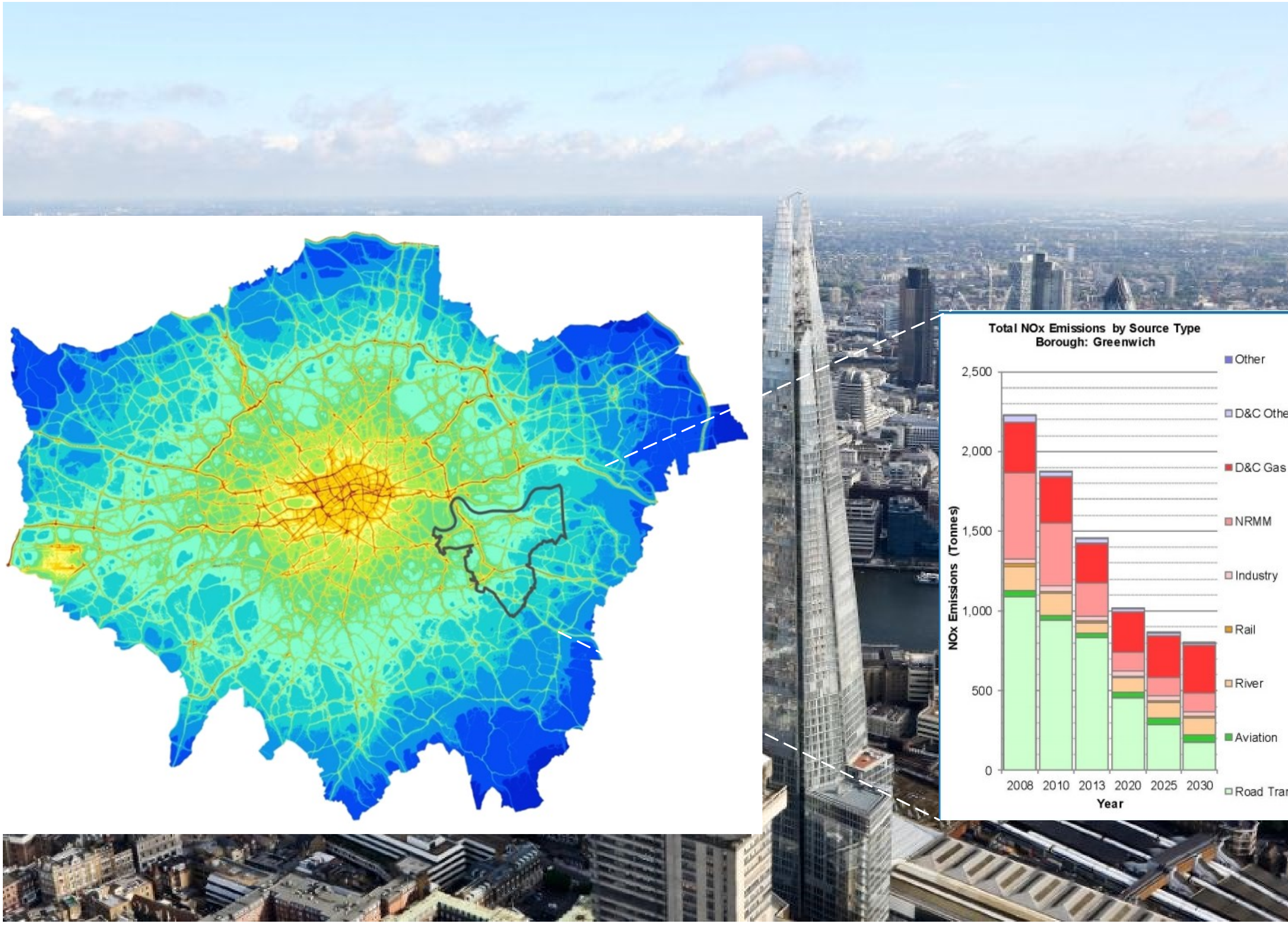
London Atmospheric Emissions Inventory (LAEI) 2013

Methodology



October 2016

Contents

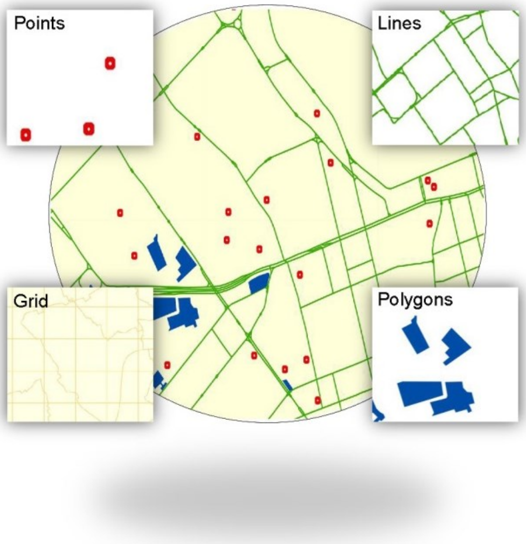
Overview

The LAEI is a database of geographically referenced datasets of pollutant emissions and sources in Greater London. The base year for the current LAEI is 2013, with a back projections 2008 and 2010, and forward projections to 2020, 2025 and 2030. This document sets out the methodology for calculating the emissions in the inventory. The emission sources in the inventory are outlined in Figure 1.

