LONDON ATMOSPHERIC EMISSIONS INVENTORY (LAEI) 2022

METHODOLOGY REPORT

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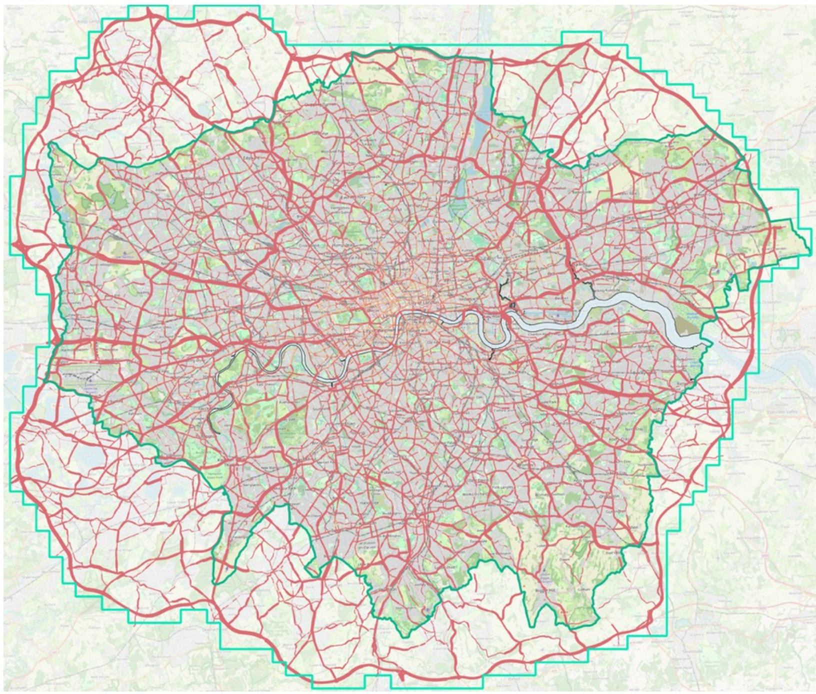
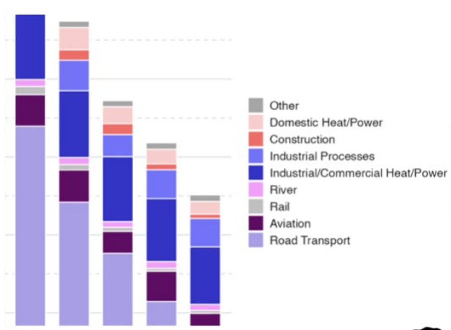
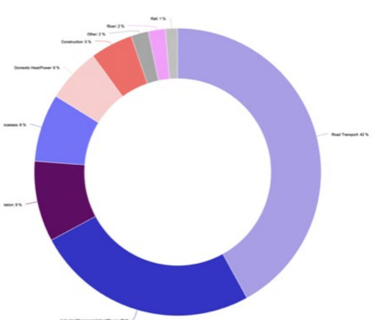
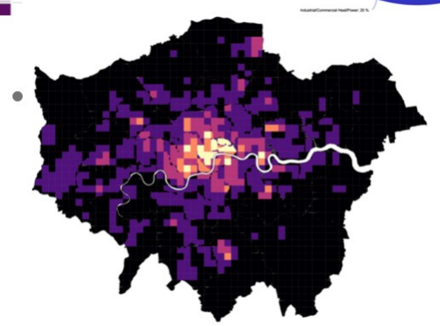
December 2025









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1. Overview

The London Atmospheric Emissions Inventory - LAEI - is a database of geographically referenced datasets of pollutant emissions and sources in Greater London[1]. This update of the LAEI (referred to hereafter as the "LAEI 2022") includes emissions for a new base year 2022. It also provides emissions from previous baseline years 2016 and 2019, as well as forecast emissions for 2025 and 2030, which were published in the previous LAEI (2019) update (referred to as the "LAEI 2019" in this document).

The LAEI 2022 is based on the latest detailed activity data, emission factors database and methodology improvements at the time of compilation of the inventory.

The emission sources in the inventory are outlined in Table 1.

Table 1: Emission Sources in the LAEI

Main Source Category	Sector	Source
Industrial and Commercial	Industrial Processes	Large Processes (Part A1)
		Small Processes (Part A2/B)
		NRMM Exhaust (Industrial Sites)
	Heat and Power Generation	Gas Combustion
		Other Fuels Combustion
	Waste	Landfill Sites
		Sewage Treatment Works
		Waste Transfer Stations
		Small Scale Waste Burning
	Construction	NRMM Exhaust (Construction Sites)
		Construction / Demolition Dust
	Commercial Catering (Cooking)	Commercial Catering (Cooking)
	Natural Gas Supply Leakage	Natural Gas Supply Leakage
Domestic	Heat and Power Generation	Gas Combustion
		Other Fuels Combustion
	NRMM (Household and Garden Machinery)	NRMM (Household and Garden Machinery)
	Domestic Wood Burning (Biomass)	Domestic Wood Burning (Biomass)
	Domestic Cooking	Domestic Cooking
Transport	River	Commercial Shipping
		Passenger Shipping
	Road	Vehicle Type (Car, PHV, LGV, Taxi, Motorcycle, Rigid HGV, Articulated HGV, TfL Bus, Other Bus / Coach
	Rail	Freight

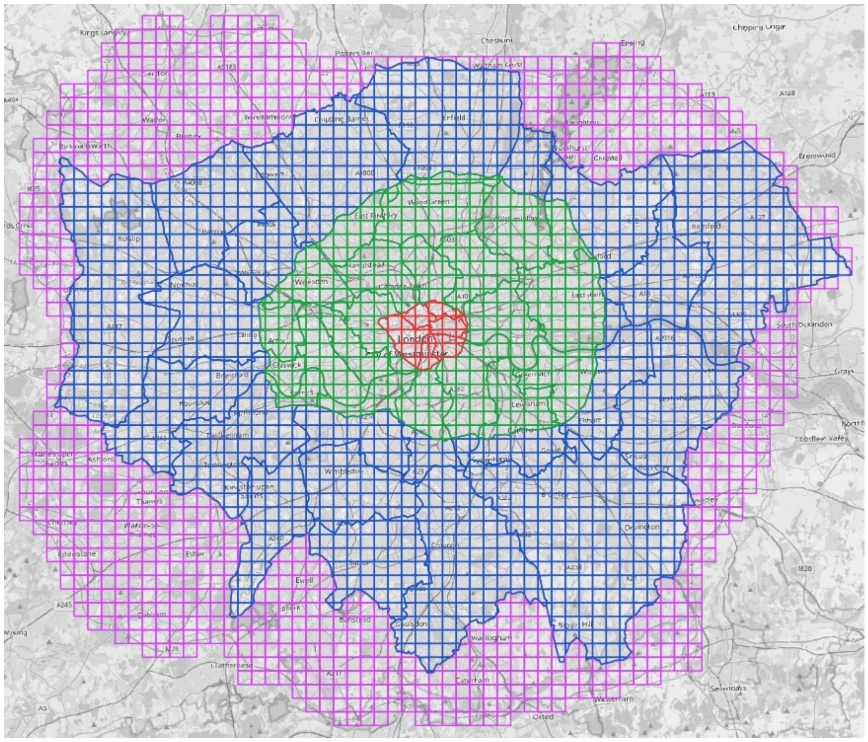
[1] The inventory actually covers a wider zone, up to the M25 motorway

Main Source Category	Sector	Source
		Passenger
	Aviation	Aircraft (Ground Level)
		Aircraft (Elevated)
		Airside Vehicles (Ground Support Equipment)
		Landside Vehiclers
		Stationary Sources
	Agriculture	Combustion
		Livestock
Miscellaneous		Fertilisers and Soils
	Accidental Fires	Accidental Fires
	Forestry - Biosynthesis	Forestry - Biosynthesis
Resuspension	Resuspension	Resuspension

Emissions are estimated by source type, represented by points, polygons, lines or areas, depending on the nature and size of each source. They are then projected on a $1km^2$ resolution grid (referred to hereafter as the “LAEI Grid”), covering an area of 2,466 km^2, further split to follow the boundary of each London borough, to allow accurate aggregations of emissions by borough. Emissions outside London boroughs (i.e. beyond the Greater London Authority (GLA) boundary) are aggregated and reported as “Non-GLA” emissions. The LAEI Grid (see Figure 1) is also split into 4 main zones, which are used to aggregate and report emissions at a higher level. These are:

- The Central London zone
- The Inner London zone
- The Outer London zone
- The Non-GLA zone (outside London, up to the M25 motorway)

Figure 1: LAEI Grid used to report emissions



The LAEI 2022 includes emissions from the following 4 key pollutants:

- Nitrogen Oxides (NO_x)
- Particulate matter with an aerodynamic diameter < 10 µm (PM_{10})
- Particulate matter with an aerodynamic diameter < 2.5 µm ($PM_{2.5}$)
- Carbon Dioxide (CO_2)

Additionally, it includes emissions from 14 subsidiary air pollutants:

- Methane (CH_4)
- Nitrous Oxide (N_2O)
- Sulphur Dioxide (SO_2)
- Non Methane Volatile Organic Compounds (NMVOC)
- 1,3-Butadiene (C_4H_6) (subset of NMVOC)
- Benzene (C_6H_6) (subset of NMVOC)
- Ammonia (NH_3)
- Carbon Monoxide (CO)
- Benzo[a]pyrene (BaP)

- PolyChlorinated Biphenyls (PCB)
- Hydrogen Chloride (HCl)
- Heavy Metals Cadmium (Cd), Mercury (Hg) and Lead (Pb)

Finally, as part of the LAEI 2022, dispersion modelling of emissions from key pollutants for the base year 2022 are used to estimate ground level concentrations of NO_x, Nitrogen Dioxide (NO_2), PM_{10} and $PM_{2.5}$ at 20m resolution across London, with resulting concentration maps and associated data available on the LAEI website.

This document details the methodology that has been used to estimate all emission sources, focusing on the changes in data source and/or methodology improvements since the last update.

2. Changes to Previous Baseline and Forecast Years

Emissions estimates from previous baseline years (2016, 2019) and forecast years (2025, 2030), remain as previously reported in the LAEI 2019, except for the following sources, where changes in methodology, revised historical activity data or emission factors were deemed significant enough to warrant a revision of emission estimates previously published for these sources, due to the impact they had on overall trends. These include:

- An increase in road transport emissions, due to the revision of motor vehicle statistics on minor roads across Great Britain published by Department for Transport (DfT), which resulted in increases in overall vehicle-kilometre estimates across London and the LAEI area. The effect of this revision by DfT on traffic volume estimates on London roads was discussed in Travel in London reports[1] from Transport for London (TfL). These changes could not be included at the time the LAEI 2019 was prepared, but have now been incorporated in the LAEI 2022. For previous baseline years and forecast years, an overall scaling factor was applied to road transport emissions, to reflect the minor road methodology changes. However, the underlying traffic trends are the same as in the LAEI 2019. Revised forecast of traffic volumes accounting for both the DfT minor road changes and new forecasts for traffic post-pandemic will be incorporated in the next LAEI update.
- An increase in Particulate Matter (PM) aviation emissions, linked to the stationary sources at Heathrow airport, which saw a significant increase in emissions from the biomass Combined Heat and Power (CHP) plant. Note that emissions from previous baselines have not been revised; only those for forecast years 2025 and 2030 have been updated by replacing estimated emissions for the stationary sources at Heathrow, (using those reported in the Heathrow Airport emission inventory 2022 instead of the previous emissions reported in the LAEI 2019.
- An increase in domestic emissions associated to the combustion of residual fuel (i.e. not natural gas) for heat and power generation, aligned with the latest revision of residual fuel consumption for UK local authorities from the Department for Energy Security and Net Zero (DESNZ).

These revisions mean that overall, LAEI emission estimates for 2016, 2019 and forecast for 2025 and 2030 are slightly higher than previously reported as part of the LAEI 2019.

Finally, for PM emissions, previous estimates for commercial cooking have now been split between commercial cooking and domestic cooking, following a revision of the methodology. The previous totals from the LAEI 2019 remain unchanged, but these have been split equally between these two categories, although the spatial distribution is different (as the commercial part of these emissions is based on the distribution of commercial premises, whilst the domestic part is based on the housing distribution across London). To be consistent,

[1] Travel in London Report 14, Transport for London, 2021. Section 7.2 'Overall trends for road traffic in London'. Available at travel-in-london-report-14.pdf

emissions for previous baseline years 2016 and 2019, and forecast years 2025 and 2030, have been split in a similar way.

Note that these revisions have been carried out at high level, based on overall scaling of previous emissions, and only apply to the above sources. However, forecast emissions for all sources will be fully revised in the next LAEI update.

3. Industrial and Commercial Sources

Emissions from the industrial and commercial sector include the following categories:

- Emissions from regulated industrial processes (Part A1/A2 and B)
- Emissions from the combustion of fuel used to generate heat and/or power for the industrial/commercial sector
- Emissions from waste
- Emissions from construction / demolition
- Emissions due to gas leakage

3.1 Industrial Processes

3.1.1 Introduction

Emissions from the Industrial Processes category include the following sources:

- Large Processes (Part A1) regulated by the Environment Agency
- Small Processes (Part A2 and B) regulated by Local Authorities as part of the Local Authority Pollution Prevention and Control regime
- Non Road Mobile Machinery (NRMM) exhaust emissions on industrial sites

Part A1 processes refer to large or complex industrial activities that have a significant potential impact on the environment. Part A1 activities are regulated by the Environment Agency, due to the potential for substantial pollution or environmental risk. Part A1 sites involve industrial operations that produce high levels of emissions or discharges affecting the air, water, or land. These include heavy industries like power stations, chemical plants, and large-scale metal production.

Part A2 processes refer to industrial activities that have a significant but more localised environmental impact, compared to Part A1 sites. Part A2 activities are regulated by local authorities rather than the Environment Agency, and they involve operations that could affect the environment, primarily on a local scale.

Part B processes represent the smallest scale of regulated industrial activities when it comes to potential environmental impact. Unlike Part A1 and Part A2 sites, which have broader regulatory scopes involving emissions to air, water, and land, Part B sites are regulated solely for their emissions to air.

3.1.2 Large Processes (Part A1)

The method used for identifying sites and estimating emissions from Part A1 activities remains largely similar to previous LAEI updates, with some changes to which sites were included / excluded, as detailed further below.

The primary source of data for Part A1 sites is the 2022 Environment Agency's Pollution Inventory (EA-PI)[1]. Sites within the geographical scope of the LAEI were extracted from this dataset by selecting sites with co-ordinates falling within the LAEI boundary. The list of sites from the EA-PI was supplemented with the 2022 data reported to the UK Registry on Industrial Sites (UK-Registry)[2] from the Department for Environment, Food and Rural Affairs (Defra), a database of administrative data only (i.e. emissions data is not included) with a slightly smaller activity scope than the EA-PI, although there is significant overlap. It contains all facilities that fall within the activity scope, regardless of the emissions released, and whether the site is currently active. Of the 79 Part A1 sites identified for 2022 within the LAEI boundary, 76 came from the EA-PI and 3 came from the UK-Registry.

3.1.2.1 Pollutants

Emissions from Part A1 sources have been estimated for the pollutants shown in Table 2.

Table 2: Pollutants Reported for Industrial Part A1 Sources

Main Source	Category	Number of Pollutants Reported	Key Pollutants				Other Pollutants
			NOx	PM_{10}	$PM_{2.5}$	CO_2	
Industrial and Commercial	Industrial Processes - Part A1	15	✔	✔	✔	✔	BaP, C_6H_6, CH_4, CO, HCl, Hg, N_2O, NH_3, NMVOC, PCB, SO_2

3.1.2.2 Emissions

Emissions estimates were primarily sourced from the 2022 EA-PI. Where emissions data were not available from the EA-PI, the site list was compared with the 2021 National Atmospheric Emissions Inventory (NAEI) point source database, the most recent available during the compilation process. Sites within the NAEI were compared manually with those in the site list compiled from the EA-PI and UK-Registry, using the site name, operator and co-ordinates to find matches. In some cases there were slight differences in names for the same site between datasets. Where it was possible to identify a site match, emissions estimates were gap filled using the NAEI data. Where sites in the EA-PI did not report emissions, or emissions were reported as "below the reporting threshold", reported emissions from matching sites in the NAEI were used. The full list of Part A1 sites considered is provided in Table 34 in Section 7.1, and summarised below:

- 35 sites were identified and assigned emissions from the EA-PI
- 3 sites were identified from the UK-Registry and assigned emissions from the NAEI
- 14 sites were identified from the EA-PI but did not have reported emissions, so were assigned emissions from the NAEI.
- 27 sites were identified from the EA-PI but did not have associated emissions in either the EA-PI or NAEI, so were not included in the LAEI 2022.

Finally, there were 20 Part A1 sites with emissions reported in the LAEI 2019, that did not have associated emissions in the 2022 EA-PI or the NAEI 2021 point source database, and therefore were not included in the

[1] Available at https://www.gov.uk/government/collections/pollution-inventory-reporting

[2] UK Registry on Industrial Sites. Available at https://prtr.defra.gov.uk/registry-dataset

LAEI 2022 (see Table 35 in Section 7.1). Conversely, there are 21 sites with associated emissions included in the LAEI 2022, that were not included in the previous inventory.

3.1.2.3 Overlaps with other LAEI Sectors

Following previous assumptions used in previous LAEI updates, the Heathrow Airport boiler and all landfill sites were excluded from the Part A1 list due to them being represented in the Aviation (Section 5.4) and Waste, Landfill Sites (Section 3.3.2) category, respectively.

In the LAEI 2019, a number of Waste Transfer Station (WTS) sites and Sewage Treatment Works (STW) sites were also excluded from the Part A1 list, due to the potential for double counting emissions with the waste sector. However, following expert review as part of the LAEI 2022, it was decided to keep both types of sites in the Part A1 list of the LAEI 2022, as the assumption of double counting was found to be incorrect. In the case of WTS, only dust emissions associated with the movement of materials are included in the waste sector. The inclusion of 2022 EA-PI data on Part A1 sources in the industrial point sources sector of the LAEI ensures that other emissions associated with WTS are included. For STW, the total emissions from Part A1 sources reported in the 2022 EA-PI has been subtracted from the total in the waste STW sector, which is calculated using a different method (see Section 3.3.3), and so emissions in the 2022 EA-PI have been included within this section (Large Processes - Part A1).

There is an overall increase in emissions in the LAEI 2022 compared with the LAEI 2019, which is driven by increased CO_2 emissions from the previously excluded STW sites that have been re-included this time to correct the oversight in the LAEI 2019.

Emissions from 2016 and 2019 have not been revised and remain as reported in LAEI 2019.

3.1.3 Small Processes (Part A2 and B)

3.1.3.1 Part A2 sites

One Part A2 industrial site was included in the LAEI 2019. To supplement this, the UK-Registry from Defra was used to identify new sites or sites that have been decommissioned.

Part A2 sites in the UK-Registry were filtered for sites within local authorities that have some part of their boundary within the geographical scope of the LAEI. Of the new sites identified for these local authorities, none lie within the LAEI boundary, and therefore no new Part A2 sites were added to the LAEI 2022. The one Part A2 site reported to the UK-Registry in the last submission was identified to have been decommissioned and was removed, so the LAEI 2022 does not include any Part A2 sites.

3.1.3.2 Part B sites

No changes were made to the list of Part B sites for the LAEI 2022, as there are no additional sources of information available for this. In total, 2019 Part B sites were included in the LAEI 2022. The number of Part B sites by type and zone is provided in Table 36 in Section 7.1.

3.1.3.3 Pollutants

Emissions from Part A2/B sources have been estimated for the pollutants shown in Table 3.

Table 3: Pollutants Reported for Industrial Part A2/B Sources

Main Source	Category	Number of Pollutants Reported	Key Pollutants				Other Pollutants
			NOx	PM_{10}	$PM_{2.5}$	CO_2	
Industrial and Commercial	Industrial Processes - Part A2 / B	9	✔	✔	✔	✔	C_6H_6, CO, NMVOC, Pb, SO_2

3.1.3.4 Emissions and Spatial Distribution

Emissions for Part A2 and B sites are not estimated using site specific data, as activity data for most of the processes is not publicly available. Typical emissions are estimated for 35 types of site activity (e.g. dry cleaning, cremation, etc.) and applied to all sites of that type. No changes were made to estimated emissions for the listed sites compared to the LAEI 2019, except for a select number of sectors, where updated data could be identified, and for manufactured wood products and waste wood burning, where a minor error in the LAEI 2019 was corrected.

Following the assessment of the emissions compiled in the previous inventory, sectors with high emissions that were not updated with new data in the LAEI 2019 were identified as the priority to update. These sectors were:

- blending, packing, loading, unloading and use of bulk cement
- mobile crushing and screening (of materials like bricks, tile or concrete or any other designated mineral)
- respraying of road vehicles
- waste oil and recovered oil burners
- crematoria
- roadstone coating processes

Where available, activity estimates for typical sites were sourced from previous LAEI methodology documents. For crematoria, updated activity data was sourced from The Cremation Society.

Updated emission factors were sought for in the European Monitoring and Evaluation Programme (The co-operative programme for monitoring and evaluation of the long-range transmission of air pollutants in Europe) from the European Environment Agency (EMEP/EEA) 2023 Guidebook[3] and in the UK NAEI. However, it is important to note that the EMEP/EEA 2023 Guidebook contains many of the same emissions factors as from the previous Guidebook (2019 version).

Where new activity data and emission factors were available, revised emission estimates were calculated, but only where the data was judged superior to the previous data, otherwise the previously calculated emissions were kept (the data collated is not often of better quality than that estimated previously). Of the sectors listed above, superior data was only identified for crematoria and respraying of road vehicles. Updates implemented in the LAEI 2022 included the following:

- Cremation was updated with activity data from the Cremation Society for London in 2022. EMEP/EEA Guidebook emission factors were used. This increased the emissions from NO_x and CO slightly and decreased SO_2, PM and NMVOC slightly. Lead emissions increased significantly.

[3] EMEP/EEA air pollutant emission inventory guidebook 2023, EEA Report 06/2023, European Environment Agency. Available at https://www.eea.europa.eu/en/analysis/publications/emep-eea-guidebook-2023

- Respraying of road vehicles was reassessed, and as a result, other pollutants apart from NMVOC were removed, as deemed not relevant according to the EMEP/EEA guidebook. As a result, total emissions for Part B processes for these other pollutants decreased compared to the LAEI 2019.
- A minor correction was made to an error in the 2019 inventory, where emissions from combustion of waste wood had been omitted from the category of "Manufacture of Timber and Wood-Based Products / Combustion of Waste Wood". This category now includes emissions from both combustion and manufacture.

3.1.4 Non-Road Mobile Machinery on Industrial Sites

NRMM emissions from industry and construction are estimated separately in the LAEI. This section only refers to NRMM from industrial sources. The methodology to estimate construction related NRMM emissions is provided in Section 3.4.2.

Non construction NRMM exhaust emissions are defined as those from small and large generators, machinery and off-road vehicles on industrial sites.

The methodology used to estimate emissions was kept as consistent as possible with the methodology used for the LAEI 2019, using a top-down disaggregation of emissions reported in the NAEI. However, since the previous inventory, the NRMM exhaust emissions in the NAEI are now reported in more detail, and this has necessitated some changes in methodology and reporting format for calculation of industrial NRMM exhaust emissions.

3.1.4.1 Pollutants

Exhaust emissions from NRMM industrial sources have been estimated for the pollutants shown in Table 4.

Table 4: Pollutants Reported for NRMM Exhaust Sources from Industrial Sites

Main Source	Category	Number of Pollutants Reported	Key Pollutants				Other Pollutants
			NOx	PM_{10}	$PM_{2.5}$	CO_2	
Industrial and Commercial	Industrial Processes - NRMM Exhaust	16	✔	✔	✔	✔	BaP, C_4H_6, C_6H_6, Cd, CH_4, CO, Hg, N_2O, NH_3, NMVOC, Pb, SO_2

3.1.4.2 Emissions and Spatial Distribution

As for the previous LAEI updates, NRMM exhaust emissions from industrial sites for 2022 were determined based on a top down approach, using total NRMM emissions reported in the NAEI for the UK, combined with data from the latest NAEI CO_2 emissions map[4].

NAEI CO_2 emissions reported for the "Combustion in Manufacturing Industry" sector, provided at a 1km^2 resolution across the UK, have been used as a proxy indicator of industrial activity across the UK. This is deemed representative of the spatial distribution of NRMM exhaust emissions on industrial sites.

[4] Available at http://naei.beis.gov.uk/data/map-uk-das.

This enabled to estimate the fraction of the UK industrial NRMM emissions within the LAEI area (5.2%), as well as the distribution of these emissions on the LAEI grid, using GIS to determine the proportion of emissions allocated to each LAEI grid cell.

Other industrial NRMM exhaust

Emissions from other industrial (i.e. non-construction) NRMM exhaust were estimated using a top-down method, allocating a share of total UK NRMM exhaust emissions (Nomenclature For Reporting (NFR)[5] code 1A2gvii: Mobile combustion in manufacturing industries and construction) from the NAEI to the LAEI grid.

Allocating emissions to the LAEI grid

As for previous LAEI updates, total UK industrial NRMM emissions were allocated to the LAEI grid, using the 1 km^2 NAEI gridded map of UK CO_2 emissions for the "Combustion in manufacturing industries" sector as a proxy. More specifically:

- The area of overlap of each LAEI grid cell with each NAEI grid cell was calculated using GIS
- This area was converted to a fraction of the relevant NAEI grid cell area
- This fraction of the NAEI grid cell CO_2 emissions was allocated to the overlapping LAEI grid cell
- For each LAEI grid cell, the allocated CO_2 emissions were divided by the total emissions from all NAEI grid cells across the UK to assign the correct proportion of UK emissions to each LAEI grid cell
- This proportion was then applied to the UK emissions totals from the NAEI for each pollutant and each of the NRMM exhaust emissions sub-categories, to calculate LAEI grid cell emissions per NRMM sub-category and pollutant

In total, the fraction of UK emissions allocated to the LAEI area using this proxy was 5.2%.

NAEI UK Emissions

For the LAEI 2019 update, industrial NRMM emissions estimates from the NAEI were only available as a single source category, so a bespoke breakdown was requested and supplied by the NAEI team, on behalf of DESNZ and Defra), to split out emissions between the construction and other industrial NRMM sub sectors. This allowed the construction element to be ignored, to avoid double-counting with the bottom-up method used to estimate construction exhaust emissions.

However, the NAEI now breaks down NRMM emissions into the following sub-categories:

- Construction
- Generators
- Mining and quarrying
- Other industry
- Waste

For the LAEI 2022, the NRMM from industrial sources emissions include the "Mining and quarrying", "Other industry" and "Waste" NRMM emissions, but exclude the "Construction" emissions from the NAEI.

[5] A hierarchical, code-based system used in Europe and by countries reporting under the UNECE Convention on Long-range Transboundary Air Pollution to classify and report air pollutant and greenhouse gas emissions from various human activities. Full list available at https://naei.energysecurity.gov.uk/glossary/nfr-code-list

The “Generators” sub-category from the NAEI includes both generators used on construction sites (which are also included in the NRMM register and High Speed 2 (HS2) datasets) and other types of generator used elsewhere. As the NAEI does not provide this additional breakdown, to avoid double-counting of generator emissions, for the LAEI, a separate category was defined as “non-construction” generators, using the following methodology:

- Estimate the London emissions of all pollutants for the total “Generators” sub-category, using the CO_2 emissions map proxy
- Extract the London total emissions from generators used in construction from the bottom-up NRMM construction exhaust emissions calculations (see Section 3.4.2)
- Subtract the construction generators emissions from the total “Generators” sub-category emissions, to estimate the remaining London “non-construction” generators emissions by pollutant. Where the construction generators emissions for a pollutant were larger than the total “Generators” sub-category emissions, this value was set to 0
- The LAEI total for “non-construction” generators was then spread across the LAEI grid in the same way as described above using the industrial CO_2 proxy

3.2 Heat and Power Generation

3.2.1 Introduction

Emissions from the Heat and Power Generation for the Industrial and Commercial category include the following sources:

- Gas combustion sources
- Solid and liquid fuel combustion sources

3.2.2 Gas Combustion

3.2.2.1 Pollutants

Emissions from gas combustion sources within the industrial and commercial heat and power generation category have been estimated for the pollutants shown in Table 5.

