London Wood Burning Project: Health Impact Evaluation

Final Report

For: London Borough of Camden & London Borough of Islington

Ricardo ref: ED17187 Issue: Final 10/08/2023

Customer:
London Borough of Camden
London Borough of Islington

Customer reference:
London Borough of Camden
London Borough of Islington

Confidentiality, copyright and reproduction:

Ricardo ref:
ED17187

Contact:
David Birchby, York Office, 5 St Marys Court, Blossom Street, York, YO24 1AH

T: +44 (0) 1235 753 480
E: David.Birchby@ricardo.com
salessupportteam.ee@ricardo.com

Author:
Antonella Gutierrez, James Southgate, Jack Dubey

Approved by:
David Birchby

Signed

Date:
10/08/23

CONTENTS

Glossary

CHD	Coronary heart disease
COMEAP	Committee on the Medical Effects of Air Pollutants
CRF	Concentration response function
ESCAPE	European Study of Cohorts for Air Pollution Effects
EU	European Union
GLA	Greater London Authority
IDW	Inverse distance weighting
ULEZ	Ultra-Low Emission Zone
IMD	Indices of Multiple Deprivation
IPA	Impact Pathway Approach
LAEI	London Atmospheric Emissions Inventory
LAQM	Local Air Quality Management
LAQM.TG(22)	Local Air Quality Management - Technical Guidance 2022
LSOA	Lower Layer Super Output Area
LWBP	London Wood Burning Project
LYL	Life-years lost
NHS	National Health Service
NO_2	Nitrogen dioxide
NO_X	Nitrogen oxides
O_3	Ozone
ONS	Office for National Statistics
PM	Particulate matter
$PM_{2.5}$	Particulate matter with an aerodynamic diameter of 2.5 micrometres or less
SO_2	Sulphur dioxide
US	United States of America
VOCs	Volatile organic compounds
WHO	World Health Organization

EXECUTIVE SUMMARY

The London Wood Burning Project (LWBP) is a Defra funded initiative which aims to raise awareness of the impact of air pollution upon human health as a result of domestic solid fuel burning. To support the aims of the LWBP, Ricardo Energy & Environment were commissioned to author a 'Health Impact Evaluation' to assess the impact of domestic solid fuel burning within London upon human health. This report is the *Technical Annex* and contains the in-depth results, methodology and data sources used. This report is accompanied by a public facing executive summary. The present report comprises three main sections:

1) A literature review which explored the relationship between air pollutants emitted through domestic solid fuel burning and human health. This section also describes the current national and local policy environment and action being taken to reduce air pollution from solid fuel burning within London homes.
2) The health impact assessment which evaluated the health impact of concentrations of particulate matter (PM) and nitrogen dioxide (NO_2) which are the result of domestic solid fuel use in London. This evaluation has illustrated the direct impact on local residents, indicating a range of health impacts including the 'total life years lost' and increase in hospital admissions (alongside other morbidity outcomes) as a result of domestic solid fuel burning. This determined that the greatest impacts are associated with PM concentrations generated by wood burning (relative to other pollutants emitted). However, it is important to note there are detrimental health impacts as a result of both wood burning and the burning of coal and oil. This was the case across the Greater London region and the 15 individual LWBP participating boroughs.

   The assessment calculated a monetary value associated with the health impacts upon the London population, estimating that a total annual cost of £173m linked to domestic wood burning, and £23m linked to coal and oil use for the Greater London region.
3) The final component of the report assessed the health impact of domestic solid fuel burning upon different societal groups. This analysis was undertaken in two stages:
   i. Analysis of the spatial relationship between areas with different proportions of vulnerable demographic groups, and concentrations of $PM_{2.5}$ derived from domestic wood burning activities and the domestic use of coal and oil.
   ii. A review of the relationship between the use of open fireplaces and solid fuel stoves, sensitive demographics and spatial locations using data collected in the Opinium survey which was conducted as Element 1 of the LWBP.

   The results from the analysis did not show any strong indications that any one particular demographic group considered are being disproportionately exposed to higher concentrations of $PM_{2.5}$ from domestic wood burning or the domestic use of coal and oil fuels.

1. INTRODUCTION

Exposure to air pollutants has long been associated with detrimental effects for both human and environmental health and is a focus point for local, regional and the national governments within the UK. To meet the UK Air Quality Targets and deliver health improvements for residents, many local authorities are taking action to implement measures aimed at reducing pollutant emissions and improving air quality.

To support action to tackle air pollution, Defra has funded the 'London Wood Burning Project (LWBP) under the Defra Air Quality Grant Scheme[1] which aims to raise awareness of the human health impacts from domestic solid fuel burning. The LWBP, led jointly by the London Borough of Camden and the London Borough of Islington, comprises a total of 15 London local authorities collectively aiming to gain a clearer understanding and raise awareness of the environmental and health impacts associated with domestic solid fuel burning. The 15 participating boroughs are displayed in Table 1-1 below.

Table 1-1 Boroughs participating in the London Wood Burning Project

Boroughs		
Camden (lead authority)	Haringey	Richmond
Islington (lead authority)	Kensington and Chelsea	Sutton
Brent	Kingston	Waltham Forest
Croydon	Lewisham	Wandsworth
Ealing	Merton	City of Westminster

To support the broader communications strategy and ensure the relevance of the information shared, the LWBP has commissioned a three-part study, comprised of the following components:

1) A survey of residents' current burning practices and knowledge and opinions on domestic solid fuel burning to gain an insight into the current level of understanding within the population (Element 1).
2) Indoor and outdoor air quality monitoring across the participating London boroughs to collect air quality data and investigate the impacts of domestic solid fuel burning in a real world setting (Element 2).
3) A health impact evaluation to assess the impact upon human health as a result of domestic solid fuel burning in the participating boroughs (and London more widely) (Element 3).

This report presents the methodology, data, analysis and results for Element 3, namely the health impact evaluation. Although the analysis under Element 3 was conducted separately, it has drawn upon the findings of the first and second elements, incorporating the key evidence collected as part of these separate activities where relevant. Where data has been used from Elements 1 and 2, it has been referenced throughout the report.

The analysis of the health impacts in this study has been structured into three distinct sections:

- The first part comprises a literature review of current relevant sources to assess the current understanding of the human health impacts of solid fuel burning, and the wider policy environment aiming to tackle this issue.
- The second section presents a detailed health impact assessment of domestic solid fuel burning. Where possible this evaluation has quantified and monetised the impact of $PM_{2.5}$ and NO_2 through a range of health impact pathways, following UK best-practice guidance related to the assessment of such effects[2]. This evaluation has illustrated the direct impact on local residents, indicating a range of health impacts including the 'total life years lost' and increase in hospital admissions (alongside other morbidity outcomes) as a result of domestic solid fuel burning. To complement the quantitative assessment, further qualitative analysis has been undertaken. This focused on the links between

[1] https://www.gov.uk/government/collections/air-quality-grant-programme#:~:text=Defra's%20air%20quality%20grant%20scheme,under%20the%20Environment%20Act%201995.
[2] https://www.gov.uk/government/publications/assess-the-impact-of-air-quality/air-quality-appraisal-damage-cost-guidance

indoor air pollution and human health, and the qualitative approach was used because quantitative methods to assess indoor air pollution effects are less developed.

- The third part of the study presents a detailed distributional analysis which has explored the impacts of solid fuel burning at a more granular level. This section assessed how the pollution generated from burning solid fuels affects different societal groups, for example based upon age, income or vulnerability, to determine whether certain groups are disproportionately impacted. This analysis was underpinned by the findings collected through both the survey and the air quality monitoring undertaken in Element 1 and 2.

The findings of both the health impact evaluation and distributional analysis will be used to support the wider communication and awareness raising campaign. As such, a separate public facing executive summary has also been developed for a non-expert target audience highlighting the key findings of this report.

2. KEY SOURCES AND DATASETS

This section describes the key data sources used to compile the evidence base which supported the literature review (Section 3); the analysis of the health impacts (Section 4); and the assessment of the distributional impacts (Section 5). The section has been structured into two parts. The first describes the primary dataset which provided the data underpinning the health impact analysis. The second section lists the additional sources and datasets which have further supported the evaluation.

2.1 PRIMARY DATASETS

The primary dataset used to support the health impact assessment is the 2019 London Atmosphere Emissions Inventory (LAEI)[3]. This provides air pollution emissions and ambient (outdoor) concentration estimates for each London borough for PM, NO_2 and other pollutants. The data collected through the LAEI has been input into Ricardo's Air Quality Health Impact Model which has been used to calculate the estimated health impacts associated with air pollutant concentration levels as a result of current domestic solid fuel burning. The methodological approach has been described in Section 4.2 below. Although the LAEI database is the primary data source, there are a number of additional sources used to support the assessment which have been described below.

2.2 ADDITIONAL LITERATURE AND DATASETS IDENTIFIED

2.2.1 Desk based literature

A key source of data supporting the assessment was information collected through a desk-based review of available online literature. The primary use of the data was to support a qualitative assessment of the impacts of solid fuel burning upon health to complement the quantitative analysis. The literature sources reviewed comprised of grey literature, such as policy and consultancy reports, as well as reviews of the content of implemented UK legislation. Academic journals have also been assessed to support the development of an evidence base describing the links between exposure to air pollutants and detrimental health impacts. The list of sources to review was developed through the use of key search terms in known search engines and further complemented through expert knowledge of UK air quality policy and legislation. The sources used have been referenced throughout the report.

2.2.2 Survey data – Element 1

As part of the wider LWBP, under Element 1 a survey[4] was developed to gather opinions of over 5,000 local residents. The survey sought to assess current awareness of air quality and perceptions about solid fuel burning, as well as ascertaining current behaviour with respect to the use of solid fuel burning appliances. The data collected through the survey were used for two purposes in this health impact evaluation:

1) The results of the survey fed into the qualitative assessment of the health impacts of domestic solid fuel burning. This included feeding into the literature review of relevant sources to analyse the health impacts.
2) The responses collected through the survey were used in the distributional analysis of the health impacts. The data collected indicated the use of domestic solid fuel burning at different locations and by different demographic groups. This enabled an assessment of the impact of solid fuel burning upon different societal groups.

[3] https://data.london.gov.uk/dataset/london-atmospheric-emissions-inventory--laei--2019#:~:text=The%20LAEI%202019%20is%20the,for%20the%20base%20year%202019.

[4] Survey developed by Opinium, 2022 (Link not available)

3. LITERATURE REVIEW

3.1 AIMS OF THE LITERATURE REVIEW

The literature review has analysed available desk-based sources to support and complement the findings of the health impact evaluation. The two key objectives of this review were:

1) To provide an overview of the current understanding of the human health impact as a result of domestic solid fuel burning.
2) To review the current UK and local (London) policy environment and the action taken to improve air quality and reduce pollutant emissions from domestic solid fuel burning.

The scope of the literature review has focused primarily on domestic solid fuel burning within a UK setting. However, the literature review has also provided additional wider context of the impact of pollutant emissions from sources other than domestic solid fuel. In some cases, this has also referred to impacts observed outside of the UK.

3.2 LITERATURE REVIEW RESULTS

3.2.1 UK air quality policy

Air quality policy, and associated objectives and targets, are set at the national level within the UK. An increasing focus and awareness of the impacts of air pollution has led in recent years to the UK government introducing a number of policy initiatives to reduce pollutant emissions and improve air quality across England.

The Environment Improvement Plan (2023)[5] represents the most recent action taken by the UK government and provides an outline of the government's broader air quality aspirations. A wide-ranging plan, encompassing a number of goals; including biodiversity, adaptation, circular economy, Goal 2 of the plan focuses on improving air quality. In addition to providing an overview of the detrimental impact of air pollutants, Goal 2 describes the action taken to date, government targets and commitments, and how the future delivery of these aims will be achieved. One key aim is the target to achieve a maximum annual concentration of 10 micrograms of $PM_{2.5}$ or below per cubic metre (µg/m^3) by 2040, with an interim target to not exceed 12 µg/m^3 by 2028. These targets have built upon the requirements set out in the Environment Act (2021)[6] which required the government to introduce legally binding targets to strengthen UK air quality commitments. Legal targets have also been set to restrict exposure to $PM_{2.5,}$ with an aim to reduce 2018 current exposure levels by 35% by 2040 and by 22% by 2028. In terms of other pollutants, the Plan sets out an aim to achieve compliance with a 40 µg/m^3 limit for nitrogen dioxide. To meet these targets a diverse delivery plan is being implemented which targets pollution from a range of sources including transport and industrial emissions, as well as tackling indoor emissions through a reduction in domestic burning.

The Environment Improvement Plan (2023) has followed a number of prior UK government initiatives. The Clean Air Strategy (2019)[7] was a key step and detailed actions required to support national air quality objectives, including halving the number of locations currently above a 10 µg/m^3 $PM_{2.5}$ limit. Building upon this, there are plans to introduce a revised Air Quality Strategy[8] in 2023, which will set out actions for local authorities to target a reduction in fine particulate matter ($PM_{2.5}$), as well as establishing a framework to support local authorities deliver on their climate pledges. Other key country-wide initiatives include the 25 Year Environment Plan[9] which outlined how a focus on air quality will feature in policies to support UK growth in sectors such as transport and industry. Additionally, the Net Zero Strategy (2021)[10], sets out UK climate objectives in the

---

[5] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1133967/environmental-improvement-plan-2023.pdf

[6] https://www.legislation.gov.uk/ukpga/2021/30/contents/enacted

[7] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/770715/clean-air-strategy-2019.pdf

[8] https://www.gov.uk/government/publications/the-air-quality-strategy-for-england

[9] https://www.gov.uk/government/publications/25-year-environment-plan

[10] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1033990/net-zero-strategy-beis.pdf

context of 'building back better' following the Covid pandemic, also illustrates an intent to consider the impact upon air quality in future infrastructure in UK.

A number of initiatives have also been introduced to specifically tackle pollution generated through solid fuel burning. The Clean Air Act (1993)[11] is the primary legislation governing solid fuel burning. Part III of the legislation established initial requirements concerning the creation of smoke control areas, providing local authorities with the power to enforce locations prohibiting the use of appliances which emit smoke (including solid fuel burning). These smoke control areas are enforced in locations across the UK, permitting residents and visitors to use only authorised fuels. Wood, as a designated unauthorised fuel, can only be used in certain exempt appliances which include some boilers, cookers and stoves. Further to this, Air Quality (Domestic Solid Fuels Standards) (England) Regulations (2020)[12] have been implemented to control the use of some fuel burning appliances. Under the regulations the sale of the most polluting stoves is banned (although existing older stoves can continue to be used). New wood burning stoves will be required to adhere to eco-design standards which include minimum efficiency rates and maximum emission limits[13],[14]. The Air Quality (Domestic Solid Fuels Standards) (England) Regulations (2020) regulate the supply and manufacture of wood and other solid fuels, setting out the standards and requirements which need to be met. It also designates, and identifies, enforcement responsibility with the relevant local authorities and sets their accompanying powers.

A provisional Air Quality Common Framework (2022)[15] has set out the conditions under which the four UK Devolved Associations intend to coordinate and work together on future air quality policy post Brexit. Under this framework, the four governments are committed to continue to collaborate on the reporting of data at a UK level and to work collaboratively on emission reductions to meet national and international ceilings[16], for example future National Air Pollution Control Programmes.

3.2.2 Local air quality policy

To complement the overall national policy environment is generally supportive of tackling air pollution, there is also a growing trend across the UK towards strengthening devolved powers and supporting action by local authorities. This is evidenced through the aim to 'drive effective local action through local authorities' as a key pillar of the delivery plan within the recent Environment Improvement Plan (2023).

Further to this, in 2022 the UK government updated the Local Air Quality Management (LAQM) Technical Guidance[17] which supports UK local authorities in adhering to the Environment Act (2021). Under the update, local authorities are required to present a timeline of measures which will be implemented to ensure pollution concentration limits within the local area are met. As a result of the increasing responsibility placed upon local authorities to meet nationally set targets, a range of policies and measures are being assessed and implemented across the UK.

The Greater London Assembly has led a number of initiatives in recent years to tackle air pollution. The Ultra-Low Emission Zone (ULEZ) was established in 2019 to improve air quality by charging the most polluting vehicles driving through the capital. Recent evidence has indicated that the scheme has been successful in reducing pollution within London, with estimates that pollution levels are 21% lower than in a scenario where the ULEZ was not implemented[18]. Looking ahead, current proposals aim to strengthen the scheme by widening the ULEZ area across all London Boroughs (currently it serves Central London and part of Inner London only). Further to this, a number of projects across London are supported by the Mayor's Air Quality Fund which has provided £22m over a 10 year period to support local projects aiming to reduce air pollution. More broadly, the London Environment Strategy[19] targets environmental and air quality challenges across all sectors within the

---

[11] https://www.legislation.gov.uk/ukpga/1993/11/section/19D
[12] https://www.legislation.gov.uk/uksi/2020/1095/contents/made
[13] https://uk-air.defra.gov.uk/library/burnbetter/#what
[14] https://www.gov.uk/guidance/placing-energy-related-products-on-the-uk-market
[15] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1052059/air-quality-provisional-common-framework.pdf
[16] https://researchbriefings.files.parliament.uk/documents/CBP-9600/CBP-9600.pdf
[17] https://researchbriefings.files.parliament.uk/documents/CBP-9600/CBP-9600.pdf
[18] https://www.london.gov.uk/new-report-reveals-transformational-impact-expanded-ultra-low-emission-zone-so-far#:~:text=Report%20shows%20that%20the%20ULEZ,have%20been%20without%20the%20ULEZ.&text=Each%20day%2C%2074%2C000%20fewer%20polluting,since%20expansion%20in%20October%202021.
[19] https://www.london.gov.uk/sites/default/files/london_environment_strategy_0.pdf

capital. Following the success of initiatives such as the ULEZ in tackling road transport emissions[20], focus is shifting towards tackling other emission sources – such as solid fuel burning – as the relative contribution of these non-transport sources increase. For example, recent UK government statistics[21] have highlighted a declining trend in emissions across a number of sectors, but have noted that these benefits have been partially offset by increases in wood burning in domestic settings (illustrating the importance of the LWBP).

The 15 boroughs participating in the LWBP have demonstrated leadership and commitment to reducing pollution, improving air quality, and protecting public health within their boroughs. A range of clean air and climate action policies and initiatives are being enacted across each borough, which alongside their involvement in the LWBP, showcases their ambition. The two councils leading the LWBP, namely the London Borough of Camden and the London Borough of Islington, are two such local authorities which demonstrated this.

The Camden Clean Air Action Plan[22] sets out the actions taken by the Council to improve air pollution across the borough. Specific aims within the plan include: providing help to residents and visitors to reduce emissions to air and exposure to them, using planning policy and regulation to reduce air pollution, and raising awareness on how to reduce emissions and exposure. Further to this, the 'Our Camden Plan[23]' has illustrated the intent that the Council will 'use all the resources at our disposal to play our part in improving air quality', for example through promoting active travel and lowering emissions through its own operations. Camden Council has also committed to complying with WHO guidelines and adhering to limits set for $PM_{2.5}$ and NO_2 by 2034 and for PM_{10} by 2030, a self-imposed strategic objective set out the Camden Clean Air Strategy[24]. The London Borough of Islington has similarly shown ambition to improve local air quality. The Council has worked closely with the Greater London Authority (GLA) offering support for air quality measures such as the implementation of the ULEZ and have lobbied the national government for greater strategic support to local authorities. The Islington Air Quality Strategy[25] sets out the Council's key priorities for developing air quality targeted policy. This includes: a focus on protecting the vulnerable, for example through school engagement programmes to raise awareness and encourage active travel; support for awareness raising events such as Clean Air Day, and; participation in anti-idling campaigns. The strategy also emphasises the importance of monitoring air quality across the borough to track the impact of measures and to effectively disseminate information to the public.

Action to improve air quality and reduce pollutant emissions has been replicated across all other 13 London boroughs involved in the LWBP. This can range from the 'Ealing Council Air Quality Strategy 2020-30[26]' to Lewisham Council's 'Air Quality Action Plan 2022-27[27]' and Haringey Council's 'Air Quality Action Plan 2019-2024[28]', to name a few examples. Each participating borough has taken its own steps to improve air quality with overall ambitions to improve air quality aligned with the LWBP.

3.2.3 Health impacts of exposure to pollutant concentrations

The link between air pollution and human health has been extensively studied over the preceding decades, with a growing body of evidence indicating its harmful effect. The World Health Organization (WHO) has been at the forefront of an effort to raise awareness of this relationship, using its global reach to highlight the human health impact across the globe and call for action to combat this[29]. This has included the publication of reports and the establishment of initiatives and groups such as the Scientific Advisory Group on Air Pollution and

---

[20] https://www.london.gov.uk/programmes-strategies/environment-and-climate-change/environment-and-climate-change-publications/inner-london-ultra-low-emission-zone-expansion-one-year-report?auHash=IxeIM3L6iJh-CwYvb2wek2UKMCSJvpOqMgtpRAMt5B8

[21] https://www.gov.uk/government/statistics/emissions-of-air-pollutants/emissions-of-air-pollutants-in-the-uk-particulate-matter-pm10-and-pm25

[22] https://www.camden.gov.uk/documents/20142/0/Camden+Clean+Air+Action+Plan+2023-2026_Final_2022.12.19+%282%29.pdf/ad618e94-0113-696d-5fc6-104d8969ab5a?t=1671619123044

[23] https://www3.camden.gov.uk/2025/our-camden-plan/clean-vibrant-and-sustainable-places/

[24] https://www.camdenrise.org.uk/documents/20142/0/Camden+Clean+Air+Action+Plan+2023-2026_Final_2022.12.19+%282%29.pdf/ad618e94-0113-696d-5fc6-104d8969ab5a?t=1671619123044#page=15

[25] https://www.islington.gov.uk/-/media/sharepoint-lists/public-records/environmentalprotection/information/adviceandguidance/20192020/20191018airqualitystrategy2019.pdf

[26] https://www.ealing.gov.uk/downloads/download/7039/ealing_council_air_quality_strategy_2020-30

[27] https://lewisham.gov.uk/myservices/environment/air-pollution/read-our-air-quality-action-plan-and-other-reports

[28] https://www.haringey.gov.uk/sites/haringeygovuk/files/haringey_final_aqap_2019-24_signed.pdf

[29] https://www.who.int/health-topics/air-pollution#tab=tab_1

Health. The WHO published its most recent Air Quality Guidelines in 2021, in which it revised the levels of pollution exposure which it deemed safe for humans, reducing these guidelines (i.e. suggesting even lower levels of concentrations could be harmful for health) for several pollutants[30].

In terms of the link with human health two key pollutants are the focus of this study – $PM_{2.5}$ and NO_2. The link between PM and health was first formally evidenced in the Six Cities Study[31] which investigated the impact of the ambient pollutant in six cities in the United States during the 1990's. Since then, a number of additional studies have demonstrated the relationship between PM and a range of health conditions. The WHO has been at the forefront of communicating the link between air pollutant exposure and health, noting that 'almost every organ in the body can be impacted by air pollution[32].' The WHO also identifies a number of specific health conditions that are most impacted, for example cardiovascular diseases. The World Heart Federation[33] has similarly stated the risk of cardiovascular diseases, particularly from $PM_{2.5}$, and the need to tackle this issue in urban areas. Another of the most prominent conditions linked to PM is respiratory disease. Studies have shown a clear link between PM and asthma in children[34] as well as adult lung functioning[35]. The adverse effect on human health is particularly prevalent for small particles ($PM_{2.5}$), which bypass the body's defences against dust and penetrate deep into the respiratory system.