Emissions are calculated by source type; point, polygon, line and area as illustrated below.

The LAEI2013 includes the following key pollutant emissions:

- Nitrogen oxides (NOx);
- Particulate matter with aerodynamic diameter < 10 µm (PM_{10});
- Particulate matter with aerodynamic diameter < 2.5 µm ($PM_{2.5}$); and
- Carbon dioxide (CO_2).



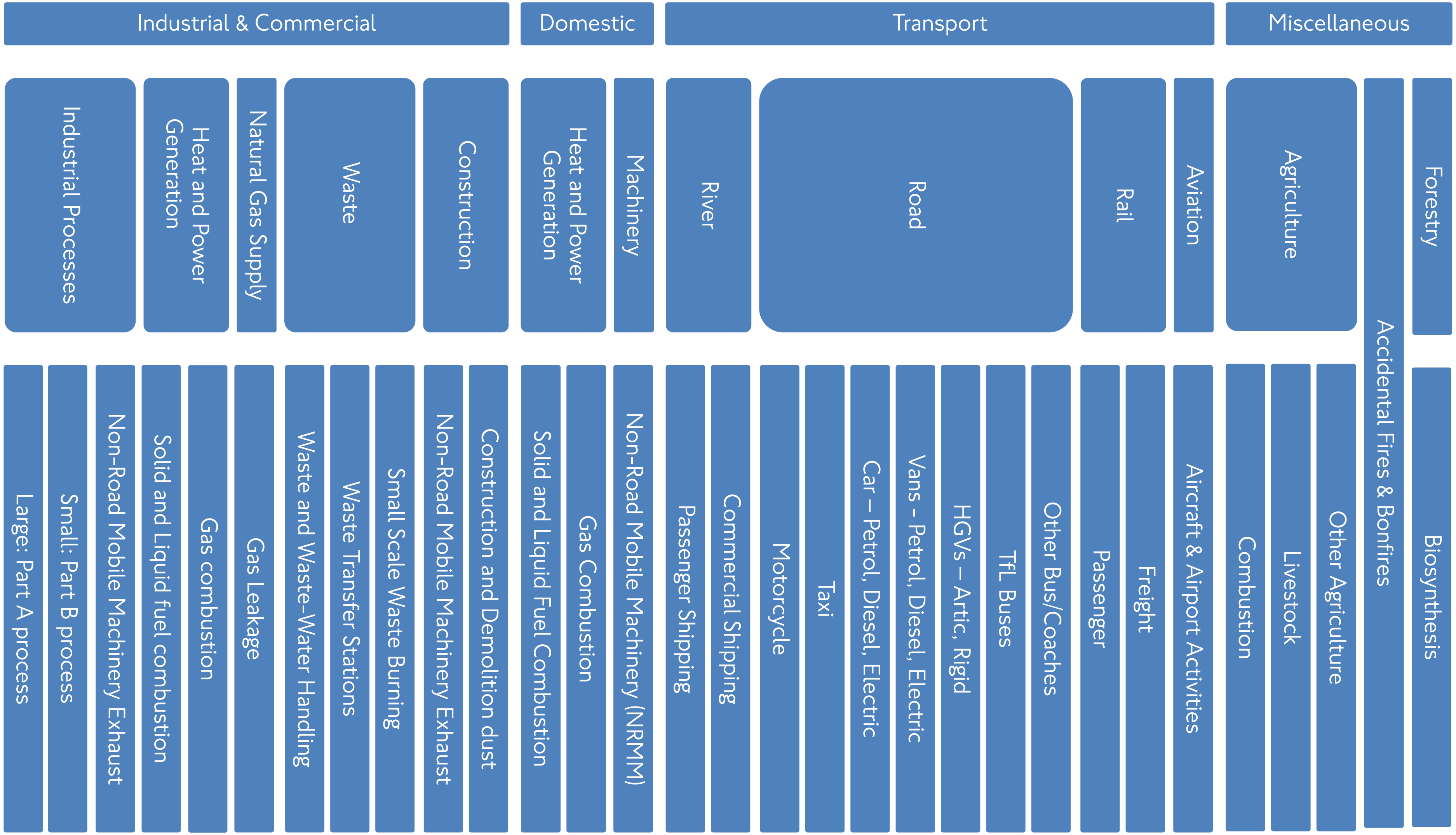
Additionally, the LAEI includes a number of subsidiary pollutants:

- Sulphur Dioxide (SO_2);
- Non Methane Volatile Organic Compounds (NMVOC);
- Benzene (C_6H_6) and 1,3-butadiene (C_4H_6) (which are part of NMVOCs);
- Methane (CH_4);
- Ammonia (NH_3);
- Carbon Monoxide (CO);
- Nitrous Oxide (N_2O);
- Heavy Metals Cadmium (Cd), Mercury (Hg) and Lead (Pb);
- Benzo[a]pyrene (BaP);
- PolyChlorinated Biphenyl (PCB); and
- Hydrogen Chloride (HCl).

