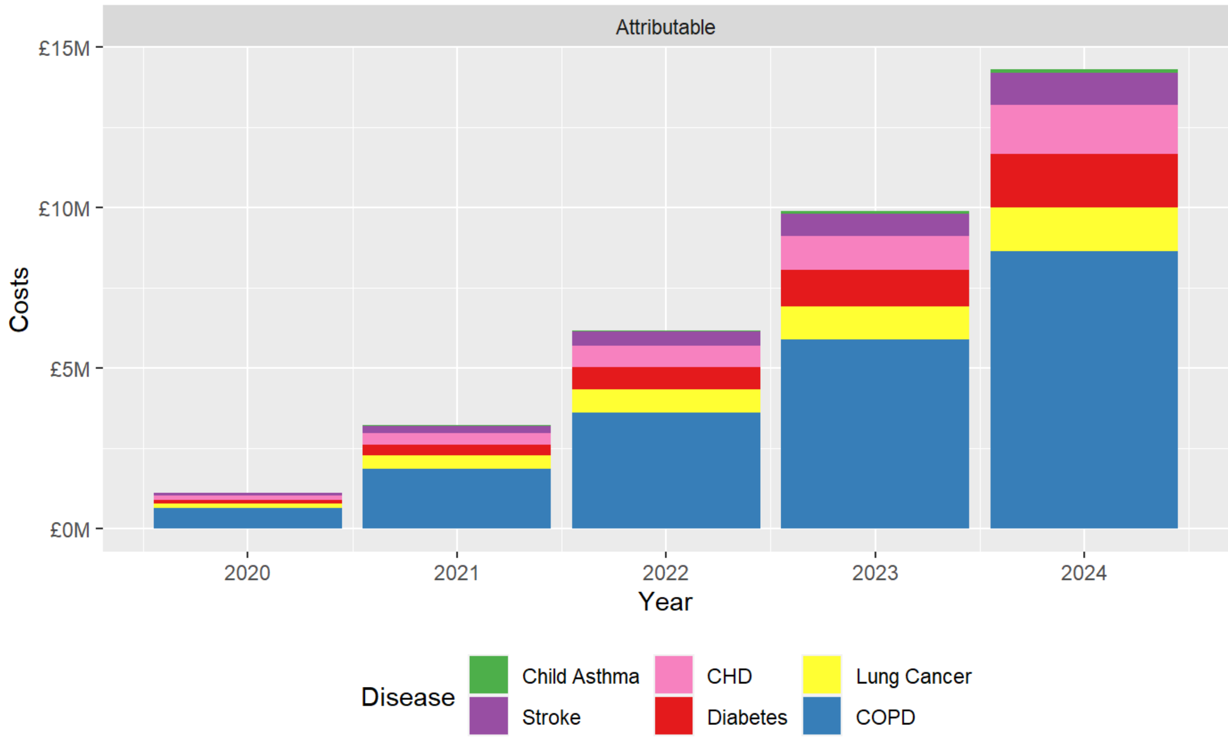
Scenario	Year	Adult Asthma	Child Asthma	COPD	Dementia	Diabetes	Lung Cancer	Total
	2023	£2,063 ± [£6,833]	£2,051 ± [£3,355]	£33,744 ± [£128,587]	£21,599 ± [£25,324]	£3,664 ± [£66,615]	£15,990 ± [£89,435]	£79,112 ± [£172,250]
	2024	£2,888 ± [£7,611]	£2,772 ± [£3,734]	£59,853 ± [£144,895]	£32,094 ± [£28,931]	£6,852 ± [£74,740]	£20,286 ± [£101,814]	£124,746 ± [£194,565]
COVID: Ambitious (Southwark)	2020	£1,850 ± [£3,463]	£1,778 ± [£1,705]	£58,966 ± [£62,663]	£27,201 ± [£11,643]	£4,408 ± [£32,985]	£18,350 ± [£40,789]	£112,553 ± [£82,637]
	2021	£5,084 ± [£4,871]	£5,371 ± [£2,394]	£180,156 ± [£89,311]	£75,563 ± [£16,963]	£17,911 ± [£46,770]	£50,659 ± [£59,933]	£334,744 ± [£118,630]
	2022	£9,647 ± [£5,939]	£10,181 ± [£2,916]	£361,293 ± [£110,289]	£145,178 ± [£21,332]	£38,709 ± [£57,476]	£90,628 ± [£75,572]	£655,636 ± [£147,232]
	2023	£14,491 ± [£6,830]	£15,932 ± [£3,349]	£608,848 ± [£128,371]	£231,652 ± [£25,222]	£65,161 ± [£66,603]	£136,692 ± [£89,228]	£1,072,777 ± [£171,961]
	2024	£20,183 ± [£7,608]	£21,926 ± [£3,726]	£912,932 ± [£144,609]	£336,196 ± [£28,801]	£95,880 ± [£74,725]	£187,912 ± [£101,560]	£1,575,028 ± [£194,194]


Low Pollution
COVID: conservative (London)
COVID: ambitious (London)
COVID: conservative (Southwark)
COVID: ambitious (Southwark)
Costs
£1.50M
£1.00M
£0.50M
£0.00M
2020
2021
2022
2023
2024
Year
Disease
Child Asthma
Adult Asthma
Diabetes
Lung Cancer
Dementia
COPD