Table 5: Pollutants Reported for Gas Combustion Sources from the Industrial/Commercial Heat and Power Generation Category

Main Source	Category	Number of Pollutants Reported	Key Pollutants				Other Pollutants
			NOx	PM_{10}	$PM_{2.5}$	CO_2	
Industrial and Commercial	Heat and Power Generation - Gas Combustion	13	✔	✔	✔	✔	BaP, C_6H_6, Cd, CH_4, Hg, N_2O, NMVOC, Pb, SO_2

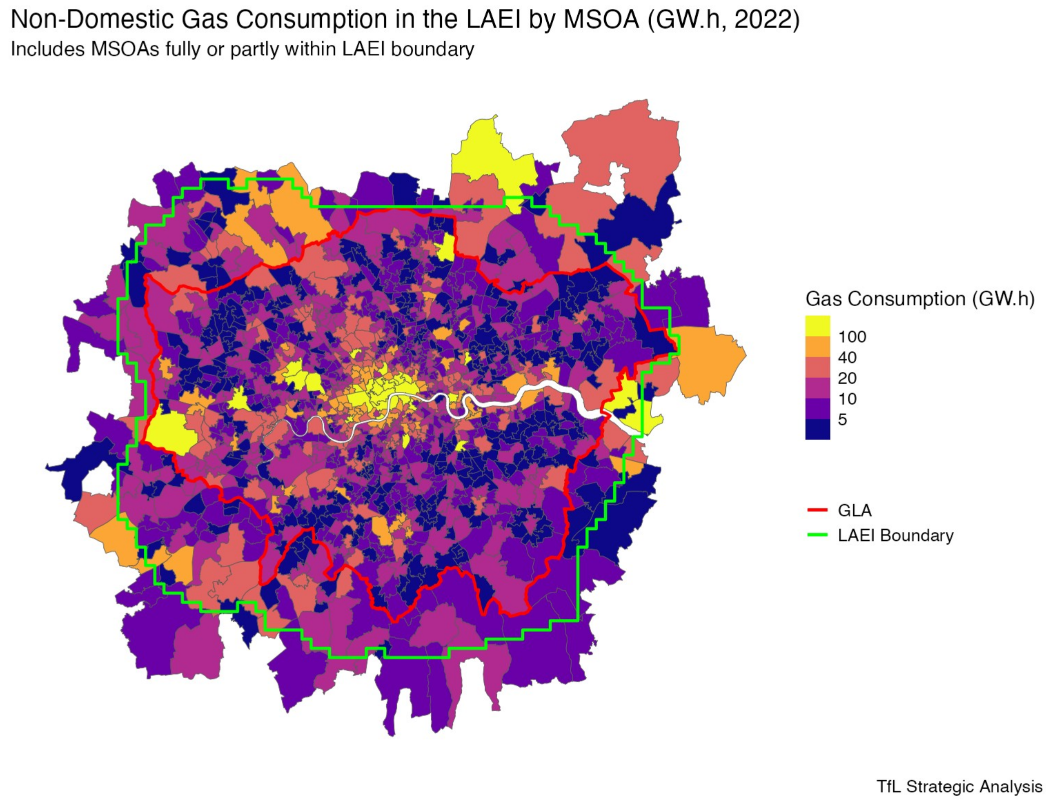
Emissions estimates have been based on the same methodology followed in previous LAEI updates, using updated data and applying the following activity-based equation, for each pollutant:

Equation
Emissions (tonnes/year) = Gas Consumption (GW.h/year) × Emission Factor (t poll/GW.h)

3.2.2.2 Activity Data and Spatial Distribution

Updated activity data (the gas consumption, expressed as energy consumed, in gigawatt-hour/year) has been collated from DESNZ website, providing non-domestic gas consumption across the UK at Middle-layer Super Output Area (MSOA) level for year 2022. MSOA gas consumption (see Figure 2) was then projected onto the LAEI grid and used as a proxy for the spatial distribution of emissions.

Figure 2: Non-Domestic Gas Consumption in the LAEI by MSOA (Middle Super Output Area)



3.2.2.3 Emission Factors

Updated emission factors (expressed as the mass of pollutant emitted per amount of energy consumed) for year 2022 were collated from the NAEI Emission Factors Database for each pollutant. These emission factors are shown in Table 37 in Section 7.1.

3.2.3 Solid and Liquid Fuel Combustion

3.2.3.1 Pollutants

Emissions from other (solid and liquid fuel, also referred to as "residual fuel") combustion sources within the industrial and commercial heat and power generation category have been estimated for the pollutants shown in Table 6.

Table 6: Pollutants Reported for Liquid/Solid Fuel Combustion Sources from the Industrial/Commercial Heat and Power Generation Category

Main Source	Category	Number of Pollutants Reported	Key Pollutants				Other Pollutants
			NOx	PM_{10}	$PM_{2.5}$	CO_2	
Industrial and Commercial	Heat and Power Generation - Oil/Coal Combustion	4	✔	✔	✔	✔	✘

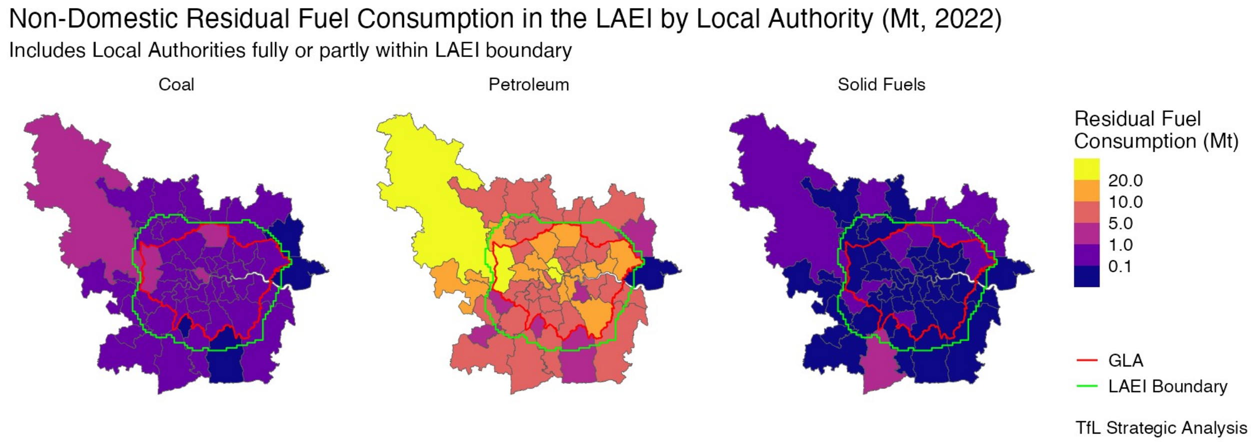
Emissions estimates have been based on the same methodology followed in the previous LAEI updates, using updated data and applying the following activity-based equation, for each fuel and each pollutant:

Equation
Emissions (tonnes/year) = Fuel Consumption (t fuel consumed/year) × Emission Factor (t poll/t fuel consumed)

3.2.3.2 Activity Data and Spatial Distribution

Updated activity data (the mass of fuel consumed, in tonnes/year) has been collated from the Sub-national residual fuel consumption data published by DESNZ, providing industrial coal, fuel oil and solid smokeless fuel consumption across the UK at local authority level for year 2022. Fuel consumption (see Figure 3) was then projected onto the LAEI grid and used as a proxy for the spatial distribution of emissions.

Figure 3: Non-Domestic Residual Fuel Consumption in the LAEI by Local Authority



3.2.3.3 Emission Factors

Updated emission factors (expressed as the mass of pollutant emitted per mass of fuel consumed) for year 2022 were collated from the from the NAEI Emission Factors Database for each pollutant. These emission factors are shown in Table 38 in Section 7.1.

3.3 Waste

3.3.1 Introduction

This source sector includes:

- Emissions from waste handling at landfill sites
- Emissions from waste water handling at STW
- Emissions from WTS
- Emissions generated by small scale waste burning activities

For the LAEI 2022, an update of the existing LAEI 2019 waste files and gridded outputs has been undertaken. Any differences in emissions data and spatial distribution between the LAEI 2022 and the previous inventories result from observed trends, new sites (e.g. for waste transfers), or from method changes at national level that have an impact on London estimates.

3.3.2 Landfill Sites

3.3.2.1 Introduction

For landfills, a bottom-up methodology was applied, allowing for London-specific activity data to be used. The Intergovernmental Panel on Climate Change (IPCC) Waste Model[6] for CH_4 was used to collate and calculate emissions. Based on a First-Order Decay model, it estimates release of CH_4 emissions that result from decay of

[6] 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 5, Waste. Available at https://www.ipcc-nggip.iges.or.jp/public/2006gl/vol5.html

waste at landfills in a given location over time. The release of CH_4 is largely dependent upon waste composition, climate and site characteristics, all represented in the model. This type of model is commonly used in national inventories, such as the NAEI, which uses a UK-specific model (MELMod) based on the same decay principles.

3.3.2.2 Pollutants

Emissions from landfill sources have been estimated for the pollutants shown in Table 7.

Table 7: Pollutants Reported for Landfill Sources

Main Source	Category	Number of Pollutants Reported	Key Pollutants				Other Pollutants
			NOx	PM_{10}	$PM_{2.5}$	CO_2	
Industrial and Commercial	Waste - Landfill	8	✘	✔	✔	✘	C_4H_6, C_6H_6, CH_4, NH_3, NMVOC, PCB

3.3.2.3 Activity Data

Data on the amount of waste (split by household/industrial/commercial and inert) disposed to landfill in London was obtained from the Environment Agency's Waste Data Interrogator database[7]. The spatial emissions distribution was maintained according to the distribution in the LAEI 2019, with emissions distributed by landfill site activity scaled to each grid. It is assumed that no new landfills have opened in London since 2019.

UK data on waste composition from Defra[8] and Dissolved Organic Carbon values from the UK National Inventory Report[9] were input into the model. For landfill categorisation, the same split as in the NAEI has been used. All landfills were therefore assumed to be 'managed' from 1980 and 'uncategorised' before this. Additionally, the UK National Inventory Report provides a UK total percentage of CH_4 captured from landfill sites. It was assumed that the same percentage of CH_4 emissions would be captured within the LAEI area.

3.3.2.4 Emissions

Emission calculations for landfill sites followed the same methodology used for previous LAEI updates. The update involved scaling down the latest landfill emissions reported in the NAEI for England to the LAEI grid.

Emissions were calculated for the majority of the other pollutants, using the amount of waste disposed in landfill in 2022 and emission factors or Implied Emission Factor (IEF) as follows:

- The emission factor for PCB, PM_{10} and $PM_{2.5}$ were sourced from the UK Informative Inventory Report[10]

[7] 2022 Waste Data Interrogator, Environment Agency. Available at https://www.data.gov.uk/dataset/aa53a313-f719-4e93-a98f-1b2572bd7189/2022-waste-data-interrogator

[8] Composition of Local Authority Waste, Defra. Available at https://www.gov.uk/government/statistics/composition-of-local-authority-waste

[9] United Kingdom. 2023 National Inventory Report (NIR), United Nations Climate Change. Available at https://unfccc.int/documents/627789

[10] EMEP Centre on Emission Inventories and Projections, UK Informative Inventory Report. Available at https://www.ceip.at/status-of-reporting-and-review-results/2024-submission

- Emissions from C_4H_6, C_6H_6 and NMVOC were calculated using the emission factors sourced from the UK Informative Inventory Report and applied to the LAEI estimated CH_4 emissions
- As no emission factor was available for NH_3, an IEF was calculated by dividing the total UK emissions of NH_3 by the corresponding activity data (amount of waste disposed in landfill)
- Upon investigation, the published emission factor for PCB was found to give an unrealistic total. This is thought to be due to an error in the UK Informative Inventory Report, or because the published emission factor is only applied to a fraction of the landfilled waste activity, however the actual cause could not be clearly identified. Instead, it was replaced by an IEF in the adopted calculations. The use of a PCB IEF gives a total emission for the LAEI which is consistent with the other pollutants

In comparison to the LAEI 2019 estimates, the total waste to landfill in the 2022 Waste Data Interrogator has been revised down, however the share of biological waste is now considerably higher in the 2022 data. This means that any pollutants that are calculated based on total landfilled waste multiplied by an independent emission factor (NH_3, PCB, PM_{10}, $PM_{2.5}$) see a lower reported total in the LAEI 2022 compared to the LAEI 2019. For CH_4, and pollutants estimated from CH_4 (C_4H_6, C_6H_6 and NMVOC), the emissions reported for the LAEI 2022 are higher than those in the LAEI 2019 due to the increased share of biological waste being entered as data into the IPCC waste model.

It is noted that the EA-PI includes emissions reporting of CH_4 and CO at two landfill sites, however these point source emissions have not been included in the LAEI 2022 waste emissions data, to avoid double counting with the above method. Emissions reported by landfill sites in the EA-PI are based on a different methodology, and do not cover as many pollutants as estimated using the above methodology. It is possible that a proportion of emissions reported in the EA-PI relate to on-site activities, such as biogas recovery or heat/energy use, as opposed to those associated with the decay of biological waste (as represented in this category for the LAEI) but it is not possible to determine that from the data provided.

3.3.2.5 Spatial Distribution

Spatial projection was determined using the latest GIS layers of landfill sites in England (represented as polygons) collated from the Environment Agency (both active sites from the "*Permitted Waste Sites - Authorised Landfill Site Boundaries*" dataset, and closed sites from the "*Historical Landfill Sites*" dataset). These two datasets were intersected with the LAEI grid to determine the landfill area in m^2 within each LAEI grid cell.

This area was then divided by the total landfill area across England, and the resulting ratio was applied to the total landfill emissions for England from the NAEI, to estimate emissions across the LAEI.

3.3.3 Sewage Treatment Works (STW)

3.3.3.1 Pollutants

Emissions from wastewater handling sources have been estimated for the pollutants shown in Table 8.

Table 8: Pollutants Reported for Wastewater Handling Sources

Main Source	Category	Number of Pollutants Reported	Key Pollutants				Other Pollutants
			NOx	PM_{10}	$PM_{2.5}$	CO_2	
Industrial and Commercial	Waste - STW	4	✔	✘	✘	✘	CH_4, N_2O, NH_3

3.3.3.2 Emissions

The emissions calculation methodology was the same as in the previous LAEI update. A top-down methodology has been used to scale the NAEI total emissions of CH_4, NH_3 and N_2O to London, based on population data. There are ten sewage treatment works that reported emissions to the EA-PI, and those emissions have been subtracted from the top-down estimated LAEI total, to avoid a double count with emissions included under the industrial processes category (see Section 3.1).

This split in emissions reporting for STW (top-down approach vs EA-PI) was applied because the facility-reported emissions are unlikely to be representative of the wider STW emissions derived from the national data. The NAEI method is designed to capture emissions from decay stages of the wastewater pathway. Whilst the EA-PI emissions may include these decay pathway emissions, they may also include point source releases from additional on-site activities, such as biogas recovery. As such, it is thought that it aids transparency to report the top-down method under 'waste' and the EA-PI data under 'industry'. For context, in 2022, the facility reported emissions equate to only 17%, 7% and 0.5% of the total LAEI estimated emissions from this source for NH_3, CH_4 and N_2O respectively.

The emissions were distributed to the sewage treatment work sites using the 2019/20 Population Equivalent[11] data from Thames Water Utilities[12], and then projected on to the LAEI Grid.

3.3.3.3 Spatial Distribution

These emissions were allocated to each of the STW operating within the LAEI boundary (Beckton, Beddington, Crossness, Deephams, Hogsmill, Longreach, Maple Lodge, Mogden and Riverside STW), using the latest Thames Water Population Equivalent estimates for each site (ratio of Population Equivalent for each site to total Population Equivalent for all sites).

Emissions for each STW were then spatially distributed on the LAEI grid, based on the proportion of site area within each grid cell.

3.3.4 Waste Transfer Stations (WTS)

3.3.4.1 Pollutants

Emissions from waste transfer station sources have been estimated for the pollutants shown in Table 9.

Table 9: Pollutants Reported for WTS Sources

Main Source	Category	Number of Pollutants Reported	Key Pollutants				Other Pollutants
			NOx	PM_{10}	$PM_{2.5}$	CO_2	
Industrial and Commercial	Waste - WTS	2	✘	✔	✔	✘	✘

[11] A 'Population Equivalent' is a way to measure the polluting potential of wastewater, used to assess and regulate wastewater treatment in the UK.

[12] Cost assessment 2019/20, Thames Water Utilities Limited. Available at https://www.thameswater.co.uk/media-library/home/about-us/investors/our-results/previous-reports/2019-20/cost-assessment-tables-2019-20.xlsx

Emissions estimates have been based on the same methodology followed in previous LAEI updates, using updated data and applying the following activity-based equation, for each pollutant:

Equation
Emissions (tonnes/year) = Material Received (tonnes/year) × Emission Factor (tonnes pollutant / tonnes of material handled)

The emissions calculation methodology that was used in the previous LAEI update has been used again for the LAEI 2022. The method estimates PM emissions using the EMEP/EEA Guidebook methodology for the 'storage, handling and transport of mineral products, uncontrolled handling'. It is noted that this emission factor would not commonly be applied to waste sector activities in a national inventory, and this source is not present within the NAEI. The use of this emission factor is considered highly uncertain, and although useful as an indicator of potential dust generating activity, may misrepresent the actual scale of emissions. However, estimated emissions remain a negligible PM source and do not warrant further research e.g. monitoring.

3.3.4.2 Activity Data

Emissions were distributed based on activity data on tonnage of waste received at waste transfer sites in 2022, obtained from the latest version of the Waste Data Interrogator database. Whilst there were a number of new sites in the 2022 data with waste received since the LAEI 2019, on the opposite, other sites previously receiving waste were no longer active in 2022.

Although 16 waste transfer sites in London reported emissions under the EA-PI, those are likely to be stack emissions or estimates of direct process emissions rather than fugitive (dust) release, which are represented in the LAEI waste sector. This is supported by the variety of pollutants reported under these sites in the EA-PI, with only two reporting PM emissions. For context, 6 sites reported CO emissions, and 4 of these also reported NO_x emissions, which indicates a combustion rather than fugitive release. As such, the EA-PI reported emissions have not been reported under the waste category, to avoid double counting, as these have been included in the industrial process category discussed in Section 3.1.

Although the total emissions from combustion sources remain negligible, PM emissions are still significantly higher than those estimated in the LAEI 2019. This is because the tonnage of waste received at waste transfer sites has increased between the 2019 and 2022 datasets by approximately 250%. There are increases across all 'fate' of waste classifications (a categorisation available in the Waste Data Interrogator to show where the waste ends up being processed), however the biggest increase is visible for energy recovery facilities. These facilities recorded over 14 million tonnes of waste received in 2022, which is more than the total tonnage received across all site classifications when this exercise was completed for the LAEI 2019. There is also a significant increase in the waste received tonnage where the fate category is landfill, which does not correlate with the landfill data collated for and discussed in Section 3.3.2. These findings suggest a fundamental change to the way data is accounted in the Waste Data Interrogator between 2019 and 2022, rather than representing a genuine trend of increased waste transfer and handling, at least to the identified magnitude.

3.3.4.3 Spatial Distribution

The inventory includes all Waste Transfer Stations in the LAEI area, which have been identified by projecting the GIS polygon layer of waste sites from the Waste Data Interrogator database on the LAEI grid. For each identified waste site, the fraction of its total area within each LAEI grid was used to determine the spatial distribution of emissions.

3.3.5 Small Scale Waste Burning

The small scale waste burning category covers the following:

- Emissions from residential bonfires
- Emissions from indoor burning of waste on open fires
- Emissions from industrial bonfires

3.3.5.1 Pollutants

Emissions from small scale waste burning sources have been estimated for the pollutants shown in Table 10.

Table 10: Pollutants Reported for Small Scale Waste Burning Sources

Main Source	Category	Number of Pollutants Reported	Key Pollutants				Other Pollutants
			NOx	PM_{10}	$PM_{2.5}$	CO_2	
Industrial and Commercial	Waste - Small Scale Waste Burning	7	✔	✔	✔	✘	BaP, CO, NMVOC, PCB

3.3.5.2 Data Inputs

The emissions calculation methodology that was used in the previous LAEI update has largely been used again for the LAEI 2022, which scales emissions from the NAEI to the LAEI as follows:

- For domestic bonfires: allocating 8.1% of the UK total emissions to the LAEI, based on suburban land cover data, available from the (Centre for Ecology and Hydrology (CEH)).
- For domestic open fireplaces: allocating 1.0% of the UK total emissions to the LAEI, based on the London share of UK residual fuel consumption for the following categories: Domestic coal, Domestic manufactured solid fuels, and Domestic bio energy and wastes (residual fuel consumption data published by DESNZ[13]). This is an update for LAEI 2022, as the value used in previous LAEI updates was derived from the 2011 census (households reporting primary heating fuel as solid fuel).
- For "Other" (industrial and construction): allocating 11.5% of the UK total emissions, based on previous NRMM LAEI estimates.

3.3.5.3 Emissions

UK NAEI emissions of all relevant pollutants have been revised upwards between the 2019 and 2022 inventories, and therefore LAEI 2022 emissions are higher than in the previous LAEI update. Activities within this reporting category (as published in the NAEI) are classified as "small-scale waste", "open fires", "industrial" and "bonfires". Activity data (material/waste incinerated) for all of these classifications has increased at the UK level since the previous LAEI update.

[13] Sub-national residual fuel consumption: 2005 to 2022, DESNZ. Available at https://www.gov.uk/government/statistics/sub-national-residual-fuel-consumption-2005-to-2022

3.4 Construction

3.4.1 Introduction

Emissions from the Construction sector include the following categories:

- Emissions from NRMM exhaust (including small and large generators, machinery and off-road vehicles used on construction sites)
- Dust emissions from construction / demolition activities (i.e. PM generated from construction and demolition at construction sites, excluding road building and maintenance)

Separate methods are used to estimate emissions from the above sources. This is driven by the availability of bottom-up data specific to the LAEI area, which can be used to estimate construction NRMM exhaust emissions, but not construction dust emissions, which are estimated using a top-down disaggregation of the NAEI emissions estimates.

3.4.2 Non-Road Mobile Machinery on Construction Sites

NRMM emissions from industry and construction are estimated separately in the LAEI. This section only refers to NRMM from construction sources. The methodology to estimate NRMM emissions from industrial sites is provided in Section 3.1.4.

NRMM exhaust emissions from generators and machinery used at construction sites were calculated using two separate bottom-up approaches: one for the majority of construction sites and one for HS2 sites specifically, since this was a large strategic project with significant activity in 2022.

3.4.2.1 Pollutants

Exhaust emissions from NRMM construction sources have been estimated for the pollutants shown in Table 11.

Table 11: Pollutants Reported for NRMM Exhaust Sources from Construction Sites

Main Source	Category	Number of Pollutants Reported	Key Pollutants				Other Pollutants
			NOx	PM_{10}	$PM_{2.5}$	CO_2	
Industrial and Commercial	Construction - NRMM Exhaust	10	✔	✔	✔	✔	CH_4, CO, N_2O, NH_3, NMVOC, SO_2

3.4.2.2 Activity Data (Excluding High Speed 2)

To estimate emissions from most types of construction activity (excluding HS2 related activities), the approach used data from the NRMM register[14] on deployment of individual machines in use in the LAEI area. This was combined with data on development activity in London from the Planning London DataHub (PLDH)[15].

[14] Available at https://www.london.gov.uk/programmes-and-strategies/environment-and-climate-change/pollution-and-air-quality/nrmm

[15] The Planning London DataHub has superseded the London Development Database (LDD). Available at https://www.london.gov.uk/programmes-strategies/planning/digital-planning/planning-london-datahub

The NRMM register is an online website where all developers must log machinery with a 37 kW - 560 kW power rating. It is completed by machinery operators, and contains information on machine type, power, deployment dates and site location. It represents the most complete record available of NRMM used across London. However, it does not represent a full census of machines used across London on construction sites, both in terms of number of sites (as for example, smaller construction sites using machinery below 37 kW power rating are not included), and machinery (not all machines need to be listed for each construction site). Therefore, a simple aggregation of emissions calculated at machine-level would underestimate total emissions from NRMM.

The PLDH is a list of the status and details of all planning applications in London, providing information on the type, size, location and duration of construction activities. Because it is mandatory, this is likely to be a complete record of all legal development activity occurring in London.

The approach taken to estimating emissions from NRMM exhaust for these types of developments involved 3 steps:

- Daily emissions were calculated for each individual machine used in 2022 in the NRMM register.
- Sites in the NRMM register were linked to matching sites in the PLDH based on site location, and emissions (and other relevant characteristics) of machines at those sites were averaged and annualised, to create an average annual machinery activity and emissions profile for different types of site.
- The average profiles were then applied to all sites (by type of site) listed in the PLDH to estimate emissions, then summed across sites within the LAEI grid cells to produce gridded emissions.

Using this three-step approach, a more complete estimate of NRMM emissions is obtained than would be the case if using the NRMM register alone.

3.4.2.3 Activity Data (High Speed 2)

To estimate emissions from NRMM used for HS2 construction sites, a separate register - representing a full census of machines operating at HS2 sites during 2022 - was used to estimate emissions at a machine level, which was then aggregated up[16].

3.4.2.4 Individual Machine-Level Emissions

Individual machine-level emissions were calculated based on the Tier 3 technology-specific methodology provided in the EMEP/EEA 2023 Guidebook[17].

With this method, various machinery characteristics and other data were used to estimate the energy consumption (in kWh) of a machine, which is then multiplied by an energy-based emission or fuel consumption factor per kWh. The emissions *E* of pollutant *i* (or fuel consumption) from a given machine *m* were calculated using the following equation:

[16] Data extract received from HS2 (October 2024)

[17] Available at https://www.eea.europa.eu/publications/emep-eea-guidebook-2023/part-b-sectoral-guidance-chapters/1-energy/1-a-combustion/1-a-4-non-road/view (Chapter 1.A.4)

Equation
$E_{i,m} = P_m \times LF_m \times HRS_m \times EF_{i,m} \times (1 + DFA_{i,m}) \times LFA_{i,m}$ Where: - P_m = the rated maximum Power output of machine *m* - LF_m = the average engine Load Factor (fraction between 0 and 1 of the maximum power output) over a typical duty cycle for that type of machine - HRS_m = the number of operational Hours - $EF_{i,m}$ = the base Emission Factor (in g/kWh) for pollutant *i* or for fuel consumption, which is a function of the engine technology level and engine power band of machine *m* - $DFA_{i,m}$ = the Deterioration Factor Adjustment for pollutant *i* and machine *m*, representing an uplift to the emission factor as a machine ages - $LFA_{i,m}$ = the Load Factor Adjustment for pollutant *i* and machine *m*, which applies an uplift to emission factors of certain pollutants (NO_x, CO, NMVOC and fuel consumption) during periods of low engine load. The load factor adjustment depends on the load factor

The deterioration factor adjustment was not applied here due to lack of information about the age of each machine.

In the absence of information on fuel type in either the NRMM register or list of HS2 machinery, all machines were assumed to use low-sulphur diesel.