This document details the method used to estimate the emissions. The major improvements to the LAEI since the previous publication (2010 base year) are also highlighted in Travel in London 9 report[1].

[1] https://tfl.gov.uk/corporate/publications-and-reports/travel-in-london-reports

Figure 1 Emissions Sources in the LAEI



Industrial & Commercial

Industrial Processes

Large (Part A1) Processes

Base Year 2013	• Emissions data from existing pollution registers/inventories for 2012, 2013 or 2010.
Future Years 2020, 2020, 2025, 2030	• Assumed to be the same as those for 2013

Activity data

Emissions data have been gathered from the European Pollutant Release and Transfer Register (E-PRTR)[2] and the Environment Agency's Pollution Inventory (PI). The most recent available data were obtained for all Part A1 sources in London. Emissions were first sourced from the E-PRTR, beginning with the baseline year of 2013 and then moving back to 2012 where 2013 data was not yet available. The Environment Agency's What's in My Backyard (WIMBY) website was then used to search for emissions from the PI for the remaining processes, with the latest data provided for 2012. Where emissions for a particular pollutant were considered necessary to report, but were reported as being below a certain threshold, the threshold was used as a conservative approach. The emissions for the remaining Part A1 processes were assumed to be the same as was reported in the LAEI 2010. However, note that Part A1 processes for Wastewater plants have been transferred to the Sewage Treatment Plants (STW) category.

Where available, fuel use and energy consumption data were obtained from the Environment Agency via the public register. Operators are obliged to include this information in their annual reporting submissions to the Environment Agency, but it is not published on the PI or PRTR. Data was provided electronically by the Kent and South London Environment Agency and Essex, Norfolk and Suffolk offices and a visit was made to the Hertfordshire and North London Environment Agency office in Hatfield to obtain this data. Whilst some data was obtained, it was not possible to obtain this for all sources.

Back projections and future scenarios

Back projections used the 2008 and 2010 emissions data from the LAEI 2010. In the absence of detailed information on developments at individual sites, emissions for future years are assumed to be the same as those for 2013.

Spatial information

LAEI 2010 included Part A1 sources outside the M25, as far away as Didcot Power Station due to their potential impact on air quality within Greater London. However, the contribution of sources from outside the LAEI domain is taken into account in the air quality modelling methodology and therefore they do not need to be included

[2] http://prtr.ec.europa.eu/

in the emissions inventory explicitly. The LAEI 2013 Part A1 inventory therefore only covers sources up to the M25.

Small (Part A2 & B) Processes

Base Year 2013	• Data provided by London Boroughs
Future Years 2020, 2020, 2025, 2030	• Assumed to be the same as those for 2013

Activity data

London Boroughs were asked to provide the location and number of processes (Part A2 and Part B) in their area for 2013 and annual pollutant emissions[3]. Updated process lists were provided for 23 of the 33 London boroughs. In many cases, no emissions have been reported for dry cleaners. Where data was not available for Part A2 & B Processes, data was obtained from published borough Local Air Quality Management (LAQM) Updating and Screening Assessments (USAs). Where emissions have not been reported, estimates have been made based on similar facilities or taken from the LAEI 2010.

The data provided by London Boroughs was reviewed to ensure the data used in the inventory is accurate. This review involved:

- Ensuring there is no duplication between the Part A2 & B Part A1 datasets;
- Carefully comparing address (including postcode) data from LAEI 2010 and 2013 looking for duplicates or accidental omissions; and
- Graphically checking the location and magnitude of emissions, comparing LAEI 2010 and 2013.

Dry cleaning activities have recently been brought into the scope of Part B sources. These have been included in the inventory when emissions were provided. As activity data was not available for most dry cleaners, a subset of dry cleaners was sampled to consider the average size of machine and therefore average the mass of clothes cleaned each year. Non Methane Volatile Organic Compound (NMVOC) emissions were assumed to be 20g per kilogram of product cleaned and dried[4]. The average clothes cleaned per year was calculated to be 4,208 kg, therefore NMVOC emissions was calculated to be 0.084 t/a per dry cleaner.

Back projections and future scenarios

Back projections use the 2008 and 2010 emissions data from the LAEI 2010. Future emissions are assumed to be the same as 2013.

Spatial information

[3] sulphur dioxide (SO_2), nitrogen oxides (NO_X), carbon monoxide (CO), carbon dioxide (CO_2), Particulate Matters smaller than 10 µm (PM_{10}), Non Methane Volatile Organic Carbon (NMVOC), benzene (C_6H_6) and lead (Pb)

[4] Defra (2014). Process Guidance Note 6/46(11) Statutory guidance for dry cleaning

The inventory includes all Part A2 and Part B sources in all London Boroughs, up to the M25. Sources beyond the M25 are accounted for in the dispersion modelling methodology.