$PM_{2.5}$

Cumulative NHS costs attributable to $PM_{2.5}$

Year	CHD	Child Asthma	COPD	Diabetes	Lung Cancer	Stroke	Total
2020	£125,308 ± [£11,112]	£6,810 ± [£1,664]	£636,486 ± [£63,733]	£118,943 ± [£33,051]	£141,489 ± [£40,194]	£82,789 ± [£28,182]	£1,111,826 ± [£87,694]
2021	£351,570 ± [£15,745]	£20,505 ± [£2,337]	£1,850,388 ± [£90,193]	£352,180 ± [£46,750]	£423,031 ± [£58,628]	£228,661 ± [£40,010]	£3,226,335 ± [£124,947]
2022	£668,957 ± [£19,321]	£40,826 ± [£2,847]	£3,615,073 ± [£110,596]	£689,766 ± [£57,308]	£723,065 ± [£73,441]	£436,215 ± [£49,198]	£6,173,901 ± [£153,984]
2023	£1,067,565 ± [£22,349]	£66,675 ± [£3,270]	£5,881,259 ± [£127,873]	£1,125,057 ± [£66,246]	£1,041,352 ± [£86,303]	£694,029 ± [£57,019]	£9,875,936 ± [£178,744]
2024	£1,541,107 ± [£25,028]	£97,061 ± [£3,639]	£8,633,381 ± [£143,158]	£1,646,236 ± [£74,152]	£1,375,668 ± [£97,807]	£1,000,988 ± [£63,964]	£14,294,440 ± [£200,723]

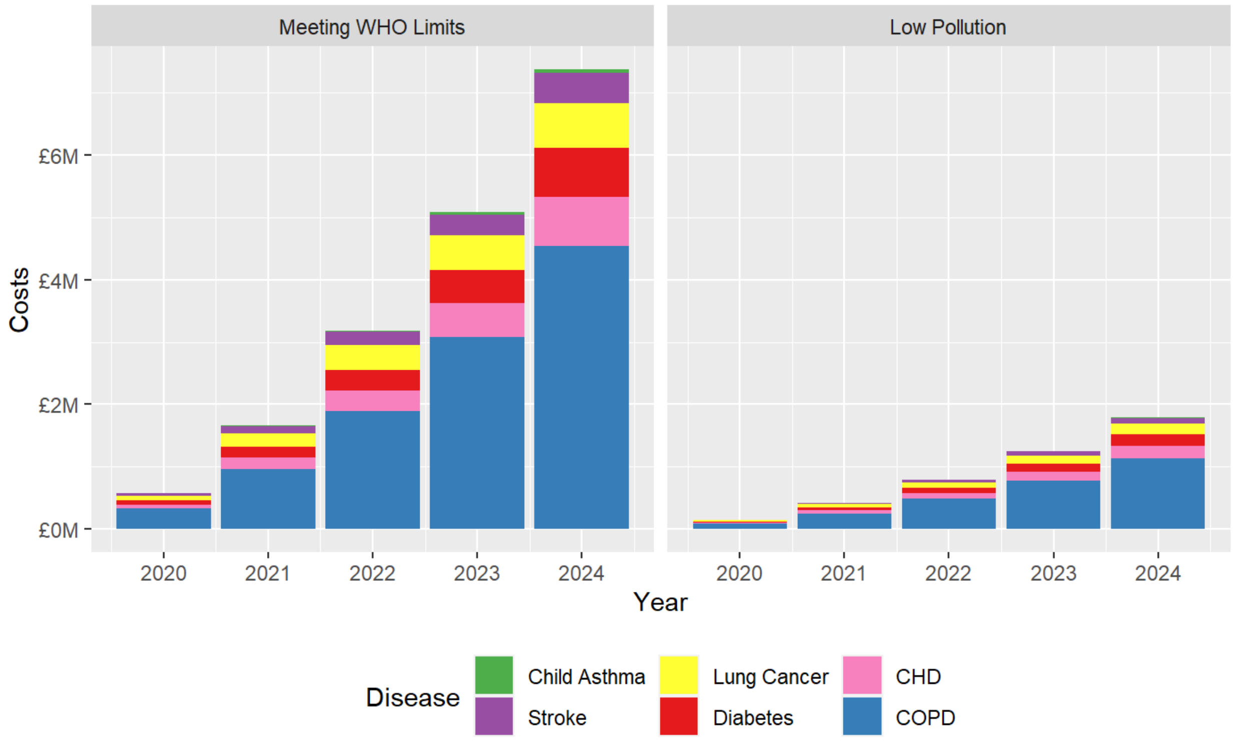


Attributable
£15M
£10M
£5M
£0M
Costs
2020
2021
2022
2023
2024
Year
Disease
Child Asthma
Stroke
CHD
Diabetes
Lung Cancer
COPD