Emission factors and load factor adjustments were sourced from tables 3-6 and 3-14 respectively of the 2023 EMEP/EEA Guidelines, Chapter 1.A.4. These emission factors assume that the diameter of PM from exhaust is smaller than 2.5μm, so emissions of PM_{10} are assumed equal to those of $PM_{2.5}$.

Emissions of CO_2 and SO_2 were calculated slightly differently to those of other pollutants. Because these depend largely on fuel composition, independent of other engine characteristics, these were derived as a mass-balance from calculated fuel consumption. The following values for gas oil from the NAEI 2022 were used:

- Carbon content 870 g/kg carbon
- Sulphur content of 6.18 ppm (0.0006%)[18]

3.4.2.4.1 Time Scope

The NRMM register used had been filtered to include only those machines reported as operating in 2022. Records had a “start_date” on or before 31st December 2022 and an “end_date” on or after 1st January 2022; using this filter covers all cases where a machine is active for some of 2022, including:

- when it started prior to 2022 and finished after the end of 2022
- both started and ended in 2022

[18] Based on implied carbon and sulphur content from the UK NAEI emission factors database, available at https://naei.energysecurity.gov.uk/emission-factors/emission-factors-database, and net calorific values from the 2022 greenhouse gas inventory report background data, available at https://naei.energysecurity.gov.uk/sites/default/files/2024-10/Energy_background_data_uk_2024.xlsx

- starts prior to 2022 and finished in 2022
- started during 2022 and finished after the end of 2022

3.4.2.4.2 Engine Power

Information on maximum engine power *P* for each machine is provided in the NRMM register and the HS2 machinery list. Where engine power was not provided, this was gap-filled using the average power rating for machines with the same name in the "machine_type" field. The engine power was categorised into bands, in order to match the engine power bands specified in the emission factors dataset.

3.4.2.4.3 Engine Technology Level

The NRMM register and HS2 data also contain fields which showed the type-approval standard between Stage I and Stage V. Missing type approval standards were gap-filled based on the NRMM low emission zone rules in place in 2022, assuming that machines were compliant with the rules:

- For constant speed engines, Stage V standards were applied across London
- For variable speed engines of less than 56 kW in power, Stage V standards were applied within the Central Activities Zone and Opportunity Areas (CAZ/OAs), and Stage IIIB were applied elsewhere in London (the NRMM register contains a field showing which zone the site is located in)
- For all other variable speed engines, Stage IV standards were applied in the CAZ/OAs, and Stage IIIB were applied elsewhere.

Some adjustments to the type approval standard field were required to ensure that the combination of engine power band and engine stage for the machine matched one of the combinations available in the emission factor table (tables 3-6 of the 2023 EMEP/EEA Guidelines). In such cases, the oldest (highest emission) standard available in the emission factor table for the relevant engine power band was assigned to the machine.

3.4.2.4.4 Load Factor

Typical engine load factors were sourced from a study from the National Environmental Research Institute in Denmark[19], which provides default values for different categories of construction machinery (e.g. excavator, roller, generator etc.). Matching the names in the "machine_type" field in the NRMM register to the categories, a lookup table was created to assign the load factor to each machine. Where the machine type was missing or not specific, a default load factor of 0.5 was applied.

3.4.2.4.5 Operating Hours

Total operating hours were calculated as number of days deployed multiplied by typical operating hours per day. The "start_date" and "end_date" fields in the NRMM register were used to infer the deployment duration in days of each machine. The conservative assumption was made that machines operated on all days of the week between the start and end dates. Average operational hours per day of 5 hours for variable speed engines, and 10 hours for constant speed engines were used[20]. In the 2022 NRMM register extract, no type approval number

[19] Fuel Use and Emissions from non-road machinery in Denmark from 1985-2004 - and projections from 2005-2030. National Environmental Research Institute, Denmark, 2006. Available at https://www2.mst.dk/udgiv/publications/2006/87-7052-085-2/pdf/87-7052-086-0.pdf. This data source is recommended by the EMEP/EEA 2023 Guidebook where local data sources are not available, and remains the most recent comprehensive source of data on load factors.

[20] From NRMM enforcement team at Merton Borough Council

was provided from which to deduce whether an engine was constant or variable speed, so it was assumed that the machine type categories with constant speed engines seen in the extract used in previous LAEI update (generators, pumps, graders etc.) still applied.

The HS2 machinery list included a start date and a deployment duration column. In some cases, the deployment duration was unknown (missing, or only qualitative value available). In these cases, the conservative assumption was made that the machine was in operation until the end of 2022.

Section 7.1.3 contains further details of the gap-filling undertaken, and the number of machines reported in the registers.

The result of these individual machine calculations was a table of total emissions for each machine at a site. For machines in the HS2 dataset, emissions were calculated for the period of deployment falling within the calendar year 2022. For machines in the NRMM register, emissions were calculated for the full period of deployment of a machine at a site (both within and outside of 2022).

3.4.2.5 Overall Emissions (Excluding High Speed 2)

3.4.2.5.1 Site Matching in the NRMM register and the PLDH

In order to create machinery profiles for particular types of site, developments in the PLDH were matched to a site in the NRMM register by location and the start and end dates of machinery deployment and of the development activity. Sites were deemed to match where:

- The postcode from the PLDH was identical to a record in the NRMM register
- Site coordinates from the PLDH fell within 100m of the implied coordinates derived from the postcode in the NRMM register[21]

Missing postcodes were gap-filled based on the site name, to increase the number of NRMM register sites which could potentially be matched to the PLDH.

Around half (53%) of sites within the PLDH did not have an end date, with the status of the development flagged as “Commenced” rather than “Completed”. For the purposes of matching, it was assumed that these sites were still operational at the time of analysis.

Following this process, 1,097 (17%) out of the 6,563 machines in the NRMM register were successfully matched to a site in the PLDH, representing 23% of the unique sites in the NRMM register.

Further information on the number of records affected is provided in Section 7.1.3.

3.4.2.5.2 PLDH Development Type Categorisation

The sites in the PLDH were classified into one of 8 groups following a scheme used by the GLA, defined by the following parameters:

- Dwellings or non-dwellings development
- Major ($\geq$ 10 dwellings, or >1ha in size for other developments) or minor (smaller than these thresholds)
- Inside or outside of the CAZ/OAs, where different EU emissions standards applied in 2022

The decision on whether a development was classed as “Dwellings” or “Non-dwellings” was based primarily on the development type field in the PLDH where available, but where missing or not clear, a combination of the

[21] Coordinates geocoded from postcodes in the NRMM register using the open-source R package “PostcodesioR”, itself using the ONS postcode database

number of new dwellings planned and the ratio of residential area to total site area were used as a proxy. About 10% of developments had insufficient information to be classified, so were not included further in emissions calculations.

3.4.2.5.3 Average Emissions Profiles Calculations

Typical machinery activity and emissions profiles for each of the 8 development types were then calculated, by:

- Taking the individual machine-level emissions data calculated previously (see Section 3.4.2.4) where a match to a PLDH development could be found, and categorising each machine by its power band and engine stage (hereafter “machine category”)
- Summing up emissions from all machine categories, by site, across the relevant PLDH sites for the entire deployment duration
- Dividing emissions by the number of years the development was active for, to obtain an annual emissions per machine category per year for each site
- Averaging this across all sites with the same development type, to obtain average annual emissions from each machine category and each development type (the “profile”).

The emissions profiles generated were based on the developments in the PLDH which had been matched to sites in the NRMM register. Table 12 below provides the matched PLDH developments active in 2022, used to create the emissions profiles.

Table 12: PLDH construction sites used to create site type emissions profiles

Development Type	Area	Total PLDH developments (2022)	PLDH developments used to create profile	PLDH developments used to create profile (% of total)
Major dwellings	CAZ/OA	434	38	8.8%
Major dwellings	Other London Areas	890	87	9.8%
Major other	CAZ/OA	129	6	4.7%
Major other	Other London Areas	171	14	8.2%
Minor dwellings	CAZ/OA	707	5	0.7%
Minor dwellings	Other London Areas	4,259	35	0.8%
Minor other	CAZ/OA	1,242	14	1.1%
Minor other	Other London Areas	2,157	28	1.3%

3.4.2.5.4 Total Emissions Calculations and Spatial Distribution

The annual emissions profiles by development type and zone (CAZ/OAs versus other London areas) were then applied to each classified development in the PLDH, according to its type and zone, then adjusted down based on what fraction of the year the site was active for, e.g. if a site was only active for 6 months in 2022, emissions for that site have been assumed as half of the profile annual total.

Emissions were then gridded by projecting the point locations of the active PLDH sites onto the LAEI grid and summing emissions from all sites within each grid cell.

Section 7.1.3 contains further details on NRMM register and PLDH data processing and cleaning.

3.4.2.6 Overall Emissions (High Speed 2)

Data on NRMM used at HS2 construction sites were provided separately, as this activity data is not included in either the PLDH or NRMM register.

To estimate emissions from HS2 machinery, emissions were first calculated at the individual machine level, as per the method described in Section 3.4.2.4. Total emissions from the HS2 machinery register for 2022 were calculated by summing individual machine emissions, having truncated the deployment period to only the part within 2022.

Site name, but no site coordinates were provided in the HS2 data, so in order to assign emissions to LAEI grid cells, coordinates had to be assigned to each distinct HS2 site name present in the machinery list. This built on work done for the LAEI 2019 where possible, but new site names were allocated coordinates through internet searches, use of HS2 local community webpages and air quality impact reports. Data for 46 HS2 machines, where the location could not be found, or where it was outside of the LAEI area (3.3% of machines, representing 13 unique site names), were removed.

The HS2 site coordinates were then projected onto the LAEI grid, and the emissions from sites summed within each LAEI grid cell. The grid cell emissions totals for HS2 machinery were then added to those calculated for other construction sites present in the PLDH.

3.4.3 Construction / Demolition Dust

The methodology for estimating PM as dust emissions from construction and demolition activity is largely the same as that used in the LAEI 2019.

Emissions were estimated as a top-down disaggregation of NAEI PM emissions[22]. These emissions are divided into four sub-categories:

- Construction of houses
- Apartment buildings
- Non-residential construction
- Road construction

As in previous LAEI updates, UK total emissions for this latter category have not been considered, as not deemed significant for the LAEI.

The disaggregation to LAEI grid cell was done in two steps:

- Estimation of London area total emissions
- Allocation of the London total emissions to LAEI grid cells

3.4.3.1 Pollutants

Emissions from construction and demolition dust sources have been estimated for the pollutants shown in Table 13.

[22] UK 2022 emissions from NFR code 2A5b: Construction and Demolition. Available at https://naei.energysecurity.gov.uk/data/data-selector

Table 13: Pollutants Reported for Construction / Demolition Dust Sources

Main Source	Category	Number of Pollutants Reported	Key Pollutants				Other Pollutants
			NOx	PM_{10}	$PM_{2.5}$	CO_2	
Industrial and Commercial	Construction - Construction / Demolition Dust	2	✘	✔	✔	✘	✘

3.4.3.2 Estimation of the London area total emissions

The London share of UK emissions was estimated using regional statistics on employment in construction in Great Britain[23] and Northern Ireland[24], by calculating the fraction of people employed in the construction sector in London versus the total for the UK (14.3% in 2022).

3.4.3.3 Allocation of London emissions to LAEI grid cells

London-level construction and demolition dust emissions were allocated to LAEI grid cells based on site locations and activity indicators in the PLDH. The calculation involved several steps:

- Development sites in the PLDH were categorised into houses, apartment buildings or non-residential construction categories. The classification approach matched that used for the bottom-up construction exhaust emissions calculations (see Section 3.4.2.5) to identify dwelling versus non-residential construction. The distinction between house and apartment construction was based on planned dwelling density, where sufficient site area information was available, or the number of dwellings (using 10 as the threshold) otherwise
- For each site, an indicator of activity was calculated as site area multiplied by development duration ("size-duration")
- The size-duration value for each site was divided by the total size-duration across all PLDH sites (for houses, apartments and non-residential categories separately), to give a share of total activity by site
- Site level dust emissions were calculated as the London total multiplied by the share of total activity by site
- The site level emissions were summed up within each LAEI grid cell (using location data as described in Section 3.4.2.5).

3.5 Commercial Catering (Cooking)

A new emission source category for commercial catering (cooking) PM emissions generated by commercial catering (cooking) activities was first introduced as a new source in the LAEI 2016 update. The methodology was based on measurements of Cooking Organic Aerosols (COA) fraction within PM concentrations, which were used to estimate a total for PM_{10} and $PM_{2.5}$ concentrations across the LAEI. The total emissions were then first estimated based on previous knowledge of cooking source apportionment, and spatially distributed using

[23] Available at https://www.ons.gov.uk/businessindustryandtrade/constructionindustry/datasets/constructionstatisticsAnnualtables, Table 3.6

[24] Available at https://www.nisra.gov.uk/publications/quarterly-employment-survey-historical-tables-june-2024

available activity data on commercial catering. Dispersion modelling of these emissions was then carried out, and modelled outputs were compared to the measured concentrations. The difference between modelled and observed COA concentrations was then used to modify emissions estimates and run the dispersion model iteratively, until modelled output was in close agreement with the COA measurements. Activity data on commercial catering premises were then used to spatially distribute these total emissions across the LAEI grid.

The LAEI 2022 follows the same methodology. However, due to new data analysis of the COVID-19 pandemic lockdown period, it has been found that observed COA levels were not mainly due to commercial catering, and that domestic cooking was a significant contributor as well. Therefore, it has been decided to split this source into 2 parts:

- One part attributed to commercial catering activities, still reported under the Industrial and Commercial sector
- One part attributed to domestic cooking, now reported under the Domestic sector (see Section 4.4)

3.5.1 Pollutants

Emissions from kitchen flue due to cooking in commercial catering premises have been estimated for the pollutants shown in Table 14.

Table 14: Pollutants Reported for Commercial Catering Kitchen Flues

Main Source	Category	Number of Pollutants Reported	Key Pollutants				Other Pollutants
			NOx	PM_{10}	$PM_{2.5}$	CO_2	
Industrial and Commercial	Commercial Cooking	2	✘	✔	✔	✘	✘

3.5.2 Source Measurement Methodology

Quadrupole Aerosol Chemical Speciation Monitor (ACSM) have been widely used to measure organic aerosols in PM_1 or $PM_{2.5}$ at an hourly time resolution (Ng et al., 2011[25]). The fraction of COA can then be quantified using Positive Matrix Factorization (PMF) of the organic aerosol mass spectra using a standardized protocol (G. Chen et al., 2022[26]). Some studies report that this type of PMF analysis tends to overestimate COA concentrations by a factor of around 2–3 (Reyes-Villegas et al., 2018[27]). However, more recent work demonstrates that COA

[25] Ng, N. L., Herndon, S. C., Trimborn, A., Canagaratna, M. R., Croteau, P. L., Onasch, T. B., Sueper, D., Worsnop, D. R., Zhang, Q., Sun, Y. L., & Jayne, J. T. (2011). An Aerosol Chemical Speciation Monitor (ACSM) for Routine Monitoring of the Composition and Mass Concentrations of Ambient Aerosol. Aerosol Science and Technology, 45(7), 780–794. Available at https://doi.org/10.1080/02786826.2011.560211

[26] Chen, G., Canonaco, F., Tobler, A., Aas, W., Alastuey, A., Allan, J., Atabakhsh, S., Aurela, M., Baltensperger, U., Bougiatioti, A., De Brito, J. F., Ceburnis, D., Chazeau, B., Chebaicheb, H., Daellenbach, K. R., Ehn, M., El Haddad, I., Eleftheriadis, K., Favez, O., … Prévôt, A. S. H. (2022). European aerosol phenomenology − 8: Harmonised source apportionment of organic aerosol using 22 Year-long ACSM/AMS datasets. Environment International, 166, 107325. Available at https://doi.org/10.1016/j.envint.2022.107325

[27] Reyes-Villegas, E., Bannan, T., Le Breton, M., Mehra, A., Priestley, M., Percival, C., Coe, H., & Allan, J. D. (2018). Online Chemical Characterization of Food-Cooking Organic Aerosols: Implications for Source Apportionment. Environmental Science & Technology, 52(9), 5308– 5318. Available at

concentrations derived from the ACSM are within uncertainty estimates of other approaches (Katz et al., 2021[28]; Nault et al., 2023[29]) and therefore uncorrected COA concentrations from the ACSM have been used for the LAEI.

3.5.3 Source Measurement Results

3.5.3.1 Mean concentrations of COA (expressed as measurements from PMF)

Measurements of COA in London have been quantified using ACSM data for periods between Jan 2018 and Oct 2023 at four locations in London (see Table 15):

- Marylebone Road (stop-and-go kerbside site)
- White City (fast-moving kerbside site)
- North Kensington (background site)
- Honor Oak Park (background site)

28 months of ACSM data is available from North Kensington, provided as 12 month means from the start date and as a total period mean, also reported in Chen et al., (2022). Mean concentrations of two periods of ACSM data are provided from Marylebone Road:

- 13 months between August 2019 and October 2020 (Chen et al., 2025[30])
- 7 months between May and November 2023

The unique dataset during the COVID-19 pandemic provided opportunities to differentiate the commercial and residential COA components in concentrations, by looking at the differences before and during the lockdown, and is examined in more detail in Section 3.5.4. Mean concentrations from two further locations (White City and Honor Oak Park) are provided for the 7 months between May and November 2023.

12-month COA concentrations were stable and contributed a similar percentage to PM_1 mass concentrations in North Kensington during each period between November 2015 and February 2018 (as shown in Table 15) with 0.58 µg/m^3 (6.0% of PM_1), 0.62 µg/m^3 (6.4%), and 0.56 µg/m^3 (6.5%) for three different periods. The mean concentration and contribution of COA for the whole period in North Kensington was 0.59 µg/m^3 (6.2%).

A second urban background site, Honor Oak Park showed slightly larger concentrations of COA than North Kensington in 2023, with 0.65 µg/m^3 (14.3% of $PM_{2.5}$). This enhanced contribution to PM_1/$PM_{2.5}$ at the more

https://doi.org/10.1021/acs.est.7b06278

[28] Katz, E. F., Guo, H., Campuzano-Jost, P., Day, D. A., Brown, W. L., Boedicker, E., Pothier, M., Lunderberg, D. M., Patel, S., Patel, K., Hayes, P. L., Avery, A., Hildebrandt Ruiz, L., Goldstein, A. H., Vance, M. E., Farmer, D. K., Jimenez, J. L., & DeCarlo, P. F. (2021). Quantification of cooking organic aerosol in the indoor environment using aerodyne aerosol mass spectrometers. Aerosol Science and Technology, 55(10), 1099–1114. Available at https://doi.org/10.1080/02786826.2021.1931013

[29] Nault, B. A., Croteau, P., Jayne, J., Williams, A., Williams, L., Worsnop, D., Katz, E. F., DeCarlo, P. F., & Canagaratna, M. (2023). Laboratory evaluation of organic aerosol relative ionization efficiencies in the aerodyne aerosol mass spectrometer and aerosol chemical speciation monitor. Aerosol Science and Technology, 57(10), 981–997. Available at https://doi.org/10.1080/02786826.2023.2223249

[30] Chen, G. I., Tremper, A. H., Priestman, M., Font, A., & Green, D. C. (2025). How COVID-19 related policies reshaped organic aerosol source contributions in central London. Available at https://doi.org/10.5194/egusphere-2024-4041

suburban location demonstrates that non-regulated cooking emissions become more important as other sources of PM start to decrease significantly since 2015.

The Marylebone Road site, which is a busy roadside site located in central London, with a number of restaurants in the surrounding area, showed significantly higher concentrations than all other sites. Specifically, the annual concentrations/contributions of 2019/2020, and the mean concentrations/contributions of 2023 (May–November) were 0.97 $\mu g/m^3$ (8.8%), and 1.19 $\mu g/m^3$ (18.0%), respectively. The lower COA concentrations for 2019/2020, compared to 2023,was assumed to result from commercial cooking emissions being dramatically reduced during to first COVID-19 pandemic lockdown.

The other roadside site (White City) is located in west London, next to the busy Westway flyover, and close to an open section of the Central Line underground. It is surrounded by tall office buildings, which create complicated dispersion patterns, and with few homes nearby, the influence of residential cooking is likely to be very low. Therefore, the sampling point is unlikely to be representative of the wider London urban environment. The COA concentration measured was of 0.29 $\mu g/m^3$ (5.4%), approximately 50% of the expected background concentration from residential cooking, and therefore should be treated with caution.

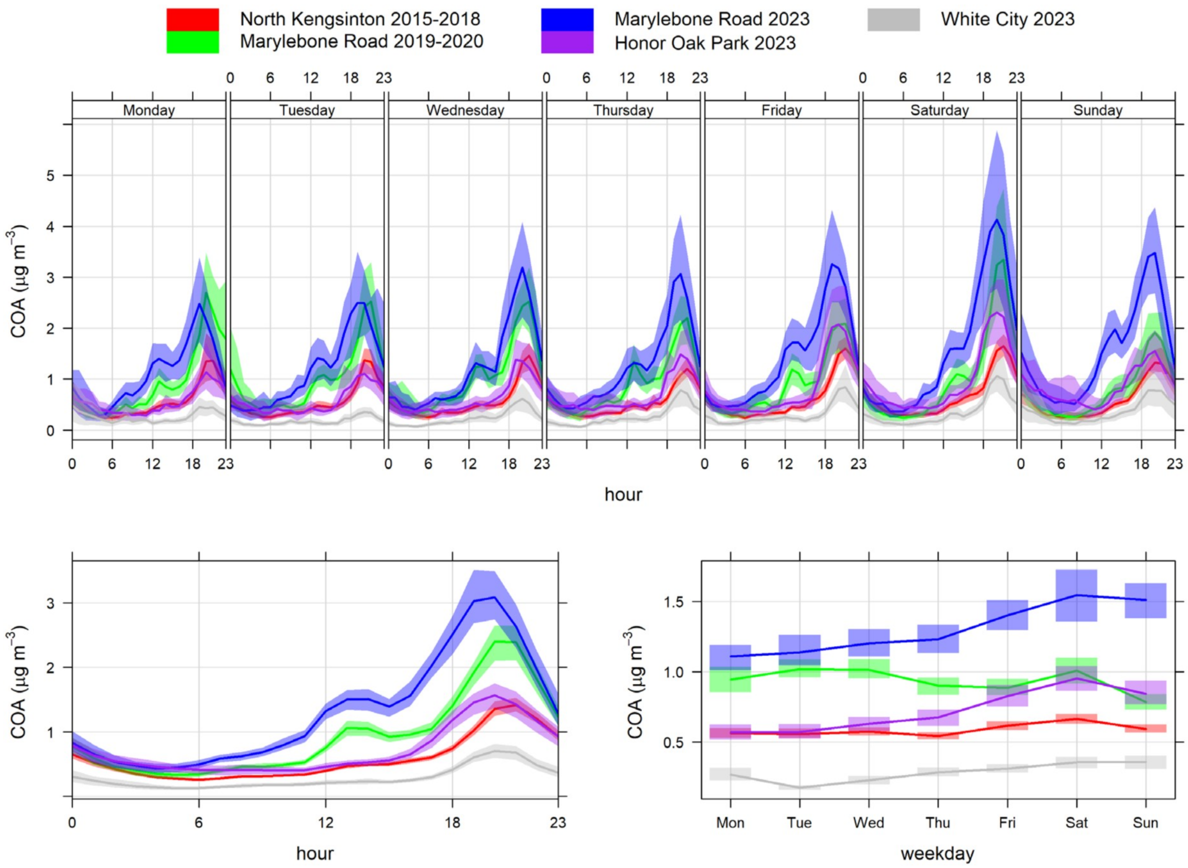
Table 15: COA Concentrations and Contribution to Total PM Measured at London Sites expressed in $\mu g/m^3$ and percentage of $PM_1/PM_{2.5}$

Period	Marylebone Road (Roadside)	White City (Roadside)	North Kensington (Urban background)	Honor Oak Park (Urban background)
Nov 2015 – Oct 2016	-	-	0.58 (6.0%)	-
Nov 2016 – Oct 2017	-	-	0.62 (6.4%)	-
Nov 2017 – Feb 2018	-	-	0.56 (6.5%)	-
Average	-	-	0.59 (6.2%)	-
Aug 2019 – Oct 2020	0.97 (8.8%)	-	-	-
May 2023 – Nov 2023	1.19 (18.0%)	0.29 (5.4%)	-	0.65 (14.3%)

3.5.3.2 Temporal patterns of COA emissions (in different locations/periods across London)

The mean diurnal pattern of COA measurements in all datasets shows two peak concentration times: one around 1pm (local time), with concentrations ranging from 0.25 µg/m^3 (White City) to 0.66 µg/m^3 (Marylebone Road 2023); and a larger one between 7pm and 9pm (local time), with concentrations ranging from 0.70 µg/m^3 (White City) to 3.09 µg/m^3 (Marylebone Road 2023). Over the average week, COA concentrations at weekends were often higher than that of weekdays except Marylebone Road 2019/2020 data. Again, this is likely due to the COVID-19 pandemic lockdown changing the pattern of commercial cooking activity. In particular, the Eat Out To Help Out (EOTHO) policy during August 2020, which offered food discounts on Mon-Wed and resulted in higher COA concentrations at Marylebone Road 2019/2020 on these days (see Figure 4).

Figure 4: COA concentration profiles at all sites from November 2015 to October 2023



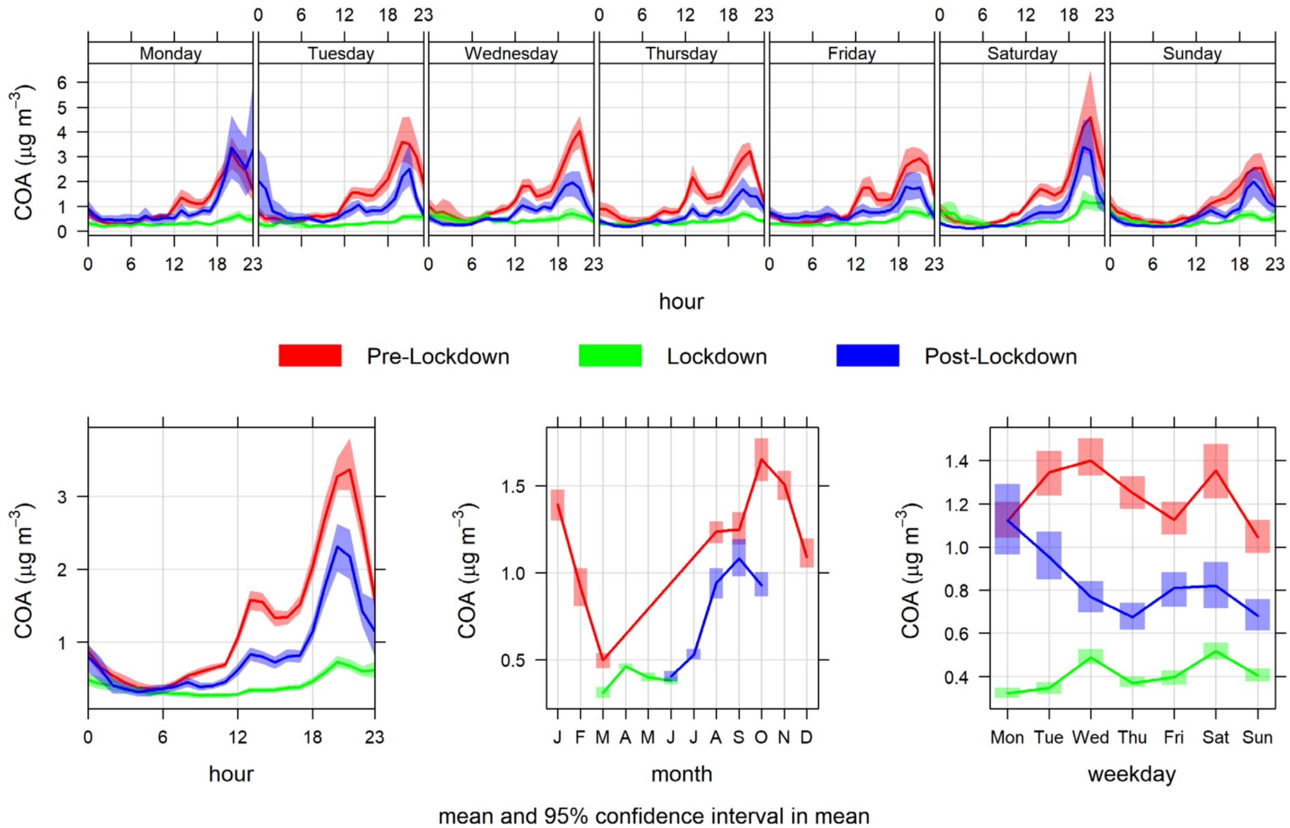
3.5.4 Marylebone Road COA during the COVID-19 Pandemic Lockdown

The diurnal pattern of COA concentrations at Marylebone Road between August 2019 and October 2020 is shown in Figure 5. This is split into three different periods:

- Pre-lockdown (1st August 2019 to 25th March 2020)
- Lockdown (Mar 26th March to 23rd June 2020)
- Post-lockdown (24th June to 22nd October 2020)

COA concentrations reduced from 1.22 µg/m^3 before the lockdown, to 0.41 µg/m^3 during the lockdown. After the lockdown, COA concentrations gradually increased to 0.84 µg/m^3, partly as a result of the EOTHO policy. However, it remained lower than the pre-lockdown concentration (1.22 µg/m^3), possibly due to remote working and suppressed economic activity. In particular, it is clear that weekday lunchtime and evening concentrations (except Monday) were lower post-lockdown than pre-lockdown, but the difference was smaller during weekends. The first COVID-19 pandemic lockdown in the UK had introduced measures to shut down the restaurants, and therefore, it has been assumed that the commercial cooking emissions during lockdown were negligible. The COA concentrations during lockdown could therefore be considered as mostly a residential cooking emission baseline in Marylebone Road as 0.41 µg/m^3, with a caveat of slight overestimation, as more domestic cooking activities were expected during this time, and some restaurants were still open for take away.