Non-Road Mobile Machinery

Base Year 2013	• Derived from the the London fraction of the NAEI
Future Years 2020, 2020, 2025, 2030	• Projected using same approach as construction NRMM

Activity data

The LAEI incorporates Non-Road Mobile Machinery (NRMM) emission from industry and construction. The approach to estimating the construction related NRMM is later in this document. This section just refers to NRMM from industrial sources. UK emissions estimates are available from the NAEI for all years to 2013.

The fraction of the UK industrial NRMM emissions within the LAEI area (4.2%) was estimated using the 2012 NAEI industrial combustion CO_2 emissions map as a proxy indicator of industrial activity across the UK. The same CO_2 map was used to distribute emissions within the LAEI area.

Back projections and future scenarios

Emissions of industrial NRMM were projected forward from 2013 based on weighted average emission factor described in the Construction NRMM section of this document, but using a national average emission factor rather than modifying for the impact of the Supplementary Planning Guidance, which just applies to construction and does not apply to NRMM in the industrial sector.

Mapping future emissions

The distribution of industrial NRMM emissions was assumed to stay the same as in 2013, based on the NAEI map of industrial combustion emissions of CO_2.

Heat and Power Generation

Solid and Liquid Fuel Combustion

Base Year 2013	• Department of Energy and Climate Change (DECC) residual fuels data by Borough were combined with NAEI emission factors.
Future Years 2020, 2020, 2025, 2030	• Projections derived from DECC Energy Projections high growth scenario, and predicted growth in the numbers of jobs at ward level

For the LAEI2013, DECC data are used to estimate emissions from oil, instead of the previously used boilers dataset which was outdated. Emissions estimates for oil have increased significantly for this sector as a result of this change. Solid fuel emissions have reduced but to a lesser extent.

Activity data

DECC data on solid and liquid fuel consumption in the industrial and commercial sectors is available at Borough level[5]. The sectors named Industry, Public Administration and Commercial were combined together for emission estimates for the Industrial and Commercial sector in the LAEI. The fuel consumption data were disaggregated across the LAEI grid simply in proportion to the area of each grid square because there is no other proxy data available to map the consumption more accurately. There are therefore significant uncertainties in the estimates in this sector, which could be improved in future if data on geographic variations in fuel use become available.

Data for Local Authorities outside the GLA were also included but the very large consumption reported for both oil and coal in Thurrock was removed because, based on analysis of the NAEI point source database[6] it was assumed that that large majority of Thurrock's consumption is used in point sources outside the LAEI area.

Emission factors

Emission factors from the NAEI emission factors database were applied to calculate emissions. These emission factors are shown in Table A1 in the Appendix.

Future emissions projections

Estimates of future emissions from industrial and commercial solid and liquid fuels are based on the 2013 emissions calculations all pollutants combined with projections drivers for fuel use from the DECC Energy Projections[7] high growth scenario, and also with GLA predictions of growth in the numbers of jobs at ward level. The DECC projection factors are shown in Table A6 in the Appendix, with solid fuels predicted to reduce much more rapidly than liquid fuels.

The DECC 'high growth scenario' was used because London is likely to grow at a faster pace that the rest of the UK.

The distribution of emissions was adjusted in future years using employment drivers (growth factors from a 2013 base) calculated from GLA projections of numbers of jobs at Ward level.

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[5] https://www.gov.uk/government/statistical-data-sets/estimates-of-non-gas-non-electricity-and-non-road-transport-fuels-at-regional-and-local-authority-level

[6] http://naei.defra.gov.uk/data/map-large-source

[7] https://www.gov.uk/government/publications/updated-energy-and-emissions-projections-2014

Gas Combustion

Base Year 2013	• DECC Medium Layer Super Output Area (MSOA) gas consumption data combined with NAEI emission factors.
Future Years 2020, 2020, 2025, 2030	• Derived from DECC Energy Projections high growth scenario, and predicted growth in the numbers of jobs at ward level

Historic emissions estimates for the 2013 inventory have been updated with revised emission factors from the NAEI. The same method has been used for mapping emissions as for the 2010 inventory except that an improvement has been made to reduce double counting with gas consumption by Part A1 processes.

Emission factors

The NAEI emission factors for the sector 'Miscellaneous industrial/commercial combustion' have been converted to give factors appropriate to the DECC activity data[8] which is reported in kWh. Emission factors for 2013 were not available from the NAEI Emission Factors database at the time the calculations were undertaken so it was assumed that 2013 factors are the same as 2012. These are shown in Table A3 in the Appendix. Since the estimates were made, emission factors are available for 2013. There are no significant changes.

Activity data

The DECC MSOA gas consumption data were joined to the MSOA boundary GIS dataset and the MSOAs covering the LAEI area have been extracted and combined with the LAEI grid GIS dataset. Each MSOA was divided up by the LAEI grid boundaries and the fraction of the MSOA area covered by the parts of the LAEI grid was calculated. This fraction of area was used to disaggregate the MSOA data to the LAEI grid. This is a simple proxy for distributing consumption but no other data were available to improve this. Consumption at the LAEI grid level was then combined with the NAEI emission factors above.