Cumulative NHS costs avoided for $PM_{2.5}$

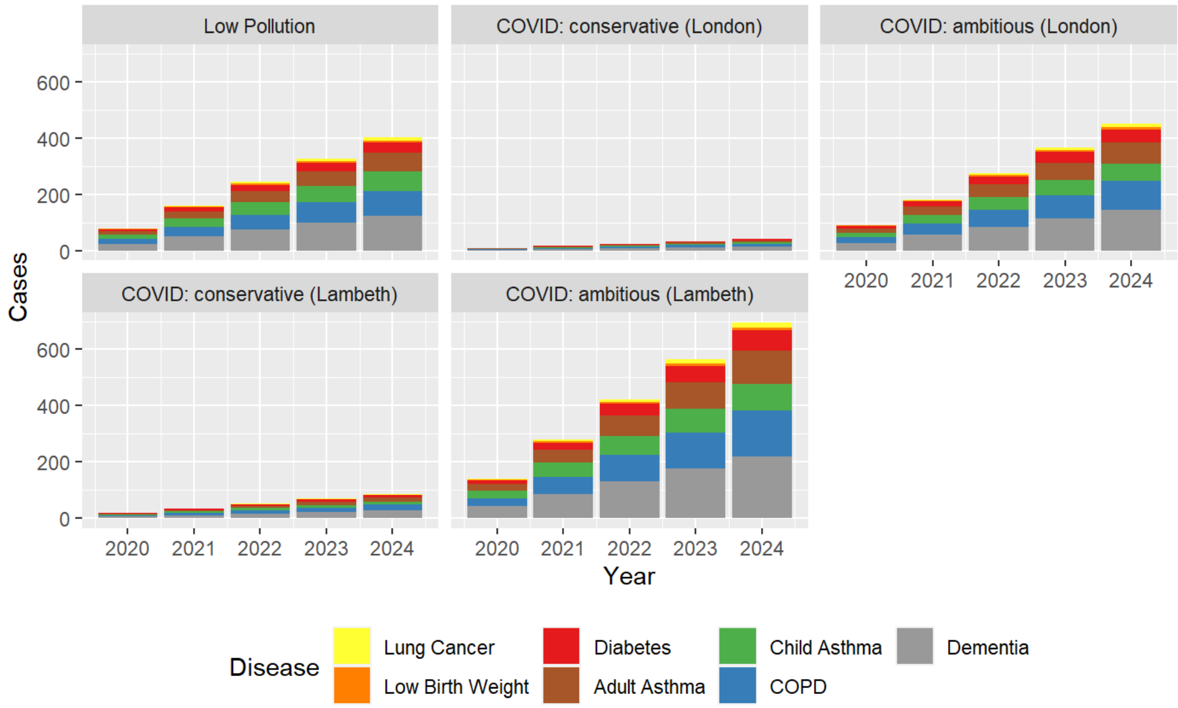
Scenario	Year	CHD	Child Asthma	COPD	Diabetes	Lung Cancer	Stroke	Total
WHO Limits	2020	£62,061 ± [£11,190]	£3,616 ± [£1,666]	£331,399 ± [£63,962]	£59,301 ± [£33,073]	£73,242 ± [£40,451]	£42,007 ± [£28,224]	£571,625 ± [£88,011]
	2021	£176,758 ± [£15,899]	£10,918 ± [£2,343]	£963,323 ± [£90,665]	£172,002 ± [£46,798]	£220,226 ± [£59,154]	£112,731 ± [£40,095]	£1,655,958 ± [£125,599]
	2022	£340,500 ± [£19,557]	£21,804 ± [£2,857]	£1,886,801 ± [£111,348]	£330,978 ± [£57,385]	£388,962 ± [£74,134]	£214,774 ± [£49,329]	£3,183,818 ± [£154,956]
	2023	£546,377 ± [£22,673]	£35,614 ± [£3,285]	£3,076,945 ± [£128,934]	£538,671 ± [£66,355]	£547,514 ± [£87,180]	£338,473 ± [£57,202]	£5,083,594 ± [£180,067]
	2024	£790,910 ± [£25,447]	£51,627 ± [£3,658]	£4,543,444 ± [£144,547]	£790,323 ± [£74,295]	£713,358 ± [£98,850]	£485,995 ± [£64,202]	£7,375,657 ± [£202,405]
Low Pollution	2020	£17,486 ± [£11,245]	£1,375 ± [£1,669]	£86,813 ± [£64,145]	£16,280 ± [£33,089]	£18,539 ± [£40,656]	£6,719 ± [£28,260]	£147,213 ± [£88,262]
	2021	£46,796 ± [£16,012]	£3,448 ± [£2,348]	£250,988 ± [£91,041]	£45,299 ± [£46,831]	£55,050 ± [£59,578]	£20,100 ± [£40,162]	£421,681 ± [£126,119]
	2022	£88,381 ± [£19,735]	£6,394 ± [£2,865]	£483,867 ± [£111,955]	£84,085 ± [£57,437]	£92,413 ± [£74,745]	£39,165 ± [£49,433]	£794,306 ± [£155,759]
	2023	£138,815 ± [£22,923]	£10,017 ± [£3,297]	£779,993 ± [£129,795]	£133,484 ± [£66,430]	£125,947 ± [£87,921]	£63,922 ± [£57,343]	£1,252,177 ± [£181,148]

Scenario	Year	CHD	Child Asthma	COPD	Diabetes	Lung Cancer	Stroke	Total
	2024	£196,726 ± [£25,774]	£14,204 ± [£3,674]	£1,135,362 ± [£145,694]	£193,153 ± [£74,395]	£161,504 ± [£99,710]	£95,794 ± [£64,382]	£1,796,743 ± [£203,780]

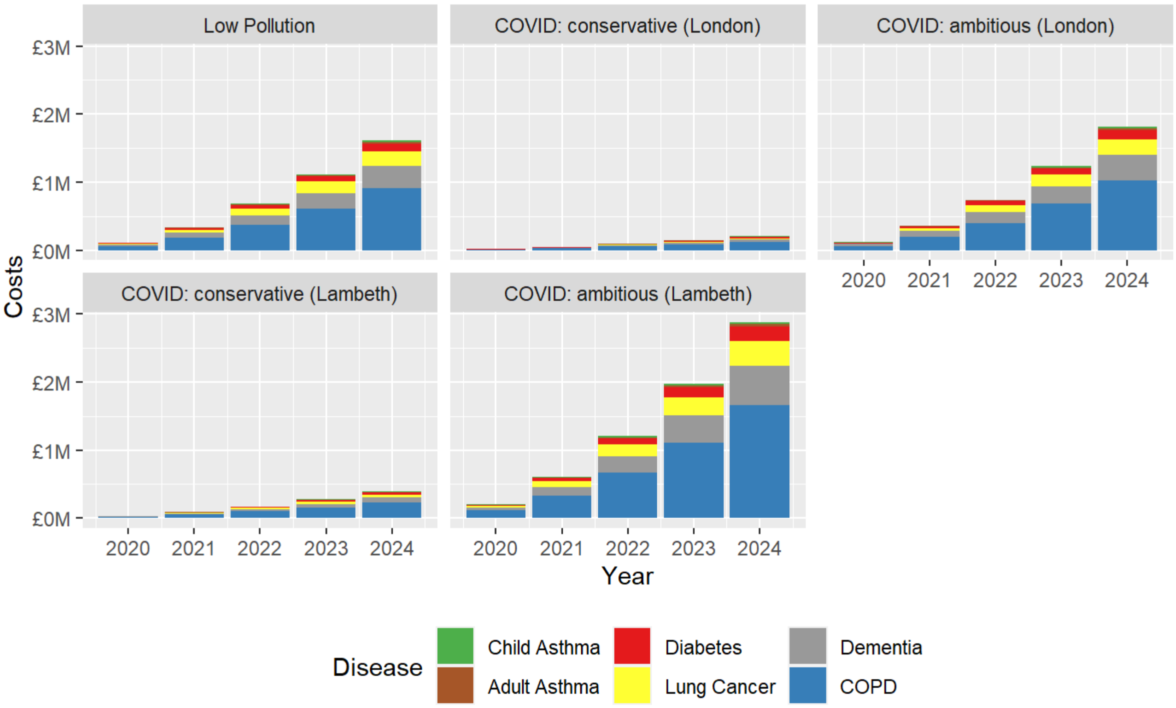

Meeting WHO Limits
Low Pollution
Costs
£6M
£4M
£2M
£0M
2020
2021
2022
2023
2024
Year
Disease
Child Asthma
Stroke
Lung Cancer
Diabetes
CHD
COPD