In addition to PM, NO_2 is also linked with a range of health impacts when inhaled. Reporting by the Committee on the Medical Effects of Air Pollutants (COMEAP)[36] has linked exposure to NO_2 concentrations with respiratory and cardiovascular diseases, although acknowledges the challenges in isolating the impacts of one specific pollutant given the presence of other ambient pollutants (similar COMEAP studies have also identified impacts for PM). COMEAP also provides reference to a number of other studies which similarly present evidence of the adverse relationship between health and NO_2. The European ESCAPE studies, for example, have identified the impact upon long-term exposure to NO_2 and respiratory issues through a range of studies[37], whilst the US Environment Protection Agency also noted likely respiratory effects.[38]

There also exists a growing body of evidence highlighting the specific impact of solid fuel burning on air quality (and the subsequent health impacts), including identifying the impacts from specific solid fuel appliances. The use of one such appliance, namely residential wood stoves, has become increasingly prevalent over recent years. A study in the US (New England)[39] explored the relationship between the use of wood stoves and indoor air pollution – and more specifically exposure to $PM_{2.5}$. The study found that the homes which did operate these stoves were also exposed to higher concentrations of $PM_{2.5}$ (as well as other pollutants such as black carbon) demonstrating the potential detrimental health impacts. These findings have further supported within the literature, for example, a UK based study[40] also demonstrated the increased risk of exposure to $PM_{2.5}$ in an indoor setting as a result of the use of residential stoves. One further determination from this study was the conclusion that the indoor air pollution recorded within the residential homes had not originated outdoors, with the pollution directly linked to the use of the stoves.

More broadly, evidence has shown the impact of pollution linked to residential heating and cooking across the UK and European Union (EU), revealing that substantial health-related social costs are caused as a result[41]. The study associates these costs with both indoor and outdoor pollution, although it notes the need for further research into health impacts of indoor air pollution. Other studies have investigated the direct health links. One has established the link between $PM_{2.5}$ exposure (noted as being generated in part by wood burning) with an

---

[30] https://apps.who.int/iris/handle/10665/345329
[31] https://pubmed.ncbi.nlm.nih.gov/8179653/
[32] https://www.who.int/teams/environment-climate-change-and-health/air-quality-and-health/health-impactshttps://www.who.int/teams/environment-climate-change-and-health/air-quality-and-health/health-impacts
[33] https://world-heart-federation.org/news/air-pollution-and-cardiovascular-disease-a-window-of-opportunity/
[34] https://pubmed.ncbi.nlm.nih.gov/36608946/
[35] https://respiratory-research.biomedcentral.com/articles/10.1186/s12931-020-01514-w
[36] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/411756/COMEAP_The_evidence_for_the_effects_of_nitrogen_dioxide.pdf
[37] http://www.escapeproject.eu/publications.php
[38] https://www.epa.gov/no2-pollution/basic-information-about-no2
[39] https://pubmed.ncbi.nlm.nih.gov/31253828/
[40] https://www.mdpi.com/2073-4433/11/12/1326
[41] https://cedelft.eu/wp-content/uploads/sites/2/2022/03/CE_Delft_210135_Health-related_social_costs_of_residential_heating_and_cooking_Def_V1.2.pdf

increased risk of emergency hospital admissions[42] and respiratory health issues[43]. Similarly, recent studies across Northern Europe (focused in the Nordics) showed the harmful impact of residential heat combustion, acknowledging it as a significant source of $PM_{2.5}$ emission and the subsequent impact on premature mortality.

In addition to the direct physical impacts, a further consideration is the relationship between exposure to air pollution and mental health, which is typically less explored, and less visible, than the impact upon physical health conditions. However, research in recent years has shown that breathing polluted air is linked to a higher propensity to develop mental health problems[44]. In particular, exposure to air pollutants can exacerbate already existing mental health issues such as psychotic and mood disorders[45]. A further study illustrated the link between the frequency of use of mental healthcare services and exposure to ambient pollutants, demonstrating that these services were more commonly used (in South London) by those living in poor air quality areas[46]. These studies, amongst others, have demonstrated the need to improve air quality for mental, as well as physical health benefits.

The available literature has leaned more heavily towards providing an overview of the link between ambient air pollution and health. However, the relationship with indoor air quality is a growing area of interest. This has been explored in section 4.3.3.

[42] https://pubmed.ncbi.nlm.nih.gov/19590690/

[43] https://pubmed.ncbi.nlm.nih.gov/27315241/

[44] https://www.weforum.org/agenda/2022/11/impact-air-pollution-brain-mental-health

[45] https://www.cambridge.org/core/journals/the-british-journal-of-psychiatry/article/association-between-air-pollution-exposure-and-mental-health-service-use-among-individuals-with-first-presentations-of-psychotic-and-mood-disorders-retrospective-cohort-study/010F283B9107A5F04C51F90B5D5F96D6

[46] https://www.kcl.ac.uk/news/exposure-to-air-pollution-linked-with-increased-mental-health-service-use-new-study-finds

4. HEALTH IMPACT ASSESSMENT

4.1 INTRODUCTION

4.1.1 Aims and objectives

The aim of the health impact assessment is to quantify and monetise (as far as possible) the public health impact of domestic solid fuel combustion across the Greater London region as well as within the 15 participating LWBP boroughs. The key findings of the study are included in the public-facing executive summary document to support the LWBP awareness raising campaign and improve local understanding of the health impacts of solid fuel burning.

4.1.2 Scope

The assessment was focused on the health impacts from domestic solid fuel burning only. As noted, the analysis has been primarily supported by the use of data collected through London Atmospheric Emissions Inventory (LAEI) and was therefore limited by the granularity of the separate domestic categories within the dataset. Specifically, the disaggregation of domestic fuel burning was limited to being split by a number of categories, of which "wood combustion" and "oil and coal for heating and cooking" are those most relevant to domestic solid fuel. For the purpose of the analysis the latest inventory dataset (2019), published in 2022, has been used.

The target pollutants of the study are $PM_{2.5}$ and NO_2. These pollutant groups have been selected as there exists a stronger body of evidence linking exposure to adverse effects on human health, as noted in the Literature Review section above. The assessment of health impacts has adhered to UK best practice appraisal guidance (in line with the HM Treasury Green Book[47]). In this study, the quantification of health impacts as a result of changes in air pollution followed the widely recognised Impact Pathway Approach (IPA). The IPA uses concentration response functions (CRFs) to link a given air pollutant concentration to a specific health outcome. Defra's air pollution appraisal guidance[48] sets out a peer-reviewed set of CRFs (peer review undertaken by COMEAP) to be used when assessing the impacts of changes in air quality following the IPA. According to Defra's guidance, nine health impact pathways have been included in the assessment and they are presented in Table 4-1.

Table 4-1 Selected Health Pathways

Health pathways	
Mortality associated with long-term exposure ($PM_{2.5}$ and NO_2)	Stroke ($PM_{2.5}$)
Respiratory hospital admissions associated with acute exposure ($PM_{2.5}$ and NO_2)	Lung cancer ($PM_{2.5}$ and NO_2)
Cardio-vascular hospital admissions associated with acute exposure to particulate matter ($PM_{2.5}$)	Asthma in adults (NO_2)
Asthma in children ($PM_{2.5}$ and NO_2)	Coronary heart disease ($PM_{2.5}$)
Diabetes ($PM_{2.5}$ and NO_2)	

[47] https://www.gov.uk/government/publications/the-green-book-appraisal-and-evaluation-in-central-governent/the-green-book-2020
[48] https://www.gov.uk/government/publications/assess-the-impact-of-air-quality/air-quality-appraisal-damage-cost-guidance#damage-costs

The Defra damage costs guidance[49] estimates and monetises the mortality effects associated with chronic exposure through the expression of life-years lost (LYL) – i.e. the sum of years of life lost across all those exposed to harmful air pollutants, which causes a shortening of life. That said, this expression is more challenging to comprehend than other metrics of mortality, such as number of deaths, or a change in life expectancy. However, Defra selects LYL on the basis of advice from COMEAP, which views LYL as a more accurate expression of the effects of air pollution on mortality, whilst also noting the trade-off between accuracy and accessibility[50]. Air pollution is often a contributing factor in death, but is infrequently the sole cause. Hence it is challenging to attribute a certain number of deaths to air pollution alone and as such attributing LYL to air pollution is viewed as being more robust. That being said, given the public facing nature of the present document, in addition to the analysis following the Defra damage cost approach, additional calculations to express the mortality effects in alternative, more accessible ways – namely as a number of deaths and as a change in life expectancy at birth have also been undertaken. The geographic scope of the assessment was the wider Greater London region comprising all 32 boroughs and the City of London. In addition, the health impact of solid fuel burning within each of the 15 boroughs participating in the LWBP was separately analysed in order to present a more granular assessment.

4.2 METHODOLOGY

4.2.1 Overview

The LAEI dataset provided total estimated gridded concentrations for NO_2 and $PM_{2.5.}$ To estimate the health impact of these pollutants for domestic solid fuel burning only, source apportionment modelling was carried out for the whole of London using the latest version of the RapidAir® dispersion model. This model uses dispersion kernels derived from the US EPA AERMOD model. Modelling was carried out using meteorological data for 2019 from the Met Office Heathrow monitoring station and emissions data from the London Atmospheric Emissions Inventory (LAEI) 2019, published in 2022. The 2019 LAEI data are the most recent available and also the last year to capture emissions representative of the pre-Covid pandemic situation. The 2019 Met Office data were used to make the modelling temporally consistent with the emissions data. Background pollutant concentrations were derived from the LAEI 2019 concentration maps.

Emissions were modelled as a 1km grid of volume sources, matching the resolution of the input emissions inventory. The source apportionment modelling considers primary $PM_{2.5}$ and NO_x emissions. Formation of NO_2 as a secondary pollutant is calculated following the methodology outlined in LAQM.TG(22)[51].

To estimate the health effects associated with exposure, the calculation uses a metric known as 'population-weighted concentrations' (i.e. rather than concentrations as observed in the LAEI). Population-weighted mean concentrations were derived by overlaying concentration data from the LAEI with population data from the 2011 census at the Lower Super Output Area (LSOA) level published by ONS, to weight more highly concentrations of air pollutants which occur closer to where London residents live.

The next step applied concentration response function (CRF) for each health pathway (outlined in table 4-1), which define a given health impact per unit change in the ambient concentration of a pollutant. The CRF and population-weighted concentrations were subsequently multiplied by the following:

- the underlying risk rate of the health outcome (for example, number of hospital admissions per 100,000 persons per increase in $\mu g/m^3$); and
- size of the affected population.

The resulting values were used to determine the change in each individual health impact pathway as a consequence of the pollutant concentrations. Finally, the impact upon each pathway was monetised by applying unit impact costs which place a monetary value on each health endpoint.

[49] https://www.gov.uk/government/publications/assess-the-impact-of-air-quality/air-quality-appraisal-damage-cost-guidance#damage-costs
[50] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/304641/COMEAP_mortality_effects_of_long_term_exposure.pdf
[51] https://laqm.defra.gov.uk/wp-content/uploads/2022/08/LAQM-TG22-August-22-v1.0.pdf

4.2.2 Sources of pollutant concentrations for the Greater London region

Table 4-2 presents the total concentrations for solid fuel burning in the Greater London region for NO_2 and $PM_{2.5}$ concentrations. The table includes the categories included within the LAEI dataset relevant to solid fuel burning (both domestic and industrial/commercial) as well as the total concentrations in the Greater London region. A few key findings when comparing the concentrations from the sectors included in the table are:

- 'Wood burning' in London contributes around 22% of all $PM_{2.5}$ concentrations from local sources in London. Amongst these local 'wood burning' sources, the domestic sector is the largest local contributor to $PM_{2.5}$ concentrations of all solid fuel burning activities in London, at 16.2%.
- 'Wood burning' within the domestic sector is not a significant local contributor to NO_2 concentrations in London. It should also be noted that the LAEI does not provide estimates for NO_2 concentrations associated with wood burning as this is not considered to be significant pollutant arising from this activity.
- The contribution of background concentration is less relevant for NO_2, as almost 56% of the total concentration is locally produced.
- The contribution of background concentration is more relevant for $PM_{2.5}$, as almost 74% of the total concentration is not locally produced but 'imported' from elsewhere by the wind (including, for example, wood burning in other regions, among other human activities responsible for air pollutant emissions).

Table 4-2 Population Weighted Concentrations based on annual averages (µg/m^3) and proportions (%) of different sectors and fuels for Greater London region.

Sectors		Fuels	NO_2			$PM_{2.5}$		
			Concentration (µg/m^3)	Proportion without background (%)	Proportion with background (%)	Concentration (µg/m^3)	Proportion without background (%)	Proportion with background (%)
Domestic	Heating & Power	Oil/ Coal	0.06	0.3%	0.2%	0.07	2.1%	0.6%
	Wood burning	Wood	0.00	0.0%	0.0%	0.51	16.2%	4.3%
Industry & Commercial	Heating & Power	Oil/ Coal	1.34	6.5%	3.6%	0.14	4.3%	1.1%
Total Greater London region (local sources only)			20.63	100%	N/A	3.16	100%	N/A
Total including background			37.02	N/A	100%	11.97	N/A	100%

4.3 FINDINGS

4.3.1 Outdoor air pollution

4.3.1.1 Impact of domestic solid fuel burning on outdoor air quality

This section presents the impacts for NO_2 and $PM_{2.5}$ concentrations generated by coal and oil combustion and wood burning in a domestic setting. The impacts are first presented for the Greater London region (comprising all 32 boroughs and the City of London) and subsequently for the 15 individual boroughs participating in the London Wood Burning Project.

Table 4-3 displays the concentrations for NO_2 and $PM_{2.5}$ as a result of domestic solid fuel burning for the specific fuel types selected. The results show that on average, the Greater London region population are exposed to a higher concentration of $PM_{2.5}$ as a result of wood burning compared to the burning of coal and oil (approximately seven times greater exposure).

Table 4-3 Population Weighted Concentrations for the Greater London region (µg/m^3).

NO_2	$PM_{2.5}$	
Coal and oil	**Coal and oil**	**Wood**
0.06	0.07	0.51

In addition to determining the concentrations for the Greater London region, Table 4-4 presents the concentrations of each pollutant for the 15 individual boroughs participating in the LWBP. Similar to Table 4-3, it shows there is a greater exposure as a result of wood burning (compared to the burning of oil and coal) across all boroughs. In terms of $PM_{2.5}$ concentrations caused by wood burning, the most affected borough is Waltham Forest (0.62 µg/m^3) followed by Haringey and Merton (0.59 µg/m^3). The least affected is shown to be Camden (0.43 µg/m^3). The $PM_{2.5}$ and NO_2 concentrations as a result of domestic coal and oil burning fall within a range of 0.06 – 0.09 µg/m^3 for all boroughs. Furthermore, it should be noted that concentrations from solid fuel combustion in the domestic sector are estimated from annual emissions, which do not take into account differences in winter and cold weather. Therefore, these concentrations will represent an even higher proportion of the total $PM_{2.5}$ air pollution during winter compared to the annual average.

Table 4-4 Population Weighted Concentrations in each borough participating in the LWBP (µg/m^3).

Borough	NO_2	$PM_{2.5}$	
	Coal and oil	**Coal and oil**	**Wood**
Brent	0.06	0.06	0.52
Camden	0.08	0.06	0.43
Croydon	0.06	0.06	0.50
Ealing	0.06	0.06	0.50
Haringey	0.07	0.07	0.59
Islington	0.08	0.07	0.47
Kensington and Chelsea	0.09	0.07	0.54
Kingston upon Thames	0.06	0.07	0.44
Lewisham	0.07	0.08	0.58
Merton	0.07	0.08	0.59
Richmond upon Thames	0.06	0.06	0.45
Sutton	0.06	0.07	0.49
Waltham Forest	0.07	0.09	0.62
Wandsworth	0.07	0.08	0.57
Westminster	0.09	0.06	0.45

Table 4-5 below displays the monetised annual costs of NO_2 and $PM_{2.5}$ concentrations for the Greater London region due to domestic solid fuel burning. The costs present a monetary value for the exposure to air pollution and the subsequent health effects (as described in Section 4.2). This captures the combined value that people place on their own good health, 'productivity' impacts (such as lost time at work) and costs to NHS as a result of the need for treatment for conditions associated with long-term air pollution exposure.

In the Greater London region, the most significant cost is associated with exposure to $PM_{2.5}$ concentrations. This is estimated to result in an impact upon human and environmental health with a monetary value (or cost burden) of £173m and £22.6m per year as a result of the burning of wood, and of coal and oil respectively. As a result of the existing NO_2 concentrations caused by coal and oil burning an annual cost of approximately £2.1m is estimated.

Table 4-5 Total annual costs for the Greater London region (£m, 2022).

NO_2	$PM_{2.5}$	
Coal and oil	**Coal and oil**	**Wood**
2.1	22.6	173.3

A breakdown of the estimated costs per year and borough have been provided in Table 4-6. The most impacted borough is Croydon followed by Wandsworth and Ealing. For each of those boroughs, an annual cost burden of exposure to air pollutants associated with domestic solid fuel burning of over £7m has been estimated. Conversely, the least impacted boroughs are estimated to be Kingston upon Thames and Richmond upon Thames. As the damage cost factors used for each borough are the same, the impact is driven by either: the concentrations of pollutants associated with use of solid fuels, and/or the population size of each borough.

Table 4-6 Total annual costs per Borough (£, 2022).

Borough	NO_2	$PM_{2.5}$	
	Coal and oil	**Coal and oil**	**Wood**
Brent	73,000	754,000	6,668,000
Camden	73,000	540,000	3,967,000
Croydon	84,000	963,000	7,495,000
Ealing	79,000	865,000	7,060,000
Haringey	68,000	743,000	6,278,000
Islington	64,000	589,000	4,057,000
Kensington and Chelsea	58,000	439,000	3,549,000
Kingston upon Thames	36,000	454,000	2,908,000
Lewisham	81,000	917,000	6,596,000
Merton	55,000	644,000	4,886,000
Richmond upon Thames	44,000	468,000	3,459,000
Sutton	44,000	546,000	3,858,000
Waltham Forest	78,000	926,000	6,636,000
Wandsworth	92,000	976,000	7,218,000
Westminster	79,000	577,000	4,130,000

4.3.1.2 Specific health impacts

The annual detrimental health impacts associated with exposure to NO_2 and $PM_{2.5}$ as a result of domestic solid fuel burning across all 32 London boroughs and the City of London are presented in Table 4-7. These are the same impacts that are captured in the 'aggregate' analysis in the preceding section, but here are split out by the different contributing impact types.

For each pollutant the relevant health impact pathways were considered. The table shows that a total equivalent 3,035 life years are lost (LYL) each year[52] as a result of the $PM_{2.5}$ produced by domestic wood burning. In the case of coal and oil burning, approximately 439 life years are lost each year as a result of $PM_{2.5}$ and NO_2 concentrations. Further to this, an impact equivalent to 84 new cases of asthma per year in the Greater London region could be attributed to domestic wood burning. There are also hospital admissions and cases for all the health pathways explored attributable to solid fuel burning each year.

Table 4-7 Assessment of attributable health impacts per annum for the Greater London region

Health Pathway	Incidence	NO_2	$PM_{2.5}$	
		Coal and oil	**Coal and oil**	**Wood**
Mortality associated with chronic exposure	LYL	44	395	3,035
Respiratory hospital admission	No. Hospital admissions	5	9	73
Cardiovascular hospital admission	No. Hospital admissions	N/A	0	0
CHD	No. New cases	N/A	6	48
Stroke	No. New cases	N/A	8	59
Lung Cancer	No. New cases	0	4	28
Asthma (Older Children)	No. New cases	1	11	84
Asthma (Small Children)	No. New cases	3	N/A	N/A
Asthma (Adults)	No. New cases	0	N/A	N/A
Diabetes	No. New cases	0	0	0

N/A: Not applicable as CRF not available to associate health impact with exposure to that specific pollutant

[52] Regarding mortality associated with chronic exposure, it should be noted that not all years of life lost are accounted for in the first year, but some occur in later years, over a period of 100 years.

Table 4-8 below presents the monetised costs of the human health impacts, split by impact type. The greatest cost is estimated to be attributed to the mortality associated with chronic exposure, with the costs associated with all other health pathways significantly lower. A greater cost is borne as a result of wood burning compared to the burning of coal and oil for all health pathways. All the health impacts assessed have a total cost of around £198 million per year, which generates a cost per London resident of approximately £24 per year.

Table 4-8 Monetised Health Impacts per annum for the Greater London region (£, 2022).

Health pathways	NO_2	$PM_{2.5}$	
	Coal and oil	**Coal and oil**	**Wood**
Respiratory hospital admission	59,000	103,000	794,000
Mortality associated with chronic exposure	2,037,000	18,356,000	141,035,000
Asthma (Adults)	0	N/A	N/A
Diabetes	0	0	0
Lung Cancer	0	232,000	1,783,000
Asthma (Small Children)	21,000	N/A	N/A
Asthma (Older Children)	6,000	85,000	651,000
Cardiovascular hospital admission	N/A	0	0
CHD	N/A	1,761,000	13,526,000
Stroke	N/A	834,000	6,406,000
Productivity	N/A	1,186,000	9,115,000
Totals	**2,123,000**	**22,557,000**	**173,310,000**
	197,990,000		
Total per London Resident	**24.22**		

N/A: Not applicable

The assessment of the impact upon each health pathway and the monetised costs of each impact have also been calculated individually for each of the 15 LWBP participating boroughs. These costs and impacts are presented in a series of tables within the Annex.

The above outputs are produced following the approaches underpinning the Defra damage costs, and hence adhere to UK best practice guidance in the estimation and monetisation of such effects. As a complement, the analysis has also produced expressions of the mortality effects using alternative metrics that are more understandable to the public. Note: these effects are not additional to the mortality effects estimated above in terms of LYL – they are an alternative way of expressing the same effects. These effects have only been estimated for the $PM_{2.5}$ contribution, given this is the most prominent effect.

Summary of outdoor air pollution findings

The study finds that the contribution to $PM_{2.5}$ concentrations across the Greater London region from the burning of wood and coal and oil:

- Reduces life expectancy at birth for all persons of around 3 weeks (assuming individuals are exposed to air pollutant concentrations over their lifetime)
- Is associated with an effect on mortality equivalent to 284 deaths each year, at typical ages of death in 2019 in the UK (implying an average loss of life of around 11 years per death)

Estimating the number of deaths is very uncertain, and more uncertain than estimating years of life lost. As explored by COMEAP, the mortality effect associated with exposure to air pollution could be expressed as a relatively larger loss of life years associated with fewer deaths (i.e. 11 years of life lost across 284 deaths). Alternatively COMEAP also noted it is equally justifiable that a smaller loss of life per death is associated with a larger number of deaths, in particular given that much of the impact of air pollution on mortality is linked with cardiovascular deaths. Adopting the approach of COMEAP, it is equally reasonable therefore to consider the air pollution associated with domestic solid fuel burning in London makes a smaller contribution (loss of 2 life years per death) to a larger, 1600 deaths each year.

4.3.2 Sensitivity analysis

This section presents the sensitivity analysis of the impact of NO_2 and $PM_{2.5}$ concentrations upon health. Due to the inherent uncertainty in estimating and monetising this impact, the sensitivity analysis provides a lower and upper range within which the estimated is expected to fall. The range of sensitivity results have been calculated by adjusting the CRFs to a low and high factor, which generates a change in the health pathways included and in the monetary unit impacts. It should be noted that in some cases negative results on health impacts and monetisation of health impacts have been obtained. This is due to the lower limit of the specified CRF taken from the literature (used in the case of low sensitivity) being negative, i.e. in some studies an increase in pollution was associated with a reduction in health effects. It is recognised that this may appear counterintuitive, but simply represents the findings available from the underlying literature (and their strength and ability to account for other variables).

For comparison purposes, Table 4-9 and Table 4-10 also include the central case in addition to the low and high sensitivity cases.

Table 4-9 Assessment of specific health impacts for the Greater London region and damage cost sensitivity.