MSOA data for 2008 was distributed using the 2001 MSOA boundaries whereas the 2010 and 2013 gas data was distributed using 2011 MSOA boundaries. Some modifications to the gas consumption data were made to avoid double counting with Part A1 industrial processes (see below).

Some MSOA records for 2008 and 2010 include aggregations of data to prevent disclosure of individual records. However, a split between the aggregated MSOA consumption data was necessary in order to make a map without gaps. In most cases this split was made evenly between the MSOAs listed as a simple approximation where no other data was available. In other cases where the aggregated emission was very large it was assumed that a Part A1 process was present and adjustments were made to the MSOA data to remove a double count.

Emissions for large point sources are included elsewhere in the LAEI, mostly within Part A processes but also some Part B processes and within the Aviation category.

[8] https://www.gov.uk/government/statistics/lower-and-middle-super-output-areas-gas-consumption

However there is no data available on fuel types for most of these large point sources and it is therefore not possible to directly compare gas consumed with the MSOA dataset. In order to reduce double counting between these datasets, expert judgement has been applied to decide which point sources burn gas and at these locations large gas consumption within the MSOA dataset has been removed. The relevant point sources are listed in Table A4 in the Appendix. Adjustments were made to the DECC gas consumption data for each relevant year based on the assumptions outlined below. The remaining gas consumption at MLSOA level was distributed across the LAEI grid squares as described above. There are also 4 Part A1 processes which are assumed to be already excluded from the published DECC dataset, based on notes within the local authority level DECC datasets identifying the number of large industrial users and power stations excluded. These are shown in Table A5 of the Appendix.

Future emissions projections

Projections of emissions from industrial and commercial gas consumption were made based on the latest Energy projections from DECC[9]. The DECC high growth scenario was used because London is likely to grow at a faster pace that the rest of the UK, and the commercial services sector was used to best represent the dominance of the service industries in London. However within the DECC projection the impact of growth is offset by energy efficiency measures resulting in emissions reductions. The factors used to project forward from 2013 for all pollutants are shown in Table A6

The distributions of emissions has also been adjusted in future years by employment drivers (growth factors from a 2013 base) calculated from projected numbers of jobs at Ward level derived from data obtained by TfL from the GLA demand modelling team (GLA unpublished).

Natural Gas Supply - Gas Leakage

Base Year 2013	• Estimated by gas network providers based on length of network.
Future Years 2020, 2020, 2025, 2030	• Projections include estimates of reduced leakage due to improvements

Activity Data

There are two gas network operators in London: National Grid for the North and SGN in the South. Gas leakage estimates are reported to Ofgem on an annual basis for the Local Distribution Zone (LDZ) areas. Both network operators have estimated gas leakage from their networks that are within the LAEI grid area, based on length of pipes within the LAEI area, using data from their geographic leakage models. The data received is summarised in Table A7 in the Appendix. The data were converted into kilotonnes of natural gas in order to apply emission factors.

[9] https://www.gov.uk/government/publications/updated-energy-and-emissions-projections-2014

Emission factors and emission distribution

Emission factors were obtained from the NAEI Emission Factors Database. These are shown in the Table A8 in the Appendix.

LAEI total emissions were calculated by combining the activity and emissions data. These have been compared with UK totals, as 12% of the UK emissions in 2013.

The emissions distribution for the LAEI grid was calculated using gas consumption emissions of CO_2 as a proxy for the leakage distribution across London but also retaining the correct totals within the north and south regions, which were identified as those grid cells north and south of the River Thames.

Projections

Estimates of improvements to reduce leakage to 2030 have been received from National Grid. SGN did not provide equivalent data therefore North London reduction factors have been applied to the South London data from SGN. The reduction factors are show in the Appendix Table A9.

Emission factors and emissions distributions for future years were assumed to be the same as for 2013 for all pollutants.

Waste

Waste and Waste-Water Handling

Base Year 2013	• NAEI emissions for London have been assigned to each sites based on its capacity/area
Future Years 2020, 2020, 2025, 2030	• Emissions projected using GLA population forecasts

This source sector includes waste handling at landfill sites and waste water handling at Sewage Treatment Works (STWs). A change of source type from area sources to EMEP/EEA emission factors polygon sources is used in the 2013 update for landfill and STWs emissions.

For STWs, the polygon sources are defined based on the extent of the sources (usually the settling and treatment tanks). The area of the nine STWs to be included in the LAEI was determined by drawing polygons around the site boundary on aerial photography of the sites. The emissions for London have been assigned to individual sewage treatment works on the basis of each site's population equivalent (PE) a parameter used to describe the capacity of a sewage treatment works. This is a more direct method than the previous method which estimated the population served from population distribution.