Figure 5: COA Concentration Profiles at Marylebone Monitoring Site around COVID-19 Pandemic Lockdown



The PMF analyses conducted for Marylebone Road datasets in both 2019/2020 and 2023 also resolved a Biomass Burning Organic Aerosol (BBOA) source concentration. In typical atmospheric studies, this source is associated with PM from domestic wood-burning, wildfires or agricultural residue burning. However, here BBOA concentrations in both Marylebone Road datasets showed a cooking-like diurnal profile, with a peak at lunchtime and dinnertime, as shown in Figure 6. Furthermore, the diurnal cycles for BBOA on different weekdays showed patterns similar to those observed in COA during EOTHO period in Aug 2020 (Figure 7). This is due to some of the cooking styles (e.g., barbecue, wood-fired pizza ovens) emitting organic compounds, which are normally classified as BBOA emissions. It is not expected to be influenced by domestic wood-burning emissions, as EOTHO occurred in August. Therefore, reducing commercial cooking emissions could have a co-benefit of decreasing BBOA, which was considered as one of the most health relevant emission sources. There is also the possibility that this type of cooking emissions currently contributes to the concentrations of wood-burning PM currently measured in London. This would be unaffected by any currently policies which aim to reduce emissions from wood-burning stoves.

Figure 6: BBOA Concentration Profiles at all Sites from November 2015 to October 2023

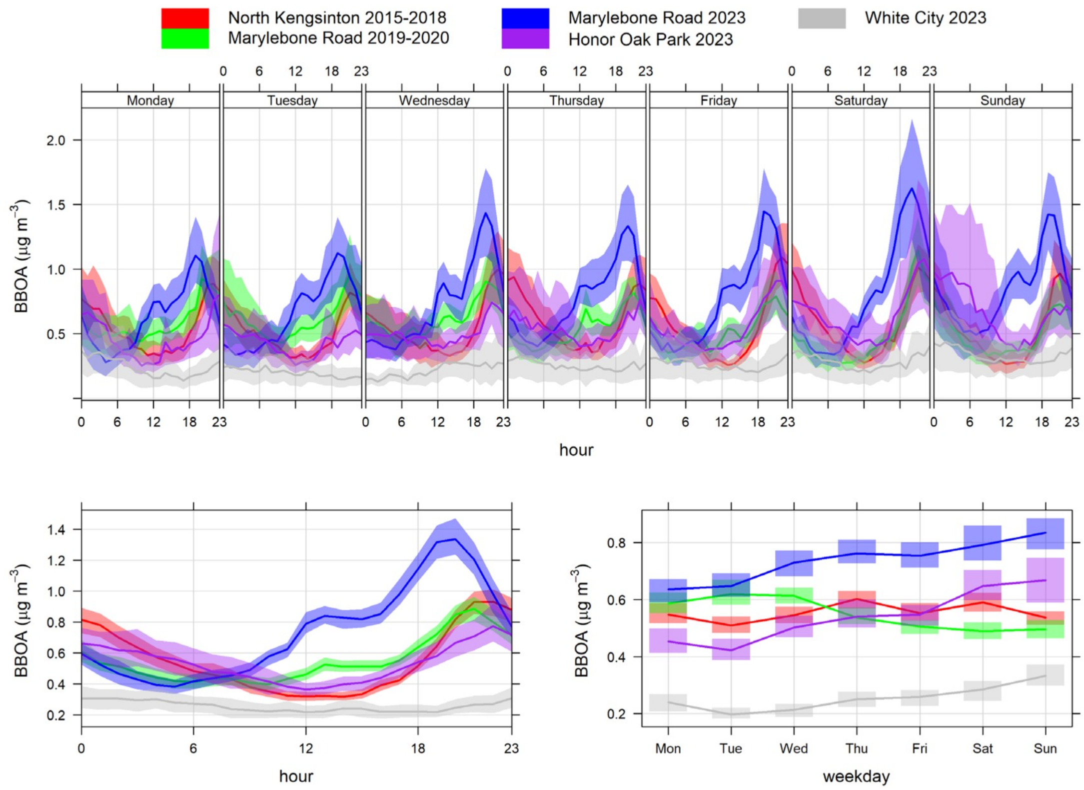
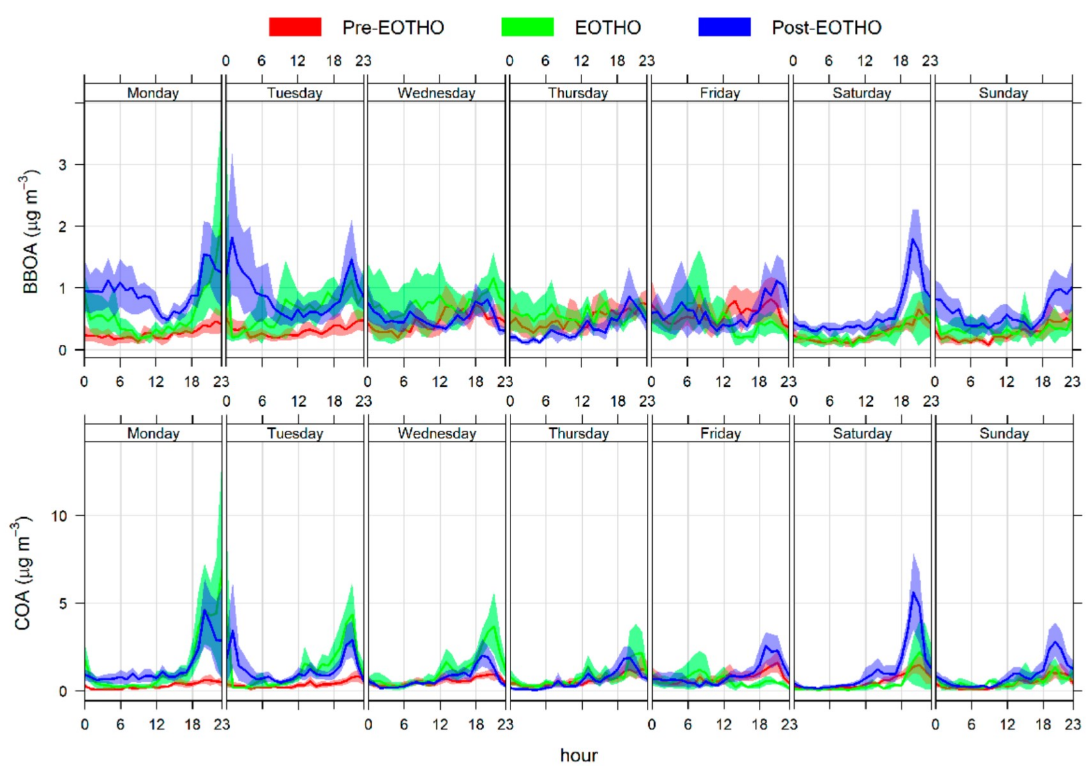


Figure 7: BBOA and COA Diurnal Cycle Concentration Profiles around Lockdown and EOTHO



3.5.5 Source Measurement Conclusions

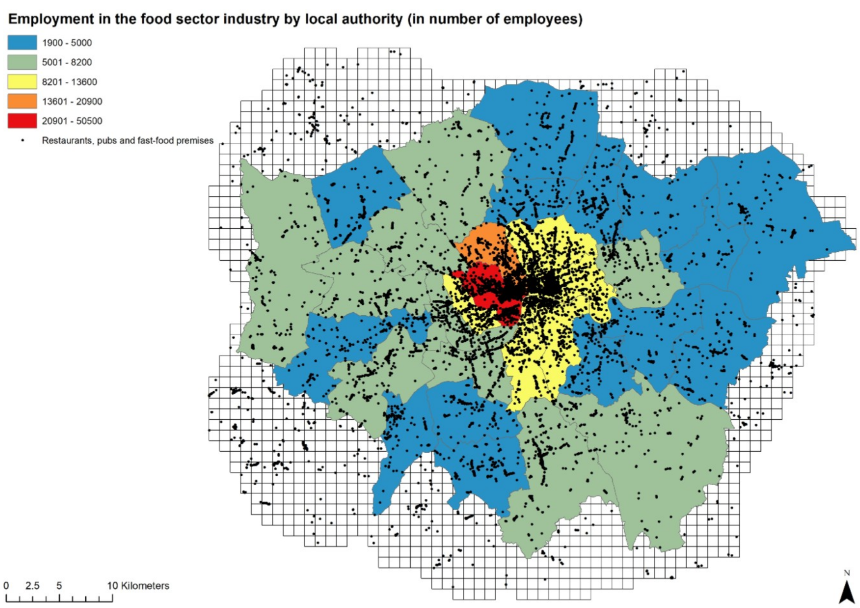
In previous work carried out for the previous LAEI update, measurements and methodology suggested that PM cooking concentrations could range between 1.2 μg/m^3 and 2.4 μg/m^3 at Marylebone Road, and between 0.4 μg/m^3 and 0.7 μg/m^3 at North Kensington. More recent work (as discussed in Section 3.5.2) suggested that PM cooking concentrations should be reported using uncorrected COA concentrations, such as 1.19 μg/m^3 at Marylebone Road, 0.59 μg/m^3 at North Kensington and 0.65 μg/m^3 at Honor Oak Park. Thus, the LAEI 2022 measurement analysis showed that both Marylebone Road and North Kensington were within the range derived as part of the previous LAEI update. To reflect the measurements, and following an iterative process (modelling the dispersion of cooking emissions, comparing modelled concentrations against measurements, and modifying the total emissions estimates until the best fit between modelled and observed concentration was obtained), the total PM emissions for cooking sources across the LAEI was estimated to be 548 tonnes.

3.5.6 Cooking Source Emissions and Spatial Distribution

Based on new evidence from measurement results during the COVID-19 pandemic, the total estimated cooking emissions source of PM was split equally between the commercial catering premises and the residential dwellings. The method to distribute the commercial cooking emissions is provided below. The method used to distribute the domestic emissions is discussed in Section 4.4.

The total estimated for commercial catering cooking emissions was spatially distributed onto the LAEI grid using the catering premises. In order to do that, commercial catering premises data from OpenStreetMap, combined with the food industry (pubs, restaurants and takeaways) sector employment in London was used as a proxy to represent the spatial distribution of restaurants, pubs and fast-food cooking emissions by local authority[31] (see (Figure 8).

Figure 8: Distribution of Employment in the Food Sector by local authority (2017 data) and Location of Catering Commercial Premises (registered Restaurants, Pubs and Fast-Food, December 2018 from OpenStreetMap)

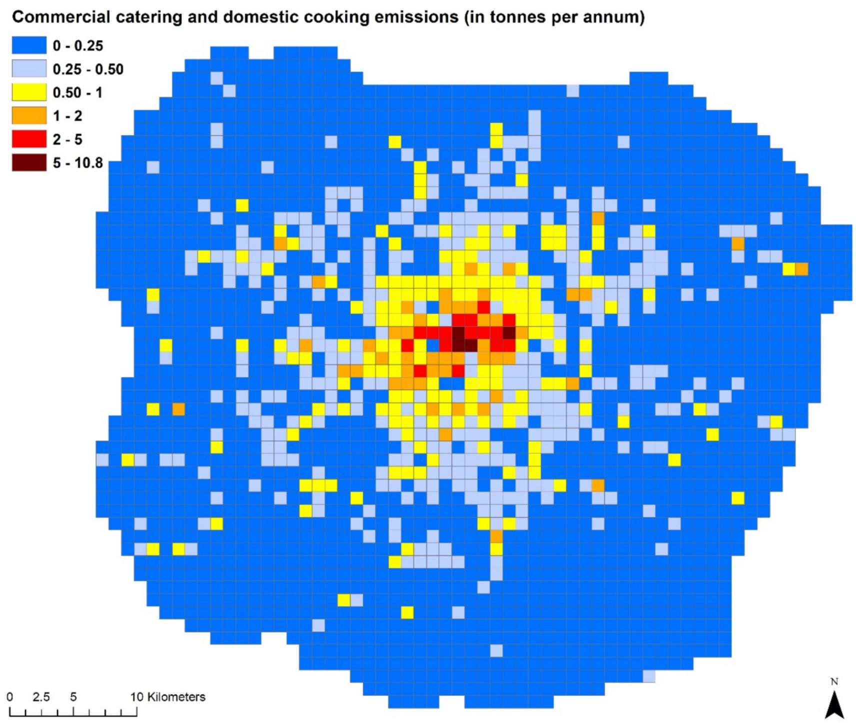


[31] Available at https://data.london.gov.uk/dataset/pubs-clubs-restaurants-takeaways-borough

3.5.6.1 Total (commercial and domestic) cooking source and modelling results

Figure 9 shows the total distribution of commercial catering and domestic cooking emissions sources across the LAEI. COA annual average concentration of PM_{10} and $PM_{2.5}$ was estimated to be 1.14 µg/m³ at Marylebone Road, 0.72 µg/m³ at North Kensington, 0.51 µg/m³ at Honor Oak Park, 0.41 µg/m³ as an average across the Greater London area and 0.34 µg/m³ over the entire LAEI area.

Figure 9: Distribution of Commercial Catering and Domestic Cooking Emissions



3.6 Natural Gas Supply - Gas Leakage

3.6.1 Pollutants

Emissions from gas leakage on the natural gas supply network have been estimated for the pollutants shown in Table 16.

Table 16: Pollutants Reported for Gas Leakage from Natural Gas Supply Sources

Main Source	Category	Number of Pollutants Reported	Key Pollutants				Other Pollutants
			NOx	PM_{10}	$PM_{2.5}$	CO_2	
Industrial and Commercial	Gas Leakage	4	✘	✘	✘	✔	C_6H_6, CH_4, NMVOC

Emissions estimates have been based on the same methodology followed in the previous LAEI updates, applying the following activity-based equation, for each pollutant:

Equation
Emissions (tonnes/year) = Gas Leakage (t/year) × Emission Factor (t poll/t of natural gas leaked)

However, considering that this source accounts for a very small fraction of the total LAEI emissions (typically, less than 0.01% of total CO_2 emissions across the LAEI), and that the estimates of gas leakage is very uncertain, this source has not been updated and emissions remain the same as reported in previous LAEI updates. The methodology used in previous LAEI updates is provided below.

3.6.1.1 Activity Data

The estimated gas leakage across the London distribution network was estimated as ~ 285 GW.h. In order to combine activity data with emission factors, the data was converted into tonnes of natural gas leaked using a conversion factor (GW.h leaked to tonne of natural gas leaked) of 67.2, derived from literature review.

3.6.1.2 Emission Factors

Emission factors were obtained from the NAEI. These are expressed as tonne of pollutant / tonne of natural gas leaked. The value used in the LAEI are:

- 0.035 for CO_2
- 0.814 for CH_4
- 0.001 for C_6H_6
- 0.132 for NMVOC

3.6.1.3 Spatial Distribution

The map of CO_2 emissions from industrial gas consumption across the UK, available on the NAEI website at a 1km^2 resolution, was used as a proxy for the gas leakage emissions distribution across London.

4. Domestic Sources

Emissions from the Domestic Sector include the following categories:

- Emissions from the combustion of fuel used to generate heat and/or power for the domestic sector
- Emissions from household and garden machinery (NRMM)
- Emissions from biomass (wood) burning
- Emissions from domestic cooking

4.1 Heat and Power Generation

4.1.1 Introduction

Emissions from the Heat and Power Generation for the Domestic category include the following sources:

- Gas combustion sources
- Solid and liquid fuel combustion sources

4.1.2 Gas Combustion

4.1.2.1 Pollutants

Emissions from gas combustion sources within the domestic heat and power generation category have been estimated for the pollutants shown in Table 17.

Table 17: Pollutants Reported for Gas Combustion Sources from the Domestic Heat and Power Generation Category

Main Source	Category	Number of Pollutants Reported	Key Pollutants				Other Pollutants
			NOx	PM_{10}	$PM_{2.5}$	CO_2	
Domestic	Heat and Power Generation - Gas Combustion	9	✔	✔	✔	✔	C_6H_6, CH_4, CO, N_2O, NMVOC

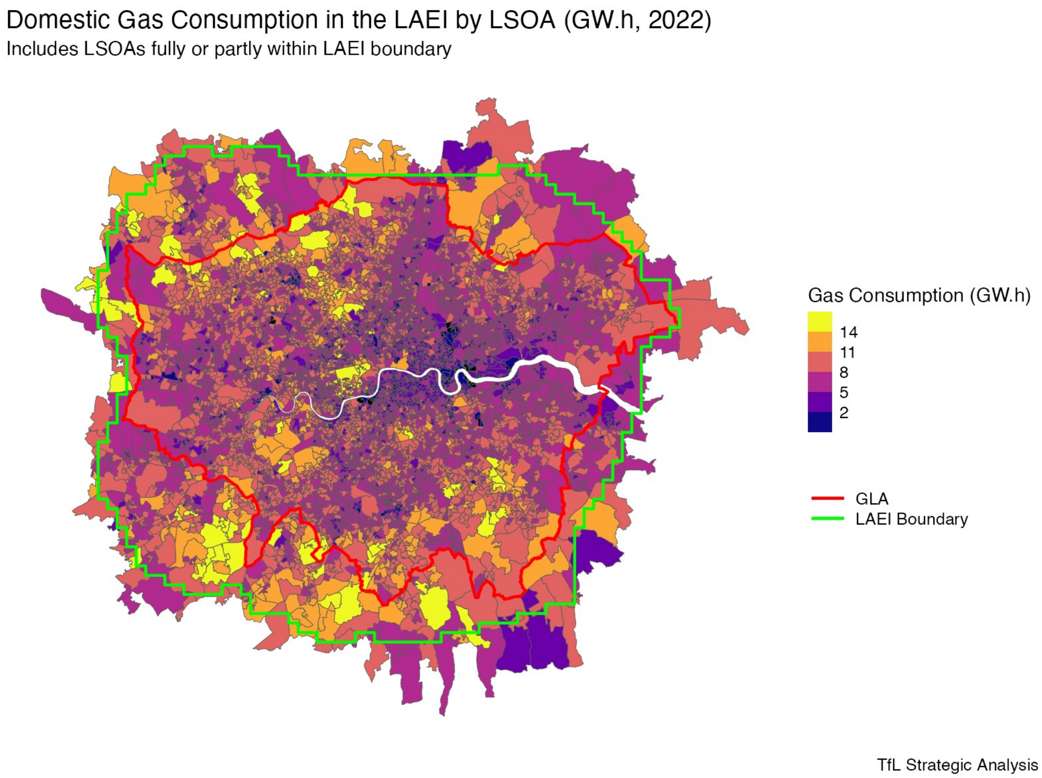
Emissions estimates have been based on the same methodology followed in previous LAEI updates, using updated data and applying the following activity-based equation, for each pollutant:

Equation
Emissions (tonnes/year) = Gas Consumption (GW.h/year) × Emission Factor (t poll/GW.h)

4.1.2.2 Activity Data

Updated activity data (the gas consumption, expressed as energy consumed, in gigawatt-hour/year) has been collated from the Lower and Middle Super Output Areas gas consumption data published by DESNZ, providing domestic gas consumption across the UK at Lower-layer Super Output Area (LSOA) level for year 2022 (see Figure 10).

Figure 10: Domestic Gas Consumption in the LAEI by LSOA (Lower Super Output Area)



4.1.2.3 Emission Factors

For all pollutants except NO_x, updated emission factors (expressed as the mass of pollutant emitted per amount of energy consumed) were collated from the NAEI Emission Factors Database. These emission factors are shown in Table 42 in Section 7.2.1.

For NO_x, updated emission factors based on the age distribution of boilers in London have been used. NO_x emission factors are shown in Table 43 in Section 7.2.1.

4.1.2.4 Spatial Distribution

As for previous LAEI updates, further geographical disaggregation of gas consumption - and hence emissions - was made using the latest Census data (2021) related to the number of households using gas for central heating in each census output area. This data, which is published by the Office of National Statistics (ONS) at Output Area (OA) level, was combined with the LSOA gas consumption data to estimate average household gas consumption and then calculate total emissions within each of the LAEI grid area.

4.1.3 Solid and Liquid Fuel Combustion

4.1.3.1 Pollutants

Emissions from other (liquid and solid fuel) combustion sources within the domestic heat and power generation category have been estimated for the pollutants shown in Table 18.

Table 18: Pollutants Reported for Liquid/Solid Fuel Combustion Sources from the Domestic Heat and Power Generation Category

Main Source	Category	Number of Pollutants Reported	Key Pollutants				Other Pollutants
			NOx	PM_{10}	$PM_{2.5}$	CO_2	
Domestic	Heat and Power Generation - Oil/Coal Combustio n	16	✔	✔	✔	✔	BaP, C_6H_6, Cd, CH_4, CO, Hg, N_2O, NH_3, NMVOC, Pb, PCB, SO_2

Emissions estimates have been based on the same methodology followed in previous LAEI updates, using updated data and applying the following activity-based equation, for each fuel and each pollutant:

Equation
Emissions (tonnes/year) = Fuel Consumption (t fuel consumed/year) × Emission Factor (t poll/t fuel consumed)

4.1.3.2 Activity Data

Updated activity data (the mass of fuel consumed, in tonnes /year) has been collated from the Sub-national residual fuel consumption data published by DESNZ, providing industrial coal, fuel oil and solid smokeless fuel consumption across the UK at local authority level for year 2022. Fuel consumption was then projected onto the LAEI grid and used as a proxy for the spatial distribution of emissions.

4.1.3.3 Emission Factors

Updated emission factors (expressed as the mass of pollutant emitted per mass of fuel consumed) were collated from the NAEI Emission Factors Database for each pollutant. These emission factors are shown in Table 44 in Section 7.2.1.

4.1.3.4 Spatial Distribution

As for the domestic gas consumption data, further geographical disaggregation of the solid and liquid fuel consumption - and hence emissions - was made using the latest ONS Census data (2021) related to the number of households using fuel other than gas for central heating in each census output area. This data, combined with the fuel consumption data at local authority level, was used to estimate average household consumption of solid and liquid fuel and then calculate total emissions within each of the LAEI grid area.

4.2 House and Garden Non-Road Mobile Machinery

Emissions from from household and garden NRMM are classed into the Domestic sources, and include estimated emissions from a range of domestic house and garden mobile machinery, such as lawn and garden tractors, lawn mowers, leaf blowers, trimmers, chain saws etc.

Emissions estimates have been based on the same methodology followed in the previous LAEI updates, using emissions from the use of machinery in the domestic sector as reported in the NAEI scaled down to London, using the UK suburban land cover data as a proxy for spatial distribution.

4.2.1 Pollutants

Emissions from household and garden NRMM sources have been estimated for the pollutants shown in Table 19.

Table 19: Pollutants Reported for Household and Garden NRMM Sources

Main Source	Category	Number of Pollutants Reported	Key Pollutants				Other Pollutants
			NOx	PM_{10}	$PM_{2.5}$	CO_2	
Domestic	Machinery - Household and Garden NRMM	16	✔	✔	✔	✔	BaP, C_4H_6, C_6H_6, Cd, CH_4, CO, Hg, N_2O, NH_3, NMVOC, Pb, SO_2

4.2.2 Emissions

Updated data used for the LAEI 2022 include UK emissions published in the NAEI[1]. UK emissions files have been combined into a single dataset, as these are grouped into the following separate pollutant categories on the NAEI:

- Greenhouse gases (CO_2, CH_4, …)
- Particulate matter (PM_{10}, $PM_{2.5}$)
- "Air quality" pollutants (NO_x, …)
- Heavy metals (Cd, Hg, Pb, …)

4.2.3 Spatial Distribution

The estimated fraction of household and garden NRMM UK emissions to be allocated to the LAEI area was derived from the CEH Land Cover Map 2022[2], combining the 1km^2 summary raster datasets for Great Britain

[1] UK 2022 emissions from NFR code 1A4bii: House and Garden Machinery. Available at https://naei.energysecurity.gov.uk/data/data-selector

[2] Land Cover Map 2022, UK CEH. 1km summary rasters, GB and N. Ireland. Available at https://catalogue.ceh.ac.uk/documents/a413d1c9-5c2a-4864-a3ff-2b9f764ec32d

and Northern Ireland. These datasets summarise the dominant land cover class and provide the percentage coverage of each land cover class across the UK at a 1km^2 resolution.

Land Cover Class Identifier 21, which provides the percentage of suburban land cover in each 1km^2 grid area, was used to calculate the area of suburban land, in m^2, and then the fraction of the total UK suburban land area, for each LAEI grid cell. This fraction was then combined with the total UK emissions to determine the relevant emissions across the LAEI grid.

4.3 Domestic Wood Burning (Biomass)

Estimates of Domestic Wood Burning (DWB) emissions was first introduced as a new source in the LAEI 2016 update, based on the analysis of monitoring concentrations of PM wood burning across London and rural locations outside the city. Further information is provided in the LAEI 2016 methodology report[3].

4.3.1 Background

Wood burning is a non-negligible source of fine particles, contributing to the deterioration of air quality in both rural and urban areas. Previous work concluded that domestic wood burning in the UK has been systematically underestimated by a factor of 3 in the national emissions inventory (Waters, 2016[4]). Earlier work in London suggested that wood burning took place in the capital and that represented ~10% of the winter PM_{10} concentration in inner London in 2010 (Fuller et al., 2014[5]).

4.3.2 Pollutants

Emissions from domestic wood burning sources have been estimated for the pollutants shown in Table 20.