Health pathway	Incidence	NO_2			$PM_{2.5}$					
		Coal and oil			Coal and oil			Wood		
		Low	Central	High	Low	Central	High	Low	Central	High
Mortality associated with chronic exposure	LYL	10	44	96	299	395	440	2301	3,035	3,380
Respiratory hospital admission	# Hospital admissions	3	5	8	-6	9	25	-48	73	196
Cardiovascular hospital admission	# Hospital admissions	N/A	N/A	N/A	0	0	5	0	0	41
CHD	# New cases	N/A	N/A	N/A	-1	6	14	-7	48	109
Stroke	# New cases	N/A	N/A	N/A	-1	8	17	-5	59	133
Lung Cancer	# New cases	0	0	1	2	4	6	12	28	43
Asthma (Older Children)	# New cases	0	1	2	6	11	19	43	84	144
Asthma (Small Children)	# New cases	0	3	4	N/A	N/A	N/A	N/A	N/A	N/A
Asthma (Adults)	# New cases	0	0	4	N/A	N/A	N/A	N/A	N/A	N/A
Diabetes	# New cases	0	0	29	0	0	30	0	0	231

Table 4-10 Monetised Health Impacts for the Greater London region and damage cost sensitivity per year (£, 2022).

Health pathways	NO_2			$PM_{2.5}$					
	Coal and Oil			Coal and Oil			Wood		
	Low	Central	High	Low	Central	High	Low	Central	High
Respiratory hospital admission	12,000	59,000	142,000	-23,000	103,000	462,000	-176,000	794,000	3,549,000
Mortality associated with chronic exposure	335,000	2,037,000	5,561,000	10,420,000	18,356,000	25,484,000	80,058,000	141,035,000	195,798,000
Asthma (Adults)	0	0	1,885,000	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Diabetes	0	0	342,000	0	0	710,000	0	0	5,452,000
Lung Cancer	0	0	66,000	52,000	232,000	481,000	396,000	1,783,000	3,698,000
Asthma (Small Children)	3,000	21,000	31,000	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Asthma (Older Children)	0	6,000	12,000	43,000	85,000	145,000	334,000	651,000	1,111,000
Cardiovascular hospital admission	#N/A	#N/A	#N/A	0	0	98,000	0	0	751,000
CHD	#N/A	#N/A	#N/A	-126,000	1,761,000	5,365,000	-966,000	13,526,000	41,223,000
Stroke	#N/A	#N/A	#N/A	-76,000	834,000	1,895,000	-582,000	6,406,000	14,559,000
Productivity	#N/A	#N/A	#N/A	401,000	1,186,000	2,629,000	3,079,000	9,115,000	20,201,000
Total	**350,000**	**2,123,000**	**8,039,000**	**10,691,000**	**22,557,000**	**37,269,000**	**82,143,000**	**173,310,000**	**286,342,000**

Summary of sensitivity analysis findings

The results of the health impacts and the monetised health impacts vary depending on the CRF value applied. The application of a higher CRF value will lead to a greater expected impact. The variation in the use of different CRF values are known as changes to the 'sensitivity' of the analysis. For example, the mortality associated with chronic exposure due to $PM_{2.5}$ concentrations from wood combustion can go from £80m in a low-sensitivity analysis to almost £196m in a high-sensitivity analysis. The changes are even more relevant when comparing the results derived for $PM_{2.5}$ concentrations from wood combustion with those from coal and oil combustion. In the case of NO_2, the results differ less compared to the $PM_{2.5}$ results. It should be noted that some health impacts, such as cardiovascular hospital admissions due to $PM_{2.5}$ concentrations, lung cancer and asthma in adults due to NO_2 concentrations, and diabetes due to both pollutants' concentrations are not captured at a low or medium sensitivity level. This is because the link between exposure and impact is less researched in the underlying epidemiological evidence base, so there is less confidence in the quantitative relationships used to assess these conditions.

4.3.3 Indoor air pollution

The UK population spend an average of 80-90% of their time indoors, the majority of which (60%) is spent in their own household[53]. Given this, it is important to be mindful of the air quality within domestic settings, in addition to the more commonly considered ambient (or outdoor) air quality (as explored and assessed in preceding sections). To date, policy makers have typically focused their attention on improving outdoor air quality, with comparatively little emphasis, or acknowledgement, on the importance of reducing air pollution within UK homes. However, as concentrations of outdoor air pollutants continue to decline, there is a growing trend towards understanding the impact of indoor pollution among policy makers, scientists and health experts.

Indoor air pollution has a significant impact upon human health and globally has been linked to millions of deaths annually[54], especially in low- and middle-income countries[55]. It contributes to a number of health issues, including asthmatic symptoms, airborne respiratory infections, chronic obstructive pulmonary disease, cardiovascular disease and lung cancer[56]. Whilst there is a range of pollutants which contribute to indoor air pollution, including volatile organic compounds (VOCs), ozone (O_3) and sulphur dioxide (SO_2), it is NO_2 and PM which are most closely linked with health effects, and are the most frequently quantified. The inhalation of these particles within the home has been directly linked to lung and heart issues[57]. NO_2 concentrations are also prevalent within an indoor setting, and can similarly often exceed outdoor levels when gas stoves (hobs) are used for cooking[58]. Although studies are starting to make this health link, methods do not yet exist to quantify the impacts on health for the UK.

Further to this, in an environment where home working has become increasingly frequent, it is important to understand the impact upon productivity and mental well-being. There are also significant distributional elements to consider, as people who typically spend the greatest amount of time indoors – young children and older people – are also potentially most at risk from the effects of poor indoor air quality. Further to this, pregnant women and those living with existing health pre-conditions are also more likely to spend a greater amount of time indoors[59].

Indoor air pollution can be caused through a number of sources. Buildings located in high pollution hotspots are most at risk as outdoor pollution seeps into domestic homes through open windows and other entrances. However, pollution can also be produced indoors within domestic settings. Domestic solid fuel burning, such as wood and oil and coal is one such example. Research has explored the impact that the use of residential stoves has on indoor air pollution, finding that the daily average indoor PM concentrations when a stove was used were higher for $PM_{2.5}$ by 66%[60]. The introduction of more efficient appliances has helped to alleviate this issue, but it does not completely solve the problem of emissions of air pollutants generated. To illustrate this point, we look again at outdoor air pollution – as shown in the sections above, 2019 LAEI data has shown that wood-burning in the domestic sector is the second largest single source of $PM_{2.5}$ emissions in London, behind only road transport. The use of wood burning has also increased in recent years[61], in part driven as an attempt to reduce domestic heating costs, as stated across UK news sources[62]. There exist substantial differences between wood burning appliances such as fireplaces in terms of design, age and maintenance all of which also impact the level of pollutants emitted[63].

Many personal actions and behavioural changes can have a significant impact on improving air quality indoors. However, it is important to note that individual agency may be limited for some vulnerable individuals and certain socioeconomic and demographic groups. The most effective individual actions to improve indoor air quality are often rather simple – increasing ventilation and reducing emissions at source. In that sense, public

[53] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/831319/VO__statement_Final_12092019_CS__1_.pdf
[54] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7215772/
[55] https://apps.who.int/iris/rest/bitstreams/632228/retrieve
[56] https://www.researchgate.net/profile/Eduardo-De-Oliveira-Fernandes/publication/320878024_ENVIE_-_EU_co-ordination_action_on_indoor_air_quality_and_health_effects/data/5a0085ce4585159634ba4e8c/ENVIE-EU-co-ordination-action-on-indoor-air-quality-and-health-effects.pdf
[57] https://www.epa.gov/indoor-air-quality-iaq/indoor-particulate-matter
[58] https://www.epa.gov/indoor-air-quality-iaq/nitrogen-dioxides-impact-indoor-air-quality#Levels
[59] https://ec.europa.eu/health/scientific_committees/opinions_layman/en/indoor-air-pollution/index.htm#4
[60] https://eprints.whiterose.ac.uk/168893/1/atmosphere-11-01326-v2%20%282%29.pdf
[61] https://consult.defra.gov.uk/airquality/domestic-solid-fuel-regulations/
[62] https://www.newscientist.com/article/2336109-uk-energy-crisis-sparks-rush-for-firewood-despite-air-pollution-fears/
[63] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1124738/chief-medical-officers-annual-report-air-pollution-dec-2022.pdf

knowledge of indoor pollution and its effects are relatively limited. It is evident more can be done in the sphere of communication of the science, health impacts and of potential mitigating actions[64].

[64] https://uk-air.defra.gov.uk/library/reports.php?report_id=1101

5. DISTRIBUTIONAL ANALYSIS

5.1 APPROACH TO UNDERTAKING THE DISTRIBUTIONAL ANALYSIS

An evaluation was undertaken to understand the relationship between vulnerable social groups and solid fuel burning activities and air pollutant emissions. The evaluation comprised of two tasks:

The evaluation was carried out in two tasks:

1. Review of the relationship between source apportioned concentrations of $PM_{2.5}$ emitted from wood and solid fuel (oil and coal) burning activities and publicly available London borough demographic statistics.
2. Review of the relationship between activities declared in the Opinium led survey and London borough demographic statistics.

Task 1- Existing datasets

The main aim of this task was to understand whether wood burning activities and solid fuel use are likely to adversely impact specific social and/or demographic groups. $PM_{2.5}$ data published by the London Atmospheric Emission Inventory (LAEI) was used as a proxy to represent the overall exposure to air pollution and its potential effects for a given spatial region. As detailed in section 3.2.3 the use of $PM_{2.5}$ as a proxy was appropriate due to its influence on human health[65].

Two levels of spatial resolution were used to examine the potential public exposure to particles released by domestic wood burning activities and solid fuel use. The resolutions were:

- London borough resolution-provided insights as to whether there are any links between borough location, sensitive populations and exposure to particles generated by wood burning activities and solid fuel use.
- Lower Super Output Area (LSOA) resolution- provided a greater insight into the relationship between sensitive demographics and exposure to particles generated by wood burning activities and solid fuel use regardless of borough location.

The LAEI provides modelled air pollutant concentration values for the entirety of Greater London on a 1 km by 1 km grid. In its published format, many of these gridded values did not fall within the smaller LSOA spatial areas. As a result, the spatial aggregation was undertaken using an inverse distance weighting (IDW)[66] method to generate new concentration values across a gridded resolution of 100m across Greater London. This allowed some areas at boundary regions between the original 1km grid squares to have a concentration that better reflects exposure to $PM_{2.5}$ produced by domestic wood and solid fuel burning.

To understand the impacts on demographics compositions at borough level, a population weighted concentration mean was calculated and used (detailed in Table 4-4). The population weighted mean was chosen for this phase of the evaluation as it enabled a better comparison of variance in exposure across boroughs, reflecting different population sizes.

The concentration values for each level of analysis were compared to statistics published in the Ministry for Housing, Communities and Local Government's '*Indices of Multiple Deprivation'* (IMD) dataset (2019)[67]. This dataset provides an indication of the level of deprivation experienced across England. This task then proceeded through two steps based on each resolution considered:

- Step 1 – A 'high-level' review was undertaken where the IMD dataset was aggregated up to match population weighted concentration data at borough level.
- Step 2 – Spatial aggregation of the concentration data to allow comparison with population demographics living with within Lower Super Output Layer (LSOAs) spatial regions. LSOA's are spatial

[65] https://www.sciencedirect.com/science/article/pii/S0269749122013197
[66] https://pro.arcgis.com/en/pro-app/latest/help/analysis/geostatistical-analyst/how-inverse-distance-weighted-interpolation-works.htm
[67] https://www.gov.uk/government/statistics/english-indices-of-deprivation-2019

regions defined by population size (1,000 – 3,000 citizens) which are widely used by government bodies for the generation of population statistics.

Task 2- Opinium Survey

Task 2 used data abstracted from the Opinium survey under Element 1 to compare stated use of a fireplace and of a solid fuel stove by participants in each borough, with the corresponding borough IMD ratings used in Task 1. The analysis included a review of the responses from different demographic groups, to two selected questions related to the use of an open fireplace (Q65) and the use of a solid fuel stove (Q66). This was undertaken to identify whether particular social groups exhibited prevalent behaviours that could adversely impact the concentration of air pollutants. The results were a subset of the number of participants responding to the survey and do not include participants who stated that they do not have access to a fireplace or solid fuel stove.

The results of both sets of analysis are considered in terms of a Spearman's rank correlation coefficient value[68]. This value is given in a range between -1 and 1 which captures how closely related two variables are, and the nature of that relationship. E.g. 1 representing a perfect positive correlation between two ranked variables. For Task 1 and Task 2; the $PM_{2.5}$ concentration of a spatial location was ranked and compared to the same location's ranking value for a second factor, such as its level of deprivation. Box 5-1 details further information on the interpretation of Spearman Rank Correlation Coefficients.

Box 5-1: Approach to Spearman Rank Correlation Coefficients

A simplistic approach to Interpretating of the Spearman's rank correlation coefficient value:

- A score between 0.0 – 0.3 shows that there is no/very weak relationship between the two variables
- A score between 0.3 – 0.7 shows that there is a weak relationship between the two variables
- A score between 0.7 – 0.9 shows that there is a strong relationship between the two variables
- A score of 1 shows a perfect correlation between the two variables
- A score showing negative values represents a correlation in reverse (negative trend) and should be interpretated in the same way as points (1-4 above) (e.g. a score of -1 shows a perfect correlation between the two variables)

Example

A score of 1 represents that there is a linear relationship between pollutant concentration and the ascending deprivation group.

A score of -1 represents that there is a perfect correlation in the opposite direction (e.g. there is a linear relationship between pollutant concentration and descending deprivation group).

5.2 OVERVIEW OF LEVELS OF DEPRIVATION ACROSS LONDON

5.2.1 Approach to understanding level of economic deprivation

Borough resolution analysis

The IMD dataset contains deprivation scores for each Lower Super Output Area (LSOA) in London. Each LSOA within the London subset of the IMD dataset was assigned to the London borough that the LSOA sits within, forming borough groupings of LSOAs. The IMD deprivation score was averaged for each borough (across the LSOAs within each borough), producing an overall deprivation score for each borough. The boroughs were then ranked in ascending order by their deprivation score and assigned a quintile value[69] to reflect their level of deprivation in relation to all other boroughs within the London subset.

[68] https://www.rgs.org/CMSPages/GetFile.aspx?nodeguid=882169d2-8f96-4c55-84f5-fbb7614870e9&lang=en-GB
[69] https://www.bmj.com/content/309/6960/996

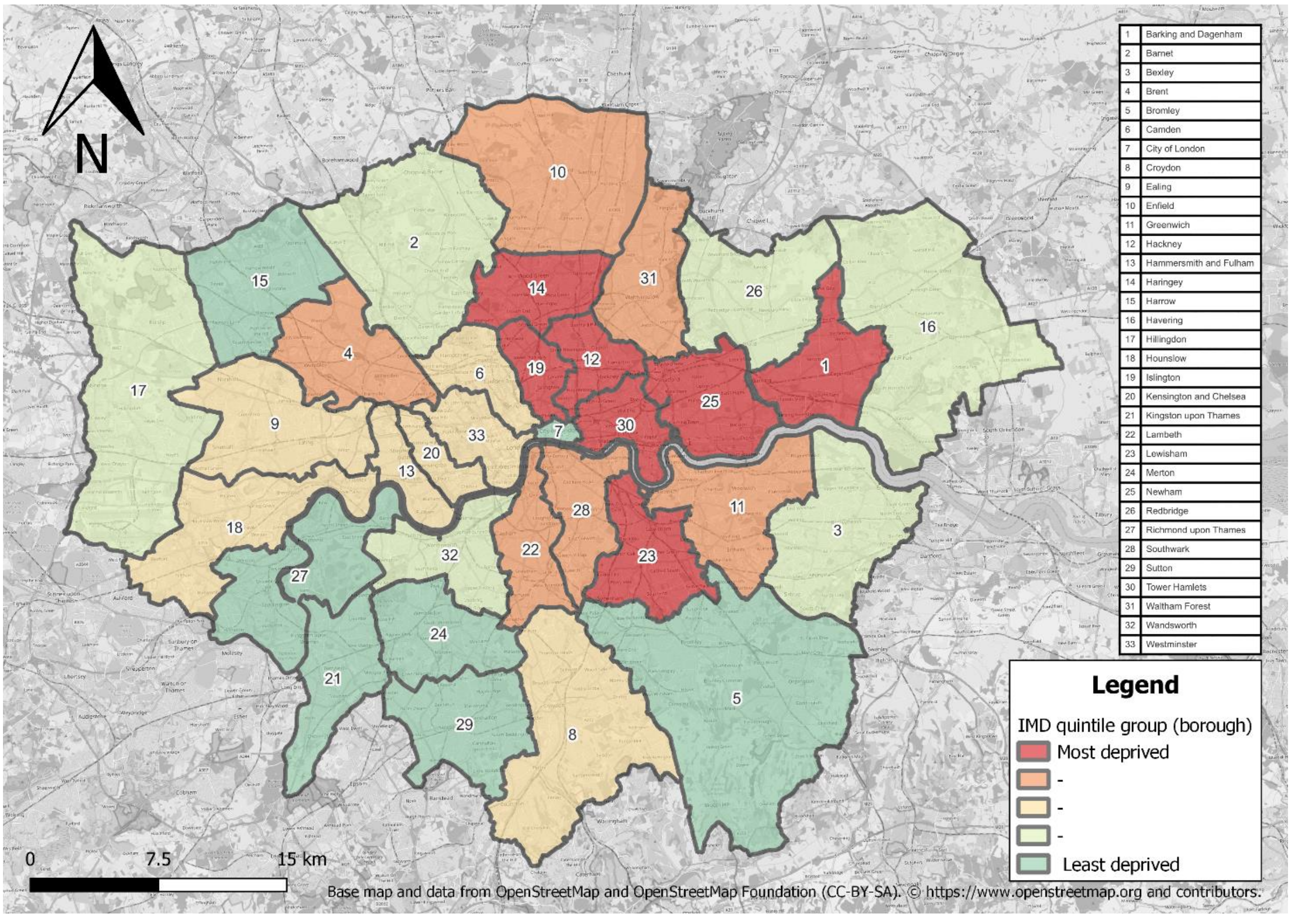
LSOA Resolution Analysis

The LSOA resolution analysis was undertaken using the same approach detailed for the borough resolution analysis. The LSOA resolution quintile value differs to those assigned to the borough resolution as the LSOA's were not grouped to form borough subsets. The LSOA quintile value was assigned based on the individual LSOA's deprivation score rank within the entire London subset (regardless of borough).

5.2.2 Overview of level of deprivation across London Boroughs

Figure 5-1 and Figure 5-2 illustrate the relationship between the IMD and geographic location, represented by the 32 London boroughs and the City of London. Both these datasets were used in Task 1.

Figure 5-1: Overview of IMD quintiles across London boroughs.



Note 1: The London borough numbering key is ordered alphabetically and is independent of the quintile grouping.

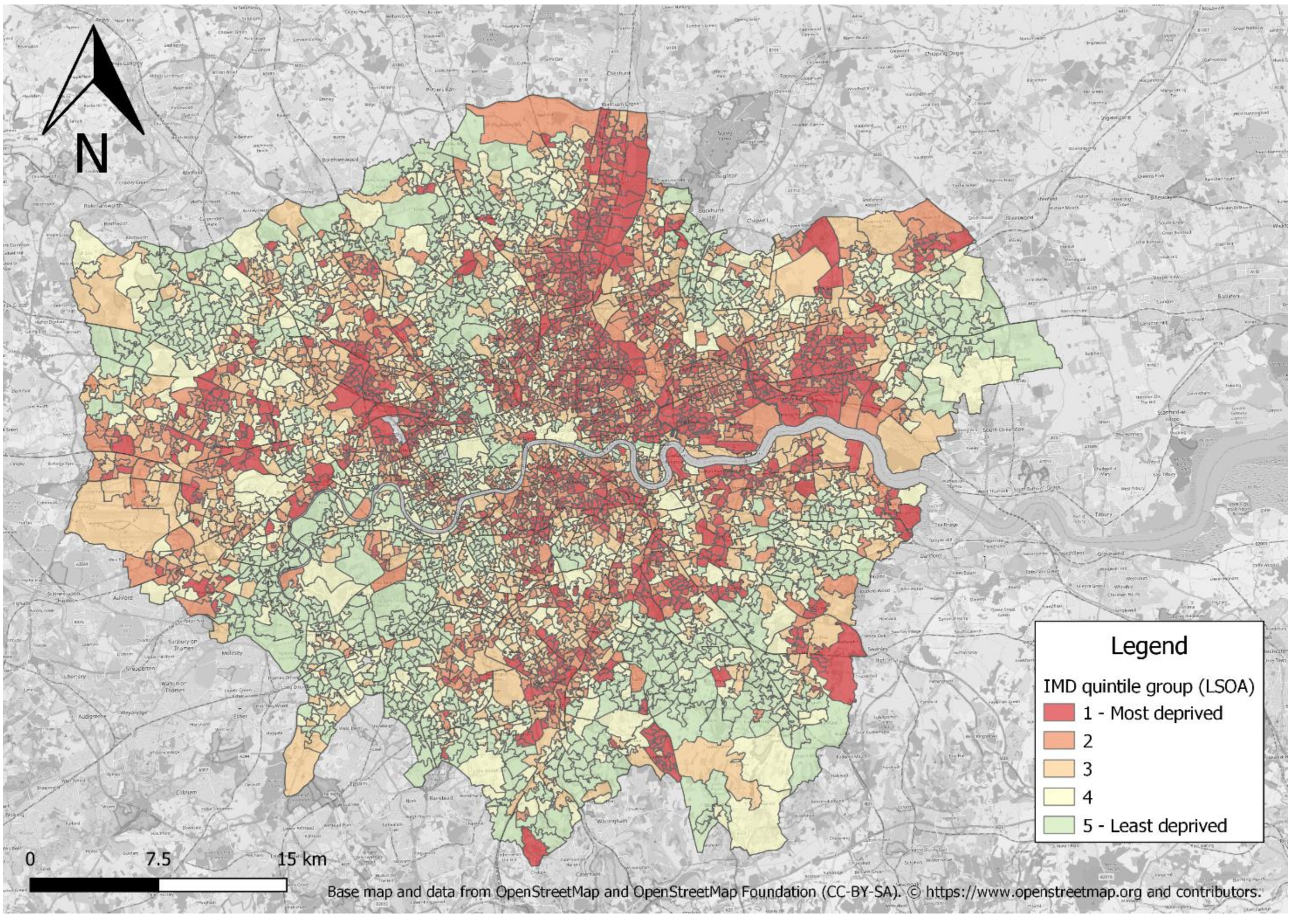
The figure shows that:

- The IMD database suggests that the most deprived areas of London are located in the central eastern boroughs with Barking, Hackney and Newham the most deprived.
- The database also suggests that boroughs located in the southern areas of greater London are likely to be the least deprived with Richmond, Kingston and Bromley ranked the three least deprived.

5.2.3 Overview of level of deprivation across London LSOAs

Figure 5-2 shows a visualisation of the relationship between London LSOAs and populations classed as the most and least deprived by the IMD ranking database. The figure shows that populations living in the most deprived LSOAs (quintile 1, shown in red) are present throughout Greater London, including areas where the overall level of deprivation is categorised as least deprived as shown in Figure 5-1.

Figure 5-2: Overview of IMD rankings across LSOAs.



5.3 KEY CONCLUSIONS FROM THE DISTRIBUTIONAL ANALYSIS

5.3.1 Results from Task 1

A summary of the key results drawn from Tasks 1 are presented in Table 5-1.

Table 5-1: Summary of results from the distributional analysis.

		Spearman Rank Correlation Coefficient			
Spatial resolution	Fuel	IMD	Citizens under the age of 16 (<16)	Citizens over the age of 65 (>65)	Ethnicity
Borough	Wood	0.39	Not estimated	Not estimated	Not estimated
Borough	Coal and oil	0.52	Not estimated	Not estimated	Not estimated
LSOA	Wood	0.08	0.07	-0.17	0.15
LSOA	Coal and oil	0.25	0.07	-0.37	0.17

The key findings from task 1 are:

- With respect to understanding the relationships between $PM_{2.5}$ produced by the use of each type of fuel and the level of deprivation of a spatial region:
  - The Spearman correlation rank coefficient value shows a weak (defined as a correlation score of 0.3 – 0.7) positive relationship between borough averaged level of deprivation and the $PM_{2.5}$ concentrations attributed to domestic wood burning activities or the domestic use of coal and oil fuels. I.e. this suggests that air pollutant concentrations are higher where there is a greater level of deprivation. However, the relationship is not strong.