For landfill sites, the polygon sources are defined based on the extent of authorised and historic landfills in the Environment Agency (EA) National Dataset of Permitted Waste Sites and the EA National Dataset of Historic Landfill Sites. The emissions for London have been proportioned on the basis of landfill area in London compared to that in the UK as a whole, rather than population. This is an improvement to the methodology as London Boroughs and commercial providers will be likely to export material for landfill outside the city and therefore outside the LAEI.

Landfill Sites

Pollutants

NAEI gives emissions of the following pollutants for disposal of solid waste on land:

- Non Methane Volatile Organic Compounds (NMVOC);
- Ammonia (NH_3);
- Polychlorinated Biphenyls (PCB); and
- Methane (CH_4).

EMEP/EEA 2013 gives emission factors for NMVOC (1.56 kg/Mg), PM_{10} (0.219 g/Mg) and $PM_{2.5}$ (0.033g/Mg). Therefore PM_{10} and $PM_{2.5}$ have been calculated using the NAEI NMVOC emissions as an intermediate parameter based on the relative emission rates.

Activity data

A similar top-down scaling approach used in the 2010 LAEI has been used but with a key differences. In order to calculate total local emissions, the emissions for London have been proportioned on the basis of landfill area in London compared to that in the UK as a whole, rather than population. This is an improvement to the methodology as London Boroughs and commercial providers will be likely to export material for landfill outside the city and therefore outside the LAEI domain.

Landfill emissions have been obtained from the NAEI for the years 2008, 2010 and 2012. Information on the landfill sites in London and the UK has been obtained from the Environment Agency (EA) National Dataset of Permitted Waste Sites – Authorised Landfill Site Boundaries and the EA National Dataset of Historic Landfill Sites. The total area of both types of landfill has been used to determine the proportion of landfill area that is in the LAEI area in order to scale the NAEI emissions accordingly. This shows that 7.3% of landfill area, and therefore assumed emissions, is in the LAEI area.

As in the LAEI 2010, the emissions have been assigned to individual landfill sites (both active and closed) which have taken biodegradable waste. Emissions have been allocated in proportion to the area covered by the landfill site. This method assumes that the emission per square metre of landfill is the same irrespective of the age of the landfill. Importantly, this approach ensures that emissions are not assigned to landfill sites that have only taken inert waste – which would not produce methane.

PM_{10} and $PM_{2.5}$ emissions have been calculated for sites taking biodegradable and inert waste, assuming the same emissions rate of particulates per unit area.

Back projections and future scenarios

New back projections for 2008 and 2010 have been calculated due to the change in methodology of determining the London proportion of emissions on the basis of landfill area rather than population. NAEI 2008 and 2010 emissions have been used to produce London emissions according to landfill area.

Emissions for future scenarios have been calculated using the projected population growth rate for London as a whole recently supplied by TfL, assuming that non-Part A1 emissions from landfill are directly proportional to the population. Only emissions for active landfill sites have been increased in accordance with projected population growth. Emissions for historic sites have been kept constant from 2013 as no new waste will be added. The population growth rates provided are shown in Table A 10.

Emission factors

EMEP/EEA emission factors have been used to calculate PM_{10} and $PM_{2.5}$, using NMVOC emissions from the NAEI as an intermediate parameter.

Spatial information

The inventory includes all active and closed landfill sites in the LAEI area.

Sewage treatment works

Emissions have been reported as the new source type: polygon, based on the extent of the non-Part A1 sources (usually the settling and treatment tanks) at the sewage treatment works. The area of the nine STWs (defined below in spatial information) to be included in the LAEI was determined by drawing polygons around the site boundary on aerial photography of the sites.

Pollutants

NAEI gives emissions of the following pollutants for wastewater treatment:

- CH_4; and
- N_2O.

Activity data

Emissions from Part A1 sources at sewage treatment works have been excluded from this source section. The non-Part A1 emissions for London have been assigned to individual sewage treatment works on the basis of each site's Population Equivalent (PE) a parameter used to describe the capacity of a sewage treatment works. This is a more direct method than the previous method which estimated the population served from population distribution. NOx emissions from biogas for individual sites have been provided by David Hutchinson (currently co-chair of Air Pollution Research in London (APRIL), previously from GLA).

Back projections and future scenarios

New back projections for 2008 and 2010 have been calculated to take into account the two changes in methodology: subtracting Part A1 emissions from the UK total rather than adding the Part A1 emissions; and distributing the emissions between sites in London using the PE parameter to describe the capacity of a sewage treatment works rather than an estimated population served. These back projections have been calculated using GLA population projections.

Future scenarios have been projected using the projected population growth rate for London as a whole recently supplied by TfL, assuming that non-Part A1 emissions from wastewater are directly proportional to the population.

Spatial information

The new inventory includes all major sewage treatment works in the LAEI area. The following are included:

- Hogsmill STW;
- Deephams STW;
- Mogden STW;
- Beckton STW;

- Crossness STW;
- Riverside STW;
- Beddington STW;
- Maple Lodge STW; and
- Longreach STW.