Appendix 4. Supplementary figures

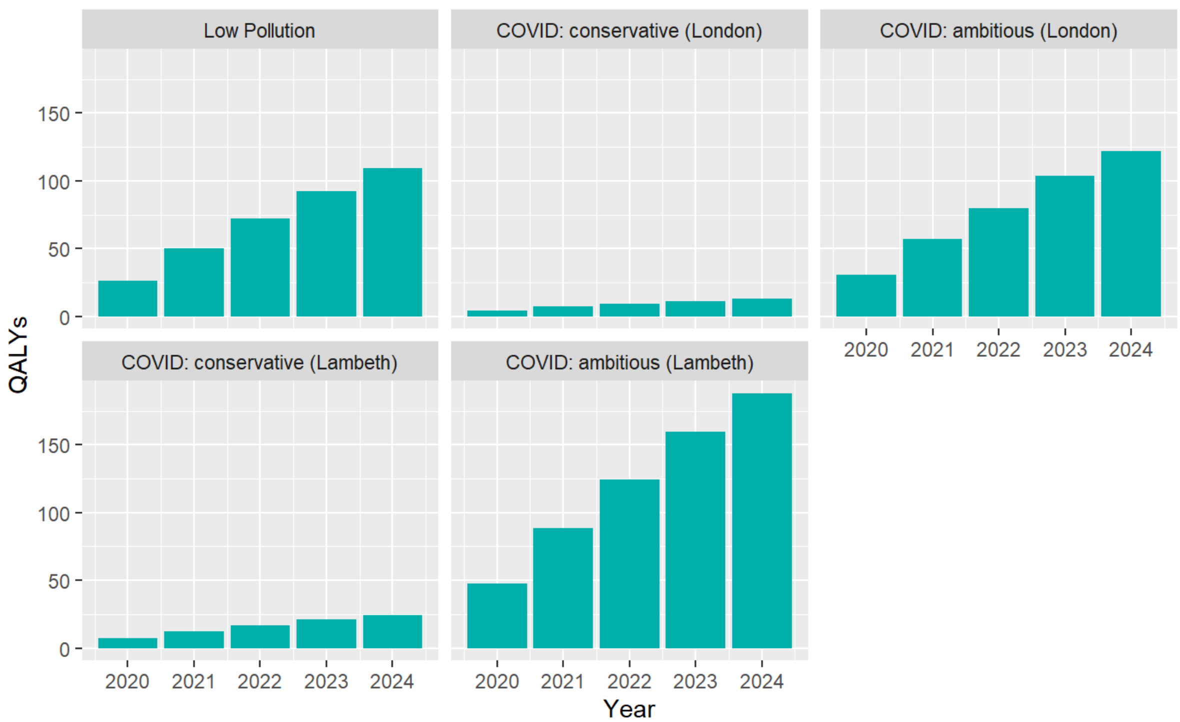
Appendix 4.1. Cumulative disease incidence avoided by year and NO_2 scenario for Lambeth



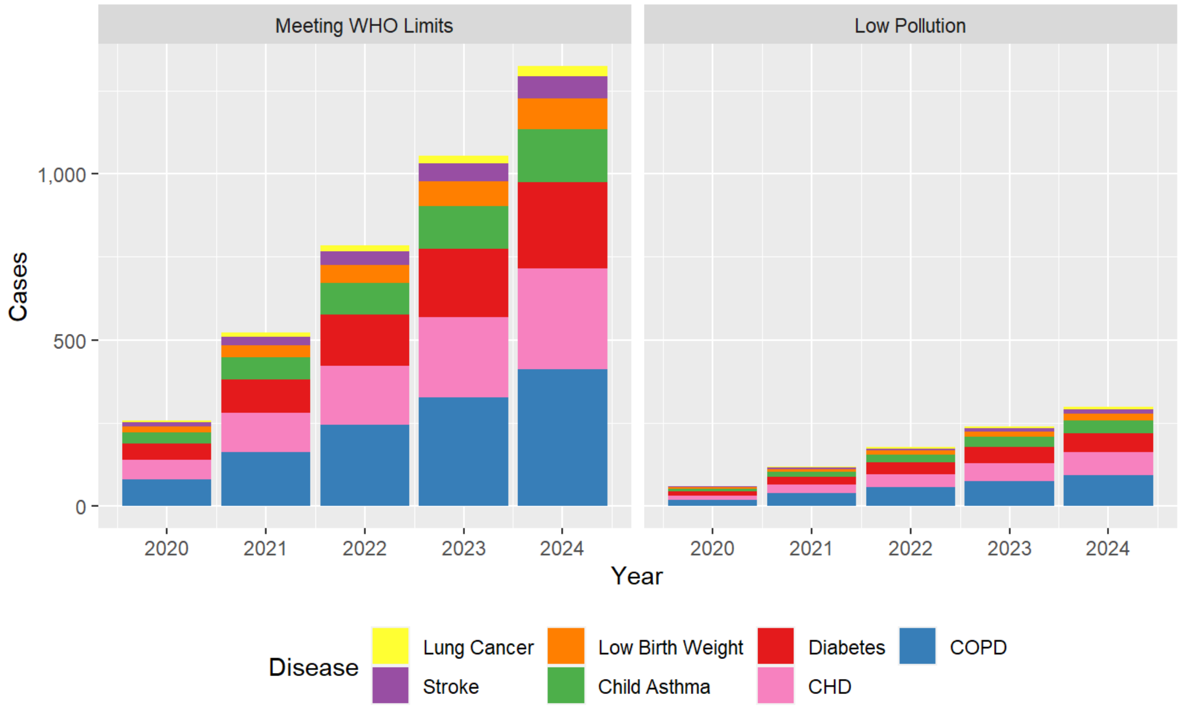
Appendix 4.2. Cumulative NHS costs avoided by year and NO_2 scenario for Lambeth