    - The Spearman correlation rank coefficient value shows a very weak positive relationship between the individual level of deprivation of LSOA’s across London and the $PM_{2.5}$ concentrations attributed to domestic wood burning activities or the domestic use of coal and oil fuels. I.e. this suggests that air pollutant concentrations are higher where there is a greater level of deprivation, but the relationship is even weaker when viewed at LSOA level.
- There is a very weak correlation between the concentration of $PM_{2.5}$ produced by domestic wood burning activities or through the domestic use of coal and oil fuels, and areas where there are high proportions of other sensitive demographics (when assessed at LSOA level).

5.3.2 Results from Task 2

The key findings from task 2 are:

- There was a very weak relationship found between the use of an open fireplace or a solid fuel stove and the overall level of deprivation of the borough that the survey participant resided within.
- Age is likely to play a factor in the use of an open fireplace. The results from the survey showed that those in younger age groups tended to use an open fireplace more than those in the older groups.

  The results from the survey also showed that age, gender and ethnicity had no influence in the level of domestic use of a solid fuel stove.

Summary of the Distributional Analysis

The results from the distributional analysis show that there is no significant relationship between exposure to $PM_{2.5}$ from solid fuel burning and demographic characteristics. Therefore, there is no evidence from this analysis to suggest that the exposure to air pollution differs between different demographic groups.

6. ANNEX

6.1 HEALTH IMPACTS AND MONETISED HEALTH IMPACTS

This section presents the health impacts and the monetisation of these impacts for the selected health pathways in the 15 boroughs that are participating in the LWBP. It is worth noting that for many health pathways the results were zero because the CRFs for the central sensitivity have very low values and do not capture the effects at low $PM_{2.5}$ and NO_2 concentrations.

All health impacts are estimated based on a per year of exposure basis.

It should also be noted that the health impact assessment methods are better suited, and hence more robustly applied, to a wider geographical area. Consequently these results at borough level will have a higher uncertainty, and should therefore be treated as more illustrative, than the results presented in the main body of the report covering Greater London.

6.1.1 Brent

The results of the health impacts caused by NO_2 and $PM_{2.5}$ concentrations in Brent are presented in Table 6-1. For each pollutant, the relevant health impact pathways were considered. The table shows that as a result of domestic solid fuel burning a total of approximately 117 life years are lost each year as a result of wood burning. In the case of coal and oil burning, approximately 13 life years are lost each year as a result of $PM_{2.5}$ concentrations generated by emissions from this activity. Further to this, the equivalent of three new cases of asthma in older children and three new hospital admissions could be attributed to domestic wood burning.

Table 6-1 Assessment of specific health impacts for Brent per year of exposure.

Health pathway	Metric	NO_2	$PM_{2.5}$		Total $PM_{2.5}$
		Coal and oil	Coal and oil	Wood	
Mortality associated with chronic exposure	LYL	2	13	117	130
Respiratory hospital admission	# Hospital admissions	0	0	3	3
Cardiovascular hospital admission	# Hospital admissions	N/A	0	0	0
CHD	# New cases	N/A	0	2	2
Stroke	# New cases	N/A	0	2	3
Lung Cancer	# New cases	0	0	1	1
Asthma (Older Children)	# New cases	0	0	3	4
Asthma (Small Children)	# New cases	0	N/A	N/A	0
Asthma (Adults)	# New cases	0	N/A	N/A	0
Diabetes	# New cases	0	0	0	0

N/A: Not applicable

The table below presents the monetised costs as a result of the concentrations of NO_2, and $PM_{2.5}$ associated with domestic solid fuel burning in Brent. The greatest cost is estimated to be attributed to an increase in mortality associated with chronic exposure, amounting to over £6 million per year, with the costs associated with all other health pathways significantly lower. A greater cost is borne as a result of wood burning compared to the burning of coal and oil for all health pathways.

Table 6-2 Monetised Health Impacts for Brent per year of exposure (£, 2022).

Health pathways	NO_2	$PM_{2.5}$		Total $PM_{2.5}$
	Coal and oil	Coal and oil	Wood	
Respiratory hospital admission	2,000	3,000	31,000	34,000
Mortality associated with chronic exposure	70,000	613,000	5,426,000	6,039,000
Asthma (Adults)	0	N/A	N/A	0
Diabetes	0	0	0	0
Lung Cancer	0	8,000	69,000	77,000
Asthma (Small Children)	1,000	N/A	N/A	0
Asthma (Older Children)	0	3,000	25,000	28,000
Cardiovascular hospital admission	N/A	0	0	0
CHD	N/A	59,000	520,000	579,000
Stroke	N/A	28,000	246,000	274,000
Productivity	N/A	40,000	351,000	391,000
Total	**73,000**	**754,000**	**6,668,000**	**7,422,000**

N/A: Not applicable

6.1.2 Camden

The results of the health impacts caused by NO_2 and $PM_{2.5}$ concentrations in Camden are presented in Table 6-3. For each pollutant, the relevant health impact pathways were considered. The table shows that as a result of domestic solid fuel burning a total of approximately 69 life years are lost each year as a result of wood burning. In the case of coal and oil burning, approximately 9 life years are lost each year as a result of $PM_{2.5}$ concentrations generated by emissions from this activity. Further to this, approximately two new cases of asthma in older children and two new hospital admissions could be attributed to domestic wood burning.

Table 6-3 Assessment of specific health impacts for Camden per year of exposure.

Health pathway	Metric	NO_2	$PM_{2.5}$		Total $PM_{2.5}$
		Coal and oil	Coal and oil	Wood	
Mortality associated with chronic exposure	LYL	2	9	69	79
Respiratory hospital admission	# Hospital admissions	0	0	2	2
Cardiovascular hospital admission	# Hospital admissions	N/A	0	0	0
CHD	# New cases	N/A	0	1	1
Stroke	# New cases	N/A	0	1	2
Lung Cancer	# New cases	0	0	1	1
Asthma (Older Children)	# New cases	0	0	2	2
Asthma (Small Children)	# New cases	0	N/A	N/A	0
Asthma (Adults)	# New cases	0	N/A	N/A	0
Diabetes	# New cases	0	0	0	0

N/A: Not applicable

The table below presents the monetised costs as a result of the concentrations of NO_2 and $PM_{2,5}$ associated with domestic solid fuel burning in Camden. The greatest cost is estimated to be attributed to an increase in mortality associated with chronic exposure to $PM_{2.5}$, amounting to over £3.6 million per year, with the costs associated with all other health pathways significantly lower. A greater cost is borne as a result of wood burning compared to the burning of coal and oil for all health pathways.

Table 6-4 Monetised Health Impacts for Camden (£, 2022) per year of exposure.

Health pathways	NO_2	$PM_{2.5}$		Total $PM_{2.5}$
	Coal and oil	Coal and oil	Wood	
Respiratory hospital admission	2,000	2,000	18,000	20,000
Mortality associated with chronic exposure	70,000	440,000	3,229,000	3,669,000
Asthma (Adults)	0	N/A	N/A	0
Diabetes	0	0	0	0
Lung Cancer	0	6,000	41,000	47,000
Asthma (Small Children)	1,000	N/A	N/A	0
Asthma (Older Children)	0	2,000	15,000	17,000
Cardiovascular hospital admission	N/A	0	0	0
CHD	N/A	42,000	310,000	352,000
Stroke	N/A	20,000	147,000	167,000
Productivity	N/A	28,000	209,000	237,000
Total	**73,000**	**540,000**	**3,969,000**	**4,509,000**

N/A: Not applicable

6.1.3 Croydon

The results of the health impacts caused by NO_2 and $PM_{2.5}$ concentrations in Croydon are presented in Table 6-5. For each pollutant, the relevant health impact pathways were considered. The table shows that as a result of domestic solid fuel burning a total of approximately 131 life years are lost each year as a result of wood burning. In the case of coal and oil burning, approximately 17 life years are lost each year as a result of $PM_{2.5}$ concentrations generated by emissions from this activity. Further to this, approximately four new cases of asthma in older children, four new hospital admissions and three new cases of stroke could be attributed to domestic wood burning.

Table 6-5 Assessment of specific health impacts for Croydon per year of exposure.

Health pathway	Metric	NO_2	$PM_{2.5}$		Total $PM_{2.5}$
		Coal and oil	Coal and oil	Wood	
Mortality associated with chronic exposure	LYL	2	17	131	148
Respiratory hospital admission	# Hospital admissions	0	0	3	4
Cardiovascular hospital admission	# Hospital admissions	N/A	0	0	0
CHD	# New cases	N/A	0	2	2
Stroke	# New cases	N/A	0	3	3
Lung Cancer	# New cases	0	0	1	1
Asthma (Older Children)	# New cases	0	0	4	4
Asthma (Small Children)	# New cases	0	N/A	N/A	0
Asthma (Adults)	# New cases	0	N/A	N/A	0
Diabetes	# New cases	0	0	0	0

N/A: Not applicable

The table below presents the monetised costs as a result of the concentrations of NO_2, and $PM_{2,5}$ associated with domestic solid fuel burning in Croydon. The greatest cost is estimated to be attributed to an increase in mortality associated with chronic exposure, amounting to over £6.8 million per year, with the costs associated with all other health pathways significantly lower. A greater cost is borne as a result of wood burning compared to the burning of coal and oil for all health pathways.

Table 6-6 Monetised Health Impacts for Croydon (£, 2022) per year of exposure.

Health pathways	NO_2	$PM_{2.5}$		Total $PM_{2.5}$
	Coal and oil	Coal and oil	Wood	
Respiratory hospital admission	2,000	4,000	34,000	38,000
Mortality associated with chronic exposure	81,000	784,000	6,100,000	6,884,000
Asthma (Adults)	0	N/A	N/A	0
Diabetes	0	0	0	0
Lung Cancer	0	10,000	77,000	87,000
Asthma (Small Children)	1,000	N/A	N/A	0
Asthma (Older Children)	0	4,000	28,000	32,000
Cardiovascular hospital admission	N/A	0	0	0
CHD	N/A	75,000	585,000	660,000
Stroke	N/A	36,000	277,000	313,000
Productivity	N/A	51,000	394,000	445,000
Total	**84,000**	**964,000**	**7,495,000**	**8,459,000**

N/A: Not applicable

6.1.4 Ealing

The results of the health impacts caused by NO_2 and $PM_{2.5}$ concentrations in Ealing are presented in Table 6-7. For each pollutant, the relevant health impact pathways were considered. The table shows that as a result of domestic solid fuel burning a total of approximately 124 life years are lost each year as a result of wood burning. In the case of coal and oil burning, approximately 15 life years are lost each year as a result of $PM_{2.5}$ concentrations generated by emissions from this activity. Further to this, approximately four new cases of asthma in older children and four new hospital admissions could be attributed to domestic wood burning.

Table 6-7 Assessment of specific health impacts for Ealing per year of exposure.

Health pathway	Metric	NO_2	$PM_{2.5}$		Total $PM_{2.5}$
		Coal and oil	Coal and oil	Wood	
Mortality associated with chronic exposure	LYL	2	15	124	139
Respiratory hospital admission	# Hospital admissions	0	0	3	3
Cardiovascular hospital admission	# Hospital admissions	N/A	0	0	0
CHD	# New cases	N/A	0	2	2
Stroke	# New cases	N/A	0	2	3
Lung Cancer	# New cases	0	0	1	1
Asthma (Older Children)	# New cases	0	0	3	4
Asthma (Small Children)	# New cases	0	N/A	N/A	0
Asthma (Adults)	# New cases	0	N/A	N/A	0
Diabetes	# New cases	0	0	0	0

N/A: Not applicable

The table below presents the monetised costs as a result of the concentrations of NO_2, and $PM_{2,5}$ associated with domestic solid fuel burning in Ealing. The greatest cost is estimated to be attributed to an increase in mortality associated with chronic exposure, amounting to over £6.4 million per year, with the costs associated with all other health pathways significantly lower. A greater cost is borne as a result of wood burning compared to the burning of coal and oil for all health pathways.

Table 6-8 Monetised Health Impacts for Ealing (£, 2022) per year of exposure.

Health pathways	NO_2	$PM_{2.5}$		Total $PM_{2.5}$
	Coal and oil	Coal and oil	Wood	
Respiratory hospital admission	2,000	4,000	32,000	36,000
Mortality associated with chronic exposure	76,000	704,000	5,745,000	6,449,000
Asthma (Adults)	0	N/A	N/A	0
Diabetes	0	0	0	0
Lung Cancer	0	9,000	73,000	82,000
Asthma (Small Children)	1,000	N/A	N/A	0
Asthma (Older Children)	0	3,000	27,000	30,000
Cardiovascular hospital admission	N/A	0	0	0
CHD	N/A	68,000	551,000	619,000
Stroke	N/A	32,000	261,000	293,000
Productivity	N/A	45,000	371,000	416,000
Total	**79,000**	**865,000**	**7,060,000**	**7,925,000**

N/A: Not applicable

6.1.5 Haringey

The results of the health impacts caused by NO_2 and $PM_{2.5}$ concentrations in Haringey are presented in Table 6-9. For each pollutant, the relevant health impact pathways were considered. The table shows that as a result of domestic solid fuel burning a total of approximately 110 life years are lost each year as a result of wood burning. In the case of coal and oil burning, approximately 13 life years are lost each year as a result of $PM_{2.5}$ concentrations generated by emissions from this activity. Further to this, approximately three new cases of asthma in older children and three new hospital admissions could be attributed to domestic wood burning.

Table 6-9 Assessment of specific health impacts for Haringey per year of exposure.

Health pathway	Metric	NO_2	$PM_{2.5}$		Total $PM_{2.5}$
		Coal and oil	Coal and oil	Wood	
Mortality associated with chronic exposure	LYL	1	13	110	123
Respiratory hospital admission	# Hospital admissions	0	0	3	3
Cardiovascular hospital admission	# Hospital admissions	N/A	0	0	0
CHD	# New cases	N/A	0	2	2
Stroke	# New cases	N/A	0	2	2
Lung Cancer	# New cases	0	0	1	1
Asthma (Older Children)	# New cases	0	0	3	3
Asthma (Small Children)	# New cases	0	N/A	N/A	0
Asthma (Adults)	# New cases	0	N/A	N/A	0
Diabetes	# New cases	0	0	0	0

N/A: Not applicable

The table below presents the monetised costs as a result of the concentrations of NO_2, and $PM_{2,5}$ associated with domestic solid fuel burning in Haringey. The greatest cost is estimated to be attributed to an increase in mortality associated with chronic exposure, amounting to over £5.7 million per year, with the costs associated with all other health pathways significantly lower. A greater cost is borne as a result of wood burning compared to the burning of coal and oil for all health pathways.

Table 6-10 Monetised Health Impacts for Haringey (£, 2022) per year of exposure.

Health pathways	NO_2	$PM_{2.5}$		Total $PM_{2.5}$
	Coal and oil	Coal and oil	Wood	
Respiratory hospital admission	2,000	3,000	29,000	32,000
Mortality associated with chronic exposure	65,000	605,000	5,108,000	5,713,000
Asthma (Adults)	0	N/A	N/A	0
Diabetes	0	0	0	0
Lung Cancer	0	8,000	65,000	73,000
Asthma (Small Children)	1,000	N/A	N/A	0
Asthma (Older Children)	0	3,000	24,000	27,000
Cardiovascular hospital admission	N/A	0	0	0
CHD	N/A	58,000	490,000	548,000
Stroke	N/A	27,000	232,000	259,000
Productivity	N/A	39,000	330,000	369,000
Total	**68,000**	**743,000**	**6,278,000**	**7,021,000**

N/A: Not applicable

6.1.6 Islington

The results of the health impacts caused by NO_2 and $PM_{2.5}$ concentrations in Islington are presented in Table 6-11. For each pollutant, the relevant health impact pathways were considered. The table shows that as a result of domestic solid fuel burning a total of approximately 71 life years are lost each year as a result of wood burning. In the case of coal and oil burning, approximately 10 life years are lost each year as a result of $PM_{2.5}$ concentrations generated by emissions from this activity. Further to this, approximately two new cases of asthma in older children and two new hospital admissions could be attributed to domestic wood burning.

Table 6-11 Assessment of specific health impacts for Islington per year of exposure.

Health pathway	Metric	NO_2	$PM_{2.5}$		Total $PM_{2.5}$
		Coal and oil	Coal and oil	Wood	
Mortality associated with chronic exposure	LYL	1	10	71	81
Respiratory hospital admission	# Hospital admissions	0	0	2	2
Cardiovascular hospital admission	# Hospital admissions	N/A	0	0	0
CHD	# New cases	N/A	0	1	1
Stroke	# New cases	N/A	0	1	2
Lung Cancer	# New cases	0	0	1	1
Asthma (Older Children)	# New cases	0	0	2	2
Asthma (Small Children)	# New cases	0	N/A	N/A	0
Asthma (Adults)	# New cases	0	N/A	N/A	0
Diabetes	# New cases	0	0	0	0

N/A: Not applicable

The table below presents the monetised costs as a result of the concentrations of NO_2, and $PM_{2,5}$ associated with domestic solid fuel burning in Islington. The greatest cost is estimated to be attributed to an increase in mortality associated with chronic exposure, amounting to over £3.7 million per year, with the costs associated with all other health pathways significantly lower. A greater cost is borne as a result of wood burning compared to the burning of coal and oil for all health pathways.

Table 6-12 Monetised Health Impacts for Islington (£, 2022) per year of exposure.

Health pathways	NO_2	$PM_{2.5}$		Total $PM_{2.5}$
	Coal and oil	Coal and oil	Wood	
Respiratory hospital admission	2,000	3,000	19,000	22,000
Mortality associated with chronic exposure	61,000	479,000	3,302,000	3,781,000
Asthma (Adults)	0	N/A	N/A	0
Diabetes	0	0	0	0
Lung Cancer	0	6,000	42,000	48,000
Asthma (Small Children)	1,000	N/A	N/A	0
Asthma (Older Children)	0	2,000	15,000	17,000
Cardiovascular hospital admission	N/A	0	0	0
CHD	N/A	46,000	317,000	363,000
Stroke	N/A	22,000	150,000	172,000
Productivity	N/A	31,000	213,000	244,000
Total	**64,000**	**589,000**	**4,058,000**	**4,647,000**

N/A: Not applicable

6.1.7 Kensington and Chelsea

The results of the health impacts caused by NO_2 and $PM_{2.5}$ concentrations in Kensington and Chelsea are presented in Table 6-13. For each pollutant, the relevant health impact pathways were considered. The table shows that as a result of domestic solid fuel burning a total of approximately 62 life years are lost each year as a result of wood burning. In the case of coal and oil burning, approximately 8 life years are lost each year as a result of $PM_{2.5}$ concentrations generated by emissions from this activity. Further to this, approximately two new cases of asthma in older children could be attributed to domestic wood burning.

Table 6-13 Assessment of specific health impacts for Kensington and Chelsea per year of exposure.

Health pathway	Metric	NO_2	$PM_{2.5}$		Total $PM_{2.5}$
		Coal and oil	Coal and oil	Wood	
Mortality associated with chronic exposure	LYL	1	8	62	70
Respiratory hospital admission	# Hospital admissions	0	0	1	2
Cardiovascular hospital admission	# Hospital admissions	N/A	0	0	0
CHD	# New cases	N/A	0	1	1
Stroke	# New cases	N/A	0	1	1
Lung Cancer	# New cases	0	0	1	1
Asthma (Older Children)	# New cases	0	0	2	2
Asthma (Small Children)	# New cases	0	N/A	N/A	0
Asthma (Adults)	# New cases	0	N/A	N/A	0
Diabetes	# New cases	0	0	0	0

N/A: Not applicable

The table below presents the monetised costs as a result of the concentrations of NO_2, and $PM_{2,5}$ associated with domestic solid fuel burning in Kensington and Chelsea. The greatest cost is estimated to be attributed to an increase in mortality associated with chronic exposure, amounting to over £3.2 million per year, with the costs associated with all other health pathways significantly lower. A greater cost is borne as a result of wood burning compared to the burning of coal and oil for all health pathways.

Table 6-14 Monetised Health Impacts for Kensington and Chelsea (£, 2022) per year of exposure.

Health pathways	NO_2	$PM_{2.5}$		Total $PM_{2.5}$
	Coal and oil	Coal and oil	Wood	
Respiratory hospital admission	2,000	2,000	16,000	18,000
Mortality associated with chronic exposure	55,000	357,000	2,888,000	3,245,000
Asthma (Adults)	0	N/A	N/A	0
Diabetes	0	0	0	0
Lung Cancer	0	5,000	37,000	42,000
Asthma (Small Children)	1,000	N/A	N/A	0
Asthma (Older Children)	0	2,000	13,000	15,000
Cardiovascular hospital admission	N/A	0	0	0
CHD	N/A	34,000	277,000	311,000
Stroke	N/A	16,000	131,000	147,000
Productivity	N/A	23,000	187,000	210,000
Total	**58,000**	**439,000**	**3,549,000**	**3,988,000**

N/A: Not applicable

6.1.8 Kingston upon Thames

The results of the health impacts caused by NO_2 and $PM_{2.5}$ concentrations in Kingston upon Thames are presented in Table 6-15. For each pollutant, the relevant health impact pathways were considered. The table shows that as a result of domestic solid fuel burning a total of approximately 51 life years are lost each year as a result of wood burning. In the case of coal and oil burning, approximately 8 life years are lost each year as a result of $PM_{2.5}$ concentrations generated by emissions from this activity. Further to this, approximately one new case of asthma in older children, CHD and stroke and one new hospital admission could be attributed to domestic wood burning.

Table 6-15 Assessment of specific health impacts for Kingston upon Thames per year of exposure.

Health pathway	Metric	NO_2	$PM_{2.5}$		Total $PM_{2.5}$
		Coal and oil	Coal and oil	Wood	
Mortality associated with chronic exposure	LYL	1	8	51	59
Respiratory hospital admission	# Hospital admissions	0	0	1	1
Cardiovascular hospital admission	# Hospital admissions	N/A	0	0	0
CHD	# New cases	N/A	0	1	1
Stroke	# New cases	N/A	0	1	1
Lung Cancer	# New cases	0	0	0	1
Asthma (Older Children)	# New cases	0	0	1	2
Asthma (Small Children)	# New cases	0	N/A	N/A	0
Asthma (Adults)	# New cases	0	N/A	N/A	0
Diabetes	# New cases	0	0	0	0

N/A: Not applicable

The table below presents the monetised costs as a result of the concentrations of NO_2, and $PM_{2,5}$ associated with domestic solid fuel burning in Kingston upon Thames. The greatest cost is estimated to be attributed to an increase in mortality associated with chronic exposure, amounting to over £2.7 million per year, with the costs associated with all other health pathways significantly lower. A greater cost is borne as a result of wood burning compared to the burning of coal and oil for all health pathways.

Table 6-16 Monetised Health Impacts for Kingston upon Thames (£, 2022) per year of exposure.

Health pathways	NO_2	$PM_{2.5}$		Total $PM_{2.5}$
	Coal and oil	Coal and oil	Wood	
Respiratory hospital admission	1,000	2,000	13,000	15,000
Mortality associated with chronic exposure	34,000	369,000	2,366,000	2,735,000
Asthma (Adults)	0	N/A	N/A	0
Diabetes	0	0	0	0
Lung Cancer	0	5,000	30,000	35,000
Asthma (Small Children)	0	N/A	N/A	0
Asthma (Older Children)	0	2,000	11,000	13,000
Cardiovascular hospital admission	N/A	0	0	0
CHD	N/A	35,000	227,000	262,000
Stroke	N/A	17,000	107,000	124,000
Productivity	N/A	24,000	153,000	177,000
Total	**35,000**	**454,000**	**2,907,000**	**3,361,000**

N/A: Not applicable

6.1.9 Lewisham

The results of the health impacts caused by NO_2 and $PM_{2.5}$ concentrations in Lewisham are presented in Table 6-17. For each pollutant, the relevant health impact pathways were considered. The table shows that as a result of domestic solid fuel burning a total of approximately 116 life years are lost each year as a result of wood burning. In the case of coal and oil burning, approximately 16 life years are lost each year as a result of $PM_{2.5}$ concentrations generated by emissions from this activity. Further to this, approximately three new cases of asthma in older children and three new hospital admissions could be attributed to domestic wood burning.