Waste Transfer Stations (WTS)

Base Year 2013	• 2013 EMEP/EEA emission factors with LAEI2010 activity data.
Future Years 2020, 2020, 2025, 2030	• Projected using GLA population forecasts

The main change for WTSs is the use of emission factors based on the 2013 EMEP/EEA emission factors which are higher than the 2009 EMEP/EEA emission factors used previously. The source type has also been changed from point to polygon, based on the extent of each of the WTSs. OS mapping has been used to describe the surface area of each source.

Pollutants

The following pollutants have been considered:

- PM_{10}; and
- $PM_{2.5}$.

Activity data

The Environment Agency (EA) Waste Data Interrogator 2013 was identified as the appropriate source of the most recent available activity data. However, it was not possible to obtain access to this source, so the activity data from the LAEI 2010 was used.

Emission factors

Factors based on the 2013 EMEP/EEA emission factors for the storage, handling and transport of mineral products (2.A.5.c Storage, handling and transport of mineral products) have been used. They are 20% higher than the 2009 EMEP/EEA emission factors used previously.

In the LAEI 2010 the EMEP/EEA emission factors for mineral products, which are not directly applicable to waste transfer stations, were multiplied by factors between 1% (hazardous and clinical waste) and 20% (inert waste) with 5% being applied to non-hazardous WTS and civic amenity sites to account for the differing potential for particulate emissions. Compared with handling mineral products a factor of 20% is probably too high and it is not obvious why emissions for inert waste would be higher than for non-hazardous WTS and civic amenity sites. Therefore, a factor of 5% has been used for all three categories.

Back projections and future scenarios

As no new activity data was available and only the emission factors have changed, 2010 emissions are the same as those calculated for the LAEI 2013 (as the activity data is the same).

Future scenarios have been projected using the projected population growth rate for London supplied by TfL

Spatial information

The inventory includes all Waste Transfer Stations in the LAEI area.

Small Scale Waste Burning

Base Year 2013	• Derived from NAEI emissions and distributed using census and land cover data.
Future Years 2020, 2020, 2025, 2030	• Projected using household growth forecasts

Small scale waste burning covers residential bonfires, indoor burning of waste on open fires and industrial bonfires.

The NAEI report on updating the Persistent Organic Pollutants (POPs) multi inventory in 2012[10] describes the data used to calculate emissions from small scale waste burning in the UK. This sector comprises emissions from waste burnt in open fireplaces in homes and on bonfires in gardens or allotments and in industry. The estimates are based on literature emission factors combined with data from a MORI conducted survey of over 800 households across the UK and NAEI estimates of the average amounts of waste burnt.

Data are not available in that NAEI report on a regional basis therefore it was not possible to derive London-specific emissions from the outputs. However it has been assumed that the amount of waste burnt in London households on open fires will be significantly smaller that the UK average because of the lack of solid fuel burning in the city. The number of households in London that have a garden is also assumed to be smaller than the national average.

In order to calculate and map emissions for the three sub-sectors of the emission estimate – bonfires, indoor open fires and industry - the NAEI emission total for the UK was first divided into these sub-sectors using data from the NAEI (obtained via a data request to the NAEI team), see Table A 11 in the Appendix. LAEI area fractions were estimated for each of the UK total for each of these sources, see Table A 12.

There are no data on the number of households using an open fire as a secondary source of heat. Therefore, for the open fireplaces fraction, census data on the number of households that use solid fuel for heating has been used as a proxy for allocating a fraction of emissions to the LAEI area. From the census data it has been calculated that only 0.73% of households using solid fuel are in London. It is assumed that bonfire activity is concentrated in suburban areas therefore the CEH suburban land cover data was used as a proxy to calculate a fraction of the UK

10 http://randd.defra.gov.uk/Default.aspx?enu=Menu&Module=More&Location=None&ProjectID=17145&FromSearch

emissions for the LAEI area. The fraction of emissions from small scale waste burning in industry in London is assumed to be proportional to construction activity, as construction is the most likely sector to burn waste. However it is acknowledged that this is a very uncertain emission estimate and therefore it is a conservative (likely too high) estimate but there is currently no other data available.

The emissions for both residential sub-sectors is distributed within the LAEI area based on the CEH suburban land cover distribution because this reflects the likely distribution of emissions away from the most densely built up parts of the city. The emissions from the industrial and construction waste burning are mapped based the NAEI Industrial CO_2 emissions map for 2012 but only in the grid squares where there is also data in the CEH suburban land cover distribution.

Future emissions projections

Future estimates for the residential fraction of the small scale waste emissions are based on household growth forecasts from GLA derived from ward level data. It is assumed that there will be no change in the industrial/construction portion of the small scale waste emissions in future year

Construction

Non-Road Mobile Machinery Exhaust and Construction Dust

Base Year 2013	• Proportion of NAEI emissions determined by employment in the construction sector, and distributed geographically using the London Development Database
Future Years 2020, 2020, 2025, 2030	• Projections are in line with the Supplementary Planning Guidance and London Plan (2011) projections of development

Estimates of emissions from NRMM have been significantly improved since the 2010 LAEI. Historic estimates were calculated using a combination of top-down UK emissions estimates from the NAEI and bottom up estimates of emission locations from the London Developments database. Future emission estimates have been improved to take account of the new Supplementary Planning Guidance for NRMM.