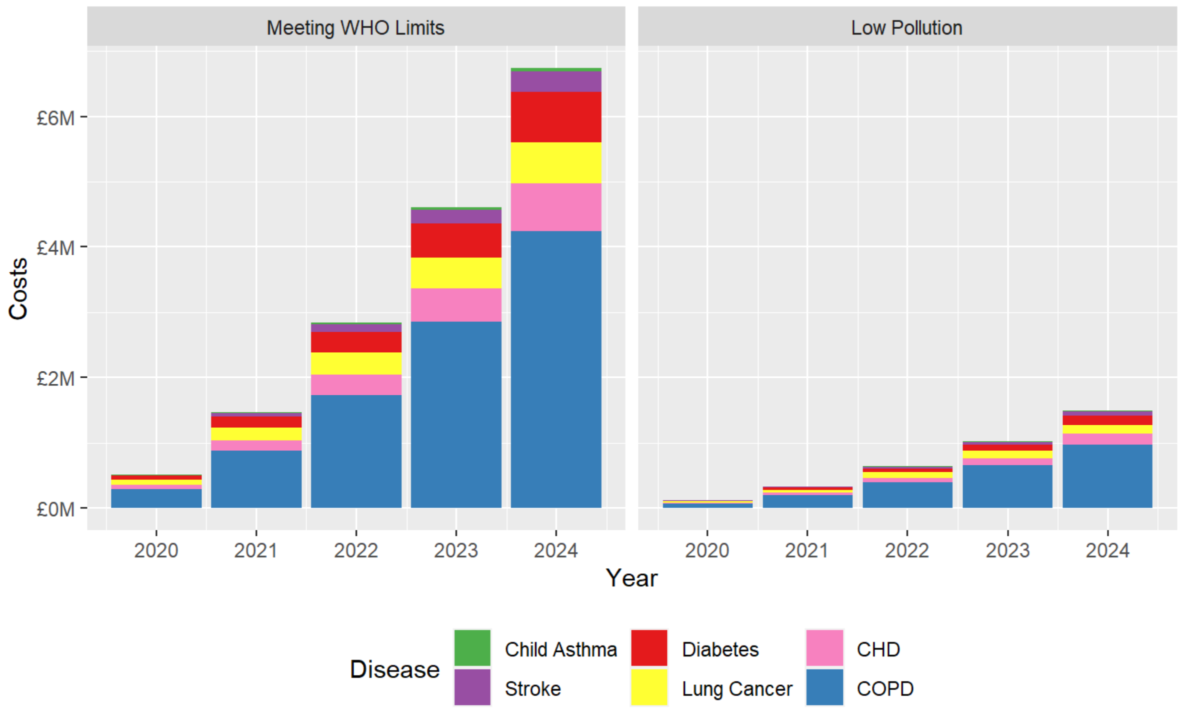
Appendix 4.3. Annual QALYs gained by year and NO_2 scenario for Lambeth



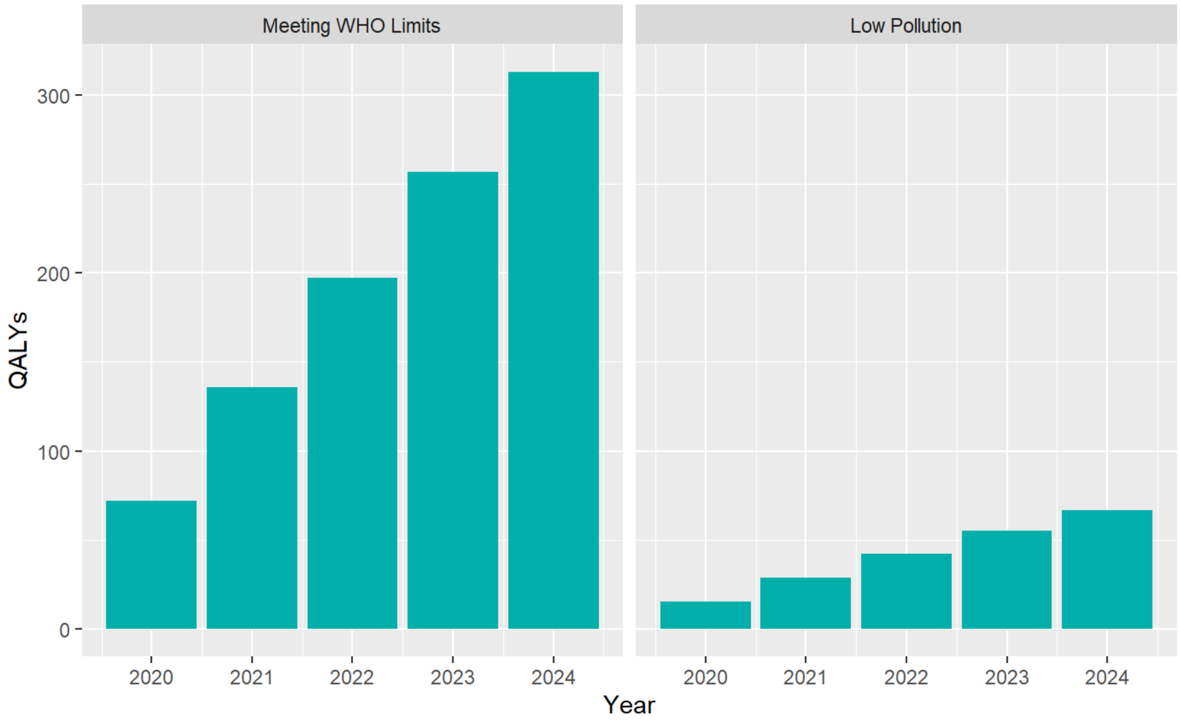
Appendix 4.4. Cumulative disease incidence avoided by year and $PM_{2.5}$ scenario for Lambeth