Table 6-17 Assessment of specific health impacts for Lewisham per year of exposure.

Health pathway	Metric	NO_2	$PM_{2.5}$		Total $PM_{2.5}$
		Coal and oil	Coal and oil	Wood	
Mortality associated with chronic exposure	LYL	2	16	116	132
Respiratory hospital admission	# Hospital admissions	0	0	3	3
Cardiovascular hospital admission	# Hospital admissions	N/A	0	0	0
CHD	# New cases	N/A	0	2	2
Stroke	# New cases	N/A	0	2	3
Lung Cancer	# New cases	0	0	1	1
Asthma (Older Children)	# New cases	0	0	3	4
Asthma (Small Children)	# New cases	0	N/A	N/A	0
Asthma (Adults)	# New cases	0	N/A	N/A	0
Diabetes	# New cases	0	0	0	0

N/A: Not applicable

The table below presents the monetised costs as a result of the concentrations of NO_2, and $PM_{2.5}$ associated with domestic solid fuel burning in Lewisham. The greatest cost is estimated to be attributed to an increase in mortality associated with chronic exposure, amounting to over £6.1 million per year, with the costs associated with all other health pathways significantly lower. A greater cost is borne as a result of wood burning compared to the burning of coal and oil for all health pathways.

Table 6-18 Monetised Health Impacts for Lewisham (£, 2022) per year of exposure.

Health pathways	NO_2	$PM_{2.5}$		Total $PM_{2.5}$
	Coal and oil	Coal and oil	Wood	
Respiratory hospital admission	2,000	4,000	30,000	34,000
Mortality associated with chronic exposure	78,000	747,000	5,368,000	6,115,000
Asthma (Adults)	0	N/A	N/A	0
Diabetes	0	0	0	0
Lung Cancer	0	9,000	68,000	77,000
Asthma (Small Children)	1,000	N/A	N/A	0
Asthma (Older Children)	0	3,000	25,000	28,000
Cardiovascular hospital admission	N/A	0	0	0
CHD	N/A	72,000	515,000	587,000
Stroke	N/A	34,000	244,000	278,000
Productivity	N/A	48,000	347,000	395,000
Total	**81,000**	**917,000**	**6,597,000**	**7,514,000**

N/A: Not applicable

6.1.10 Merton

The results of the health impacts caused by NO_2 and $PM_{2.5}$ concentrations in Merton are presented in Table 6-19. For each pollutant, the relevant health impact pathways were considered. The table shows that as a result of domestic solid fuel burning a total of approximately 86 life years are lost each year as a result of wood burning. In the case of coal and oil burning, approximately 11 life years are lost each year as a result of $PM_{2.5}$ concentrations generated by emissions from this activity. Further to this, approximately two new cases of asthma in older children and stroke and two new hospital admissions could be attributed to domestic wood burning.

Table 6-19 Assessment of specific health impacts for Merton per year of exposure.

Health pathway	Metric	NO_2	$PM_{2.5}$		Total $PM_{2.5}$
		Coal and oil	Coal and oil	Wood	
Mortality associated with chronic exposure	LYL	1	11	86	97
Respiratory hospital admission	# Hospital admissions	0	0	2	2
Cardiovascular hospital admission	# Hospital admissions	N/A	0	0	0
CHD	# New cases	N/A	0	1	2
Stroke	# New cases	N/A	0	2	2
Lung Cancer	# New cases	0	0	1	1
Asthma (Older Children)	# New cases	0	0	2	3
Asthma (Small Children)	# New cases	0	N/A	N/A	0
Asthma (Adults)	# New cases	0	N/A	N/A	0
Diabetes	# New cases	0	0	0	0

N/A: Not applicable

The table below presents the monetised costs as a result of the concentrations of NO_2, and $PM_{2.5}$ associated with domestic solid fuel burning in Merton. The greatest cost is estimated to be attributed to an increase in mortality associated with chronic exposure, amounting to over £4.5 million per year, with the costs associated with all other health pathways significantly lower. A greater cost is borne as a result of wood burning compared to the burning of coal and oil for all health pathways.

Table 6-20 Monetised Health Impacts for Merton (£, 2022) per year of exposure.

Health pathways	NO_2	$PM_{2.5}$		Total $PM_{2.5}$
	Coal and oil	Coal and oil	Wood	
Respiratory hospital admission	2,000	3,000	22,000	25,000
Mortality associated with chronic exposure	52,000	524,000	3,976,000	4,500,000
Asthma (Adults)	0	N/A	N/A	0
Diabetes	0	0	0	0
Lung Cancer	0	7,000	50,000	57,000
Asthma (Small Children)	1,000	N/A	N/A	0
Asthma (Older Children)	0	2,000	18,000	20,000
Cardiovascular hospital admission	N/A	0	0	0
CHD	N/A	50,000	381,000	431,000
Stroke	N/A	24,000	181,000	205,000
Productivity	N/A	34,000	257,000	291,000
Total	**55,000**	**644,000**	**4,885,000**	**5,529,000**

N/A: Not applicable

6.1.11 Richmond upon Thames

The results of the health impacts caused by NO_2 and $PM_{2.5}$ concentrations in Richmond upon Thames are presented in Table 6-21. For each pollutant, the relevant health impact pathways were considered. The table shows that as a result of domestic solid fuel burning a total of approximately 61 life years are lost each year as a result of wood burning. In the case of coal and oil burning, approximately 8 life years are lost each year as a result of $PM_{2.5}$ concentrations generated by emissions from this activity. Further to this, approximately two new cases of asthma in older children could be attributed to domestic wood burning.

Table 6-21 Assessment of specific health impacts for Richmond upon Thames per year of exposure.

Health pathway	Metric	NO_2	$PM_{2.5}$		Total $PM_{2.5}$
		Coal and oil	Coal and oil	Wood	
Mortality associated with chronic exposure	LYL	1	8	61	69
Respiratory hospital admission	# Hospital admissions	0	0	1	2
Cardiovascular hospital admission	# Hospital admissions	N/A	0	0	0
CHD	# New cases	N/A	0	1	1
Stroke	# New cases	N/A	0	1	1
Lung Cancer	# New cases	0	0	1	1
Asthma (Older Children)	# New cases	0	0	2	2
Asthma (Small Children)	# New cases	0	N/A	N/A	0
Asthma (Adults)	# New cases	0	N/A	N/A	0
Diabetes	# New cases	0	0	0	0

N/A: Not applicable

The table below presents the monetised costs as a result of the concentrations of NO_2, and $PM_{2,5}$ associated with domestic solid fuel burning in Richmond upon Thames. The greatest cost is estimated to be attributed to an increase in mortality associated with chronic exposure, amounting to over £3.1 million per year, with the costs associated with all other health pathways significantly lower. A greater cost is borne as a result of wood burning compared to the burning of coal and oil for all health pathways.

Table 6-22 Monetised Health Impacts for Richmond upon Thames (£, 2022) per year of exposure.

Health pathways	NO_2	$PM_{2.5}$		Total $PM_{2.5}$
	Coal and oil	Coal and oil	Wood	
Respiratory hospital admission	1,000	2,000	16,000	18,000
Mortality associated with chronic exposure	42,000	381,000	2,815,000	3,196,000
Asthma (Adults)	0	N/A	N/A	0
Diabetes	0	0	0	0
Lung Cancer	0	5,000	36,000	41,000
Asthma (Small Children)	0	N/A	N/A	0
Asthma (Older Children)	0	2,000	13,000	15,000
Cardiovascular hospital admission	N/A	0	0	0
CHD	N/A	36,000	270,000	306,000
Stroke	N/A	17,000	128,000	145,000
Productivity	N/A	25,000	182,000	207,000
Total	**43,000**	**468,000**	**3,460,000**	**3,928,000**

N/A: Not applicable

6.1.12 Sutton

The results of the health impacts caused by NO_2 and $PM_{2.5}$ concentrations in Sutton are presented in Table 6-23. For each pollutant, the relevant health impact pathways were considered. The table shows that as a result of domestic solid fuel burning a total of approximately 68 life years are lost each year as a result of wood burning. In the case of coal and oil burning, approximately 10 life years are lost each year as a result of $PM_{2.5}$ concentrations generated by emissions from this activity. Further to this, approximately two new cases of asthma in older children and two new hospital admissions could be attributed to domestic wood burning.

Table 6-23 Assessment of specific health impacts for Sutton per year of exposure.

Health pathway	Metric	NO_2	$PM_{2.5}$		Total $PM_{2.5}$
		Coal and oil	Coal and oil	Wood	
Mortality associated with chronic exposure	LYL	1	10	68	77
Respiratory hospital admission	# Hospital admissions	0	0	2	2
Cardiovascular hospital admission	# Hospital admissions	N/A	0	0	0
CHD	# New cases	N/A	0	1	1
Stroke	# New cases	N/A	0	1	1
Lung Cancer	# New cases	0	0	1	1
Asthma (Older Children)	# New cases	0	0	2	2
Asthma (Small Children)	# New cases	0	N/A	N/A	0
Asthma (Adults)	# New cases	0	N/A	N/A	0
Diabetes	# New cases	0	0	0	0

N/A: Not applicable

The table below presents the monetised costs as a result of the concentrations of NO_2, and $PM_{2.5}$ associated with domestic solid fuel burning in Sutton. The greatest cost is estimated to be attributed to an increase in mortality associated with chronic exposure, amounting to over £3.5 million per year, with the costs associated with all other health pathways significantly lower. A greater cost is borne as a result of wood burning compared to the burning of coal and oil for all health pathways.

Table 6-24 Monetised Health Impacts for Sutton (£, 2022) per year of exposure.

Health pathways	NO_2	$PM_{2.5}$		Total $PM_{2.5}$
	Coal and oil	Coal and oil	Wood	
Respiratory hospital admission	1,000	3,000	18,000	21,000
Mortality associated with chronic exposure	42,000	445,000	3,140,000	3,585,000
Asthma (Adults)	0	N/A	N/A	0
Diabetes	0	0	0	0
Lung Cancer	0	6,000	40,000	46,000
Asthma (Small Children)	0	N/A	N/A	0
Asthma (Older Children)	0	2,000	15,000	17,000
Cardiovascular hospital admission	N/A	0	0	0
CHD	N/A	43,000	301,000	344,000
Stroke	N/A	20,000	143,000	163,000
Productivity	N/A	29,000	203,000	232,000
Total	**43,000**	**548,000**	**3,860,000**	**4,408,000**

N/A: Not applicable

6.1.13 Waltham Forest

The results of the health impacts caused by NO_2 and $PM_{2.5}$ concentrations in Waltham Forest are presented in Table 6-25. For each pollutant, the relevant health impact pathways were considered. The table shows that as a result of domestic solid fuel burning a total of approximately 116 life years are lost each year as a result of wood burning. In the case of coal and oil burning, approximately 16 life years are lost each year as a result of $PM_{2.5}$ concentrations generated by emissions from this activity. Further to this, approximately three new cases of asthma in older children and three new hospital admissions could be attributed to domestic wood burning.

Table 6-25 Assessment of specific health impacts for Waltham Forest per year of exposure.

Health pathway	Metric	NO_2	$PM_{2.5}$		Total $PM_{2.5}$
		Coal and oil	Coal and oil	Wood	
Mortality associated with chronic exposure	LYL	2	16	116	132
Respiratory hospital admission	# Hospital admissions	0	0	3	3
Cardiovascular hospital admission	# Hospital admissions	N/A	0	0	0
CHD	# New cases	N/A	0	2	2
Stroke	# New cases	N/A	0	2	3
Lung Cancer	# New cases	0	0	1	1
Asthma (Older Children)	# New cases	0	0	3	4
Asthma (Small Children)	# New cases	0	N/A	N/A	0
Asthma (Adults)	# New cases	0	N/A	N/A	0
Diabetes	# New cases	0	0	0	0

N/A: Not applicable

The table below presents the monetised costs as a result of the concentrations of NO_2, and $PM_{2,5}$ associated with domestic solid fuel burning in Waltham Forest. The greatest cost is estimated to be attributed to an increase in mortality associated with chronic exposure, amounting to over £6.1 million per year, with the costs associated with all other health pathways significantly lower. A greater cost is borne as a result of wood burning compared to the burning of coal and oil for all health pathways.

Table 6-26 Monetised Health Impacts for Waltham Forest (£, 2022) per year of exposure.

Health pathways	NO_2	$PM_{2.5}$		Total $PM_{2.5}$
	Coal and oil	Coal and oil	Wood	
Respiratory hospital admission	2,000	4,000	30,000	34,000
Mortality associated with chronic exposure	74,000	754,000	5,400,000	6,154,000
Asthma (Adults)	0	N/A	N/A	0
Diabetes	0	0	0	0
Lung Cancer	0	10,000	68,000	78,000
Asthma (Small Children)	1,000	N/A	N/A	0
Asthma (Older Children)	0	3,000	25,000	28,000
Cardiovascular hospital admission	N/A	0	0	0
CHD	N/A	72,000	518,000	590,000
Stroke	N/A	34,000	245,000	279,000
Productivity	N/A	49,000	349,000	398,000
Total	**77,000**	**926,000**	**6,635,000**	**7,561,000**

N/A: Not applicable

6.1.14 Wandsworth

The results of the health impacts caused by NO_2 and $PM_{2.5}$ concentrations in Wandsworth are presented in Table 6-27. For each pollutant, the relevant health impact pathways were considered. The table shows that as a result of domestic solid fuel burning a total of approximately 126 life years are lost each year as a result of wood burning. In the case of coal and oil burning, approximately 17 life years are lost each year as a result of $PM_{2.5}$ concentrations generated by emissions from this activity. Further to this, approximately four new cases of asthma in older children and three new hospital admissions could be attributed to domestic wood burning.

Table 6-27 Assessment of specific health impacts for Wandsworth per year of exposure.

Health pathway	Metric	NO_2	$PM_{2.5}$		Total $PM_{2.5}$
		Coal and oil	Coal and oil	Wood	
Mortality associated with chronic exposure	LYL	2	17	126	143
Respiratory hospital admission	# Hospital admissions	0	0	3	3
Cardiovascular hospital admission	# Hospital admissions	N/A	0	0	0
CHD	# New cases	N/A	0	2	2
Stroke	# New cases	N/A	0	2	3
Lung Cancer	# New cases	0	0	1	1
Asthma (Older Children)	# New cases	0	0	4	4
Asthma (Small Children)	# New cases	0	N/A	N/A	0
Asthma (Adults)	# New cases	0	N/A	N/A	0
Diabetes	# New cases	0	0	0	0

N/A: Not applicable

The table below presents the monetised costs as a result of the concentrations of NO_2, and $PM_{2,5}$ associated with domestic solid fuel burning in Wandsworth. The greatest cost is estimated to be attributed to an increase in mortality associated with chronic exposure, amounting to over £6.6 million per year, with the costs associated with all other health pathways significantly lower. A greater cost is borne as a result of wood burning compared to the burning of coal and oil for all health pathways.

Table 6-28 Monetised Health Impacts for Wandsworth (£, 2022) per year of exposure.

Health pathways	NO_2	$PM_{2.5}$		Total $PM_{2.5}$
	Coal and oil	Coal and oil	Wood	
Respiratory hospital admission	3,000	4,000	33,000	37,000
Mortality associated with chronic exposure	88,000	794,000	5,874,000	6,668,000
Asthma (Adults)	0	N/A	N/A	0
Diabetes	0	0	0	0
Lung Cancer	0	10,000	74,000	84,000
Asthma (Small Children)	1,000	N/A	N/A	0
Asthma (Older Children)	0	4,000	27,000	31,000
Cardiovascular hospital admission	N/A	0	0	0
CHD	N/A	76,000	563,000	639,000
Stroke	N/A	36,000	267,000	303,000
Productivity	N/A	51,000	380,000	431,000
Total	**92,000**	**975,000**	**7,218,000**	**8,193,000**

N/A: Not applicable

6.1.15 Westminster

The results of the health impacts caused by NO_2 and $PM_{2.5}$ concentrations in Westminster are presented in Table 6-29. For each pollutant, the relevant health impact pathways were considered. The table shows that as a result of domestic solid fuel burning a total of approximately 72 life years are lost each year as a result of wood burning. In the case of coal and oil burning, approximately 10 life years are lost each year as a result of $PM_{2.5}$ concentrations generated by emissions from this activity. Further to this, approximately two new cases of asthma in older children and two new hospital admissions could be attributed to domestic wood burning.

Table 6-29 Assessment of specific health impacts for Westminster per year of exposure.

Health pathway	Metric	NO_2	$PM_{2.5}$		Total $PM_{2.5}$
		Coal and oil	Coal and oil	Wood	
Mortality associated with chronic exposure	LYL	2	10	72	82
Respiratory hospital admission	# Hospital admissions	0	0	2	2
Cardiovascular hospital admission	# Hospital admissions	N/A	0	0	0
CHD	# New cases	N/A	0	1	1
Stroke	# New cases	N/A	0	1	2
Lung Cancer	# New cases	0	0	1	1
Asthma (Older Children)	# New cases	0	0	2	2
Asthma (Small Children)	# New cases	0	N/A	N/A	0
Asthma (Adults)	# New cases	0	N/A	N/A	0
Diabetes	# New cases	0	0	0	0

N/A: Not applicable

The table below presents the monetised costs as a result of the concentrations of NO_2, and $PM_{2,5}$ associated with domestic solid fuel burning in Westminster. The greatest cost is estimated to be attributed to an increase in mortality associated with chronic exposure, amounting to over £3.8 million per year, with the costs associated with all other health pathways significantly lower. A greater cost is borne as a result of wood burning compared to the burning of coal and oil for all health pathways.

Table 6-30 Monetised Health Impacts for Westminster (£, 2022) per year of exposure.

Health pathways	NO_2	$PM_{2.5}$		Total $PM_{2.5}$
	Coal and oil	Coal and oil	Wood	
Respiratory hospital admission	2,000	3,000	19,000	22,000
Mortality associated with chronic exposure	76,000	469,000	3,361,000	3,830,000
Asthma (Adults)	0	N/A	N/A	0
Diabetes	0	0	0	0
Lung Cancer	0	6,000	42,000	48,000
Asthma (Small Children)	1,000	N/A	N/A	0
Asthma (Older Children)	0	2,000	16,000	18,000
Cardiovascular hospital admission	N/A	0	0	0
CHD	N/A	45,000	322,000	367,000
Stroke	N/A	21,000	153,000	174,000
Productivity	N/A	30,000	217,000	247,000
Total	**79,000**	**576,000**	**4,130,000**	**4,706,000**

N/A: Not applicable

6.2 DISTRIBUTIONAL ANALYSIS

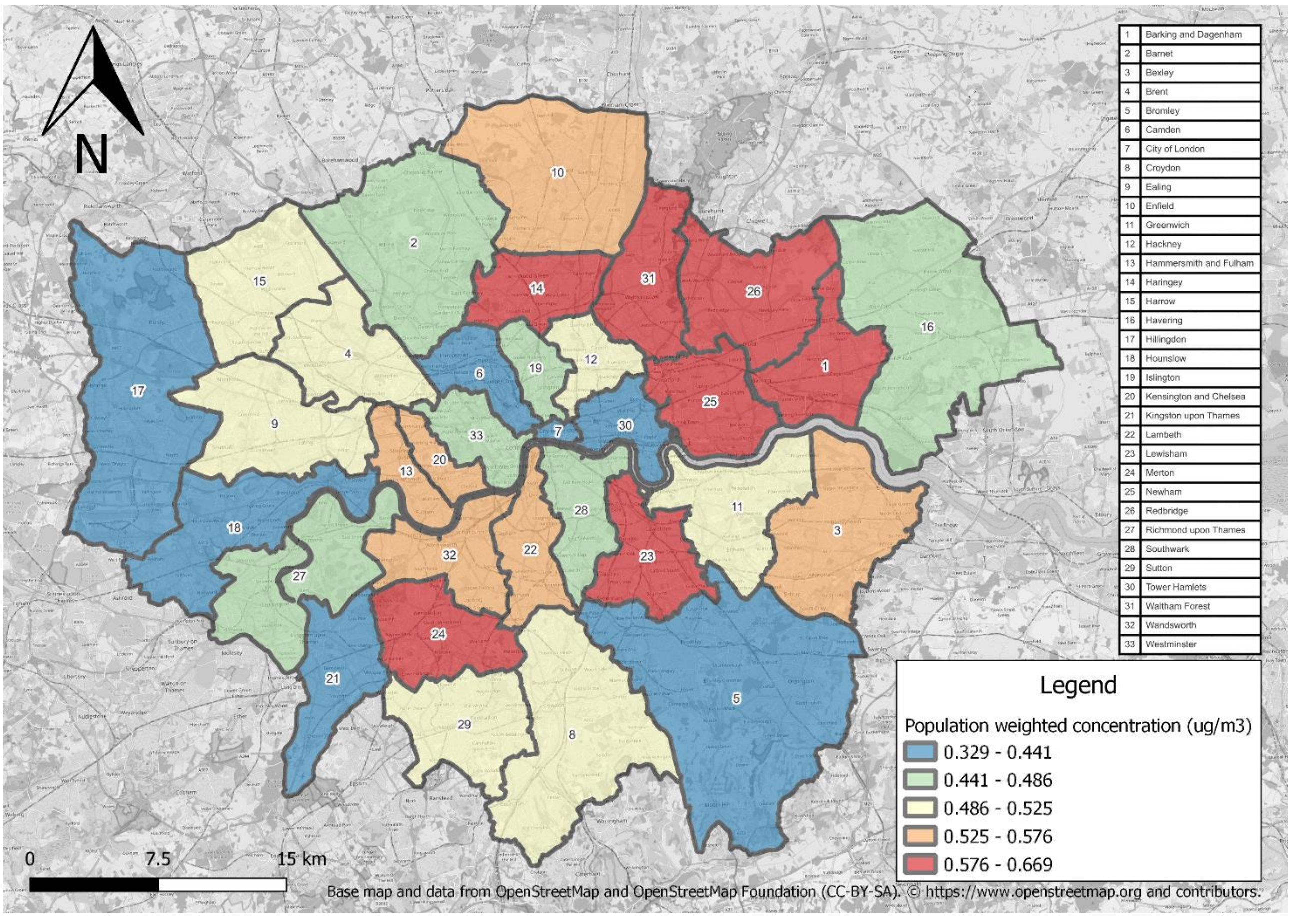
This section provides detailed findings from the distributional analysis.

6.2.1 Results from Task 1

6.2.1.1 Impacts from Wood Burning Activities at Borough-Wide Resolution – Step 1 – Correlation with IMD

Figure 6-1 shows the 32 London boroughs and the City of London colour coded with mean population weighted $PM_{2.5}$ concentration attributed from wood burning activities.

Figure 6-1: Population weighted contribution to $PM_{2.5}$ from wood burning activities.



Note 2: The London borough numbering key is ordered alphabetically and is independent of the quintile grouping.

The figure shows that:

- Population weighted concentrations of $PM_{2.5}$ attributed to wood burning activities are generally highest in the north-east boroughs and lowest in the western boroughs.
- The data also shows a relationship between the least deprived London boroughs and areas where the lowest level of $PM_{2.5}$ generated by wood burning activities are detailed. This is most apparent in the London boroughs of Kingston upon Thames and Bromley.