Table 20: Pollutants Reported for Domestic Wood Burning Sources

Main Source	Category	Number of Pollutants Reported	Key Pollutants				Other Pollutants
			NOx	PM_{10}	$PM_{2.5}$	CO_2	
Domestic	Biomass - Wood Burning	2	✘	✔	✔	✘	✘

4.3.3 Source Measurement Methodolgy

Concentrations of PM from wood burning (C_{wood}) can be quantified using the so-called aethalometer method (Sandradewi et al., 2008a[6]). It is based on the distinct light absorption behaviour of wood burning and traffic fossil fuel combustion aerosols, with biomass aerosols absorbing more at shorter wavelengths (Kirchstetter et

[3] London Atmospheric Emissions Inventory (LAEI) 2016 - Methodology, May 2020, Transport for London / Greater London Authority. Available at https://data.london.gov.uk/download/london-atmospheric-emissions-inventory--laei--2016/02dc3d47-2324-43af-bada-aee4805e64b6/LAEI%202016%20methodology%20-%20Final.pdf

[4] E. Waters, March 2016. Summary Results of the Domestic Wood Use Survey. Available at https://www.gov.uk/government/publications/summary-results-of-the-domestic-wood-use-survey

[5] Fuller et al. April 2014. Contribution of Wood Burning to PM_{10} in London. Available at: https://doi.org/10.1016/j.atmosenv.2013.12.037

al., 2004[7]; Zotter et al., 2017[8], and Sandradewi et al., 2008[9]). Details about the methodology can be found elsewhere (Fuller et al., 2014 and Font and Fuller, 2017[10]). Aethalometers are operated with $PM_{2.5}$ cyclones and therefore the C_{wood} discussed in this section is in this size range.

4.3.4 Wood Burning Source Measurement Results

The latest DWB report by Imperial researchers Casey et al. (2023)[11] includes fixed aethalometer measurements of the contribution of wood and solid-fuel burning to PM in London and south-east England.

Annual mean concentrations of C_{wood} have been summarised for the three urban and two rural monitoring sites in Table 21. Only three sites (North Kensington and Honor Oak Park at the urban environment and Chilbolton at the rural) had data for year 2022. Measurement instrumentation was upgraded in 2019 from the dual wavelength Magee Scientific aethalometer AE-22 to the Magee Scientific aethalometer AE-33. Potential effects of this change were considered in Font et al. 2022[12], although there was no evidence of a step change in measurement.

The rural time-series observed a change of site in 2015/2016 and it is split in two locations (Harwell and Chilbolton). The two sites are located in south east England, west of London. Focusing on the last two LAEI years (2019 and 2022), Chilbolton is the site with available data. The minimum concentration measured at rural sites at midday is supposed to be least influenced by local sources and therefore considered to be representative of the regional background concentration. Rural background concentrations ranged from 0.24 $\mu g/m^3$ to 0.46 $\mu g/m^3$. There was no clear trend in the rural background concentration, potentially masked by the change of rural reference site.

[6] Sandradewi J, Prévôt ASH, Szidat S, et al. May 2008. Using aerosol light absorption measurements for the quantitative determination of wood burning and traffic emission contribution to particulate matter. Environmental Science & Technology. 42(9):3316-23. Available at: https://doi.org/10.1021/es702253m

[7] Kirchstetter T.W. November 2004. Evidence that the spectral dependence of light absorption by Aerosols is affected by organic carbon. Journal of Geophysical Research Atmospheres. Available at: https://doi.org/10.1029/2004JD004999

[8] Zotter P, Herich H, Gysel M, et al. Evaluation of the absorption Ångström exponents for traffic and wood burning in the Aethalometer based source apportionment using radiocarbon measurements of ambient aerosol. March 2017. Atmos. Chem. Phys., 17, 4229–4249. Available at: https://doi.org/10.5194/acp-17-4229-2017

[9] Sandradewi J, Prévôt a. SH, Weingartner E, Schmidhauser R, Gysel M, Baltensperger U. September 2007. A study of wood burning and traffic aerosols in an Alpine valley using a multi-wavelength Aethalometer. Atmos. Environ. Available at: https://doi.org/10.1016/j.atmosenv.2007.09.034

[10] Font A., Fuller G. Airborne Particles from Wood Burning in UK Cities. 2017. Available at: https://uk-air.defra.gov.uk/assets/documents/reports/cat05/1801301017_KCL_WoodBurningReport_2017_FINAL.pdf

[11] John Casey, Louise Mittal, Laura Buchanan, Dr Gary Fuller, Dr Iq Mead (2023). London wood burning project: air quality data collection. Environmental Research Group, Imperial College London. Available at https://woodburning.london/wp-content/uploads/2023/10/London-Wood-Burning-Project-Report_final.pdf

[12] Font, A., Ciupek, K., Butterfield, D. and Fuller, G.W., 2022. Long-term trends in particulate matter from wood burning in the United Kingdom: Dependence on weather and social factors. Environmental Pollution, 120105. Available at https://doi.org/10.1016/j.envpol.2022.120105

The urban contribution to PM from wood and solid-fuel burning was quantified using the Lenschow approach[13] and the results are summarised in Table 21. The approach is based on the assumption that the concentration measured at an urban location can be partitioned between the urban contribution lying on top of a uniform regional background. Mathematically this can be written as follows:

Equation
$C_{total.urban} = C_{background} + C_{local.urban}$

The regional background concentration for 2022 was estimated from the Chilbolton measurements ($C_{background}$ in Table 21), and the total urban concentration was taken as the annual mean measured at North Kensington and Honor Oak Park. Note that annual means are only reported if data capture is > 75%.

The local urban contribution in 2022 was therefore 0.76 – 0.30 = 0.46 µg/m^3 at both North Kensington and Honor Oak Park urban sites.

Table 21: Estimated regional background and urban contribution C_{wood} concentrations

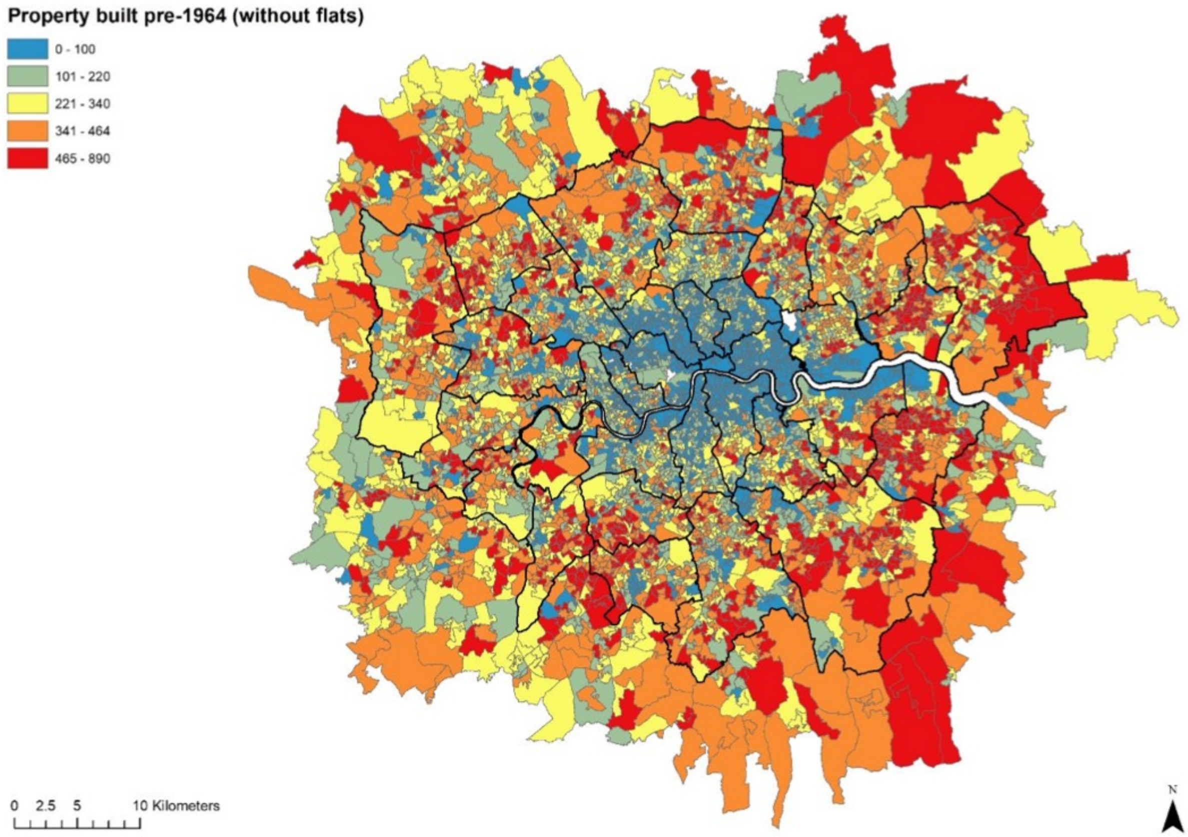
Year	Harwell (2010 to 2015) Chilbolton (2016 to 2022)		Woolwich		North Kensington		Honor Oak Park	
	Total Rural	C background	Total Urban	Local Urban	Total Urban	Local Urban	Total Urban	Local Urban
2010	0.60	0.40	0.98	0.58	1.09	0.69	-	-
2011	0.46	0.31	0.86	0.46	0.97	0.66	-	-
2012	0.52	0.32	-	-	0.93	0.61	-	-
2013	0.51	0.32	-	-	0.94	0.62	-	-
2014	0.44	0.28	-	-	0.87	0.59	-	-
2015	0.36	0.25	-	-	0.80	0.52	-	-
2016	0.79	0.46	-	-	0.85	0.39	-	-
2017	[1] 0.45	0.28	-	-	0.74	0.46	-	-
2018	[1] 0.45	0.24	-	-	0.45	0.21	-	-
[2] 2019	0.63	0.33	-	-	0.72	0.39	-	-
2020	0.58	0.35	-	-	0.70	0.35	0.85	0.50
2021	[3] 0.64	[3] 0.32	-	-	0.62	0.30	0.70	0.38
2022	0.61	0.30	-	-	0.76	0.46	0.76	0.46
[1] Lower concentrations in Chilbolton might be due to the gap in the data between end of November 2017 and March 2018, where wood burning emissions are expected to be larger								
[2] Changeover of instruments in the national black carbon network in November 2019, from Magee AE-22 to AE-33								
[3] Results with annual data capture rate < 75% should be considered with caution								

[13] Lenschow, P., Abraham, H.J. Kutzner, K. Lutz, M. Preuß, J.D., Reichenbächer, W. Some ideas about the sources of PM_{10}. Atmos. Environ., 35 (2001), pp. S23-S33. Available at https://doi.org/10.1016/S1352-2310(01)00122-4

4.3.4.1 Spatial Distribution

London urban domestic wood burning was spatially distributed across the LAEI area using the dwelling stock data down to LSOA level and categorised by the property build period[14] and types[15] covering the Greater London area, (and area up to and including the M25). These data were filtered to exclude both flats and property built after 1964 (see Figure 11).

Figure 11: Distribution of property built pre 1964 by LSOA (Lower Super Output Area) without flats



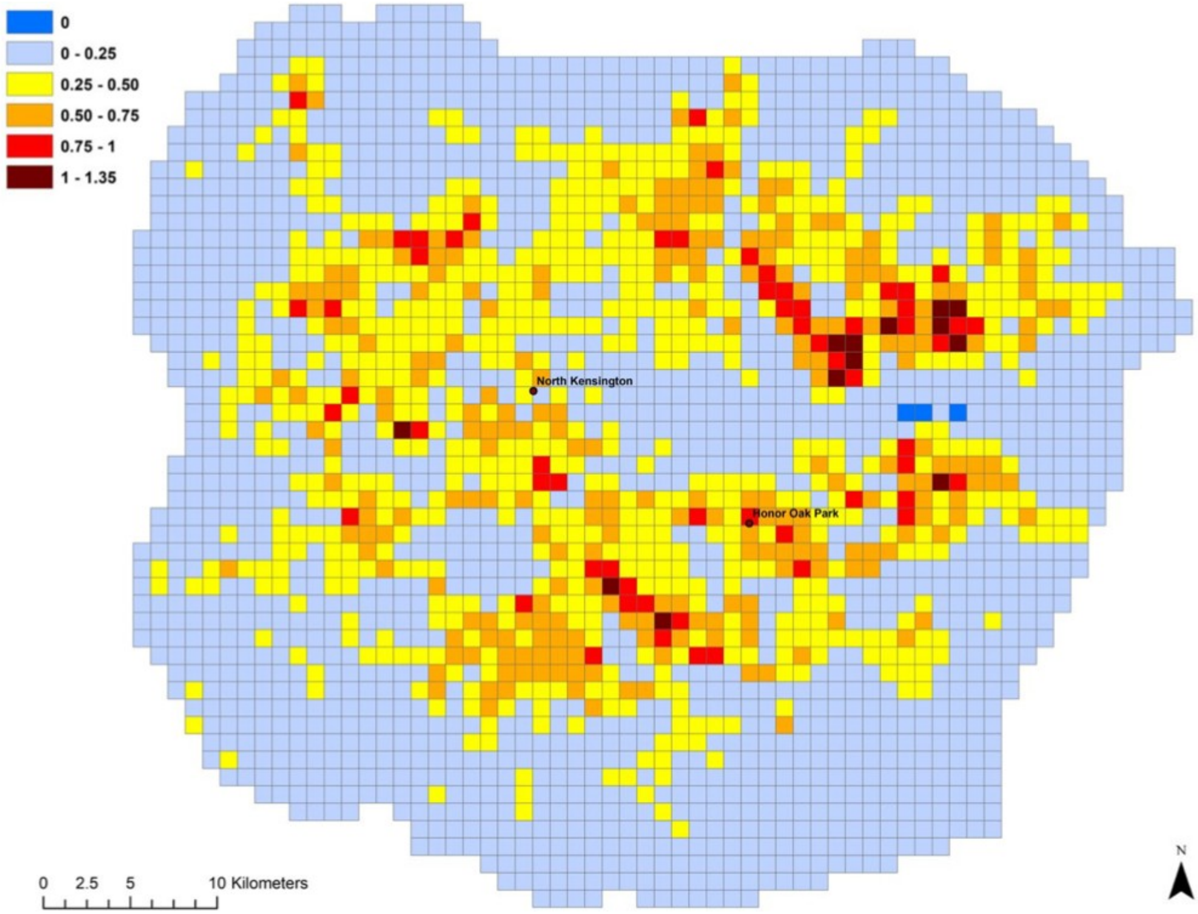
DWB emissions were spatially distributed onto the LAEI grid using residential wood burning emissions estimate and DWB PM air quality apportionment was predicted at North Kensington and Honor Oak Park.

For the LAEI 2022, the DWB emissions input to the model were scaled to reflect North Kensington and Honor Oak Park urban increment measurements of 0.46 µg/m^3 in 2022 (see Table 21). Total emissions were finally estimated to be 574 tonnes of PM in 2022 (see 2022 emissions distribution in Figure 12). Next, 2022 PM_{10} and $PM_{2.5}$ annual average urban wood burning concentration was modelled using the 574 tonnes to represent London urban wood burning PM emissions (as above) and DWB PM air quality apportionment was predicted to be 0.43 µg/m^3 at North Kensington and 0.50 µg/m^3 at Honor Oak Park, 0.37 µg/m^3 as an average across the Greater London area and 0.31 µg/m^3 over the entire LAEI area up to and including the M25.

[14] Available at http://ubdc.gla.ac.uk/dataset/property-build-period-lsoa/resource/d022a431-1687-422e-ae53-fca9ec221c45

[15] Available at http://ubdc.gla.ac.uk/dataset/property-type-lsoa

Figure 12: Distribution of wood burning emissions in tonnes per annum



4.4 Domestic Cooking

In previous LAEI updates, total cooking emissions derived from COA measurements were reported under the Industrial and Commercial section, under the Commercial Catering category. However, as explained in Section 3.5, new evidence available during the COVID-19 pandemic lockdown led to a split of these emissions, with half of the total PM emissions from cooking activities now allocated to the Domestic Cooking category.

4.4.1 Cooking Source Emissions and Spatial Distribution

The estimated domestic cooking PM emissions were spatially distributed using the distribution of domestic gas consumption data, provided at LSOA level, as described in Section 4.1.2.

The spatial distribution of domestic cooking emissions is provided in Figure 9 together with the distribution of commercial cooking emissions.

5. Transport Sources

Emissions from the transport sector include the following categories:

- Emissions from shipping on River Thames
- Emissions from road transport
- Emissions from rail
- Emissions from aviation

5.1 River

Emissions from the river transport category include the following sources:

- Passenger shipping on the River Thames
- Commercial shipping on the River Thames
- Small vessels on the Thames' tributaries and connected waterways across London, including canals

5.1.1 Pollutants

Emissions from shipping sources have been estimated for the pollutants shown in Table 22.

Table 22: Pollutants Reported for Shipping Sources

Main Source	Category	Number of Pollutants Reported	Key Pollutants				Other Pollutants
			NOx	PM_{10}	$PM_{2.5}$	CO_2	
Transport	River	8	✔	✔	✔	✔	CO, NMVOC, NO_2, SO_2

5.1.2 Emissions

Passenger and commercial shipping emissions have been updated by the Port of London Authority (PLA), using the latest estimates from their emissions inventory, and scaling these to 2022 based on activity growth for commercial and passenger vessels. Emissions for 2022 have been provided at local authority level and further distributed on to the LAEI grid using information from the previous LAEI update.

5.2 Road

5.2.1 Introduction

Emissions from road transport in the LAEI are estimated for each of the following vehicle types:

- Motorcycles
- Light Duty Vehicles (LDVs), which include:
  - Cars
  - Private Hire Vehicles (PHVs)
  - Light Goods Vehicles (LGVs)
  - Taxis
- Heavy Duty Vehicles (HDVs), which include:
  - Rigid Heavy Goods Vehicles (HGVs)
  - Articulated HGVs
  - Buses (split between TfL and Non-TfL buses)
  - Coaches

Road vehicle emissions are further split into 3 main categories:

- Exhaust emissions (all pollutants)
- Non-exhaust emissions (for PM_{10} and $PM_{2.5}$), which include:
  - emissions from brake wear
  - emissions from tyre wear
  - emissions from dust resuspension
- Cold start emissions (for NO_x, PM_{10} and $PM_{2.5}$) for LDVs only, which refer to exhaust emissions released when a vehicle is first started up after being inactive for an extended period of time.

The calculation of emissions is based on the combination of activity data related to road traffic, and vehicle emission factors. Activity data from road vehicles include:

- Vehicle-kilometres / Annual Average Daily Traffic (AADT) by vehicle type (cars, PHVs, …)
- Vehicle fleet composition by LAEI zone, including:
  - Fuel / engine type: diesel and petrol Internal Combustion Engine (ICE) / petrol Hybrid Electric Vehicles (HEVs) / Plug-in Hybrid Electric Vehicles (PHEVs) and Battery Electric Vehicles (BEVs)
  - Euro Standard (Pre-Euro, Euro 1 to 6 for LDVs, Euro I to Euro VI for HDVs)
- Vehicle speeds

5.2.2 Pollutants

Emissions from road transport sources have been estimated for the pollutants shown in Table 23.

Table 23: Pollutants Reported for Road Transport Sources

Main Source	Category	Number of Pollutants Reported	Key Pollutants				Other Pollutants
			NOx	PM_{10}	$PM_{2.5}$	CO_2	
Transport	Road Transport	6	✔	✔	✔	✔	CH_4, N_2O

Emissions estimates have been based on the same methodology followed in previous LAEI updates, using updated data and applying the following activity-based equation, for each vehicle type and each pollutant:

Equation
$E_{i,j} = VKM_{i,j} \times \sum(P_{i,j,k} \times EF_{i,j,k}) / 1000$ where: - $E_{i,j}$ is the emissions (tonnes/year) for vehicle type $_i$ and engine type $_j$ - $VKM_{i,j}$ is the volume flow (vehicle-kilometres/year) for vehicle type $_i$ and engine type $_j$ - $P_{i,j,k}$ is the proportion of vehicles of engine type $_j$ and Euro Standard $_k$ in the total fleet composition of vehicle type $_i$ - $EF_{i,j,k}$ is the emission factor (g poll/km) for vehicle type $_i$ engine type $_j$ and Euro Standard $_k$

Vehicle emission factors used in the calculation are from the latest COPERT emissions factors database[1].

5.2.3 Road Traffic Data

The road traffic flow and average speed estimates for the LAEI are derived from 3 sources:

- On the LAEI Major Roads network:
    - data from TfL's London Highway Assignment Model (LoHAM) strategic transport model[2] for all vehicle types except TfL buses
    - data from TfL's iBus system, which tracks the movement and performance of buses on all of contracted routes in London
- Aggregated DfT traffic data at local authority level for the LAEI Minor Roads network

[1] COPERT (COmputer Programme to calculate Emissions from Road Traffic) is the EU standard vehicle emissions database published by the European Environment Agency (EEA). See https://copert.emisia.com

[2] Transport for London Strategic Transport Models: https://tfl.gov.uk/corporate/publications-and-reports/strategic-transport-and-land-use-models

Additionally, vehicle fleet composition were aggregated by TfL for each LAEI zone (Central / Inner / Outer London, Non-GLA and the M25 motorway), providing, for each vehicle type, the proportion of vehicles by engine type (petrol, diesel, HEVs, PHEVs and BEVs).

The LAEI Major Roads network is defined as a set of ~80,000 road links covering all motorways, A roads, and most of B roads and C/unallocated roads (as per the DfT definition) within the LAEI zone (see Figure 13). Road traffic flows and average vehicle speeds for each vehicle type are estimated on each of these road links.

The LAEI Minor Roads contains the remaining roads, not part of the LAEI Major Roads network, mostly C/unallocated roads, and a number of B roads. It is not represented as road links in the LAEI, but the total length of this Minor Roads network is split on to the LAEI grid, based on the proportion of the road network length in each grid cell, which means that road traffic flows and emissions are estimated at grid level for the Minor Roads.

Figure 13: LAEI Major Roads Network

The full vehicle-kilometres estimated for the LAEI 2022 by LAEI zone, vehicle type and road network are summarised in Table 45 in Section 7.3.1. The following sections provide more details in relation to how the data was calculated for both the LAEI Major Roads and Minor Roads networks.

5.2.3.1 Traffic on the LAEI Major Roads Network

The process flow to estimate road traffic on the LAEI Major Roads network is illustrated in Figure 14.

AADT by vehicle type on the LAEI major roads network were estimated from the combination of modelled peak hour (am, pm and inter peak) flows from LoHAM, and observed hourly vehicle flows from Automatic Traffic

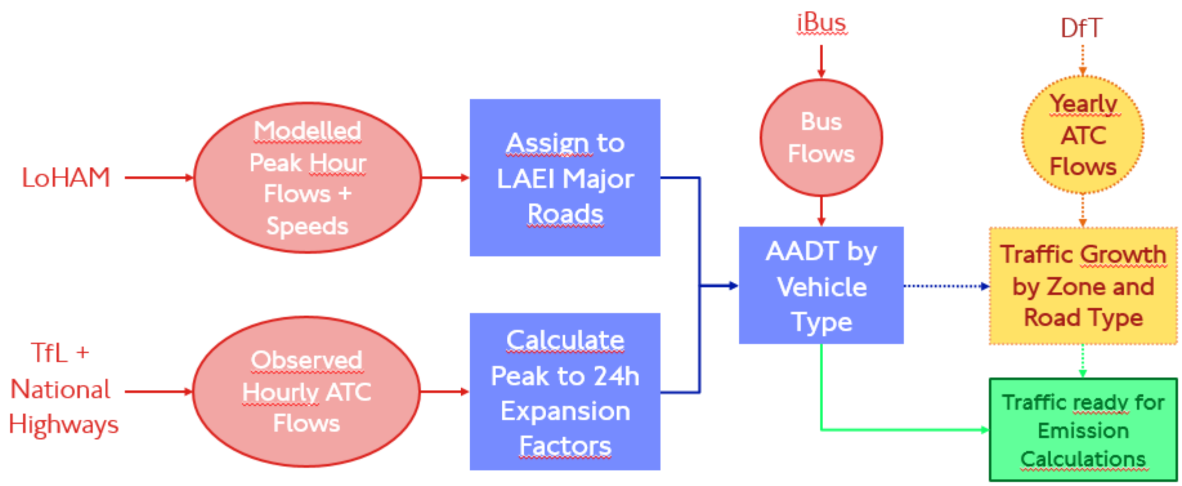
Counters (ATC) data aggregated from National Highways (for motorway road links) and TfL (for other main roads). ATC volume flows were used to derive expansion factors for each LAEI zone (Central / Inner/ Outer London / Non-GLA) and road type (Motorways, A Roads, B Roads, other roads). These expansion factors were applied to all modelled peak hour flows to estimate the equivalent 24-hour flows (AADT) on each road link part of the LAEI Major Roads Network.

As peak hour flows from LoHAM were modelled for a baseline 2019; AADT were further scaled to 2022 using DfT ATC data[3], enabling the calculation of traffic growth between 2019 and 2022 by vehicle type, averaged by LAEI zone and road class.

AADT for TfL buses for 2022 were estimated separately using the TfL iBus database, which provides detailed traffic data from bus stop to bus stop.

Average daily vehicle speeds on each road link were derived from the LoHAM modelled peak hours speeds, except for TfL buses, for which observed speeds from the iBus database were used instead.

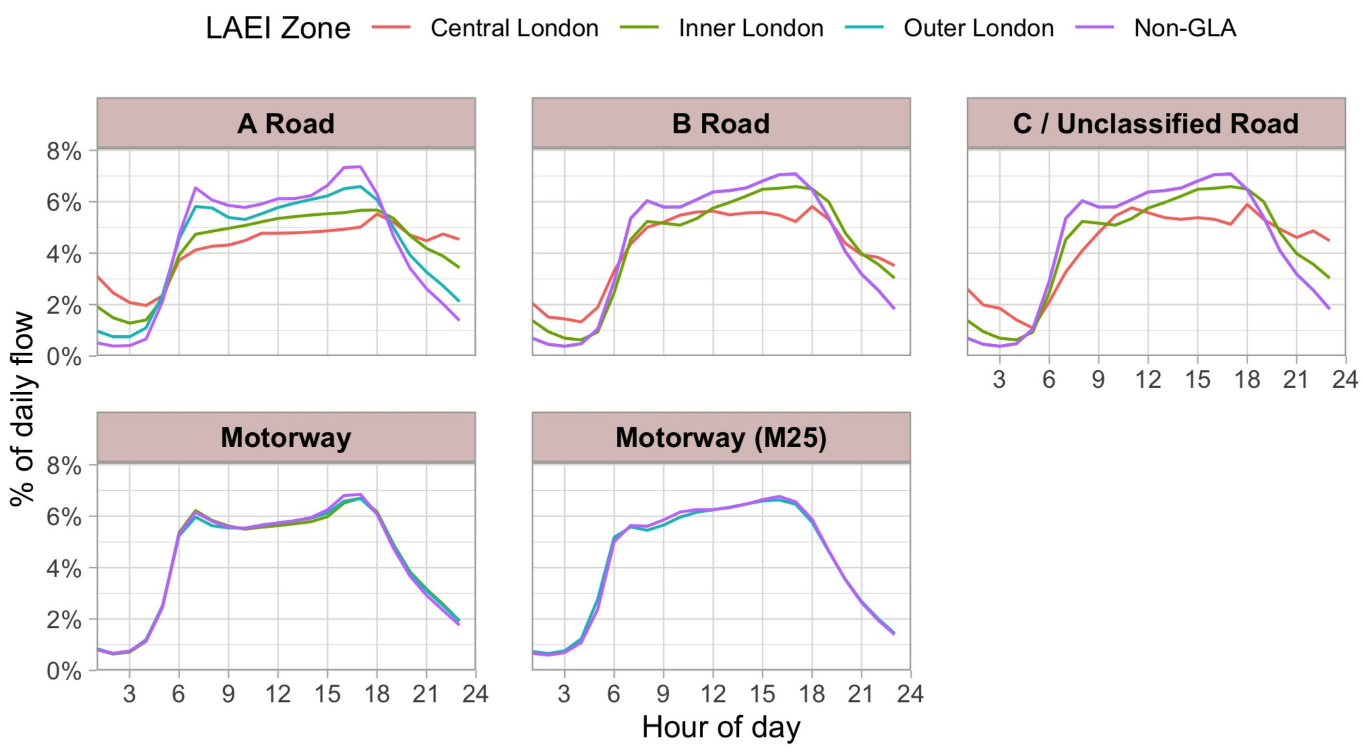
Figure 14: LAEI Major Roads Network Traffic Process Flow



Diurnal profiles were estimated using ATC data from TfL to allow the traffic flows and average speeds to be separated into each hour of the day. Separate profiles for traffic flows were created for each LAEI zone and road class (see Figure 15). A single dataset of hourly speed factors was provided to apply to the annual average speeds assigned to each road link.