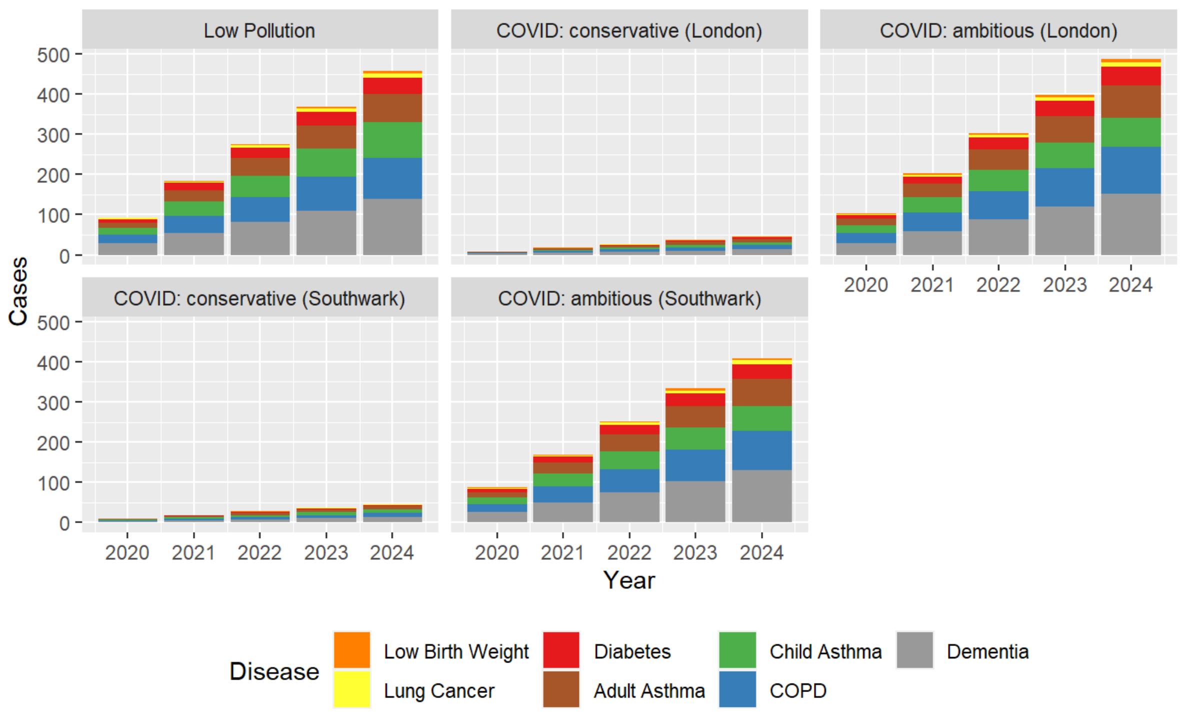
Appendix 4.5. Cumulative NHS costs avoided by year and $PM_{2.5}$ scenario for Lambeth



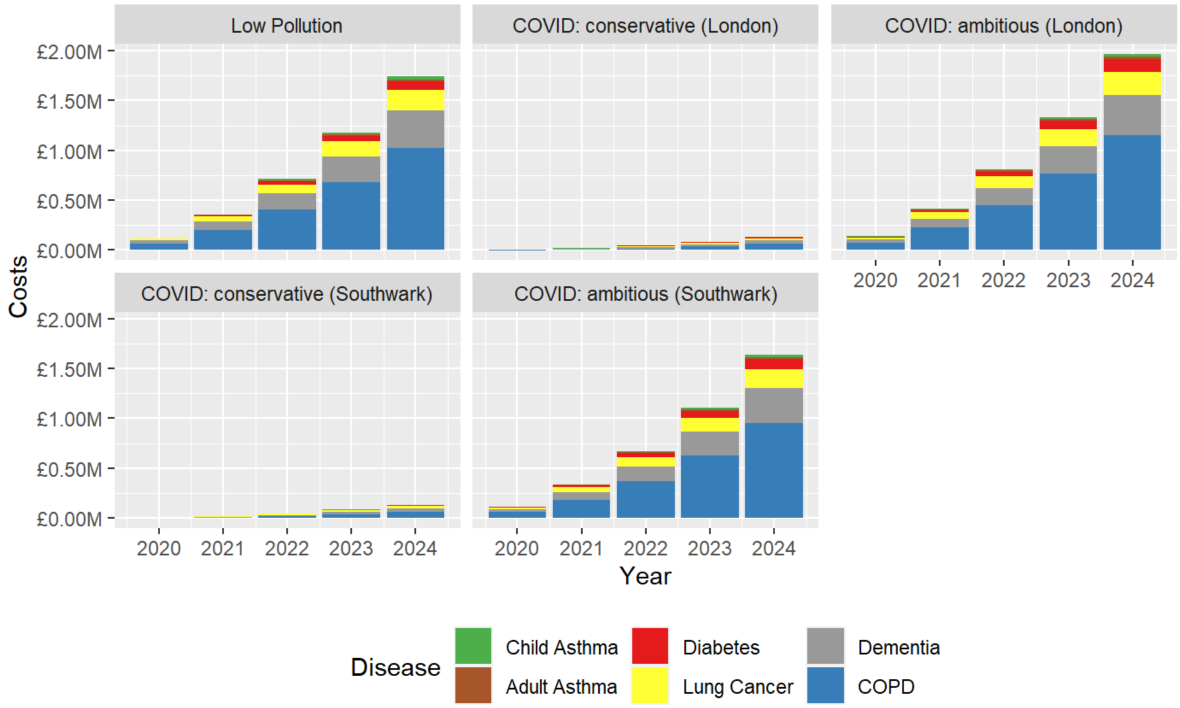
Appendix 4.6. Annual QALYs gained by year and $PM_{2.5}$ scenario for Lambeth