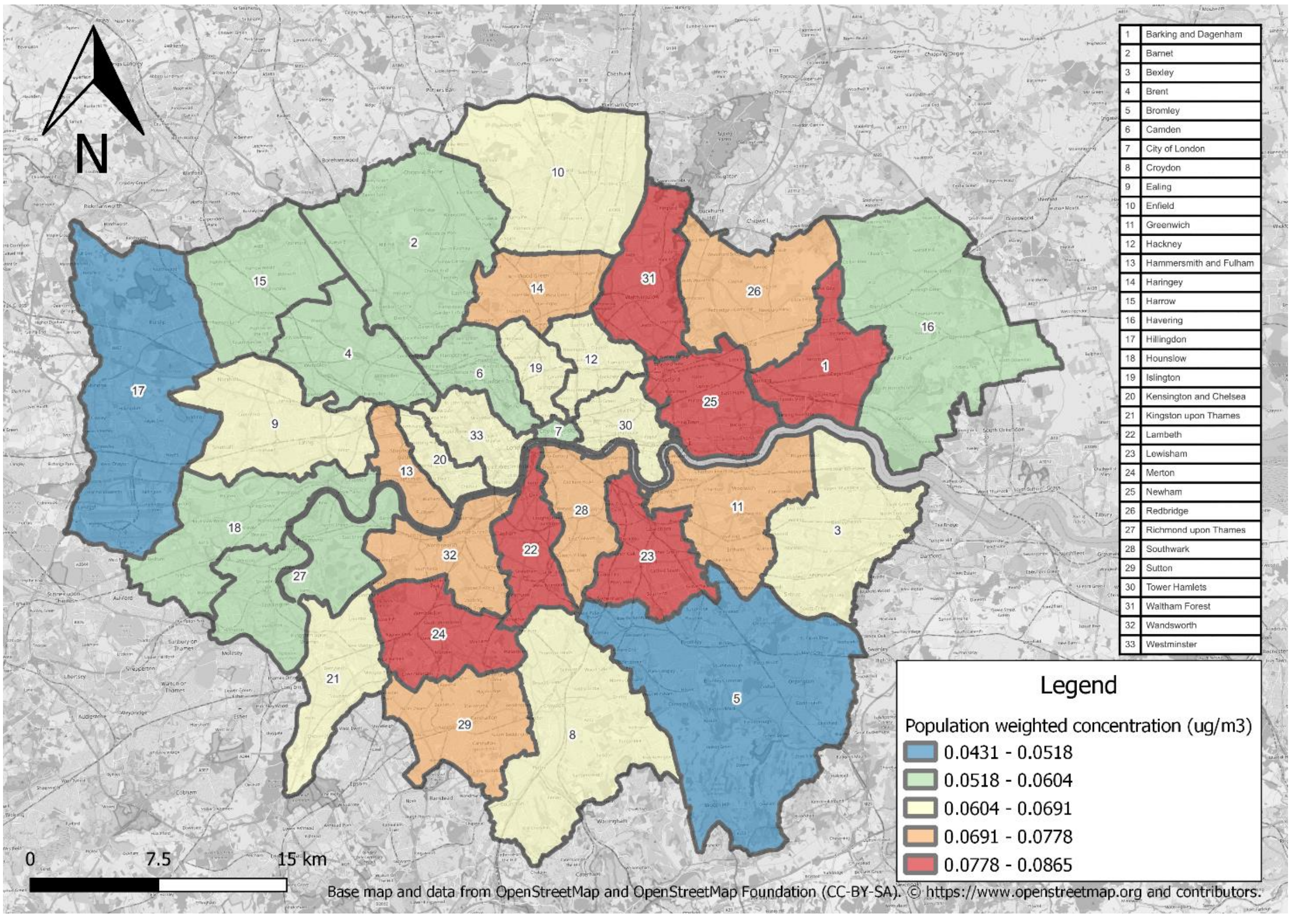
Box 6-1: Summary of impacts of domestic wood burning on IMD quintiles at borough resolution.

The Spearman's rank correlation coefficient value was calculated as 0.39. This figure suggests a weak relationship between the IMD ranking of London boroughs and concentration of $PM_{2.5}$ attributed to wood burning activities. The positive value suggests that the least deprived London boroughs are likely to have lower concentrations of $PM_{2.5}$ from wood burning activities.

6.2.1.2 Impacts from Use Of Coal And Oil at Borough-Wide Resolution – Step 1 – Correlation with IMD

Figure 6-2 shows the London boroughs colour coded with population weighted $PM_{2.5}$ concentration mean attributed from the domestic use of coal and oil fuels.

Figure 6-2: Population weighted contribution to $PM_{2.5}$ from domestic use of coal and oil fuels.



Note 3: The London borough numbering key is ordered alphabetically and is independent of the quintile grouping.

The figure shows:

- Population weighted concentrations of $PM_{2.5}$ attributed to coal and oil use are generally highest across the south central and north-east London boroughs.
- In comparison with Figure 5-1, it is evident that there is some overlap between the most deprived London boroughs and the London boroughs experiencing the highest $PM_{2.5}$ contributions from coal and oil use. This can be seen in the London boroughs of Newham, Barking and Dagenham and Waltham Forest.

Box 6-2: Summary of impacts of domestic coal and oil fuels on IMD quintiles at borough resolution.

The Spearman's rank correlation coefficient value was calculated as 0.52. This figure suggests a weak relationship between the IMD ranking of London boroughs and concentration of $PM_{2.5}$ attributed to the use of coal and oil fuel. The positive value suggests that the least deprived London boroughs are likely to have lower concentrations of $PM_{2.5}$ from coal and oil use.

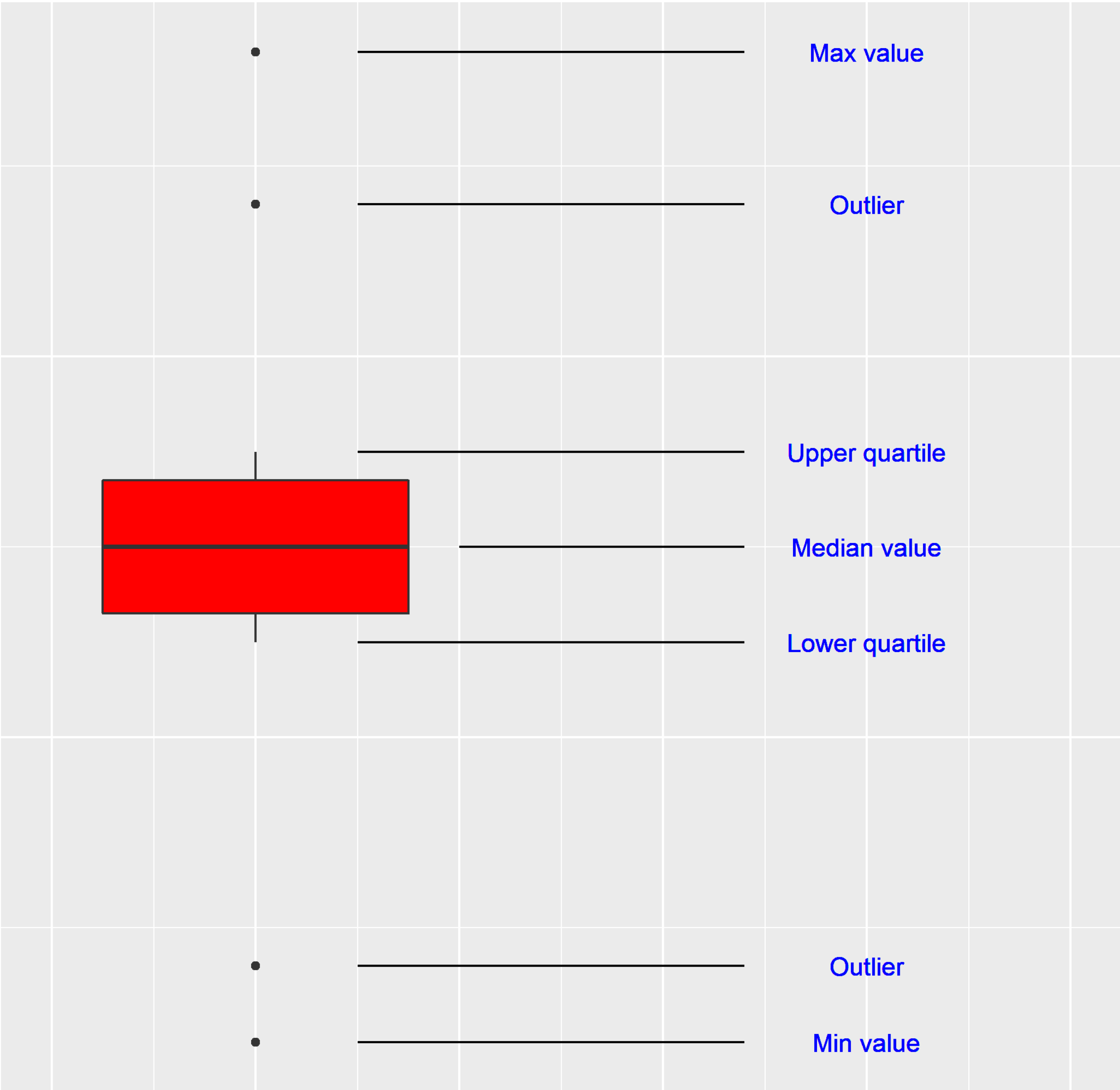
6.2.1.3 Impacts from Wood Burning Activities at Lower Super Output Layer (LSOA) Resolution – Step 2

This section details the analysis undertaken to understand the relationship between annual mean concentrations of $PM_{2.5}$ and areas with a low/high proportion of a sensitive demographic at LSOA level. The analysis was undertaken by comparing mean concentration values of $PM_{2.5}$ from both domestic wood burning activities and the domestic use of coal and oil fuels at LSOA resolution with each group considered.

Assessing $PM_{2.5}$ concentrations against population demographics at this resolution was undertaken to better understand the relationship between the $PM_{2.5}$ concentrations generated by domestic wood burning / use of domestic coal and oil fuels, and spatial areas of low/high sensitivity, relative to the analysis performed under step 1 at borough level. This approach aimed to gain better understanding of the localised impacts by each activity that may not be apparent through the evaluation of relationships at borough level.

This assessment uses the same $PM_{2.5}$ concentration data as step 1 with an extra calculation made to average the concentration values based on the spatial area of each LSOA rather than the borough area. An overall mapping of the relationship between concentrations and LSOA spatial area is not presented here due to the scale of the map. A statistic representation in the form of box plots is provided as an alternative, alongside a table of statistics.

Box 6-3: Guide to reading box and whisker plots.



The box and whisker plot shows:

- A box which represents the interquartile range of the data. The height of the box represents the upper quartile whilst the base of the box represents the lower quartile.
- A line across the box to represent the median value.
- Upper and lower whiskers are the lines leading from the top and base of each box and are representations of 1.5x the interquartile range.
- The dots outside of the boxes are outliers in the dataset with the highest and lowest dot representing the max and min value present within the dataset.

6.2.1.3.1 Impacts from Wood Burning Activities on IMD Quintile Groups

Figure 6-3 and Table 6-31 display the results from the analysis of the relationship between the level of measured deprivation within an LSOA and concentrations of $PM_{2.5}$ attributed to domestic wood burning activities.

Figure 6-3: Box and whisker plot of IMD quintiles with annual mean $PM_{2.5}$ concentrations attributed to domestic wood burning.

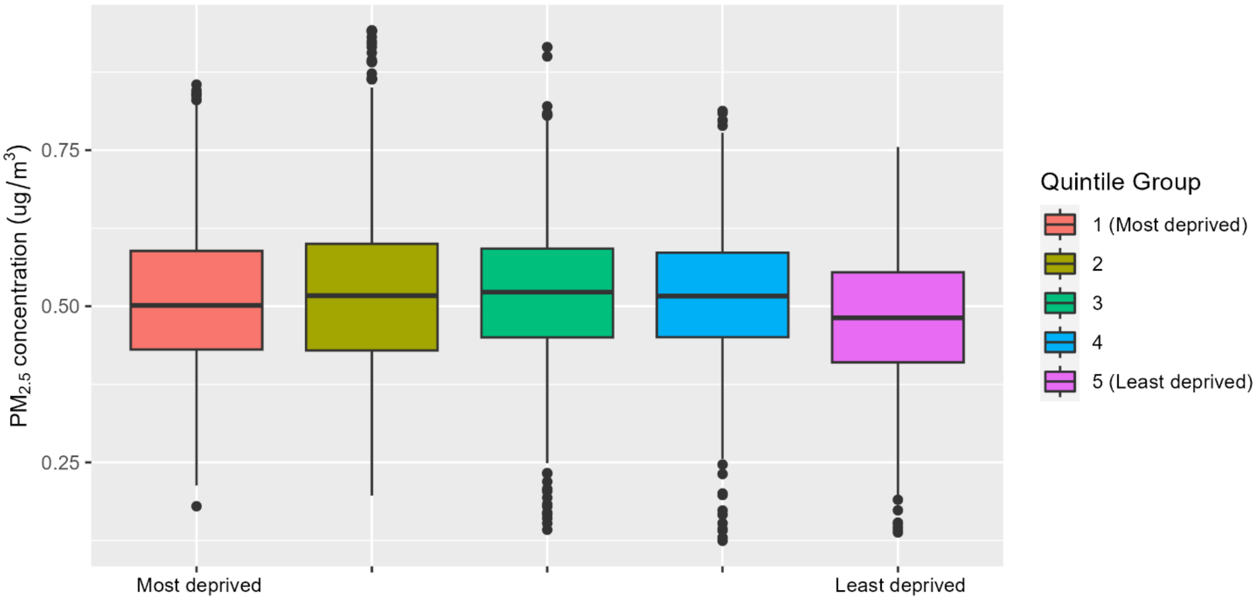


Table 6-31: Tabulated IMD quintiles with annual mean $PM_{2.5}$ concentrations attributed to domestic wood burning.

	1	2	3	4	5
Min.	0.18	0.20	0.14	0.12	0.14
1st Quartile	0.43	0.43	0.45	0.45	0.41
Median	0.50	0.52	0.52	0.52	0.48
Mean	0.52	0.52	0.52	0.51	0.48
3rd Quartile	0.59	0.60	0.59	0.59	0.55
Max.	0.85	0.94	0.91	0.81	0.75

The data shows that:

- The median value (middle line of each box) is reasonably consistent regardless of IMD quintile group.
- The max value (highest dot) was generally higher in the lower quintiles and shown to reduce in the order of quintile grouping between IMD quintiles 2 and 5.
- The min value (lowest dot) is shown to generally descend with each IMD quintile grouping with the caveat of quintile 1 (representing the most deprived) where the min value was below quintile 2.

Box 6-4: Summary of impacts of domestic wood burning on IMD quintiles at LSOA resolution

The overall Spearman's rank coefficient value of the data was calculated as 0.08. This suggests that there is no relationship between those living in the least deprived quintile groups and those exposed to lower $PM_{2.5}$ concentrations as a result of domestic wood burning.

6.2.1.3.2 Impacts from Wood Burning Activities on the Children Under the Age of 16 Quintile Groups

Figure 6-4 and Table 6-32 display the results from the analysis of the relationship between the proportion of children under the age of 16 (< 16) within an LSOA and concentrations of $PM_{2.5}$ attributed to wood burning activities.

Figure 6-4: Box and whisker plot of <16 quintiles with annual mean $PM_{2.5}$ concentrations attributed to domestic wood burning.

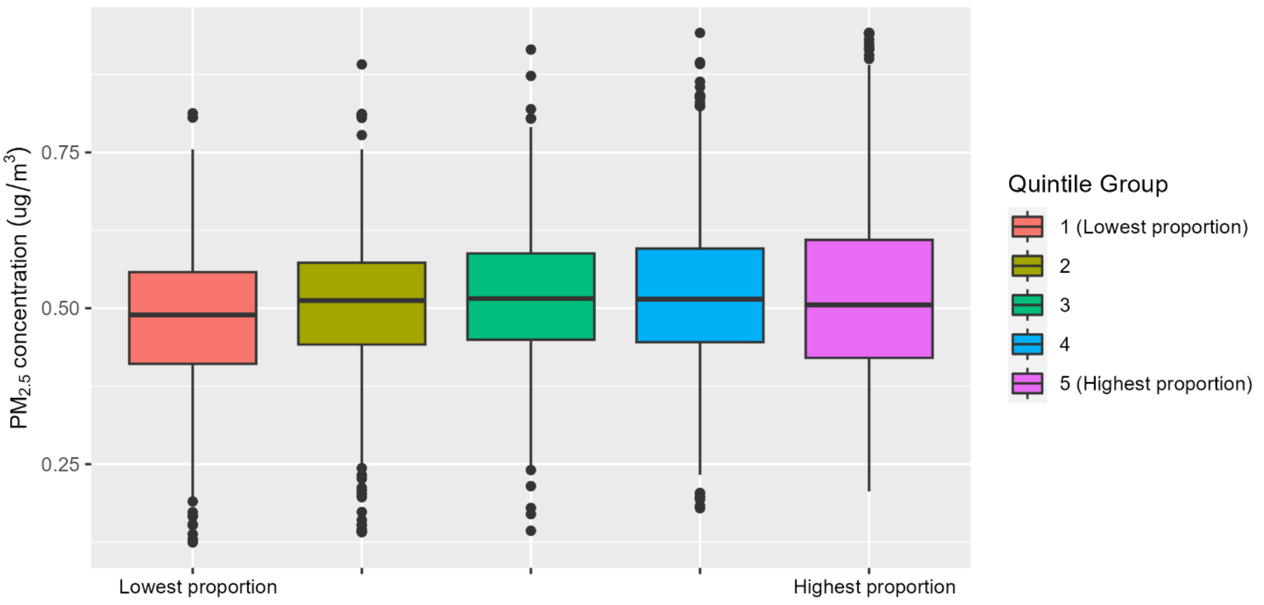


Table 6-32: Tabulated <16 quintiles with annual mean $PM_{2.5}$ concentrations attributed to wood burning.

	1	2	3	4	5
Min.	0.12	0.14	0.14	0.18	0.21
1st Quartile	0.41	0.44	0.45	0.45	0.42
Median	0.49	0.51	0.52	0.51	0.51
Mean	0.48	0.51	0.52	0.52	0.52
3rd Quartile	0.56	0.57	0.59	0.6	0.61
Max.	0.81	0.89	0.91	0.94	0.94

The data shows that:

- The median values are relatively similar across the quintile groups.
- There is a clear upward trend in the terms of the max value, with the data showing a linear relationship between increasing concentrations of $PM_{2.5}$ stemming from wood burning activities and the higher quintile groups (those with the highest proportion of children).
- There is a clear upward trend in terms of the min value, with the data showing a linear relationship between increasing concentrations of $PM_{2.5}$ stemming from wood burning activities and the higher quintile groups (those with the highest proportion of children).

Box 6-5: Summary of impacts of domestic wood burning on the children under 16 quintile groups at LSOA resolution.

The overall Spearman's rank coefficient value of the data was calculated as 0.07. This suggests that there is no relationship between the number of children living in an area and concentrations of $PM_{2.5}$ from domestic wood burning activities, despite the outlier (min/max) values increasing with each increasing quintile group.

6.2.1.3.3 Impacts from Wood Burning Activities on the Citizens Over the Age of 65 Quintile Groups

Figure 6-5 and Table 6-33 display the results from the analysis of the relationship between the proportion of citizens over the age of 65 (>65) within an LSOA and concentrations of $PM_{2.5}$ attributed to wood burning activities.

Figure 6-5: Boxplot of >65 quintiles with annual mean $PM_{2.5}$ concentrations attributed to wood burning.

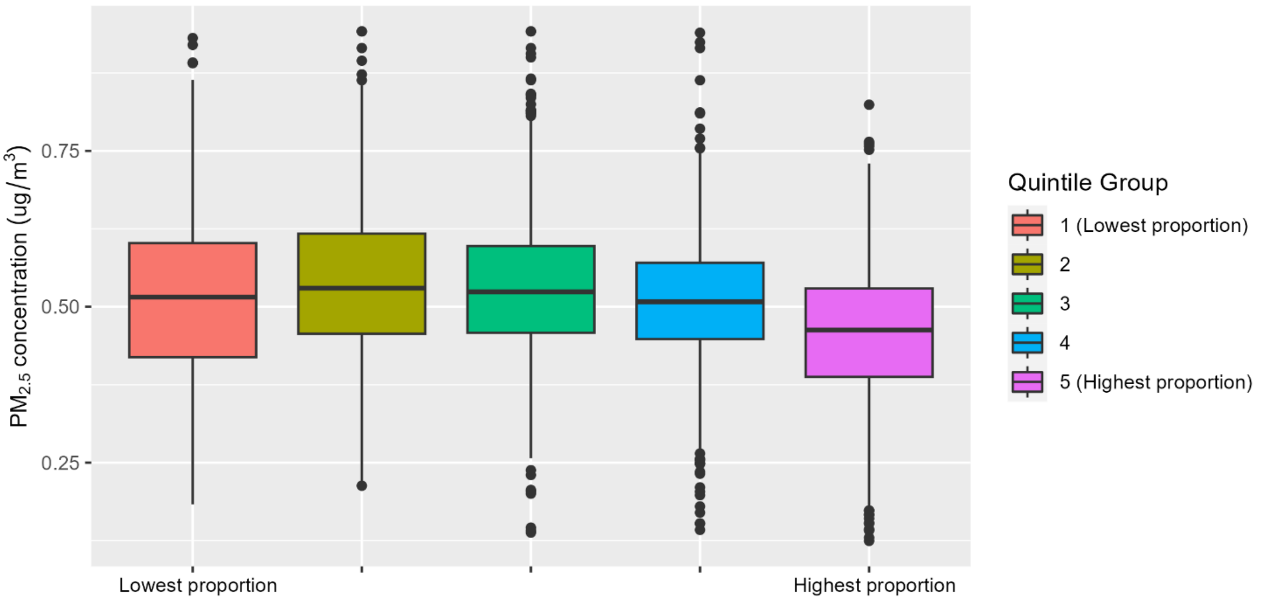


Table 6-33: Tabulated >65 quintiles with annual mean $PM_{2.5}$ concentrations attributed to wood burning.

	1	2	3	4	5
Min.	0.18	0.21	0.14	0.14	0.12
1st Quartile	0.42	0.46	0.46	0.45	0.39
Median	0.52	0.53	0.52	0.51	0.46

	1	2	3	4	5
Mean	0.52	0.54	0.53	0.51	0.46
3rd Quartile	0.60	0.62	0.60	0.57	0.53
Max.	0.93	0.94	0.94	0.94	0.82

The data shows that:

- The median value is consistent across the quintile groupings.
- The max value is reasonably consistent across the quintile groupings.
- The min value is reasonably consistent across the quintile groupings.

Box 6-6: Summary of impacts of domestic wood burning on the over 65 quintile groups at LSOA resolution.

The overall Spearman's rank coefficient value of the data was calculated as -0.17. This suggests that overall, there is no relationship between those living in the LSOAs with a higher proportion of citizens aged 65 and older, are exposed to lower $PM_{2.5}$ concentrations associated with domestic wood burning relative to those in the lower quintile groups (i.e. with fewer residents that are >65).

6.2.1.3.4 Impacts from Wood Burning Activities on BAME Ethnic Quintile Groups

Figure 6-6 and Table 6-34 display the results from the analysis of the relationship between the proportion of BAME (Black, Asian and Minority Ethnic) groups within an LSOA and concentrations of $PM_{2.5}$ attributed to domestic wood burning activities. A binary BAME/non-BAME grouping system was used to enable a simple translation of the range of groups present in the 2021 census data used[70]. This binary system was deemed appropriate to use as a simple indicator of whether minority groups are disproportionately impacted by domestic wood burning in line with historical social structures.

[70] https://www.ons.gov.uk/datasets/TS021/editions/2021/versions/2/filter-outputs/41eac1af-3034-4d0f-87b5-d1777db57668#get-data

Figure 6-6: Box and whisker plot of BAME quintiles with annual mean $PM_{2.5}$ concentrations attributed to wood burning.