[3] Road traffic data at count point level from Department from Transport. Available at https://roadtraffic.dft.gov.uk/downloads

Figure 15: Road traffic diurnal profiles by zone and road type



TfL Strategic Analysis

5.2.3.2 Traffic on the LAEI Minor Roads Network

Annual vehicle-kilometres from the LAEI Minor Roads network were estimated by TfL across each LAEI grid cell. A total of 46.51 billion vehicle-kilometres driven across the LAEI in 2022 was derived from DfT Road Traffic Estimates[4], which provides average traffic volumes by region and local authority.

The total vehicle-kilometres already accounted for on the LAEI Major Roads network (38.77 billion vehicle-kilometres) was subtracted from that LAEI total derived from DfT data. This provided an estimated 7.74 billion vehicle-kilometres to be assigned to the LAEI Minor Roads network (see details in Table 45).

This estimated minor roads vehicle-kilometres was then spatially distributed on to the LAEI grid, based on the following method using a GIS software:

- Split the LAEI Major Roads network on to the LAEI grid to calculate the road network length in each grid cell
- Similarly, split the OS Mastermap Highways[5] road network (which contains all roads, including those not included in the LAEI Major Roads network) on to the LAEI grid to calculate the total (Major + Minor) road network length in each grid cell

[4] Road Traffic Estimates (TRA) Statistical Dataset, Department for Transport. Available at https://www.gov.uk/government/statistical-data-sets/road-traffic-statistics-tra

[5] OS Mastermap Highways Network, Ordnance Survey. Available at https://www.ordnancesurvey.co.uk/products/os-mastermap-highways-network-roads

- In each LAEI grid cell, estimate the length of LAEI Minor Roads network, by subtracting the length of the LAEI Major Roads network from the length of the OS Mastermap Highways road network.
- Calculate, in each LAEI grid cell, the proportion of the total LAEI Minor Roads network length
- Spatially distribute the estimated total vehicle-kilometres on the LAEI Minor Roads network on to the LAEI grid, based on that proportion of total Minor Roads network length

This total vehicle-kilometres for Minor Roads on the LAEI grid was then further split by vehicle type, using the following method:

- For each borough, sum the LAEI Major Roads vehicle-kilometres for all vehicles, and calculate, for each vehicle type, the proportion of total vehicle-kilometres on the Major Roads in the borough
- Assign these proportions to each LAEI grid cell (based on which borough they are part of) and apply these to the LAEI Minor Roads vehicle-kilometres allocated to each grid cell to get the split by vehicle type

5.2.3.3 Note on the DfT Revised Vehicle Statistics for London

In 2020, DfT revised its motor vehicle statistics on minor roads[6] across Great Britain, from the period 2010 to 2019. This resulted in increases in overall vehicle-kilometre estimates across London and the LAEI area.

As discussed in Section 2, these changes could not be taken into account in the previous LAEI update, but are now inherently included in the total vehicle-kilometres estimates across the LAEI 2022 (and will also be in future LAEI updates), resulting in increased vehicle-kilometres on the LAEI Minor Roads network (as the vehicle-kilometre estimates on the LAEI Major Roads network are not linked to DfT but are derived from the TfL LoHAM model) compared to previous LAEI updates.

5.2.4 Vehicle Fleet Compositions and Engine Fuel Type Proportions

Detailed annual fleet composition data for 2022 were estimated by TfL, using the traffic camera network across London, and, for TfL buses, using traffic, speed and composition by individual route derived from the iBus database, to provide aggregated profiles for London zones (Central / Inner / Outer London). The Outer London fleet compositions were used for the Non-GLA zone. Vehicle fleet compositions for the M25 were taken from the latest national motorway fleet composition provided by Defra.

Fleet compositions split each vehicle category into proportions by fuel / engine type (petrol, diesel, hybrid / plug-in hybrid or electric vehicles) and Euro standards. Figure 16 shows the fleet composition by engine type for LAEI zone and each vehicle type for year 2022.

Fleet composition data also include estimates of the proportions of failed catalysts among petrol vehicles, and the proportions of Diesel Particulate Filter (DPF) and Selective Catalytic Reduction (SCR) failures among diesel vehicles.

The vehicle fleet compositions were assigned to each road link (for the Major Roads network) / LAEI grid cell (for the Minor Roads network), based on their location. These were then combined with the associated speed-emissions curve for each pollutant, based on the relevant COPERT emissions factors, to estimate road transport emissions.

[6] Note that the classification of “minor roads” for DfT is not the same as the one used in the LAEI Minor Roads network. DfT minor roads comprise B and C classified roads in addition to unclassified roads. Many of these roads are actually included in the LAEI Major Roads network, which includes motorways, A roads, but also many B roads and even a number of C / unclassified roads, as shown in Figure 13.

Figure 16: Vehicle Engine Fleet Composition by Zone and Vehicle Type

5.2.5 Cold Start Emissions

Vehicle cold start emission calculations are based on the methodology detailed in the EMEP/EEA 2023 Guidebook.

Emission estimates used estimations of the number of trip starts for each relevant vehicle categories (cars, PHVs, LGVs and taxis), provided by the TfL LoHAM model. Trip start data available in each LoHAM zone for am, pm and inter peak hours for year 2019 and 2023 were used and linearly interpolated to 2022. Zonal data was spatially intersected with the LAEI grid, thereby giving the proportion of each LoHAM zone to be allocated to each LAEI grid cell.

Vehicle-kilometre proportions by hour and vehicle category, derived from the vehicle-kilometres on the LAEI Major Road network, were used to expand the trip start data from the hours provided to represent a whole average day, and ultimately generate annual trip starts on the LAEI grid for each vehicle type. The resulting data were combined with fleet compositions by LAEI zone, as done for the LAEI Minor Roads network.

To calculate additional emissions from cold starts, information is also required on the ratios of cold to hot emissions for each vehicle class, which is dependent on ambient temperature, as well as the proportion of time spent under such driving conditions, which is dependent on both ambient temperature and average trip length. Formulas required to calculate these parameters are detailed in the EMEP/EEA 2023 Guidebook.

Temperature data measured at London Heathrow throughout 2022 were used to calculate these values on a monthly basis.

Average trip lengths for each vehicle category were calculated by dividing through the total London vehicle-kilometres for 2022 by the number of trip starts within the London boundary.

5.2.6 COPERT Emission Factors

Exhaust emissions factors in the LAEI 2022 were based on COPERT v5.7, in line with recommendations in the EMEP/EEA guidebook 2023 at the time of generation of data[7].

Included in the updates to the methodology since the prior LAEI were updates to degradation assumptions, and to the method for estimating over-emissions from cold starts among light-duty vehicles.

5.2.6.1 Cold Starts for Heavy Vehicles

A notable update to the EMEP/EEA 2023 Guidebook recommendations / COPERT emissions factors since the previous LAEI, was the inclusion of parameters to estimate additional emissions from HDVs under cold operating conditions. Inclusion of this has been shown through research work to have had a substantial impact in increasing NO_x emissions from these vehicles in the inventory, depending on the fraction of time that they are assumed to be operating under such conditions while in the LAEI area. However, in the absence of reliable data to estimate this fraction of time, these emissions were not included in the LAEI 2022, but will be considered in future updates.

5.2.7 Other Emissions Factor Updates

5.2.7.1 Primary NO_2 Fraction

The proportions of NO_x emissions emitted as NO_2 (also referred to as the primary NO_2 fraction, or f-NO_2) were updated for each vehicle category and Euro standards, in line with the figures used in the NAEI at the time of the generation of data[8].

5.2.7.2 Exhaust $PM_{2.5}$

In line with assumptions in the UK Emissions Factor Toolkit[9], 100% of Exhaust PM_{10} is now assumed to be $PM_{2.5}$ (95% was assumed in the previous LAEI).

5.2.7.3 Non-Exhaust Emissions

Emissions of PM_{10} and $PM_{2.5}$ from vehicle brake wear, tyre wear, and resuspension were estimated using the same emissions factors as in the previous LAEI updates, derived from the work by Harrison et al. (2012)[10].

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[7] The version used in the LAEI 2019 was COPERT v5.4

[8] Emission Factors for Transport, NAEI. Available at https://naei.energysecurity.gov.uk/emission-factors/emission-factors-transport

[9] Emissions Factor Toolkit v13.1, Defra. Available at https://laqm.defra.gov.uk/air-quality/air-quality-assessment/emissions-factors-toolkit

[10] Harrison, Roy M., et al. Estimation of the contributions of brake dust, tire wear and resuspension to non exhaust traffic particles derived from atmospheric measurements. Environmental Science & Technology 46.12 (2012): 6523-6529. Available at https://pubs.acs.org/doi/10.1021/es300894r

5.3 Rail

5.3.1 Introduction

Emissions from the rail transport category include exhaust emissions from both freight and passenger train diesel locomotives.

Detailed emission by train type and operator were calculated for each rail link between Timing Point Locations (TIPLOCs) - typically a station or junction) on the rail network inside and just outside the LAEI area, using detailed Network Rail activity data for actual individual train services on individual routes.

Emissions from the rail transport sector include exhaust emissions from both freight and passenger diesel trains. Electric trains result in indirect CO_2 emissions that will depend on the electricity grid's mix of renewable and combustion sources[11].

Both freight and passenger rail activity data for the national rail network (including London Overground trains) were sourced from the Network Rail Open Data platform and emission factors from the NAEI, which have been updated based on work for the Rail Safety and Standards Board (RSSB)[12]. Combustion emissions plus electricity consumption (and so associated CO_2 emissions) were calculated for individual segments of rail lines and reflect spatial variations in the density of traffic and train type. TfL data on electricity consumption (and so associated CO_2 emissions) for the London Underground, Docklands Light Railway (DLR) and London Tramlink were allocated to different lines based on link lengths.

Passenger rail NO_x emissions are significantly lower for 2022 compared to earlier years, primarily because of electrification of the Great Western Mainline and the introduction of new rolling stock on the East Coast Mainline, resulting in the removal of almost all diesel trains serving Paddington and Kings Cross stations. Freight rail NO_x emissions are generally similar to previous years. Despite the introduction of new services on the Elizabeth Line and to Barking Riverside, passenger rail electricity consumption on the national network in 2022 is reduced compared to 2019 due to the introduction of new, more energy-efficient rolling stock and reduction in services post COVID-19 pandemic. There is a small reduction in traction electricity consumption between 2019 and 2022 for the Underground, DLR and Tramlink, and thus a consequent reduction in associated CO_2 emissions.

While all train types also produce some emissions of PM from abrasion of the track, wheels, brake pads and pantographs, these emissions are not included in the LAEI estimates. There is limited information available on this source for the rail sector, abrasion PM is likely to be substantially less significant than combustion PM, and so was not considered for the LAEI 2022.

5.3.2 Pollutants

Emissions from rail transport sources have been estimated for the pollutants shown in Table 24.

[11] These indirect CO_2 emissions are not reported in the LAEI, as it focuses on direct (i.e. exhaust) emissions, but they are reported as part of the London Energy and Greenhouse Gas Inventory (LEGGI), available at https://data.london.gov.uk/dataset/london-energy-and-greenhouse-gas-inventory-leggi-2ko63/

[12] Grennan-Heaven, N. and M. Gibbs (2020). CLEAR: Fleet-wide assessment of rail emissions factors – Main report. RSSB. Available at https://aether-uk.com/CMSPages/GetFile.aspx?guid=132f6343-5901-4a43-ab4c-560f68b0fc0f

Table 24: Pollutants Reported for Rail Transport Sources

Main Source	Category	Number of Pollutants Reported	Key Pollutants				Other Pollutants
			NOx	PM_{10}	$PM_{2.5}$	CO_2	
Transport	Rail	10	✔	✔	✔	✔	C_4H_6, C_6H_6, CH_4, CO, HC, NMVOC

5.3.3 Freight Rail

5.3.3.1 Activity Data

Activity data for all actual individual train movements in 2022 were obtained from the Network Rail Open Data platform. This covers movements between all unique TIPLOCs in and just outside the LAEI area. The data allowed the calculation of emissions across all lines in London, taking into account the actual variation and density of train movements during the year along all the relevant links in the national rail network in the LAEI area.

The activity data consists of five fields: Train Service Code, Operator, Power Type, Timing Load, and Speed. Generally, the first three fields were used to identify the particular type of service and the likely locomotive class. Where a freight operator may use different locomotive classes on a service, an average based on expert knowledge of that freight operator's fleet composition was applied. Electric-hauled services form a small proportion of freight services within the London area.

Although data on movements of track monitoring and maintenance trains ("yellow plant") were available, emissions were not calculated since relevant emission factors are not available. However, engineering traffic, i.e. trains serving track renewal work and other projects, can be identified and was included.

5.3.3.2 Emissions Factors

Diesel freight rail emission estimates for air quality pollutants are based on g/km emission factors used in the NAEI with minor updates for Class 60, 68 and 70 locomotives based on the RSSB work. Where emission factors were not available for certain locomotive classes a reasonable proxy was used (e.g. Class 60 for Class 57, Class 66 UIC1 for Class 67). CO_2 emission factors for diesel combustion for different freight locomotives were based on typical distance-based fuel consumption rates per km.

Electricity consumption rates in kWh/km for different electric freight locomotives were derived from Network Rail, manufacturer and operator data sources. The government greenhouse gas conversion factor for electricity consumption for 2021 (in units of kg CO_2e per kWh)[13] was used to spatially allocate the CO_2 emissions associated with electricity consumption.

5.3.4 Passenger Rail

5.3.4.1 Activity Data

The same activity data source for freight rail was used for passenger rail on the national network (including London Overground). All trains operated by train operating companies providing scheduled passenger services (including empty carriage stock movements) were grouped in the passenger rail category. Trains run by specialist charter service operators were included in the freight rail category.

[13] Available at https://assets.publishing.service.gov.uk/media/647f50dd103ca60013039a8a/2023-ghg-cf-methodology-paper.pdf

Information provided by the five fields in the activity data – Train Service Code (generally describing types of services on certain routes), Operator, Power Type (e.g. diesel versus electric multiple unit, high speed train), Timing Load, and Speed – was used along with expert judgement to determine the typical train classes and typical train lengths (i.e. number of vehicles) used on each type of service. The activity data also captures diversions of trains away from normal routes during engineering work.

Traction energy consumption on different Underground lines was apportioned by volume of traffic, while consumption for the DLR and Tramlink was allocated uniformly to all links.

5.3.4.2 Emissions Factors

Diesel passenger rail emission estimates are based on g/vehicle-km emission factors from the NAEI with updates for Class 68 locomotives and Class 180, 185, 220, 221, 222 and 800/802 trains based on RSSB work. CO_2 emission factors for diesel combustion for different passenger rolling stock were based on typical distance-based fuel consumption rates per km.

Electricity consumption rates in kWh/km for different electric passenger rolling stock on the national network were derived from Network Rail, manufacturer and operator data sources. The government greenhouse gas conversion factor for electricity consumption for 2021 (in units of kg CO_2e per kWh) was used to spatially allocate the CO_2 emissions associated with electricity consumption on the national network, Underground, DLR and Tramlink.

5.4 Aviation

Emissions from the aviation category include the following sources:

- Heathrow Airport
- City Airport
- All other smaller airports (with paved runways) within the LAEI boundary:
    - Biggin Hill
    - Denham
    - Edmiston London Heliport
    - Elstree
    - Northolt
    - Stapleford

For each airport, emissions from aircraft, airside vehicles, landside vehicles and stationary sources have been included where relevant.

5.4.1 Introduction

There have been several significant updates to the aviation emissions in the LAEI 2022, including changes in data sources and methodology, such as:

- A new estimate of Heathrow aircraft activity data for the year 2022, compiled using the UK Civil Aviation Authority (CAA) aircraft movement data.

- New 2022 aircraft emissions calculated using the latest International Civil Aviation Organization (ICAO) emissions factors[14]
- An update of the 2022 aircraft times-in-mode for approach, landing-roll, take-off roll, initial-climb and climb out based on airport radar data.
- An update of the 2022 aircraft times-in-mode for taxi-in, taxi-out (including hold) based on Eurocontrol taxiing data as reported in the EMEP/EEA Guidebook 2023
- An update of the 2022 aircraft times-in-mode for Auxiliary Power Unit (APU), based on new compliance survey data
- An updated estimate of total hydrocarbon emissions from refuelling sources in 2022 made by scaling on whole flight CO_2 aircraft emissions changes between 2019 and 2022
- Updated estimates of Airside (Ground Support Equipment) and Landside vehicle emissions in 2022
- For London City airport, 2022 aircraft activity data compiled using the CAA aircraft movement data and new 2022 emissions produced using the latest ICAO emissions factors, consistent with those used at Heathrow airport
- Smaller airfields updated to reflect the latest available movement data and new 2022 emissions produced using the latest emissions factors and appropriate times-in-mode

5.4.2 Pollutants

Emissions from aviation sources have been estimated for the pollutants shown in Table 25.

Table 25: Pollutants Reported for Aviation Sources

Main Source	Category	Number of Pollutants Reported	Key Pollutants				Other Pollutants
			NOx	PM_{10}	$PM_{2.5}$	CO_2	
Transport	Aviation	10	✔	✔	✔	✔	C_4H_6, C_6H_6, CH_4, CO, NMVOC, SO_2

5.4.3 Heathrow Airport

Aviation emissions in the LAEI 2022 are based upon the methodology described in the (Heathrow Expansion) Preliminary Environmental Information Report (PEIR)[15] and include the following sources:

- Aircraft emissions in the standard Landing and Take-Off (LTO) cycle up to 3,000 ft height, APU, engine testing and aircraft refuelling
- Ground Support Equipment (GSE) emissions (associated with aircraft turn-around)

[14] Emission factors available at https://www.easa.europa.eu/en/domains/environment/icao-aircraft-engine-emissions-databank

[15] Heathrow Expansion Preliminary Environmental Information Report, Heathrow Airport Limited, 2019

- Landside vehicles emissions (cars parks and taxis)
- Stationary emissions (heating plant and fire-training ground)

5.4.3.1 Aircraft Emissions

Aircraft exhaust emissions are calculated by multiplying aircraft activity (from a given mode of aircraft operation) by the engine fuel flow rate, the emission factor for the pollutant of interest and the duration of the operation (times-in-mode). Total emissions are then simply calculated by summing the contributions from all the aircraft movements in a given year.

The aircraft LTO modes considered in the inventory include:

- Taxi-out (commences at stand and ends when the aircraft joins the departure queue)
- Hold at runway head
- Take-off roll (from start of roll to wheels off)
- Initial climb, from wheels off to throttle back - normally 305 m (1,000 ft) or 457 m (1,500 ft)
- Climb-out (from throttle back to 1000 m altitude)
- Approach (from 1000 m altitude to runway threshold)
- Landing roll (from runway threshold to runway exit)
- Taxi-in (commences when the aircraft leaves the runway and ends when the aircraft reaches the stand)

Aircraft exhaust emissions are calculated by multiplying aircraft activity (from a given mode of aircraft operation) by the engine fuel flow rate, the emission factor for the pollutant of interest and the duration of the operation (time-in-mode). Total emissions are then calculated by summing the contributions from all the aircraft movements each year.

The aircraft LTO modes considered in the inventory include:

- Taxi-out, which commences at stand, and includes holding at runway head prior to start of take-off roll
- Take-off roll (from start of roll to wheels off)
- Initial climb, from wheels off to throttle back (normally 1,000 ft or 1,500 ft)
- Climb-out, from throttle back to 3,000 ft altitude
- Approach (from 3,000 ft altitude to runway threshold)
- Landing roll (from runway threshold to runway exit)
- Taxi-in, which commences when the aircraft leaves the runway and ends when the aircraft reaches the stand

5.4.3.2 Activity Data

Heathrow activity data for 2022 were compiled using aircraft movements from 1st January to 31st December 2022, made available by the UK CAA. The aircraft activity data included the number of movements, disaggregated by aircraft type, flight origin/destination and operation type (arrival or departure).

The distribution of engine fits for a given aircraft type was based on the work undertaken for PEIR. The proportion of each runway (09L, 09R, 27L and 27R) used for arrivals and departures was obtained for analysis of flight records provided by Heathrow for 2022.

The aircraft movement database accounted for 376,823 air transport movements in 2022. These excluded 418 air-taxi movements and 3,064 non-air transport movements (mainly positioning and non-commercial flights). No details of aircraft type were available for the excluded movements, so emissions from these movements were estimated using more approximate techniques such as scaling. The total number of aircraft movements 380,305 in 2022 represents a decrease of 20% from 478,059 in 2019. The total number of passengers (source: CAA) was 61.60 million in 2022, which is a decrease of 24% from 80.89 million in 2019. The reductions in both aircraft movements and passenger numbers are a consequence of the COVID-19 pandemic.

5.4.3.3 Emission Factors

To calculate jet aircraft emissions, the ICAO emissions factors databank (Issue 29B released in June 2023) was linked to the CAA aircraft movement database and engine fit data provided by Heathrow. The ICAO database provides jet engines certification test results of emission factors (referred to as ‘emission index’ in the ICAO database), smoke number and fuel flow rates for every aircraft engine type. For non-jet aircraft similar datasets were used: FOI’s database for Turboprop Engine Emissions, Federal Office of Civil Aviation (Switzerland) (FOCA) piston engine database and FOCA Guidance on the Determination of Helicopter Emissions.

The pollutants in the ICAO database include NO_x, CO and total hydrocarbons (the latter being used for estimating CH_4, NMVOC, C_6H_6 and C_4H_6 emissions) by thrust setting (7%, 30%, 85% and 100%). These are used to represent the standard thrust settings for idle, approach, climb-out and take-off operations. In practice however, actual thrust settings deviate from these standard thrusts, so interpolation is used to provide factors appropriate for each mode.

Adjustments were made to the NO_x emission factors to account for speed effects on stationary engine tests and fuel flow rates and NO_x emission factors to account for engine deterioration using forward speed effect factors and degradation factors in line with the Project for Sustainable Development of Heathrow (PSDH) recommendations.

The ICAO database provides other information used in the aircraft emission calculations, e.g., engine category split between TurboFan and Mixed TurboFan, bypass ratios (both used in the PM calculations) and the engine maximum rated thrust (in kN).

Reduced Engine Taxiing

Reduced-engine taxiing is the practice of shutting down an engine during taxi operations, which helps reduce fuel use, emissions, and noise. In recent years the practice of reduced-engine taxiing has become more widespread, due in part to the achieved fuel savings. Since the summer of 2014, Heathrow have recorded the use of reduced-engine taxiing for departures. The use of reduced-engine taxiing on arrival is expected to be more common than on departures. However, systems to record its use on arrival are not yet available, so airline survey data, along with the departures records, were used to estimate its prevalence on arrival.

The estimation of taxiing emissions is made potentially more complex by the practice of reduced-engine taxiing, particularly as it is common practice for aircraft to keep their APU running whilst taxiing on reduced engines.

5.4.3.3.1 Thrust Settings by Mode

Because of the high variability in the fuel flow rate and emission factors between different engine types and thrust settings, specific estimates were used for each aircraft.

Based on PSDH recommendations, approach thrusts were assumed to be 15% between 3,000 ft and 2,000 ft altitude, and 30% from 2,000 ft to threshold (irrespective of aircraft type). For taxi, PSDH recommendations were again followed for movements that do not use reduced-engine taxiing. For these, the fuel flow rate is assumed to be 17.5% or 32.5% lower than the fuel flow rate at 7% thrust, for non-Rolls Royce and Rolls Royce engines respectively. The emission indices are set to those for the 7% thrust setting. For aircraft movements that use reduced-engine taxiing, the fuel flow rate and emissions indices are those for 7% thrust.

Aircraft sometimes use reverse thrust on landing, usually where the runway is short and/or when weather conditions are poor (e.g., wet, or icy). Following advice from Heathrow's Airline Working Group, that use of reverse thrust above idle was uncommon, thrusts setting during the landing roll were therefore assumed to be 7%, corresponding to idle, irrespective of whether reverse thrust was used.

It is common for aircraft to take-off at less than 100% thrust, sometimes as low as 75%, primarily to reduce wear on the engines. This is possible because engines are overpowered for routine take-offs since aircraft need to be able to complete the manoeuvre safely with the loss of one engine.

The take-off thrust assumptions made for historical Heathrow inventories were based on survey data compiled before the 2008/2009 Heathrow inventory (see Table 26). Heathrow's Airline Working Group recommended a simpler set of take- off thrust settings be used for PEIR, these were intended to ensure the assumptions were conservative and have been adopted for the LAEI 2022.

Table 26: Take-off Thrusts

Aircraft Type	Reduced Thrust Setting	Flights using 100% Thrust
Narrow-body, twin engine	80%	6%
Wide-body, twin engine	80%	6%
Wide-body, four engine	84%	14%

5.4.3.3.2 Times-in-Mode

Updated, aircraft times-in-mode have been derived from OPAS radar data and airline reported taxiing times as received by Eurocontrol.

Taxi-in and taxi-out (including hold) durations were updated using Eurocontrol taxiing times for 2022 and Approach, landing roll, take-off roll, initial climb and climb-out used OPAS radar data for 2022.

APU on-stand running times were updated in line with observations of running times made during 2022 for compliance survey purposes.

5.4.3.3.3 Additional Aircraft Emissions

Auxiliary Power Units (APUs)

APU emissions factors are not included in the ICAO test results, so aircraft specific emission rates were taken from the PSDH recommendations. Total APU emissions were calculated as the product of the aircraft activity, APU running time, the fuel consumption, and the emission factor for each APU, characterised into three operating modes: no load; Environmental Control System for air conditioning plus electrical power; and main engine start for main engine start plus electrical power.

In addition to APU on-stand, consideration has also been given to its use off-stand. When aircraft operate using reduced-engine taxi, they usually keep their APUs running during taxiing. Therefore, whenever aircraft are taxiing on reduced engines it is assumed that their APU will also be running.

Engine testing Engine testing represents a very small contribution, and its 2019 total emissions were kept constant in 2022.

Refuelling NMVOC and CH_4 emissions from refuelling source in 2022 have been scaled to the whole flight CO_2 aircraft emissions change between 2019 and 2022.

Start-up During the starting sequence, due to very low engine temperatures and pressures, very few NO_x emissions are produced compared to the LTO cycle and so only NMVOC and CH_4 emissions have been considered. These have been estimated in line with PSDH recommendations.