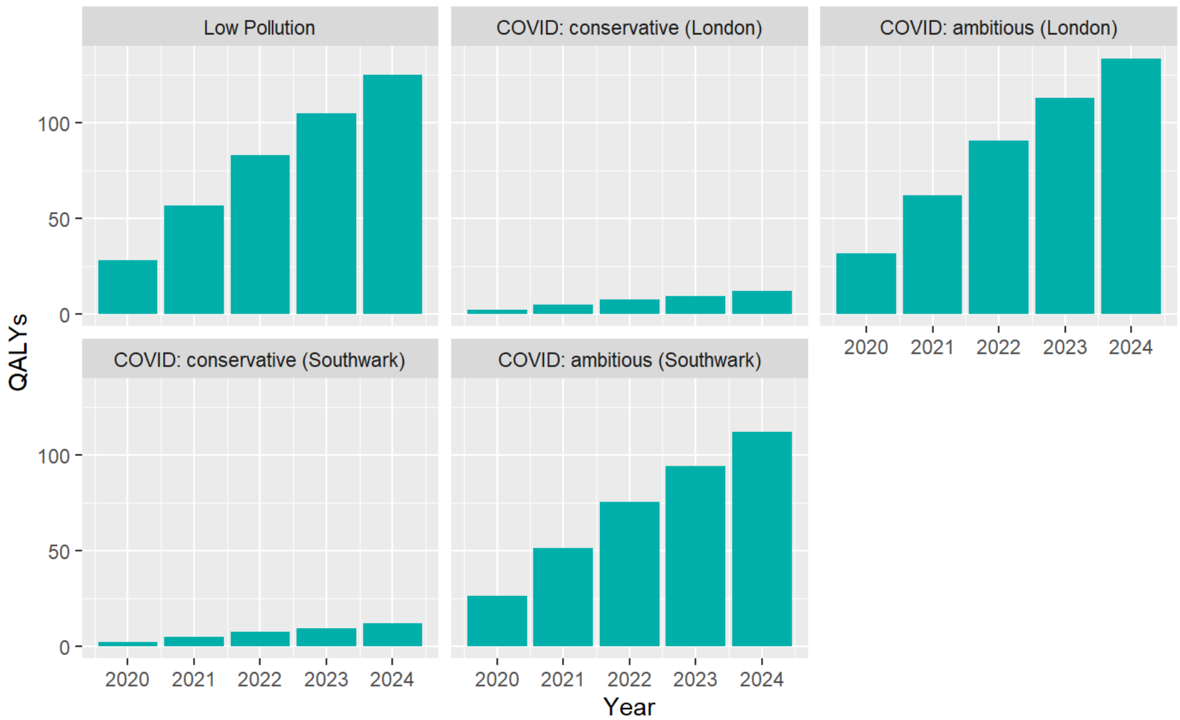
Appendix 4.7. Cumulative disease incidence avoided by year and NO_2 scenario for Southwark



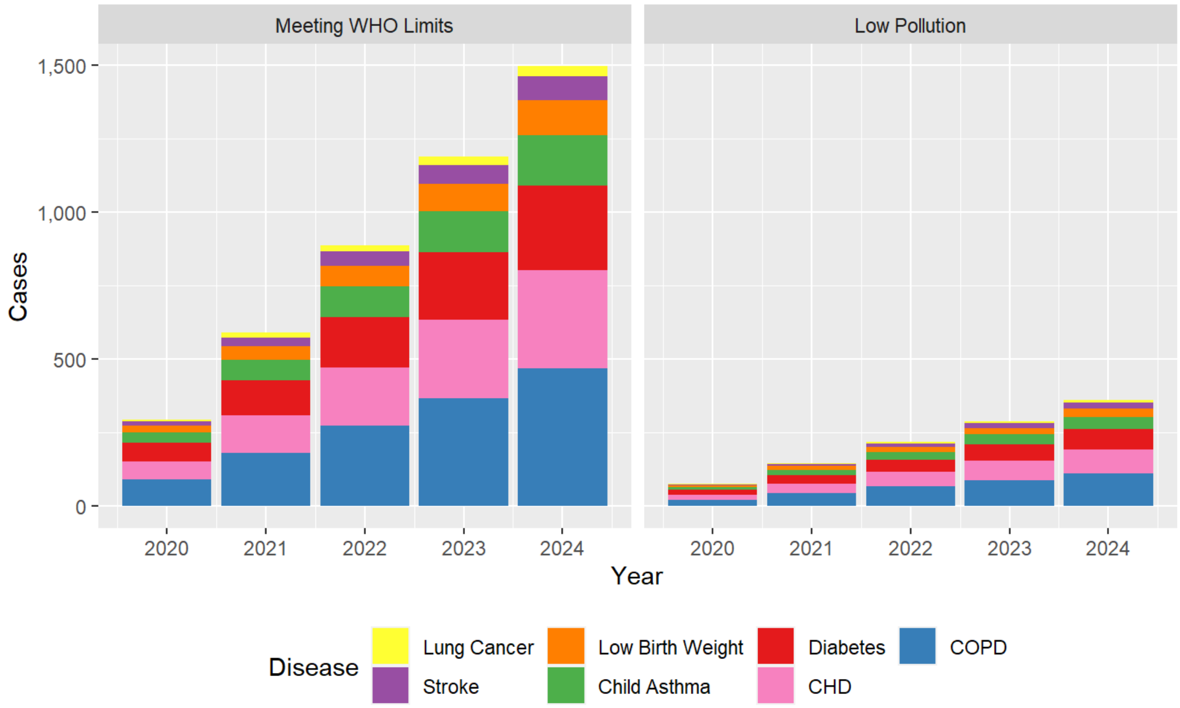
Appendix 4.8. Cumulative NHS costs avoided by year and NO_2 scenario for Southwark