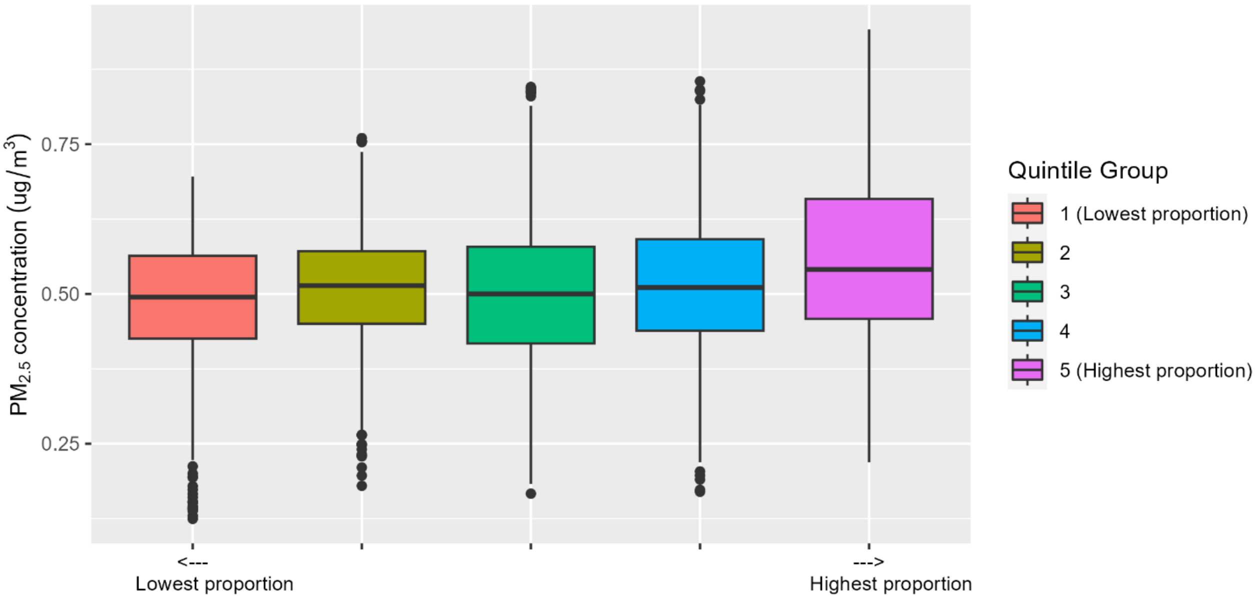


Table 6-34: Tabulated BAME quintiles with annual mean $PM_{2.5}$ concentrations attributed to domestic wood burning.

	1	2	3	4	5
Min.	0.12	0.18	0.17	0.17	0.22
1st Quartile	0.43	0.45	0.42	0.44	0.46
Median	0.49	0.51	0.50	0.51	0.54
Mean	0.48	0.50	0.50	0.52	0.56
3rd Quartile	0.56	0.57	0.58	0.59	0.66
Max.	0.70	0.76	0.85	0.85	0.94

The data shows that:

- The median value is consistent across the quintile groupings.
- The max value increases in order of quintile groupings, showing that some LSOA's with the highest proportion of BAME citizens are exposed to the highest concentration of $PM_{2.5}$ from wood burning activities.
- The min value is reasonably consistent across the mid quintile groupings. The data shows that the lowest annual average concentration coincides with the LSOA quintile group with the lowest proportion of BAME citizens whilst the opposite is shown in the LSOA quintile group with the highest proportion of BAME residents.

Box 6-7: Summary of impacts of domestic wood burning on BAME quintile groups at LSOA resolution.

The overall Spearman's rank coefficient value of the data was calculated as 0.15. This suggests that there is no relationship between the LSOAs with a higher proportion of BAME citizens and concentrations of $PM_{2.5}$ from domestic wood burning activities.

6.2.1.4 Impacts from Use of Coal and Oil Fuel Use at Lower Super Output Area (LSOA) Resolution – Step 2

This section of the report details the results from the review of the relationships between annual averaged concentrations of $PM_{2.5}$ from domestic coal and oil burning and sensitive demographics. The approach for this review mirrors that undertaken for the review of the relationship between sensitive demographics and wood burning activities.

6.2.1.4.1 Impacts from the Use of Coal and Oil Fuel on IMD Quintile Groups

Figure 6-7 and Table 6-35 display the results from the analysis of the relationship between the between the level of measured deprivation within an LSOA and concentrations of $PM_{2.5}$ attributed to the use of coal and oil fuel appliances.

Figure 6-7: Box and whisker plot of IMD quintiles with annual mean $PM_{2.5}$ concentrations attributed to domestic use of coal and oil fuels.

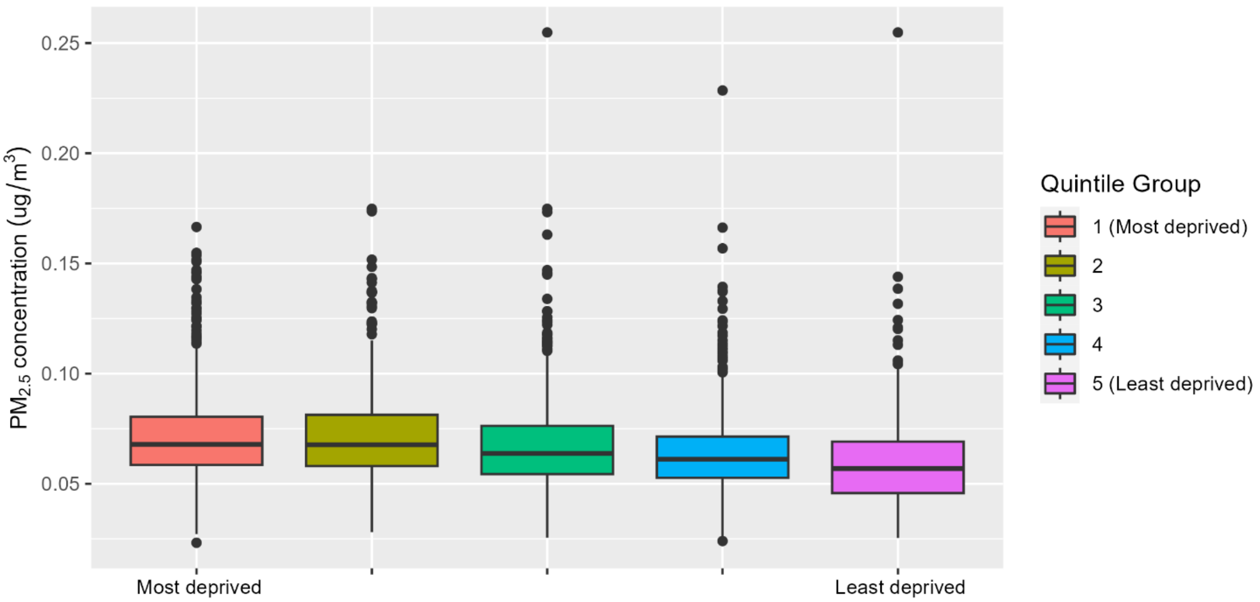


Table 6-35: Tabulated IMD quintiles with annual mean $PM_{2.5}$ concentrations attributed to domestic use of coal and oil fuels.

	1	2	3	4	5
Min.	0.02	0.03	0.03	0.02	0.03
1st Quartile	0.06	0.06	0.05	0.05	0.05
Median	0.07	0.07	0.06	0.06	0.06
Mean	0.07	0.07	0.07	0.06	0.06
3rd Quartile	0.08	0.08	0.08	0.07	0.07

	1	2	3	4	5
Max.	0.17	0.17	0.25	0.23	0.25

The data shows that:

- The median value is consistent across the quintile groupings.
- The max value increases in order of quintile groupings, showing that some LSOA's with the least deprived citizens are exposed to the highest concentration of $PM_{2.5}$ from the use of coal and oil fuel appliances. The data shows that the three highest numbered quintiles have the largest outliers in the max range.
- The min value is reasonably consistent across the mid quintile groupings.

Box 6-8: Summary of impacts of domestic use of coal and oil fuels on the IMD quintile groups at LSOA resolution.

The overall Spearman's rank coefficient value of the data was calculated as 0.25. This suggests that there is no relationship between those living in the least deprived quintile groups are those exposed to lower $PM_{2.5}$ concentrations from the domestic use of coal and oil fuels.

6.2.1.4.2 Impacts from the Domestic Use of Coal and Oil Fuel on the Children Under the Age of 16 Quintile Groups

Figure 6-8 and Table 6-36 display the results from the analysis of the relationship between the proportion of children under the age of 16 (<16) within an LSOA and concentrations of $PM_{2.5}$ attributed to the use of coal and oil fuel appliances.

Figure 6-8: Box and whisker plot of <16 quintiles with annual mean $PM_{2.5}$ concentrations attributed to domestic use of coal and oil fuels.

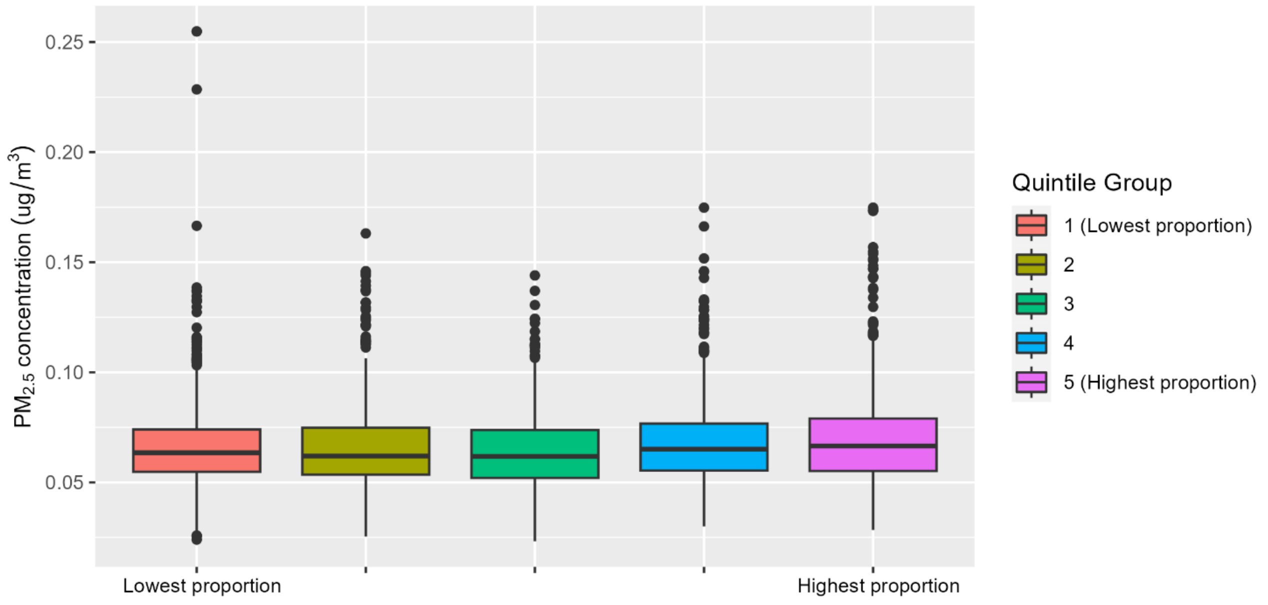


Table 6-36: Tabulated <16 quintiles with annual mean $PM_{2.5}$ concentrations attributed to domestic use of coal and oil fuels.

	1	2	3	4	5
Min.	0.02	0.03	0.02	0.03	0.03
1st Quartile	0.05	0.05	0.05	0.06	0.06
Median	0.06	0.06	0.06	0.07	0.07
Mean	0.07	0.06	0.06	0.07	0.07
3rd Quartile	0.07	0.07	0.07	0.08	0.08
Max.	0.25	0.16	0.14	0.17	0.17

The data shows that:

- The median value is consistent across the quintile groupings.
- The max value varies within each quintile group and does not show a clear trend across quintile groups.
- The min value is reasonably consistent across the mid quintile groupings.

Box 6-9 : Summary of impacts of domestic use of coal and oil fuels on the children under 16 quintile groups at LSOA resolution.

The overall Spearman's rank coefficient value of the data was calculated as 0.07. This suggests that there is no relationship between the proportion of children living within a LSOA and its corresponding mean $PM_{2.5}$ concentration value which stems from the domestic use of oil and coal fuels.

6.2.1.4.3 Impacts from the use of coal and oil fuel on the citizens over the age of 65 quintile groups

Figure 6-9 and Table 6-37 display the results from the analysis of the relationship between the proportion of citizens over the age of 65 (>65) within an LSOA and concentrations of $PM_{2.5}$ attributed to the domestic use of coal and oil fuel appliances.

Figure 6-9: Box and whisker plot of >65 quintiles with annual mean $PM_{2.5}$ concentrations attributed to domestic use of coal and oil fuels.

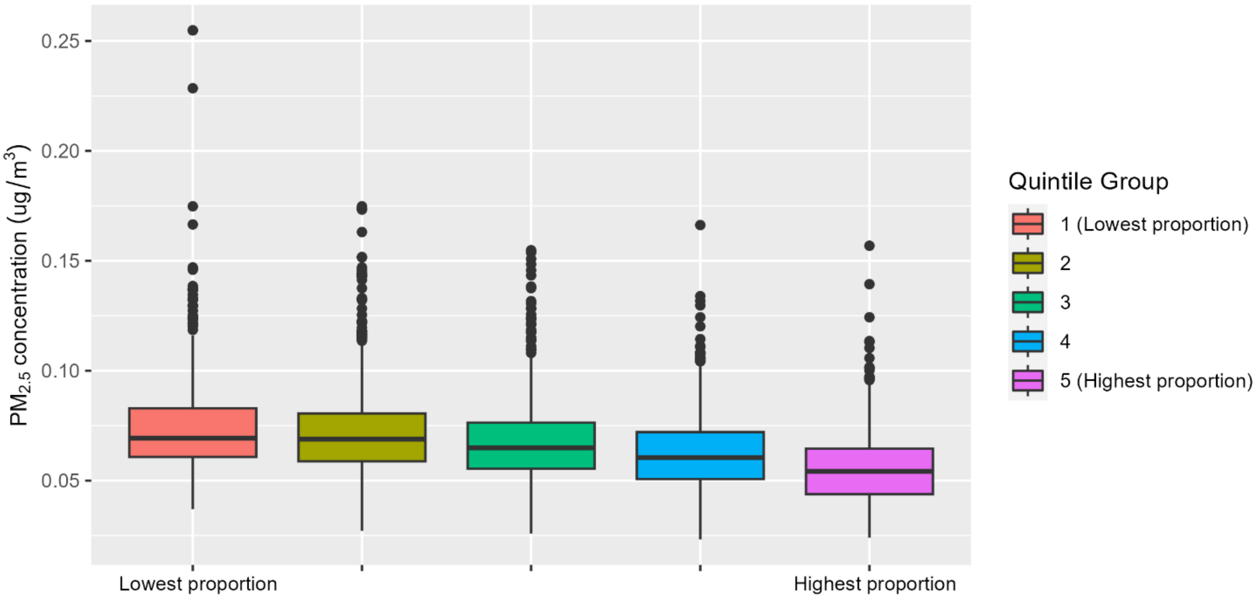


Table 6-37: Tabulated >65 quintiles with annual mean $PM_{2.5}$ concentrations attributed to domestic use of coal and oil fuels.

	1	2	3	4	5
Min.	0.04	0.03	0.03	0.02	0.02
1st Quartile	0.06	0.06	0.06	0.05	0.04
Median	0.07	0.07	0.06	0.06	0.05
Mean	0.07	0.07	0.07	0.06	0.06
3rd Quartile	0.08	0.08	0.08	0.07	0.06
Max.	0.25	0.17	0.15	0.17	0.16

The data shows that:

- The median value is consistent across the quintile groupings.
- The max value varies within each quintile group and does not show a clear trend across quintile groups.
- The min value is reasonably consistent across the mid quintile groupings but does show a slight decreasing trend as the quintile group number increases.

Box 6-10: Summary of impacts of the domestic use of coal and oil fuels on the over 65 quintile groups at LSOA resolution.

The overall Spearman's rank coefficient value of the data was calculated as -0.37. This suggests that there is a weak relationship between those living in the LSOAs with the highest proportion of citizens over the age of 65 and those who are exposed to lower $PM_{2.5}$ concentrations from the domestic use of coal and oil fuels.

6.2.1.4.4 Impacts from the Use of Coal and Oil Fuel on the Ethnic Quintile Groups

Figure 6-10 and Table 6-38 display the results from the analysis of the relationship between the proportion of BAME ethnic groups within an LSOA and concentrations of $PM_{2.5}$ attributed to the use of coal and oil fuel appliances.

Figure 6-10: Box and whisker plot of BAME quintiles with annual mean $PM_{2.5}$ concentrations attributed to coal and oil fuel use.

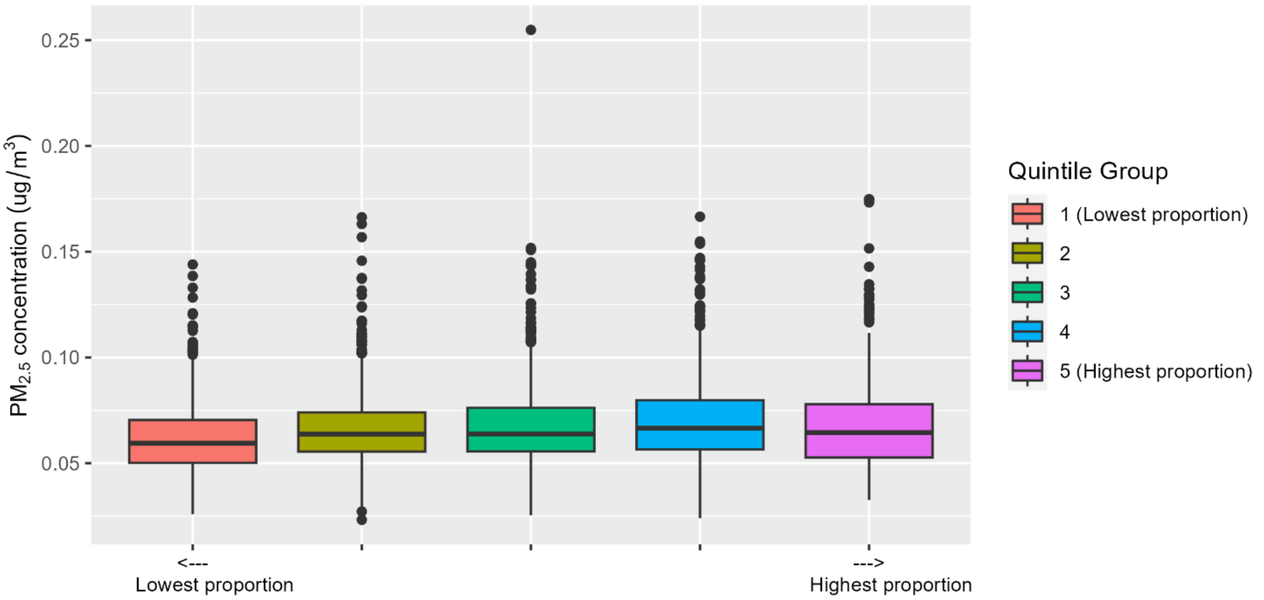


Table 6-38: Tabulated BAME ethnicity quintiles with annual mean $PM_{2.5}$ concentrations attributed to use of coal and oil fuels.

	1	2	3	4	5
Min.	0.03	0.02	0.03	0.02	0.03
1st Quartile	0.05	0.06	0.06	0.06	0.05
Median	0.06	0.06	0.06	0.07	0.06
Mean	0.06	0.07	0.07	0.07	0.07
3rd Quartile	0.07	0.07	0.08	0.08	0.08
Max.	0.14	0.17	0.25	0.17	0.17

The data shows that:

- The median value is consistent across the quintile groupings.
- The max value varies within each quintile group and does not show a clear trend across quintile groups.
- The min value is reasonably consistent across all of the quintile groupings.

Box 6-11: Summary of impacts of domestic use of coal and oil fuels on BAME quintile groups at LSOA resolution.

The overall Spearman's rank coefficient value of the data was calculated as 0.17. This suggests that there is no relationship between the concentration of $PM_{2.5}$ from the domestic use of coal and oil fuels and the proportion of BAME citizens.

6.2.1.5 Summary of findings from Task 1

Task 1 of the distributional impact analysis has shown that in:

Relation to wood burning activities:

- There is a weak relationship between the level of deprivation when assessed at London boroughs level and the annual average concentration of $PM_{2.5}$ from domestic wood burning, with a spearman rank correlation coefficient calculated to be 0.39.
- There is no relationship between the level of deprivation of a LSOA and the annual average concentration of $PM_{2.5}$ from domestic wood burning, with the caveat that some of the most deprived areas of London experience some of the highest annual averaged concentrations of $PM_{2.5}$ attributed to domestic wood burning.
- There is no relationship between LSOAs with a high/low proportion of children and the annual average concentration of $PM_{2.5}$ from domestic wood burning, with the caveat that some LSOAs with the highest proportion of children experience some of the highest annual averaged concentrations of $PM_{2.5}$ pollutant, whilst the reverse is true for LSOAs with the lowest proportion of children.
- There is no relationship between LSOAs with a high/low proportion of citizens over the age of 65 and the annual average concentration of $PM_{2.5}$ from domestic wood burning, with the caveat that some LSOAs with the lowest proportion of citizens over age 65, experience some of the highest annual averaged concentrations of $PM_{2.5}$ pollutant, whilst the reverse is true for LSOAs with the highest proportion of citizens over the age of 65.
- There is no relationship between LSOAs with a high/low proportion of BAME citizens and the annual average concentration of $PM_{2.5}$ from domestic wood burning, with the caveat that some LSOAs with the lowest proportion of BAME citizens experience some of the lowest annual averaged concentrations of $PM_{2.5}$ pollutant, whilst the reverse is true for LSOAs with the highest proportion of BAME citizens.

Relation to domestic use of coal and oil fuels:

- There is a weak relationship between the level of deprivation within a London borough and the annual average concentration of $PM_{2.5}$ from domestic use of coal and oil fuels, with a spearman correlation coefficient calculated to be 0.52.
- There is no relationship between the level of deprivation of an LSOA and the annual average concentration of $PM_{2.5}$ from domestic use of coal and oil fuels, with the caveat that some of the most deprived areas of London experience some of the highest annual averaged concentrations of $PM_{2.5}$ attributed to domestic coal and oil fuel usage.
- There is no relationship between LSOAs with a high/low proportion of children and the annual average concentration of $PM_{2.5}$ from domestic use of coal and oil fuels.
- There is a weak relationship between LSOAs with a high/low proportion of citizens over the age of 65 and the annual average concentration of $PM_{2.5}$ from domestic use of coal and oil fuels, with a spearman correlation coefficient calculated to be -0.37.
- There is no relationship between LSOAs with a high/low proportion of BAME citizens and the annual average concentration of $PM_{2.5}$ from domestic use of coal and oil fuels.

6.2.2 Results from Task 2

6.2.2.1 Review of the Relationship Between Level of Deprivation and Use of an Open Fireplace

In this section we reviewed responses to Q65, “how often, if at all, do you tend to use during a typical winter: usable open fireplace”, given in the Opinium public survey, which was Element 1 of the LWBP.

The answers submitted by participants were cross referenced to the participants corresponding London Borough. This enabled an understanding of how participants behaviours may correspond to the geographical location of their residence, and the location’s associated levels of deprivation.

Figure 6-11 and Table 6-39 show the results from data collected. Boroughs which were not represented in the survey dataset and those with a low representation (<20 survey respondents) were filtered out. The data is portrayed so that the most deprived London boroughs are represented in the left-hand side of each figure’s x-axis, whilst the least deprived are shown on the right-hand side. The number of responses from each borough were disaggregated by their selected answer. The dataset was transformed to a proportion of the total number of responses to ease comparison between London boroughs.