5.4.3.4 Emissions Calculation

NO_x, CO, NMVOC and CH_4 emissions were calculated directly using ICAO emission factors and fuel factors. The NO_2/NO_x ratio was assumed to vary with mode (see Table 27)

Table 27: Assumed f-NO_2 Values by Mode

Mode	NO_2 / NO_x Ratio
Taxi / Idle	37.5%
Approach / Auxiliary Power Unit	15.0%
Take-off / Climb-out	5.3%

CO_2 and SO_2 were derived from the fuel use, using assumed amounts of pollutant contained in aviation fuel (see Table 28), alongside a list of fuel types used by aircraft type. The fractions of NMVOC and CH_4 within total hydrocarbon emissions were 90.4% and 9.6% respectively. NMVOC was then used to calculate C_6H_6 and C_4H_6 emissions using factors of 0.0197 and 0.018 respectively (as per previous LAEI updates).

Table 28: Aviation CO_2 and SO_2 Emission Factors

Fuel Type	Emission Factor (kg/tonne)	
	CO_2	SO_2
Aviation Turbine Fuel	3,150	1,596
Aviation Spirit	3,128	1,596

PM_{10} was calculated using the ICAO Airport Air Quality Manual methodology and the ICAO smoke number, estimated by aircraft and engine type, as per previous LAEI updates. All of the aircraft exhaust PM mass was assumed to be in the $PM_{2.5}$ fraction and thus $PM_{2.5}$ and PM_{10} exhaust emissions are assumed to be the same for this source. PM_{10} non-exhaust emissions were also included as follows:

- PM_{10} brake wear emissions were estimated for each landing, using the following emission factor: PM_{10} Brake Wear Emission Factor = 2.53×10^{-7} (kg PM_{10} per kg of Maximum Take-Off Weight)
- PM_{10} tyre wear emissions were calculated as the amount of weight lost per landing using the following emission factor: PM_{10} Tyre Wear Emission Factor = 2.23×10^{-6} (kg PM_{10} per kg of Maximum Ramp Weight) - 0.0874
- $PM_{2.5}$ non-exhaust emissions were apportioned directly from PM_{10} non-exhaust totals using brake wear and tyre wear $PM_{2.5}/PM_{10}$ mass ratios of 0.4 and 0.7, respectively.

5.4.3.5 Non-Aircraft Emissions Methodology

Additional methodology details for GSE, landside vehicles and stationary sources can be found in the HAEI reports.

5.4.3.5.1 Ground Support Equipment

GSE emissions in 2022 were updated in line with calculations undertaken for PEIR. The calculations were based on fuel use data for all road and off-road vehicles and plant associated with aircraft turn-around (e.g., caterers, cleaners, fuel handlers and buses) and runway maintenance. Fuel use and associated emission factors were broken down by fuel type (gas oil, diesel, and petrol) and by vehicle categories such as road vehicles (car, LGV, HGV, bus) and off-road equipment diesel (37-75 kW, 75-13 kW and 130-560 kW) and petrol. Additional GSE operation data such as the fraction of time idling and average speed when moving were also accounted for.

5.4.3.5.2 Landside Vehicle Sources

Heating plant and fire training ground emissions were updated in line with the latest fuel data available for PEIR.

5.4.3.6 Spatial Distribution

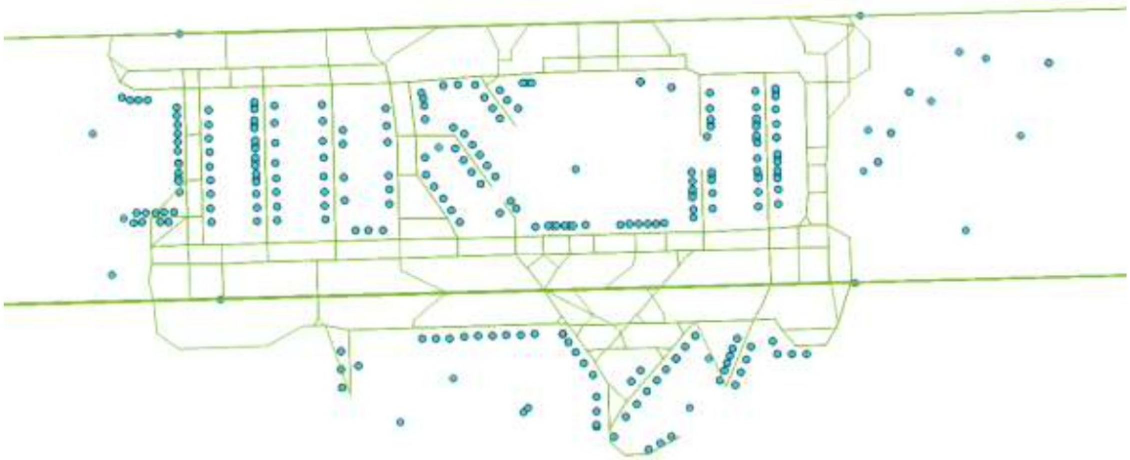
The spatial representation of all the London airport emissions is the same as in previous LAEI updates. Emission estimates were spatially analysed by source type to create geographically accurate emission source locations for use with dispersion modelling. The source locations include:

- Point sources: APU on-stand, start up, engine testing, GSE, stationary sources and refuelling of aircraft
- Line sources: taxi-out (including hold), take-off, initial climb, climb-out, approach, landing roll, taxi-in and APU during taxiing
- Area sources: landside vehicles

The spatial representation was updated to reflect the current stand layout and taxiways, in particular the redevelopment of Terminals 1 and 2 and the eastern apron.

Figure 17 illustrates Heathrow's spatial representation point, line, and area sources in 2022.

Figure 17: Heathrow Airport Spatial Representation in 2022



The Cranford Agreement was established in the 1950s and only applies when Heathrow is on easterly operations, i.e., when planes take-off flying east, and only to those aircraft using the northern runway. Heathrow switches to easterly operations when the wind is blowing from the east – which it does about 30% of the time.

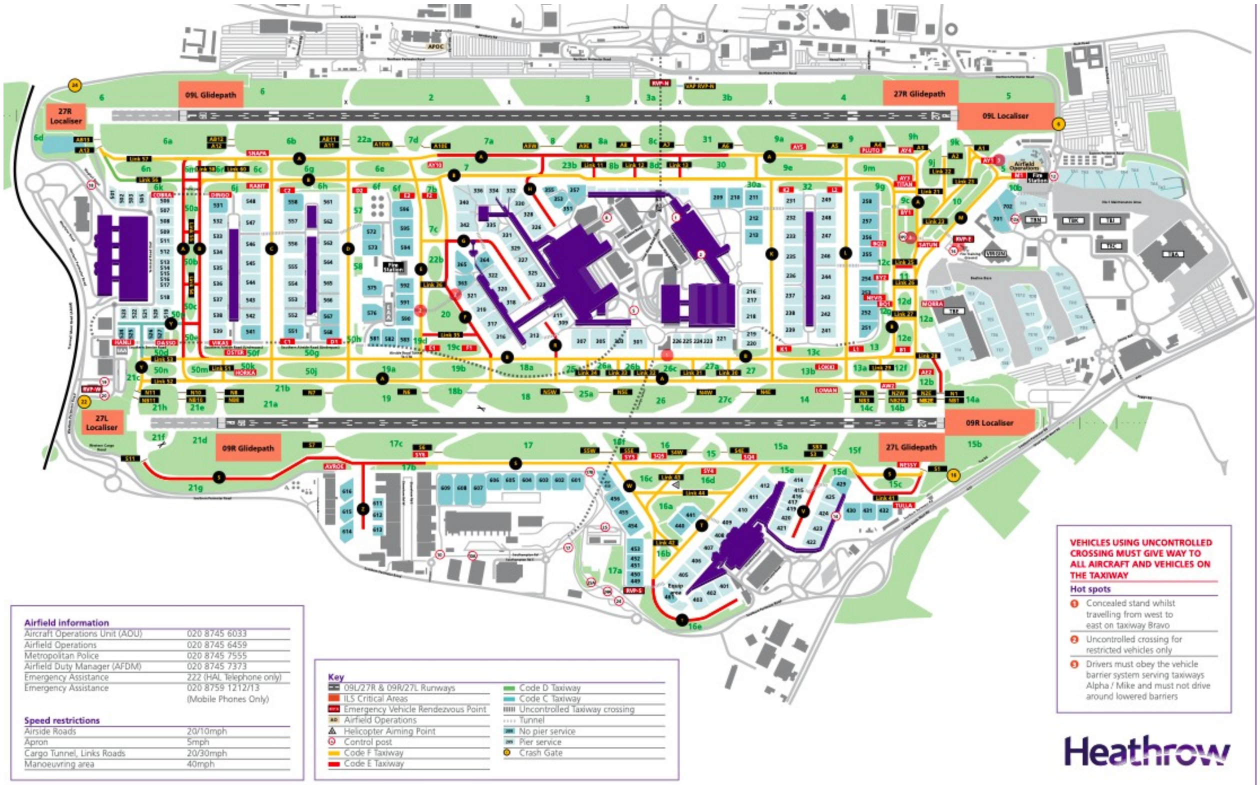
Table 29 shows runway utilisation 2022. Very few easterly departures were taking place from runway 09L due to the Cranford agreement being in place (see runway 09L, 09R, 27L, 27R location in Figure 18). Consequentially, there were also very few easterly arrivals were taking place from runway 09R.

The Cranford Agreement was established in the 1950s and only applies when Heathrow is on easterly operations, i.e., when planes take-off flying east, and only to those aircraft using the northern runway. Heathrow switches to easterly operations when the wind is blowing from the east – which it does about 30% of the time.

Table 29: Distribution of Aircraft Movements on Runways at Heathrow Airport Runway

Runway	Distribution of Aircraft Movements	
	Arrivals	Departures
09L	27.5%	0.1%
09R	0.7%	28.1%
27L	36.6%	35.0%
27R	35.2%	36.8%
Total	**100%**	**100%**

Figure 18: Heathrow Airport Airfield Map



5.4.4 London City Airport

The Heathrow Airport emissions methodology has been adapted to calculate emissions from London City Airport. Some simplifications had to be made, however, as most datasets available for London City (e.g., activity and times-in-mode) are less detailed than those available for Heathrow. A brief overview of the assumptions used to produce 2022 emissions at London City airport is provided below.

5.4.4.1 Aircraft Emissions

Aircraft activity data from London City airport have been compiled using the CAA aircraft movement data. The total number of aircraft movements at London City Airport was 49,937 in 2022.

This represents a decrease of 41% from 84,260 in 2019. The total number of passengers (source: CAA) was 3.01 million in 2022, which is a decrease of 41% from 5.12 million in 2019. The reductions in both aircraft movements and passenger numbers are a consequence of the COVID-19 pandemic.

The ICAO emission and fuel factor database has been linked to aircraft movements from the CAA using the most common engine types for each aircraft type and based upon knowledge gained at Heathrow. The aircraft movements were split equally between arrivals and departures.

Assumptions for aircraft times-in-mode (see Table 30) were extracted from the 2007 Planning Application report provided by London City.

Table 30: Aircraft Times-in-Mode for the LTO Cycle Stages

Mode	Time (s)
Taxi-out / Taxi-in / Hold	150
Take-off	18.5
Initial Climb	52
Climb-out	68
Cruising out / Cruising in	113
Approach	200
Landing	41
Auxiliary Power Unit Bodied	1974

Realistic emissions estimates for the LTO cycles (taxi-out, hold at runway head, take-off roll, initial climb, climb-out, approach, landing roll and taxi-in) and APUs have been made using a similar approach to that used in the Heathrow Airport calculations.

At London City, the climb-out was assumed to reach London Bridge at 3,000 ft altitude. This represents the steep climb slope and the stringent rules imposed to limit the noise impact from aircraft operations due to the airport's proximity to Central London. Similarly, a steep glide slope of 5° on approach was assumed. Emissions at London City were assumed to be spatially represented using easterly/westerly splits taken from Heathrow meteorological data (assuming no bias towards either easterlies or westerlies).

5.4.4.2 Other Emissions

Non-aircraft emissions at London city airport sources are considered small. In the absence of airport specific data emissions from GSE have been scaled from Heathrow on passenger numbers and emissions from stationary sources were assumed to be unchanged from 2019.

Emissions from car parks and taxis were estimated using a similar approach to that used for Heathrow with transaction numbers estimated form passenger and staff travel statistics presented in the London City Airport Annual Performance Report 2022.

A cruising-in/cruising-out mode (plotted at 1 km2 grid resolution) was included to represent the aircraft maintaining altitude just below 3,000 ft until clear of the London Heathrow inbound flight path (between London Bridge and the LAEI boundary).

5.4.4.3 Spatial Distribution

At London city, the climb-out length was reduced (to reach London Bridge at 1000 m altitude) to represent the steep glide slope and the stringent rules imposed to limit the noise impact from aircraft operations due to the airport's proximity to Central London. Emissions at London City were assumed to be spatially represented using 60 % of all arrivals approaching from the east side of the airport and 60 % of all departures taking off toward the west (both taking advantage of westerly wind).

5.4.5 Other Smaller Airports

Aircraft emissions from other smaller airports were updated. Summary CAA Movement data were available for Metro London Heliport and Biggin Hill. These did not include breakdown by aircraft type but did provide the overall number of movements.

Aircraft types and engine fits were reviewed and revised as appropriate and emissions factors were updated to the most appropriate factors from the ICAO emissions factors databank, FOI's database for Turboprop Engine Emissions, FOCA piston engine database or FOCA Guidance on the Determination of Helicopter Emissions.

Times-in-mode were also reviewed and updated to the most appropriate values for such airfields.

6. Miscellaneous

Emissions from smaller sectors not part of the main sectors (industrial and commercial / domestic / transport) are grouped under the Miscellaneous category. These include the following:

- Emissions from agriculture
- Emissions from accidental fires and bonfires
- Emissions from biosynthesis in forests

6.1 Agriculture

Emissions from the Agriculture sector include the following sources:

- Fuel combustion sources for building heating (i.e. stationary) and the use of off-road vehicle and machinery (i.e. NRMM)
- Livestock sources including animal husbandry and manure management
- Fertilisers and soils sources

6.1.1 Pollutants

Emissions from agriculture sources have been estimated for the pollutants shown in Table 31.

Table 31: Pollutants Reported for Agriculture Sources

Main Source	Category	Number of Pollutants Reported	Key Pollutants				Other Pollutants
			NOx	PM_{10}	$PM_{2.5}$	CO_2	
Miscellaneous	Agriculture	16	✔	✔	✔	✔	BaP, C_4H_6, C_6H_6, Cd, CH_4, CO, Hg, N_2O, NH_3, NMVOC, Pb, SO_2

6.1.2 Emissions

Emissions estimates have been based on the same methodology followed in previous LAEI updates, scaling down UK emissions from the NAEI based on the estimated fraction of the national emissions that should be allocated to the LAEI area for each source, using land cover data, and also (for livestock) animal census data, as a proxy.

Updated data used for the LAEI include UK emissions published in the NAEI[1] for the following categories:

- Combustion Sources:

[1] Available at https://naei.energysecurity.gov.uk/data/data-selector

  - NFR 1A4ci: Agriculture - stationary combustion
  - NFR 1A4cii: Agriculture - mobile machinery / Agricultural engines (i.e. NRMM)
- Livestock Sources:
  - NFR 3B1: Cattle
  - NFR 3B2: Sheep
  - NFR 3B3: Swine
  - NFR 3B4: Other livestock
- Fertilisers and Soils Sources:
  - NFR 3Da1: Inorganic nitrogen fertilizers (includes urea application)
  - NFR 3Da2a: Animal manure applied to soils
  - NFR 3Da2b: Sewage sludge applied to soils
  - NFR 3Da2c: Other organic fertilisers applied to soils
  - NFR 3Da3: Urine and dung deposited by grazing animals

As before, gas emissions have been excluded because these are covered in the industrial/commercial gas consumption estimates, whilst emissions from burning straw have also been excluded because these are not considered relevant for the LAEI.

6.1.3 Spatial Distribution

Emissions were spatially distributed using the CEH Land Cover Map 2022. The land cover used for the spatial distribution of emissions on to the LAEI grid was the Arable and/or Improved Grassland land cover categories (Land Cover Class Identifier 3 and 4 respectively), depending on the source (see full list in Table 46 in Section 7.4.1).

For each agriculture source sub category, the percentage of the relevant land cover in each 1km^2 grid area was used to calculate the area of land cover, in m2, and then the fraction of the total UK land cover area, for each LAEI grid cell. This fraction was then combined with the total UK emissions to determine the relevant emissions across the LAEI grid.

For livestock, an additional calculation step was carried out, using population estimates at local authority level to allocate the relevant proportion of UK emissions to the LAEI. Livestock population statistics are available at national level and updated every year, but further breakdown is provided at local authority level every few years only. The latest breakdown of national statistics at local authority level[2] available at the time (year 2021) was used. As local authority disaggregated data is provided for England only, these were combined with the proportion of total UK livestock populations in England.

For local authorities only partly within the LAEI, livestock populations were approximated using the fraction of total administrative area falling within the LAEI boundary.

[2] Structure of the agricultural industry in England and the UK at June. Available at https://www.gov.uk/government/statistical-data-sets/structure-of-the-agricultural-industry-in-england-and-the-uk-at-june

6.2 Accidental Fires

6.2.1 Introduction

This source sector includes emissions from the burning of buildings or vegetation due to accidental fires. Emissions estimates have been based on the same methodology followed in the previous LAEI updates, using a combination of updated data on accidental fires, estimates of mass burnt, and emission factors from the NAEI.

6.2.2 Pollutants

Emissions from accidental fire and bonfire sources have been estimated for the pollutants shown in Table 32.

Table 32: Pollutants Reported for Accidental Fire Sources

Main Source	Category	Number of Pollutants Reported	Key Pollutants				Other Pollutants
			NOx	PM_{10}	$PM_{2.5}$	CO_2	
Miscellaneous	Accidental Fires	7	✔	✔	✔	✘	BaP, CO, NMVOC, PCB

Emissions have been estimated by applying the following activity-based equation:

Equation
Emissions (tonnes/year) = (Mass burnt (kg/year) × Emission Factor (kg pollutant / kg of mass burnt) + Area burnt (ha/year) x Emission Factor (kg pollutant / ha burnt) / 1000

6.2.3 Activity Data

Data on accidental fires were collated from the London Fire Brigade Incidents Records[3] database update for 2022. Depending on the type of accidental fire, average mass burnt (for buildings or vehicles) or area burnt (for vegetation and forests) has been estimated.

The allocation of each fire incident to a specific NAEI emission sector, and the assumptions on estimates of mass / area burnt, based on the average size of fire (determined using the number of pumps attending the incident as a proxy) are the same as those used for the previous LAEI updates, and are summarised in Table 47, Table 48 and Table 49 in Section 7.4.2.

6.2.4 Emission Factors

Emission factors for various types of accidental fires are provided either as mass of pollutant per mass burnt (for vehicles, dwellings and other buildings) or mass of pollutant per area burnt (for forest and vegetation). Emission factors from the NAEI 2022 used to estimate emissions from accidental fires and bonfires are provided in Table 50 in Section 7.4.2.

[3] London Fire Brigade Incident Records, 2022. Available at https://data.london.gov.uk/dataset/london-fire-brigade-incident-records/

6.3 Forests - Biosynthesis

6.3.1 Pollutants

Emissions from forests (biosynthesis) sources have been estimated for the pollutants shown in Table 33.

Table 33: Pollutants Reported for the Forest (Biosynthesis) Sources

Main Source	Category	Number of Pollutants Reported	Key Pollutants				Other Pollutants
			NOx	PM_{10}	$PM_{2.5}$	CO_2	
Miscellaneous	Forestry	1	✘	✘	✘	✘	NMVOC

6.3.2 Emissions

Emissions from forestry were calculated using the same methodology followed in previous LAEI updates, scaling down UK emissions from the NAEI, based on the fraction of UK woodland within the LAEI area.

6.3.3 Spatial Distribution

Emissions were distributed on the LAEI grid using the spatial distribution of woodlands (both broadleaf and coniferous) from the CEH Land Cover Map as a proxy.

7. Appendix - Data Tables

7.1 Industrial and Commercial Sources

7.1.1 Industrial Processes

Table 34: List of Industrial Part A1 Sites within the LAEI Boundary

LAEI 2022 Unique ID	Site Name	Operator	Emissions from
1	43 Willow Lane Mitcham Surrey	Riverside Ad Limited	EA-PI
2	Warburtons Enfield Bakery,Delta Park 112 Millmarsh Lane Enfield Middlesex	Warburtons Limited	EA-PI
7	Imperial College London Sk Chp Exhibition Road London	Imperial College Of Science,Technology And Medicine	EA-PI
9	Purfleet Vegetable Oil Refinery London Road Essex	Pura Foods Limited	EA-PI
26	Mitcham Waste Treatment Centre 43 Willow Lane Surrey	Riverside Bio Limited	EA-PI
27	Clinical Waste Incinerator Queen Marys Hospital Frognal Avenue Sidcup Kent	Srcl Ltd	EA-PI
31	Erith Oil Works Church Manorway Kent	Archer Daniels Midland Erith Limited	EA-PI
34	Waxlow Road Brent	United Biscuits (Uk) Limited T/A Pladis	EA-PI
36	Charlton Lane Eco Charlton Lane Shepperton Surrey	Sita Surrey Limited	EA-PI
38	East London Energy Centre Kings Yard Cchp And Stratford Cchp,Kings Yard Energy Centre Carpenters Lane London	East London Energy Limited	EA-PI
47	Greenwich Generating Station Old Woolwich Road	London Underground Limited	EA-PI
49	Thames Refinery Factory Road London	T & L Sugars Limited	EA-PI
50	Enfield Power Station 111 Brancroft Way Brisdown	Uniper Uk Limited	EA-PI
51	Croydon Plant Factory Lane Surrey	Whitetower Energy Limited	EA-PI
54	Hogsmill A Stw	Thames Water Utilities Ltd	EA-PI
56	Long Reach Stw	Thames Water Utilities Ltd	EA-PI

LAEI 2022 Unique ID	Site Name	Operator	Emissions from
57	Maple Lodge Stw	Thames Water Utilities Ltd	EA-PI
58	Deephams Stw	Thames Water Utilities Ltd	EA-PI
59	Mogden Stw	Thames Water Utilities Ltd	EA-PI
60	Beckton Stw	Thames Water Utilities Ltd	EA-PI
61	Crossness Sewage Treatment Works Belvedere Road London Greater London	Thames Water Utilities Ltd	EA-PI
62	Riverside Stw	Thames Water Utilities Ltd	EA-PI
63	Beddington Stw	Thames Water Utilities Ltd	EA-PI
64	Beckton Sewerage Treatment Works Jenkins Lane Barking Essex	Thames Water Utilities Ltd	EA-PI
66	Riverside Resource Recovery Facility Norman Road	Riverside Resource Recovery Limited	EA-PI
68	Lakeside Clinical Waste Incinerator Lakeside Road Colnbrook Berkshire	Grundon Waste Management Ltd	EA-PI
69	Lakeside Efw Facility Lakeside Road	Lakeside Energy From Waste Limited	EA-PI
70	Viridor Waste Management,Beddington Erf 105 Beddington Lane	Viridor South London Limited	EA-PI
71	The Kennels Site Landmann Way	South East London Combined Heat And Power Limited	EA-PI
72	Rainham Clinical Treatment Centre Unit 21 Barlow Way Essex	Sharpsmart Limited	EA-PI
74	Brimsdown Precious Metal Recovery 33 Jeffreys Road	Johnson Matthey Plc	EA-PI
76	Jenkins Lane Waste Management Facility Jenkins Lane	Renewi Uk Services Limited	EA-PI
77	Organic Waste Treatment Facility London Sustainable Industries Park Halyard Street	East London Biogas Limited	EA-PI
78	Edmonton Ecopark Advent Way	Londonenergy Ltd	EA-PI
79	Frog Island Waste Management Facility Creek Way Essex	Renewi Uk Services Limited	EA-PI
3	Southall Ready Meals Factory Windmill Lane Southall Middlesex	Noon Products Limited	NAEI (as no emissions reported in EA-PI)

LAEI 2022 Unique ID	Site Name	Operator	Emissions from
5	Ridge	Cheale Meats Limited	NAEI (as no emissions reported in EA-PI)
8	73 73 Ferry Lane South Rainham Essex	Hornett Bros & Co Ltd	NAEI (as no emissions reported in EA-PI)
11	Walton Plating Works Ashley Road Walton On Thames Surrey	Walton Plating Ltd	NAEI (as no emissions reported in EA-PI)
17	Thomson Reuters Docklands Technical Centre 1 Paul Julius Close Blackwall Way London	Telehouse International Corporation Of Europe Limited	NAEI (as no emissions reported in EA-PI)
19	Romford North Data Centre Unit 3,King George Close Romford Essex	Isdc Developments (No 2) Limited	NAEI (as no emissions reported in EA-PI)
21	The Francis Crick Institute 1 Midland Road London	The Francis Crick Institute Limited	NAEI (as no emissions reported in EA-PI)
25	Kempton Park Raw Milk Processing Plant Feltham Hill Road Hanworth Middlesex	Muller Uk And Ireland Group Llp	NAEI (as no emissions reported in EA-PI)
33	Telehouse Docklands Datacentre Coriander Avenue London	Telehouse International Corporation Of Europe Limited	NAEI (as no emissions reported in EA-PI)
37	Ponders End Mills Wharf Road Enfield Middlesex	G R Wright & Sons Ltd	NAEI (as no emissions reported in EA-PI)
40	Palmers Wood Oilfield Rooks Nest Well Site,Flower Lane Surrey	Igas Energy Production Limited	NAEI (as no emissions reported in EA-PI)
41	Ponders End Aden Road Enfield Middlesex	Rimex Metals (Uk) Ltd	NAEI (as no emissions reported in EA-PI)
48	Taylors Lane Power Station Brentfield Road Willesden	Uniper Uk Limited	NAEI (as no emissions reported in EA-PI)
67	Ferry Lane South Waste Transfer Facility Unit 24 Salamons Way Ferry Lane South Essex	Adler And Allan Limited	NAEI (as no emissions reported in EA-PI)
46	Erith Oil Works Epr/Qp3331pq	Archer Daniels Midland Erith Limited	NAEI (as no emissions reported in UK Registry)
52	Veterinary Laboratories Agency	Defra	NAEI (as no emissions reported in UK Registry)
53	West Drayton Aggregates	Hanson Quarry Products Europe Ltd	NAEI (as no emissions reported in UK Registry)
65	Weybridge Incineration Plant,Animal And Plant Health Agency Woodham Lane New Haw Surrey	Defra	Not included as no emissions in EA-PI or NAEI
73	Hks Dagenham Ltd,Dagenham Docks Perry Road Dagenham Essex	Hks Dagenham Limited	Not included as no emissions in EA-PI or NAEI
75	Waste Transfer Station Unit 3 Charles Street Ind. Estate Charles	Williams Environmental Management Limited	Not included as no emissions in EA-PI or NAEI