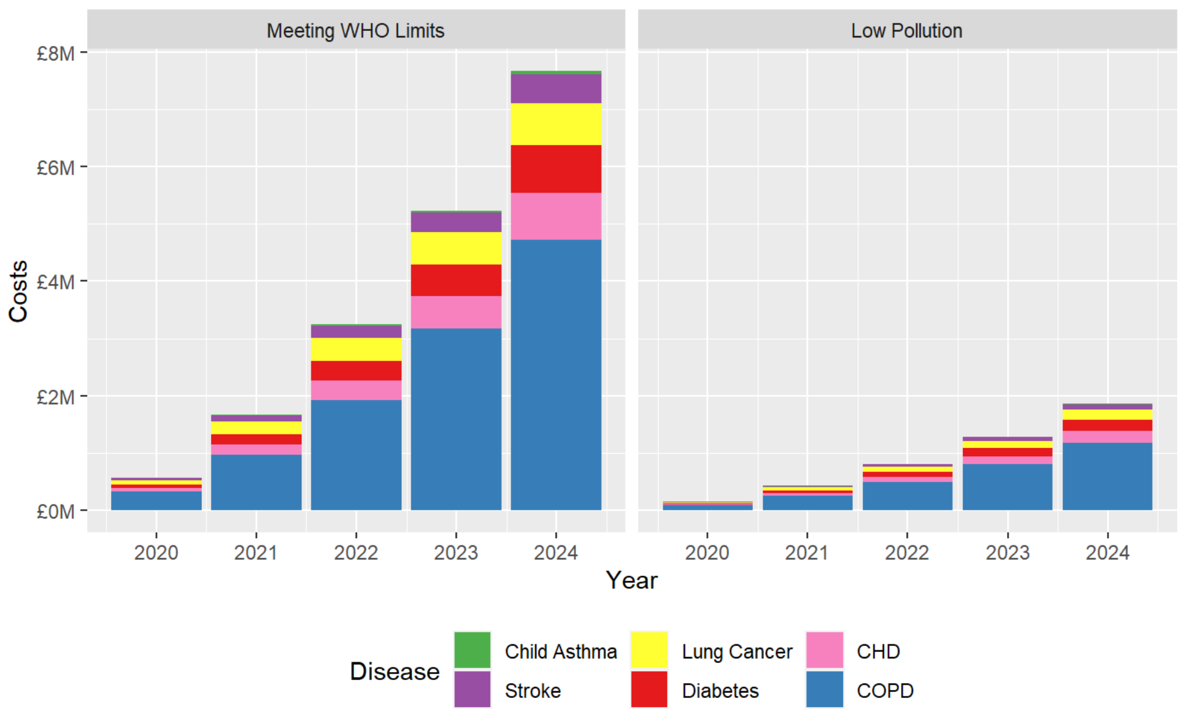
Appendix 4.9. Annual QALYs gained by year and NO_2 scenario for Southwark



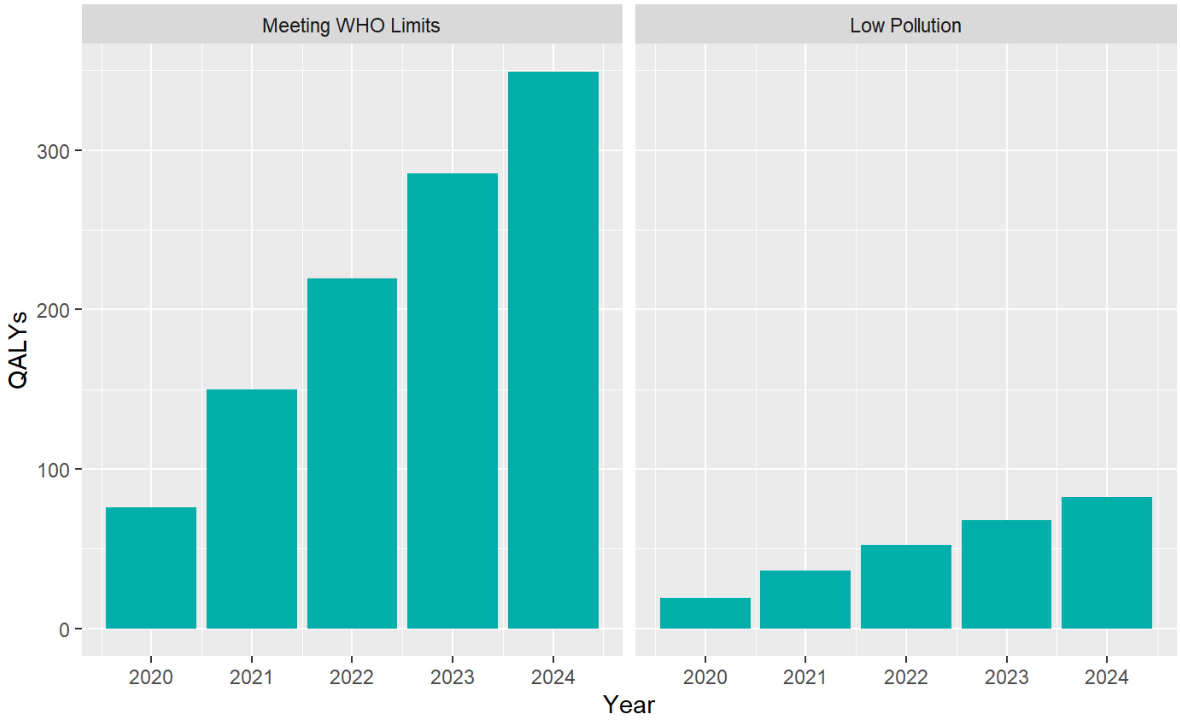
Appendix 4.10. Cumulative disease incidence avoided by year and $PM_{2.5}$ scenario for Southwark



Appendix 4.11. Cumulative NHS costs avoided by year and $PM_{2.5}$ scenario for Southwark



Appendix 4.12. Annual QALYs gained by year and $PM_{2.5}$ scenario for Southwark



Meeting WHO Limits
Low Pollution
QALYs
300
200
100
0
2020
2021
2022
2023
2024
2020
2021
2022
2023
2024
Year