Figure 6-11: Q65 - “how often, if at all, do you tend to use during winter: usable open fireplace” – results disaggregated by borough and its corresponding level of deprivation

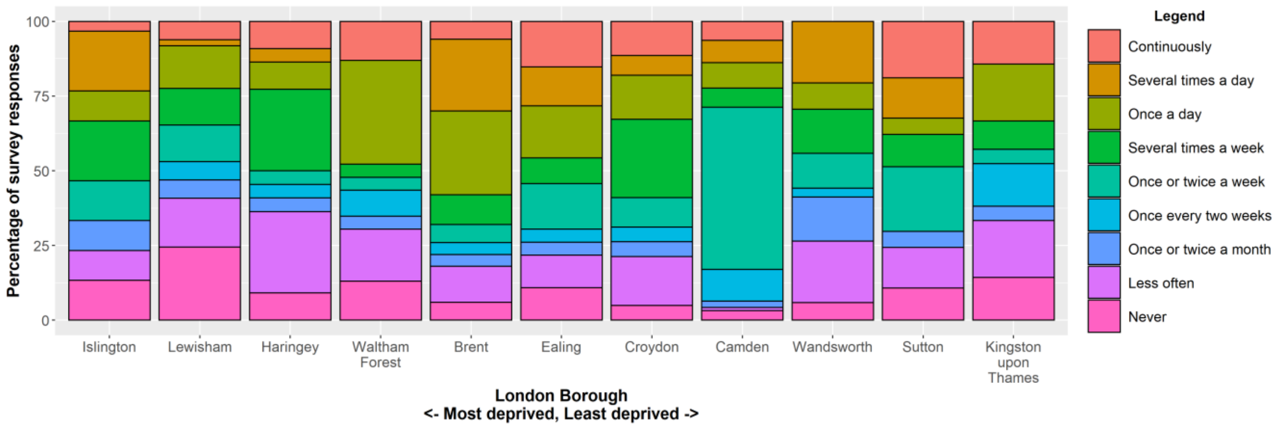


Table 6-39: Survey Q65 results tabulated, disaggregated by borough and ranked by IMD ranking

Location	IMD rank	Number of responses	Continuously (%)	Several times a day (%)	Once a day (%)	Several times a week (%)	Once or twice a week (%)	Once every two weeks (%)	Once or twice a month (%)	Less often (%)	Never (%)	Correlation coefficient
Islington	4	30	3	20	10	20	13	0	10	10	13	-0.05
Lewisham	6	49	6	2	14	12	12	6	6	16	24	0.59
Haringey	7	22	9	5	9	27	5	5	5	27	9	0.09
Waltham Forest	10	23	13	0	35	4	4	9	4	17	13	0.19
Brent	11	50	6	24	28	10	6	4	4	12	6	-0.38
Ealing	14	46	15	13	17	9	15	4	4	11	11	-0.56
Croydon	17	61	11	7	15	26	10	5	5	16	5	-0.36
Camden	19	94	6	7	9	6	54	11	2	1	3	-0.46
Wandsworth	23	34	0	21	9	15	12	3	15	21	6	0.14
Sutton	30	37	19	14	5	11	22	0	5	14	11	-0.30
Kingston upon Thames	32	21	14	0	19	10	5	14	5	19	14	0.21

The data shows that:

- There was a mixed level of response to this question. Boroughs towards the middle of the IMD scale had more respondents in the survey.
- The majority of participants in each borough tended to respond "never" or "less often" with a small proportion selecting "continuously" where the number of responses are sizable.
- There is little evidence to suggest that the use of an open fireplace is linked to the boroughs IMD ranking scale, as the correlation coefficients do not show any linearity with the IMD ranking of location.
- The data shows that participants living in Ealing selected answers that trended mostly strongly towards the 'continuous use' extreme with a correlation coefficient value of (-0.56).
- The data shows that participants living in Lewisham selected answers that trended mostly strongly towards the 'never use' extreme with a correlation coefficient value of (0.59).

6.2.2.2 Review of the Relationship Between Level of Deprivation and Use of Solid Fuel Burning Stoves

Figure 6-12 and Table 6-40 show the comparison of the stated frequency of survey participants' use of a solid fuel burning stove, disaggregated by borough and level of deprivation. The data was obtained using the same approach detailed in section 5.3.1. Fewer boroughs are shown in the figure due to the smaller number of participants who responded to this question.

Figure 6-12: Q66 – "how often, if at all, do you tend to use during a typical winter: solid fuel burning stove", disaggregated by London borough its corresponding level of deprivation.

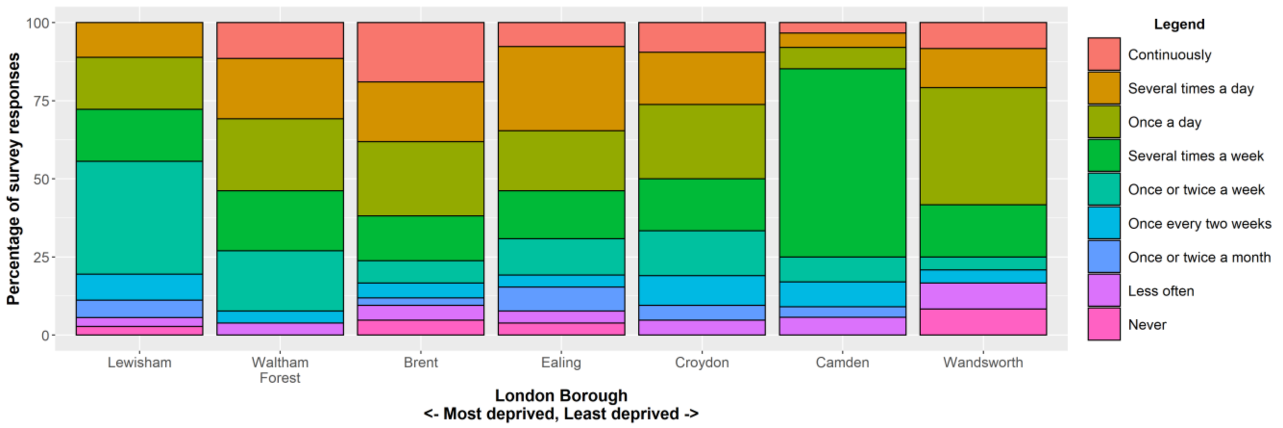


Table 6-40: Survey Q66 results tabulated, disaggregated by borough and IMD ranking position.

Location	IMD rank	Number of responses	Continuously (%)	Several times a day (%)	Once a day (%)	Several times a week (%)	Once or twice a week (%)	Once every two weeks (%)	Once or twice a month (%)	Less often (%)	Never (%)	Correlation coefficient
Lewisham	6	36	0	11	17	17	36	8	6	3	3	-0.24
Waltham Forest	10	26	12	19	23	19	19	4	0	4	0	-0.74
Brent	11	42	19	19	24	14	7	5	2	5	5	-0.86
Ealing	14	26	8	27	19	15	12	4	8	4	4	-0.73
Croydon	17	42	10	17	24	17	14	10	5	5	0	-0.76
Camden	19	88	3	5	7	60	8	8	3	6	0	-0.19
Wandsworth	23	24	8	12	38	17	4	4	0	8	8	-0.47

The data shows that:

- There was a mixed level of response to this question. Boroughs towards the middle of the IMD scale had more respondents in the survey.
- Respondents tended to select an answer that represents a reasonably frequent use of the appliance (once or twice a week).
- The correlation coefficient for each location shows that participants selected, overall, answers showing frequent use. This observation was highest in Brent (-0.86). The weakest correlation coefficient was seen in Camden (-0.19).
- The correlation coefficient of each group does not suggest that the IMD ranking is a factor in the frequent use of solid fuel stoves as the value is reasonably consistent across the boroughs.

6.2.2.3 Review of the Relationship Between Participant Age Group and the Use of an Open Fireplace

The approach detailed in section 5.3.1 was adapted so that participant responses to the question relating to the use of a domestic fireplace were disaggregated by age groups.

Figure 6-13 and Table 6-41 show the results of the analysis. Note that the analysis could not determine whether the respondent individually uses an open fireplace or whether it is used by a larger social group (family/household).

Figure 6-13: Q65 – "How often, if at all, do you tend to use during a typical winter: usable open fireplace", results disaggregated by age groupings.

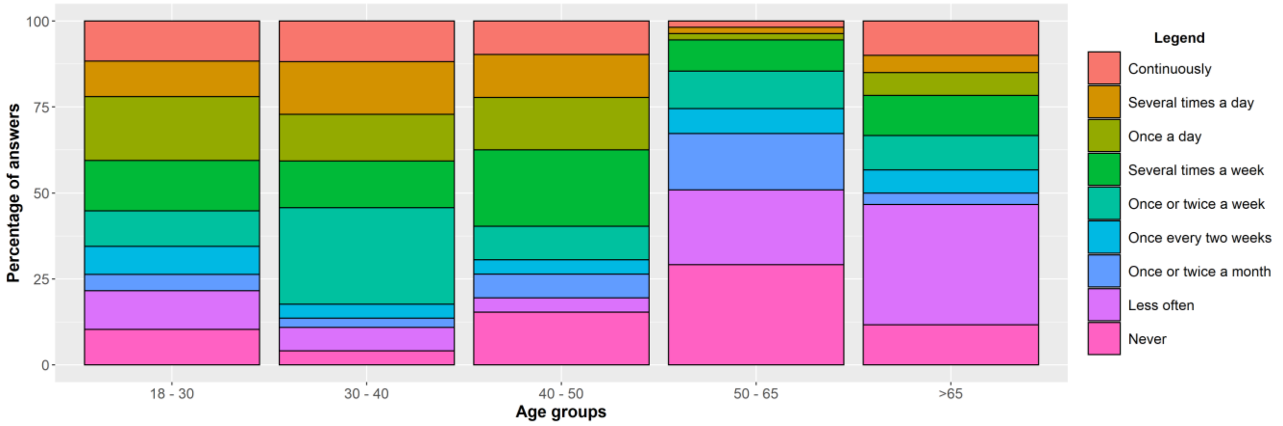


Table 6-41: Survey Q65 results tabulated, disaggregated by age group.

Age group	Total	Continuously (%)	Several times a day (%)	Once a day (%)	Several times a week (%)	Once or twice a week (%)	Once every two weeks (%)	Once or twice a month (%)	Less often (%)	Never (%)	Correlation coefficient
18 – 30	232	12	10	19	15	10	8	5	11	10	-0.47
30 – 40	221	12	15	14	14	28	4	3	7	4	-0.62
40 – 50	72	10	12	15	22	10	4	7	4	15	-0.30
50 – 65	55	2	2	2	9	11	7	16	22	29	0.93
>65	60	10	5	7	12	10	7	3	35	12	0.34

The data shows:

- A strong correlation between age groupings and the level of response to this question where the number of responses generally declines with each higher age group.

- The younger age groups tended to select answers that weighted towards more frequent use. This is reflected in the correlation coefficient value which is highest in the 30 – 40 age group (-0.62).
- The older age groups tended to select answers that weighted towards the less frequent use. This is reflected by the correlation coefficient value which is highest in the 50 – 65 age group (0.93).
- Overall, the data suggests that the respondent's age group does play a factor in how regularly they use a fireplace.

6.2.2.4 Review of the Relationship Between Participant Age Group and the Use of a Solid Fuel Stove

The methodology described in section 5.3.4 was re-applied to the question presented to participants relating to the use of solid fuel stoves. Figure 6-14 and Table 6-42 show the results from the analysis.

Figure 6-14: Q66 – "How often, if at all, do you tend to use during a typical winter: solid fuel burning stove", results disaggregated by age groupings.

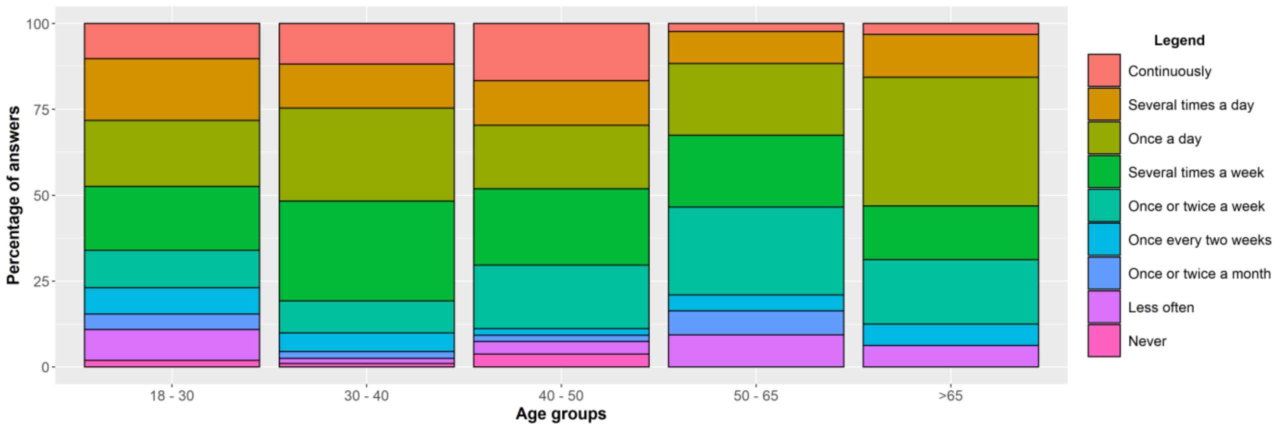


Table 6-42: Survey Q66 results tabulated, disaggregated by age group.

Age group	Total	Continuously (%)	Several times a day (%)	Once a day (%)	Several times a week (%)	Once or twice a week (%)	Once every two weeks (%)	Once or twice a month (%)	Less often (%)	Never (%)	Correlation coefficient
18 – 30	31	10	18	18	19	11	8	4	9	2	-0.73
30 – 40	156	12	13	27	29	9	5	2	1	1	-0.83
40 – 50	203	17	13	19	21	19	2	2	4	4	-0.57
50 – 65	53	2	10	20	18	28	5	8	10	0	-0.27
>65	40	3	13	39	16	16	6	0	6	0	-0.48

The data shows that:

- The question received a far greater response, >100, from participants in the 30 – 40 and 40 – 50 age ranges compared to the other age groupings.
- The selection of answers given by respondents was generally weighted towards more frequent/continuous use than frequent use, irrespective of age group. This observation is reflected in the correlation coefficient value for each age grouping.
- The data therefore suggests that age groupings are not likely to a factor in what drives the use of solid fuel stoves.

6.2.2.5 Review of the Relationship Between Participant Gender and the Use of an Open Fireplace

An analysis of the response to question 65 by different gender groups was undertaken to identify if either demographic type is likely to influence the use of an open fireplace. Table 6-43 displays the tabulated results from the analysis.

Table 6-43: Survey Q65 results tabulated, disaggregated by gender groupings.

Gender	Total	Continuously (%)	Several times a day (%)	Once a day (%)	Several times a week (%)	Once or twice a week (%)	Once every two weeks (%)	Once or twice a month (%)	Less often (%)	Never (%)	Correlation coefficient
Male	341	12	11	14	16	22	5	3	9	6	-0.55
Female	295	9	11	14	12	9	7	7	15	15	0.25

The table shows that the correlation coefficient scores were stronger in the male grouping, suggesting that males are more likely to use an open fireplace more frequently than females.

6.2.2.6 Review of the Relationship Between Participant Gender and the Use of a Solid Fuel Stove

The methodology stated in section 6.2.2.5 was repeated to identify whether gender played a role in the level of use of a solid fuel stove. Table 6-44 displays the results from the analysis.

Table 6-44: Survey Q66 results tabulated, disaggregated by gender groupings.

Gender	Total	Continuously (%)	Several times a day (%)	Once a day (%)	Several times a week (%)	Once or twice a week (%)	Once every two weeks (%)	Once or twice a month (%)	Less often (%)	Never (%)	Correlation coefficient
Male	304	12	13	23	30	11	5	2	3	1	-0.82
Female	176	9	16	23	11	16	7	6	9	3	-0.67

The table shows that the correlation coefficient scores were reasonably similar between genders, suggesting that the gender grouping is unlikely to have an impact on the frequency of the use of solid fuel stoves.

6.2.2.7 Review of the Relationship Between Participant Ethnicity and the Use of an Open Fireplace

Table 6-45 provides a tabulated overview of how participants answered Q65 based disaggregated by ethnic grouping.

Table 6-45: Survey Q65 results tabulated, disaggregated by ethnicity.

Ethnicity	Number of responses	Continuously (%)	Several times a day (%)	Once a day (%)	Several times a week (%)	Once or twice a week (%)	Once every two weeks (%)	Once or twice a month (%)	Less often (%)	Never (%)	Correlation coefficient
BAME	223	14	12	15	16	10	7	5	13	8	-0.57
non - BAME	417	9	11	13	13	20	6	5	12	12	-0.07

The table shows that:

- This question was responded by a greater proportion of participants of the non-BAME class (65%) compared to those of the BAME class (35%).
- A weak trend towards the continuous use extreme, -0.57, was identified in responses made by participants in BAME grouping.
- There was no relationship between the non-BAME demographic group and the use of an open fireplace.

6.2.2.8 Review of the Relationship Between Participant Ethnicity and the use of a Solid Fuel Stove

Table 6-46 provides a tabulated overview of how participants answered Q66 based disaggregated by ethnic grouping.

Table 6-46: Survey Q66 results tabulated, disaggregated by ethnicity

Ethnicity	Number of responses	Continuously (%)	Several times a day (%)	Once a day (%)	Several times a week (%)	Once or twice a week (%)	Once every two weeks (%)	Once or twice a month (%)	Less often (%)	Never (%)	Correlation coefficient
BAME	169	14	21	17	15	11	7	5	7	4	-0.87
non - BAME	319	8	10	28	28	14	5	2	4	0	-0.71

The table shows that the correlation coefficient value is reasonably similar for both ethnic groups and therefore suggests that ethnicity does not place an influential role in the use of a solid fuel stove.

6.2.2.9 Summary of findings from Task 2

The findings from Task 2 of the distributional impact analysis are, in:

Relation to the use of an open fireplace:

- There is overall, no clear relationship between how frequently participants used an open fireplace and the overall level of deprivation of the borough of residence. The Spearman's correlation coefficient values suggest that boroughs in the mid-levels in the order of deprivation (Ealing, Camden, Brent, Croydon) are most likely to frequently use an open fireplace.
- The survey results suggest that age is a factor in the use of an open fireplace as participants in the younger age groups had a weak correlation coefficient value that suggests frequent use, whilst those in the older groups selected answers suggesting less frequent use overall.
- The survey results suggest that gender has some effect on the use of an open fireplace. Males were found to score a weak correlation coefficient value which indicated frequent use. Females were found to score a correlation coefficient value which represented a mixed level of use.
- The survey results suggest that ethnicity has some effect on the use of an open fireplace as BAME participants were found to have a weak correlation coefficient value which indicates frequent use whilst non BAME participants scored a value close to zero, indicating a mixed use of frequency overall.

Relation to the use of a solid fuel stove:

- The data shows that, overall, participants who responded to this question tended to select answers that indicated frequent use of solid fuel appliances. This pattern was consistent in each borough, regardless of its overall ranking on the IMD database.
- The survey results suggests that age is not a factor in the use of a solid fuel stove as participants in all age groups had a correlation coefficient value showing frequent use.
- The survey results also suggest that gender is not a factor in the use of a solid fuel stove as both groups had a correlation coefficient value showing frequent use.

- The survey results also suggest that ethnicity is not a factor in the use of a solid fuel stove as both groups had a correlation coefficient value showing frequent use.

6.2.3 Summary and Conclusions from the Distributional Analysis

The distributional analysis has been undertaken through evaluation of the relationship between sensitive demographics against two datasets:

- Annual averaged $PM_{2.5}$ concentrations attributed to domestic wood burning and the use of coal and oil fuels, as provided by the London Atmospheric Emissions Inventory (LAEI). (Task 1)
- Responses to questions relating to the use of open fireplaces and solid fuel burning stoves, as gathered by the Opinium survey. (Task 2)

Task 1 was undertaken by reviewing the relationship between sensitive demographics and annual averaged concentrations at two levels of spatial resolution (London borough/LSOA). The main findings from this phase are that:

- At borough level, the data suggest that there is a weak relationship between level of deprivation and the concentration of $PM_{2.5}$ derived from wood burning activities, where citizens living in the most deprived area are slightly more likely to be exposed to higher levels of $PM_{2.5}$ stemming from wood-burning activities.
- At LSOA level, no relationship was found between level of deprivation and annual averaged concentrations of $PM_{2.5}$. However, the data shows that the maximum concentrations were highest in the quintile groups with the highest level of deprivation (the most deprived LSOA areas).
- No significant relationships between other sensitive demographics (age and ethnicity) were identified at LSOA resolution.

The above findings should only be considered as indicative as the underlying data provided by the LAEI provides emission released across points across a 1x1 km grid, with the data representing a release across a gridded square. For this assessment, the LAEI data was first converted to a concentration value and then inversely distance weighted to provide concentration maps based on 100m gridded resolutions in the absence of higher resolution data that apportions emissions or concentrations of $PM_{2.5}$ to wood burning activities or solid fuel use.

In conclusion, Task 1 of the distributional analysis has found that, overall, there are no relationships between the proportion of a sensitive demographic in a spatial region and concentrations of $PM_{2.5}$ from domestic wood burning and domestic use of coal and oil fuels.

The analysis found that at London borough resolution, there was a weak relationship between a borough's level of deprivation ranking and the concentration of $PM_{2.5}$ from domestic wood burning and coal and oil burning.

The review of this impact at LSOA resolution also found a weak relationship between the citizens over 65 demographic and concentrations of $PM_{2.5}$ released through the domestic use of coal and oil fuels. The review did not identify any other relationships between the concentration of $PM_{2.5}$ from domestic wood burning and coal and oil burning and the proportions of any of the social demographics used as a sensitive indicator.

Task 2 was undertaken by reviewing answers given by participants who responded to the Opinium survey. The two questions analysed relate to the frequency of usage of an open fireplace (Q65) and the usage of a solid fuel stove (Q66) where respondents had stated they had one or both of these inside their home. The main findings from this Task are that:

- There was only a very weak relationship found between the use of an open fireplace or a solid fuel stove and the overall level of deprivation of the borough that the participant resided within.
- The participant's age plays a role in the use of an open fireplace, as the analysis found that those in younger age groups tended to use an open fireplace more often than those in the older groups.
- The data also showed that age, gender and ethnicity had no influence on the level of use of a solid fuel stove.

Based on these observations, a social message that aims to improve public health by highlighting the impacts of wood burning activities and the use of solid fuel appliances should not be targeted to any one particular social group. It is recommended that any future messages are applied to broad demographic groups as these behavioural activities are impacting citizens across London. The limitations in the available data used for this study mean that other factors (such as a potential relationship between individual wealth and the use of a solid fuel appliance) could not be investigated, but could be considered in future research.

6.2.4 Distributional Analysis Study Limitations and Recommendations for Future Research

The conclusions drawn from the distributional analysis are based upon methodologies identified through a wide searching literature review. The literature review identified studies which investigated the exposure of vulnerable social groups to air pollutants.

Whilst a robust approach was undertaken to perform the study, there were a number of limitations which can be addressed in the future to improve understanding of the impacts of wood burning and the use of oil and coal appliances on the health of vulnerable demographic groups.

6.2.4.1 Study Limitations

Relating to Task 1

- This section of the study was underpinned by the London Atmospheric Emissions Inventory. This dataset included source apportioned emissions of $PM_{2.5}$ on a 1km grid resolution. The resolution of this grid was found to overlap many LSOA spatial areas, with the value from each gridded point generally dominated the values for each of the nearby LSOAs and is therefore unlikely to truly represent how concentrations differed between neighbouring LSOAs.
- The LAEI dataset was last updated in 2019. New emission projections and concentrations for 2025 and 2030 were published towards the end of the study but it was not possible to incorporate these into the analysis.
- It was not possible to source apportion $PM_{2.5}$ concentrations using measurements collected across greater London as the prevalent types of monitors in use do not have the capabilities to differentiate between different emission sources.

Relating to Task 2

- This section of the study was underpinned by responses to a survey undertaken by Opinium. The results were therefore limited to reflect the response of participants who had been aware of, and the time to, complete the survey.

6.2.4.2 Recommendations for Future Research

Future research into the impact of domestic wood burning activities and domestic use of coal and oil fuels can be enhanced by:

- Access to high resolution, source apportioned $PM_{2.5}$ concentration data. This data could be obtained through the enhancement of the LAEI or future upgrades to the existing air quality monitoring networks present throughout London.
- Access to increased data capture on the level of domestic wood and solid fuel burning activity in London.
- Addressing any survey limitations documented by Opinium could be used to improve data capture by future surveys.

T: +44 (0) 1235 75 3000
E: enquiry@ricardo.com
W: ee.ricardo.com