LAEI 2022 Unique ID	Site Name	Operator	Emissions from
	Street Silvertown		
4	Arla Foods Oakthorpe Chequers Way Palmers Green Middlesex	Arla Foods Limited	Not included as no emissions in EA-PI or NAEI
6	East India Dock Road,East India Dock House,240 London	Global Switch Limited	Not included as no emissions in EA-PI or NAEI
10	Cray Road	Coca-Cola Europacific Partners Great Britain Limited	Not included as no emissions in EA-PI or NAEI
12	Eley Trading Estate Nobel Road	Coca-Cola Europacific Partners Great Britain Limited	Not included as no emissions in EA-PI or NAEI
13	Southwark Integrated Waste Management Facility 43 Devon Street	Veolia Es Southwark Ltd	Not included as no emissions in EA-PI or NAEI
14	Unit 20 And 21 Gemini Business Park Hornet Way	Baird And Co. Limited	Not included as no emissions in EA-PI or NAEI
15	Greenwich Integrated Waste Management Facility Nathan Way Plumstead Marsh London	Veolia Es Cleanaway (Uk) Limited	Not included as no emissions in EA-PI or NAEI
16	Digital Realty Chessington (Lhr13),Fountain Court Cox Lane Chessington London	Digital Realty (Uk) Limited	Not included as no emissions in EA-PI or NAEI
18	Willesden Depot 106 Scrubs Lane	European Metal Recycling Limited	Not included as no emissions in EA-PI or NAEI
20	Pro-Logis Park Twelvetrees Crescent London	Greencore Food To Go Limited	Not included as no emissions in EA-PI or NAEI
22	Albert Works Kenninghall Road Edmonton Middlesex	European Metal Recycling Limited	Not included as no emissions in EA-PI or NAEI
23	The Chess Building Digital Realty Watford (Lhr14),The Chess Building 9-17 Caxton Way Hertfordshire	Digital Realty (Uk) Limited	Not included as no emissions in EA-PI or NAEI
24	Osterley Campus Grant Way Middlesex	Sky Uk Limited	Not included as no emissions in EA-PI or NAEI
28	Lufthansa Technik Landing Gear Services Uk Unit 3 Dawley Park Kestrel Way Hayes Middlesex	Lufthansa Technik Landing Gear Services Uk	Not included as no emissions in EA-PI or NAEI
29	Croydon Data Centre (Lgw13) Unit B Prologis Park Greenland Way	Digital Realty (Uk) Limited	Not included as no emissions in EA-PI or NAEI
30	Units 1, 2 And 4 Greenwich View Place London	Sof-11 Docklands Dc Uk Bidco Limited	Not included as no emissions in EA-PI or NAEI
32	Brick Lane Data Centre,5th Floor 91-95 Brick Lane London	Interxion Carrier Hotel Limited	Not included as no emissions in EA-PI or NAEI
35	2 Powergate Business Park Volt Avenue Park Royal Middlesex	Equinix (Uk) Limited	Not included as no emissions in EA-PI or NAEI

LAEI 2022 Unique ID	Site Name	Operator	Emissions from
39	Maple Lodge Wwtw Denham Way	Syracuse Waste Ltd	Not included as no emissions in EA-PI or NAEI
42	Brent Transfer Station Marsh Road Alperton Lane Middlesex	Veolia Es (Uk) Limited	Not included as no emissions in EA-PI or NAEI
43	Mitcham Polyester Resin Willow Lane Mitcham Surrey	Reichhold Uk Limited	Not included as no emissions in EA-PI or NAEI
44	Broadgate Data Centre 5 Broadgate	Ubs Ag	Not included as no emissions in EA-PI or NAEI
45	Greencore Food To Go Park Royal 8 Willenfield Road London	Greencore Food To Go Limited	Not included as no emissions in EA-PI or NAEI
55	Esher Stw	Thames Water Utilities Ltd	Not included as no emissions in EA-PI or NAEI

Table 35: List of Industrial Part A1 Sites in LAEI 2019 but not in LAEI 2022

LAEI 2019 Unique ID	Site Name	Operator
2	Oakthorpe Dairy Chequers Way Palmers Green London	Arla Foods Limited
4	Fourth Way Waste Transfer Facility Unit 28 Fourth Way Wembley Middlesex	Brent Oil Contractors Limited
9	Weybridge Clinical Incinerator	Defra
11	Kings Yard Energy Centre	East London Energy Limited
15	Chaucer Road Forest Gate London Greater London	Hovis Limited
19	Harrow Chp Plant	Kodak Alaris Limited
22	Edmonton Efw Facility	Londonenergy Ltd
25	Nuplex Resins Limited North Woolwich Road London Greater London	Nuplex Resins Ltd
39	Purfleet Margerine Factory	Upfield Foods Uk Limited
42	Harlesden Biscuit Factory	United Biscuits (Uk) Limited T/A Pladis
44	Acton Refinery	Vale Europe Limited
55	Stratford Cchp	East London Energy Limited
56	Hillingdon Clinical Waste Incinerator	Srcl Ltd
58	Riverside Ad Facility	Riverside Ad Limited
62	Riverside Bio Ltd Surrey	Riverside Bio Limited
67	Enfield Bakery	Warburtons Limited
69	Unit 5	West Middlesex Surface Treatments Ltd
73	Coca Cola Sidcup	Coca-Cola European Partners Great Britain Limited
80	Chadwell Heath Dairy	Muller Uk & Ireland Group Llp
90	Elstree Synthetic Bone Manufacturing Unit	Apatech Ltd

Table 36: List of Part B Sites by Process Type and London Zone

Process Type	Central London	Inner London	Outer London	Total
Dry Cleaning	59	550	570	1,179
Unloading of Petrol into Storage at Petrol Stations	7	147	368	522
Blending, Packing, Loading, Unloading and Use of Bulk Cement	0	30	43	73
Respraying of Road Vehicles	0	8	54	62
Mobile Crushing and Screening	0	8	46	54
Waste Oil and Recovered Oil Burners less than 0.4MW	0	8	32	40
Crematoria	0	9	17	26
PVR Stage II	0	10	5	15
Roadstone Coating Processes	0	2	9	11
Iron, Steel and Non-Ferrous Metal Foundry Processes	0	5	1	6
Unknown / To Be Updated	1	4	0	5
Manufacture of Timber and Wood-Based Products / Combustion of Waste Wood	0	2	2	4
Printworks	0	1	3	4
Manufacture of Timber and Wood-Based Products	0	1	2	3
CHP Combustion Plant	0	1	1	2
Manufacture of Coatings Materials	0	0	2	2
Adhesive Coating	0	1	0	1
Coating of Metal and Plastic / Wood Coating	0	1	0	1
Concrete Batching Plant	0	1	0	1
Surface Cleaning	0	1	0	1
Bitumen Processes	0	0	1	1
Coating and Recoating of Aircraft	0	0	1	1
Coating and Recoating of Rail Vehicles	0	0	1	1
Degreasing of Aircraft Parts	0	0	1	1
Di-isocyanate Processes	0	0	1	1
Powder Coating	0	0	1	1
Roadstone Coating Processes / Blending, Packing, Loading, Unloading and Use of Bulk Cement	0	0	1	1
Total	**67**	**790**	**1,162**	**2,019**

7.1.2 Heat and Power Generation

Table 37: NAEI Emission Factors for Non-Domestic Gas Combustion Sector, 2022

Pollutant	Emission Factor (kg pollutant/GW.h)
BaP	0.000002161
C_6H_6	0.8911
Cd	0.0000009000
CH_4	18.00
CO	78.81
CO_2[1]	202,100
Hg	0.0003600
N_2O	0.3600
NMVOC	9.830
NOx	266.4
Pb	0.004629
PM_{10}	2.808
$PM_{2.5}$	2.808
SO_2	2.412
[1] Converted from Carbon emission factor	

Table 38: NAEI Emission Factors for Non-Domestic Residual Fuel Combustion Sector

Pollutant	Emission Factor (tonne pollutant / tonne fuel consumed)								
	2016			2019			2022		
	Coal	Fuel Oil	SSF[1]	Coal	Fuel Oil	SSF[1]	Coal	Fuel Oil	SSF[1]
NOx	5.339E−03	1.245E−02	5.339E−03	5.339E−03	1.245E−02	5.339E−03	5.339E−03	1.245E−02	5.339E−03
PM_{10}	3.611E−03	8.542E−04	3.611E−03	3.611E−03	8.542E−04	3.611E−03	3.611E−03	8.542E−04	3.611E−03
$PM_{2.5}$	3.333E−03	7.321E−04	3.333E−03	3.333E−03	7.321E−04	3.333E−03	3.333E−03	7.321E−04	3.333E−03
CO_2	2.905E+00	3.222E+00	2.881E+00	2.905E+00	3.220E+00	2.881E+00	2.905E+00	3.226E+00	2.881E+00
SO_2	2.396E−02	1.390E−02	1.888E−02	2.384E−02	1.356E−02	1.888E−02	2.384E−02	1.359E−02	1.888E−02
NMVOC	5.655E−05	1.376E−04	4.969E−05	5.675E−05	1.375E−04	4.969E−05	5.675E−05	1.378E−04	4.969E−05
C_6H_6	2.138E−06	-	2.204E−06	2.146E−06	-	2.204E−06	2.146E−06	-	2.204E−06
CO	2.873E−02	3.783E−03	2.873E−02	2.873E−02	3.783E−03	2.873E−02	2.873E−02	3.783E−03	2.873E−02

Pollutant	Emission Factor (tonne pollutant / tonne fuel consumed)								
	2016			2019			2022		
	Coal	Fuel Oil	SSF[1]	Coal	Fuel Oil	SSF[1]	Coal	Fuel Oil	SSF[1]
CH_4	3.086E−04	4.067E−04	3.086E−04	3.086E−04	4.067E−04	3.086E−04	3.086E−04	4.067E−04	3.086E−04
N_2O	7.716E−05	2.440E−05	7.716E−05	7.716E−05	2.440E−05	7.716E−05	7.716E−05	2.440E−05	7.716E−05
Cd	3.393E−08	2.949E−07	2.981E−08	3.405E−08	2.946E−07	2.981E−08	3.405E−08	2.952E−07	2.981E−08
Hg	5.089E−07	1.468E−08	4.472E−07	5.108E−07	1.467E−08	4.472E−07	5.108E−07	1.469E−08	4.472E−07
Pb	5.383E−06	5.212E−07	4.730E−06	5.403E−06	5.208E−07	4.730E−06	5.403E−06	5.218E−07	4.730E−06
BaP	2.545E−09	7.728E−11	-	2.554E−09	7.728E−11	-	2.554E−09	7.728E−11	-
PCB	1.131E−09	-	-	1.135E−09	-	-	1.135E−09	-	-

[1] Solid Smokeless Fuel

7.1.3 Construction

7.1.3.1 Key Assumptions for NRMM calculations

The sections below contain additional information on the key assumptions and the number of records affected during data cleaning of the NRMM register and PLDH used to estimate emissions from construction and demolition sites.

7.1.3.1.1 Postcode Gap-Filling

A total of 668 machines were missing postcodes for their sites, representing 10.2% of all machines. There were 654 machines with incorrect postcodes for their sites, representing 10.0% of all machines.

In total, 20.1% of the machines have had their postcode data gap-filled or corrected. The gap-filling method involved searching for the site name and borough online to find the missing postcodes. For incorrect postcodes, historical records were used to correct out-of-date entries.

7.1.3.1.2 Duration Calculations

Only work performed during 2022 was considered. If the start date was before 1st January 2022, or the end date was after 31st December 2022, these were adjusted to these dates.

In cases where the start date was after the end date, it was assumed that the dates were entered in the wrong order, and the duration was calculated as the absolute difference between the two dates.

7.1.3.1.3 Power Rating Gap-Filling and Correction

Missing power ratings were checked and gap-filled based on machine type, applying the same power rating for machines of the same type.

7.1.3.1.4 EU Stage Gap-Filling and Correction

For machines missing an EU stage, a default value of Central Activities Zone was applied for gap-filling:

- Machines with operational hours equal to 10 hours were categorized as “Stage V”
- Machines in the CAZ/OAs with a power rating below 59 were categorized as “Stage V”
- Machines in the CAZ/OAs with a power rating of 59 or above were categorized as “Stage IV”
- For other registers located in Greater London, machines were categorized as “Stage IIIB”

Of the machinery originally missing an EU stage 0.4% (29 out of 6,563) have been gap-filled.

For machines that have an incorrect EU stage, lookups based on power group were used adding to the Central Activities Zone mentioned above:

- For power groups < 8 kW and EU stages II, IIIA, IIIB, or IV, updated to Stage V
- For power groups 8–19 kW and EU stages II, IIIA, IIIB, or IV, updated to Stage V
- For power groups 19–37 kW:
  - If EU stage was I, updated to Stage II
  - If EU stage wass IIIB or IV, updated to Stage V
- For power groups 37–56 kW and EU stage IV, updated to Stage V
- For power groups > 560 kW, updated to Stage V

A total of 370 machines had their EU stage modified: 29 were missing an EU stage, and 341 had an incorrect EU stage. 5.6% of all machines had their EU stage modified: 0.4% were missing the EU stage, and 5.2% had an incorrect EU stage. The original EU stage before gap-filling and correction is provided in Table 39.

Table 39: EU stage Distribution before Gap-Filling and Correction

EU Stage	Count	Percentage (%)
NA	2	0.1%
EU Stage I	40	0.6%
EU Stage II	65	1.0%
EU Stage IIIA	541	8.2%
EU Stage IIIB	1,183	18.0%
EU Stage IV	2,435	37.1%
EU Stage V	2,270	34.6%
EU_Stage_Null	27	0.4%

7.1.3.1.5 Machine Types and EU Stage Breakdown

The total number of machines in the register was 6,563, including 2,680 machines with missing key attributes (41% of all recorded machines). Note that this was only the number of machines with empty key attributes, not including the machines with incorrect attributes.

The detailed breakdown (note that the sum of the numbers below will be higher than 2,680, as some machines are missing several key attributes) was as follows:

- Machines missing EU Stage: 29/6,563 (0.4%)
- Machines missing power rating: 2,217/6,563 (33.8%)
- Machines missing post code: 668/6,563 (10.2%)
- Machines missing site name: 1/6,563 (< 0.1%)

Table 40 provides the breakdown by machine type after gap-filling and correction.

Table 40: Machine type breakdown (after gap-filling and correction)

Machine Type	Count	Percentage
Access Platform	57	0.9%
Agitator	77	1.2%
Bore rig	9	0.1%
Bulldozer	31	0.5%
Compressor	97	1.5%
Concete Pump	231	3.5%
Concrete Crusher	27	0.4%
Concrete mixer	16	0.2%
Concrete pump	37	0.6%
Crane	94	1.4%
Crane - Carry	4	0.1%
Crane - Crawler	113	1.7%
Crusher	33	0.5%
Drilling Rig	26	0.4%
Dumper	895	13.6%
Excavator	2,764	42.1%
Excavator - Wheeled	1	0.0%
Floor saw	5	0.1%
Forklift	239	3.6%
Generator	497	7.6%
Holding Drum	26	0.4%
Hydraullic Power Pack	5	0.1%
Loader	40	0.6%
Mobile Elevated Working Platform	89	1.4%
OTHER	52	0.8%
Paver	1	0.0%
Piling Rig	247	3.8%
Power Pack	12	0.2%

Machine Type	Count	Percentage
Pump	44	0.7%
Roller	152	2.3%
Scissor Lift	23	0.4%
Screeding Pump	4	0.1%
Screener	14	0.2%
Skid Steer	30	0.5%
Sweeper	3	0.0%
Telehandler	480	7.3%
Tower Light	16	0.2%
Tractor	18	0.3%
Truck - Dumper	18	0.3%
Truck - Off Road	15	0.2%
UXO RIG	21	0.3%

The EU stage after gap-filling and correction is provided in Table 41.

Table 41: EU stage Distribution after Gap-Filling and Correction

EU Stage	Count	Percentage (%)
Stage I	33	0.5%
Stage II	67	1.0%
Stage IIIA	531	8.1%
Stage IIIB	1,169	17.8%
Stage IV	2,144	32.7%
Stage V	2,619	39.9%

7.2 Domestic Sources

7.2.1 Heat and Power Generation

Table 42: NAEI Emission Factors for Domestic Gas Combustion Sector, 2022

Pollutant	Emission Factor (kg pollutant/GW.h)
C_6H_6	0.8936
CH_4	18.00
CO	93.60
CO_2 [1]	222,500
N_2O	0.3600
NMVOC	9.830
PM_{10}	4.320
$PM_{2.5}$	4.320
[1] Converted from Carbon emission factor	

Table 43: NO_x Emission Factors by Borough for Domestic Gas Combustion Sector, 2022

Borough	Emission Factor (kg pollutant/GW.h)
Barking and Dagenham	47.06
Barnet	46.09
Bexley	46.43
Brent	46.09
Bromley	51.47
Camden	42.95
City	48.67
City of Westminster	48.67
Croydon	52.24
Ealing	46.09
Enfield	46.09
Greenwich	47.37
Hackney	46.78
Hammersmith and Fulham	41.47
Haringey	48.67
Harrow	46.09
Havering	50.04
Hillingdon	46.09
Hounslow	43.04
Islington	48.67

Borough	Emission Factor (kg pollutant/GW.h)
Kensington and Chelsea	43.34
Kingston	52.31
Lambeth	52.42
Lewisham	48.67
Merton	48.20
Newham	46.01
Redbridge	48.67
Richmond	51.58
Southwark	48.05
Sutton	50.81
Tower Hamlets	43.06
Waltham Forest	43.67
Wandsworth	46.80
Non GLA	46.09

Table 44: NAEI Emission Factors for Domestic Residual Fuel Combustion Sector, 2022

Pollutant	Emission Factor (tonne pollutant / tonne fuel consumed)		
	Burning Oil	Coal	SSF[1]
NOx	2.331E−03	4.869E−03	4.441E−03
PM_{10}	6.582E−05	6.933E−03	1.265E−03
$PM_{2.5}$	6.582E−05	6.194E−03	1.130E−03
CO_2	3.153E+00	2.837E+00	2.624E+00
SO_2	1.966E−04	2.219E−02	2.529E−02
NH_3	0.000E+00	9.245E−06	8.432E−06
NMVOC	7.460E−06	5.362E−03	1.858E−03
C_6H_6	2.537E−06	6.655E−04	1.967E−04
CO	1.624E−04	1.475E−01	1.345E−01
CH_4	4.388E−04	9.245E−03	8.432E−03
N_2O	2.633E−05	1.325E−04	1.209E−04
Cd	4.388E−14	9.245E−08	8.432E−08
Hg	5.266E−12	1.849E−07	1.686E−07
Pb	5.266E−13	6.163E−06	5.621E−06
BaP	3.510E−15	8.320E−06	7.588E−06
PCB	0.000E+00	5.239E−09	4.778E−09

[1] Solid Smokeless Fuel

7.3 Transport Sources

7.3.1 Road Transport

Table 45: LAEI vehicle-kilometres by zone, vehicle type and road network, 2022

Vehicle Type	Road Network	Vehicle-kilometres (billions)					
		Central London	Inner London	Outer London	Total GLA	Non-GLA	Total LAEI
Motorcycles	LAEI Major Roads	0.061	0.275	0.293	0.630	0.096	0.725
	LAEI Minor Roads	0.009	0.077	0.093	0.179	0.017	0.196
	All Roads	0.071	0.352	0.386	0.809	0.113	0.922
Taxis	LAEI Major Roads	0.077	0.248	0.142	0.466	0.022	0.489
	LAEI Minor Roads	0.012	0.068	0.040	0.120	0.004	0.124
	All Roads	0.089	0.316	0.182	0.586	0.026	0.612
Cars	LAEI Major Roads	0.114	3.724	12.281	16.119	9.914	26.033
	LAEI Minor Roads	0.060	1.125	2.957	4.142	1.041	5.182
	All Roads	0.174	4.849	15.237	20.260	10.955	31.215
PHVs	LAEI Major Roads	0.102	0.400	0.643	1.144	0.650	1.795
	LAEI Minor Roads	0.017	0.131	0.149	0.298	0.035	0.333
	All Roads	0.119	0.531	0.792	1.442	0.685	2.128
LGVs	LAEI Major Roads	0.077	1.206	2.934	4.217	2.228	6.445
	LAEI Minor Roads	0.027	0.365	0.730	1.121	0.250	1.371
	All Roads	0.104	1.571	3.663	5.338	2.478	7.816
HGVs Rigid	LAEI Major Roads	0.014	0.225	0.549	0.788	0.479	1.267
	LAEI Minor Roads	0.004	0.067	0.119	0.190	0.035	0.225
	All Roads	0.018	0.292	0.668	0.978	0.514	1.492
HGVs Articulated	LAEI Major Roads	0.001	0.032	0.330	0.363	0.854	1.217
	LAEI Minor Roads	0.001	0.012	0.034	0.047	0.035	0.081
	All Roads	0.001	0.044	0.364	0.409	0.889	1.298
TfL Buses	LAEI Major Roads	0.022	0.161	0.216	0.398	0.006	0.404

Vehicle Type	Road Network	Vehicle-kilometres (billions)					
		Central London	Inner London	Outer London	Total GLA	Non-GLA	Total LAEI
	LAEI Minor Roads	0.005	0.050	0.066	0.121	0.002	0.122
	All Roads	0.027	0.210	0.281	0.519	0.008	0.527
Other Buses	LAEI Major Roads	0.003	0.030	0.089	0.122	0.022	0.145
	LAEI Minor Roads	0.001	0.010	0.023	0.034	0.003	0.037
	All Roads	0.004	0.040	0.112	0.156	0.025	0.181
Coaches	LAEI Major Roads	0.008	0.095	0.118	0.221	0.030	0.251
	LAEI Minor Roads	0.002	0.027	0.034	0.063	0.004	0.067
	All Roads	0.010	0.122	0.153	0.285	0.034	0.318
All Vehicles	LAEI Major Roads	0.477	6.397	17.595	24.469	14.301	38.770
	LAEI Minor Roads	0.139	1.932	4.244	6.315	1.425	7.740
	All Roads	0.617	8.328	21.839	30.784	15.726	46.510

7.4 Miscellaneous Sources

7.4.1 Agriculture

Table 46: Agriculture sector - Land Cover used for spatial distribution

Emission Source	Sub Category	Land Cover Category for Spatial Distribution
Combustion	Combustion	Arable Land + Improved Grassland
Livestock	Cattle	Improved Grassland
	Sheep	Improved Grassland
	Horses	Improved Grassland
	Swine	Arable Land + Improved Grassland
	Poultry	Arable Land + Improved Grassland
	Manure management	Improved Grassland
Fertilisers and Soils	Agricultural soils	Arable Land + Improved Grassland
	Synthetic Nitrogen fertilisers	Arable Land
	Fertiliser use	Arable Land + Improved Grassland
	Nitrogen excretion on pasture, range, and paddock	Improved Grassland

7.4.2 Accidental Fires

Table 47: Accidental Fires - Property Category and Matching NAEI Emission Factor Category

LFB Property Type	NAEI Sector	Units for Activity
Road Vehicle	Accidental fires - vehicles	mass burnt
Dwelling / Other Residential	Accidental fires - dwellings	mass burnt
Non-residential / Outdoor Structure	Accidental fires - other buildings	mass burnt
Outdoor (Loose Refuse)	Small-scale waste burning	mass burnt
Outdoor (Straw / Stubble Burning)	Accidental fires - straw	mass burnt
Outdoor (Woodland / Conifers)	Accidental fires - forests	area burnt
Other	Accidental fires - vegetation	area burnt

Table 48: Accidental Fires - Mass Burnt Assumptions

Size of Fire	Number of Pumps Attending	Assumed Average Mass Burnt (kg)
Very snall	0	62.5
Small	1	250.0
Medium	2-3	500.0
Big	4-8	750.0
Very Big	> 8	1500.0

Table 49: Accidental Fires - Area Burnt Assumptions

Size of Fire	Number of Pumps Attending	Assumed Average Area Burnt (ha)
Very small	0	0.0025
Small	1	0.0050
Small-Medium	2-3	0.010
Medium	4-5	0.020
Medium-Big	6-7	0.20
Big	8-9	0.50
Very Big	> 9	1.0

Table 50: NAEI Emission Factors for Accidental Fires

Fire Category	Units	NOx	PM_{10}	$PM_{2.5}$	NMVOC	CO	BaP	PCB
Vehicles	g/kg mass burnt	2.0	50.0	46.5	8.5	63.0	0.0012	-
Small-Scale Waste Burning	g/kg mass burnt	0.9	15.3	14.2	13.9	53.7	0.0001	0.0003
Dwellings	g/kg mass burnt	3.0	8.0	7.4	15.0	42.0	0.0012	0.0005
Other Buildings	g/kg mass burnt	3.0	8.0	7.4	15.0	42.0	0.0012	0.0005
Vegetation	kg/ha burnt	49.5	21.6	17.7	132.0	1,436.5	-	-
Forests	kg/ha burnt	190.0	324.0	265.1	500.0	5,400.0	-	-
Straw	g/kg mass burnt	2.2	11.0	9.0	9.0	58.0	-	-

8. List of Abbreviations

- **AADT**: Annual Average Daily Traffic
- **ACSM**: Aerosol Chemical Speciation Monitor
- **AMS**: Aerosol Mass Spectrometer
- **APU**: Auxiliary Power Unit
- **ATC**: Automatic Traffic Counters
- **BBOA**: Biomass Burning Organic Aerosol
- **BEVs**: Battery Electric Vehicles
- **BaP**: Benzo[a]pyrene
- **CAA**: Civil Aviation Authority
- **CAZ/OAs**: Central Activities Zone and Opportunity Areas
- **CEH**: Centre for Ecology and Hydrology
- **CHP**: Combined Heat and Power
- **CH_4**: Methane
- **CO**: Carbon Monoxide
- **COA**: Cooking Organic Aerosols
- **CO_2**: Carbon Dioxide
- **C_4H_6**: 1,3-Butadiene
- **C_6H_6**: Benzene
- **DESNZ**: Department for Energy Security and Net Zero
- **DLR**: Docklands Light Railway
- **DWB**: Domestic Wood Burning
- **Defra**: Department for Environment, Food and Rural Affairs
- **DfT**: Department for Transport
- **EA-PI**: Environment Agency's Pollution Inventory
- **EMEP/EEA**: European Monitoring and Evaluation Programme (The co-operative programme for monitoring and evaluation of the long-range transmission of air pollutants in Europe) from the European Environment Agency
- **EOTHO**: Eat Out To Help Out

- **FOCA**: Federal Office of Civil Aviation (Switzerland)
- **GLA**: Greater London Authority
- **GSE**: Ground Support Equipment
- **HCl**: Hydrogen Chloride
- **HDVs**: Heavy Duty Vehicles
- **HEVs**: Hybrid Electric Vehicles
- **HGVs**: Heavy Goods Vehicles
- **HS2**: High Speed 2
- **ICAO**: International Civil Aviation Organization
- **ICE**: Internal Combustion Engine
- **IEF**: Implied Emission Factor
- **IPCC**: Intergovernmental Panel on Climate Change
- **LDD**: London Development Database
- **LDVs**: Light Duty Vehicles
- **LGVs**: Light Goods Vehicles
- **LSOA**: Lower-layer Super Output Area
- **LTO**: Landing and Take-Off
- **LoHAM**: London Highway Assignment Model
- **MSOA**: Middle-layer Super Output Area
- **NAEI**: National Atmospheric Emissions Inventory
- **NFR**: Nomenclature For Reporting
- **NH_3**: Ammonia
- **NMVOC**: Non Methane Volatile Organic Compounds
- **NO_2**: Nitrogen Dioxide
- **NO_x**: Nitrogen Oxides
- **NRMM**: Non Road Mobile Machinery
- **N_2O**: Nitrous Oxide
- **PCB**: PolyChlorinated Biphenyls
- **PEIR**: (Heathrow Expansion) Preliminary Environmental Information Report

- **PHEVs**: Plug-in Hybrid Electric Vehicles
- **PHVs**: Private Hire Vehicles
- **PLA**: Port of London Authority
- **PLDH**: Planning London DataHub
- **PM**: Particulate Matter
- **PMF**: Positive Matrix Factorization
- **PM_{10}**: Particulate matter with an aerodynamic diameter < 10 μm
- **$PM_{2.5}$**: Particulate matter with an aerodynamic diameter < 2.5 μm
- **PSDH**: Project for Sustainable Development of Heathrow
- **RSSB**: Rail Safety and Standards Board
- **SO_2**: Sulphur Dioxide
- **STW**: Sewage Treatment Works
- **TIPLOCs**: Timing Point Locations
- **TfL**: Transport for London
- **UK-Registry**: UK Registry on Industrial Sites
- **WTS**: Waste Transfer Station