Historical emissions estimates

UK emissions estimates are available from the NAEI for all years to 2013. The emissions are defined in the NAEI for the following sub-sectors:

- Construction non-road mobile machinery
- Construction dust

The fraction of the UK construction emissions that are emitted in the LAEI area was calculated using proxy data on employment in the construction industry[11]. Employment was selected as an appropriate indicator of construction activity. This is a change since the last LAEI in which the monetary value of construction developments was used. The fraction of construction employment in London varies by year: in 2010 it was 11.5% and in 2013 it was 14.1% of the UK total.

Historic Emission Distributions

Detailed data from the London Development Database (LDD) has been used to generate maps of NRMM emissions. The LDD provides data on the locations of all construction sites across London. The emission distribution was developed based on the data on the size of the construction site. The distribution could be improved in future versions of the LAEI by using a floor area of development metric for sites but at this stage data are not available for all sites.

The site data were aggregated up to the LAEI grid and emissions from construction NRMM and construction dust were distributed in proportion to the total of sites sizes in each grid square. This is an improvement on the method used in the LAEI 2010 in which a more limited set of data on construction sites was used resulting in much of the NRMM being mapped with the Central Activity Zone and Canary Wharf.

[11] Construction Statistics Annual Tables, 2014 - http://www.ons.gov.uk/ons/rel/construction/construction-statistics/no--15--2014-edition/rft-construction-statistics-annual-2014.xls

Future emissions projections

NRMM emissions will reduce in future years because of new regulations for NRMM in London (the new '*Control of Dust and Emissions During Construction and Demolition Supplementary Planning Guidance (SPG)*[12]). A new method has been developed to estimate emission factors for NRMM for an estimated fleet mix in 2013 based on European emission limit values (engine emissions standards set in EU Directive 97/68/EC[13]). Fleet-weighted emission factors based on the SPG requirements have been used to calculate percentage reductions in emission factors by 2020 and 2025 both in the more stringent Central/Canary Wharf area and across the rest of London. These percentage reductions have then been applied to baseline emissions to calculate emissions in 2020 and 2025. It has been assumed that emissions in 2030 will be the same as 2025. The future emissions have been mapped based on planned development areas in London as given in the London Plan 2011 maps. Detailed information on spatial distribution of constructions site was not available for future years.

A detailed description of the method used to calculate emissions from construction can be found in the Appendix.

[12] https://www.london.gov.uk/priorities/planning/publications/the-control-of-dust-and-emissions-during-construction-and

[13] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CONSLEG:1997L0068:20070101:en:PDF

Domestic

Heat and Power Generation

Solid & Liquid Fuel Combustion

Base Year 2013	• DECC fuel consumption data distributed by census data and central heating fuel use
Future Years 2020, 2020, 2025, 2030	• Projected according to projections drivers for fuel use from the DECC Energy Projections and houselhold numbers from GLA.

Improvements have been to previous LAEI estimates of emissions from domestic solid and liquid fuels consumption. This has been achieved by distributing DECC fuel consumption data within Boroughs based on census data on central heating fuel use. There have also been significant changes in the DECC data time series resulting from a change in methods for its calculation. This has resulted in large increases in emissions from domestic coal, and to a lesser extent for oil, compared with the previous 2010 LAEI.

Historical emissions estimates

Activity data

Data on consumption of coal, smokeless solid fuel and burning oil at borough level are available for 2008, 2010 and 2012 in the 2012 DECC Local Authority 'residual fuels' dataset[14]. Data for 2013 were not available in time for the LAEI 2013 update, therefore 2012 has been used as an estimate of 2013. The data were converted from tonnes of oil equivalent to tonnes of fuel using a Net Calorific Value (NCV) conversion.

In order to map fuel consumption to the LAEI grid, Census data for 2011 on oil and solid fuels used for central heating in the domestic sector were used to disaggregate the DECC data within each Borough, in proportion to the number of households in each LAEI grid using the relevant fuel.

Consumption of solid and liquid fuels is low in London because gas is available and its installation and use has been promoted for many years. Although the use of solid and liquid fuels is small, there is still a significant uncertainty in the dataset because it is modelled rather than being based on reported fuel consumption. The emission estimates derived from this data are therefore considered uncertain.

Emission factors

Emission factors from the NAEI emission factors database were applied to calculate emissions. These emission factors are shown in Appendix Table B 1for burning oil, coal and smokeless solid fuel (SSF).

[14] https://www.gov.uk/government/statistical-data-sets/estimates-of-non-gas-non-electricity-and-non-road-transport-fuels-at-regional-and-local-authority-level

Future Emissions Projections

Estimates of future emission from domestic solid and liquid fuels are based on the 2013 emissions calculations combined with projections drivers for fuel use from the DECC Energy Projections[15] high growth scenario, and also GLA projections of household numbers for wards in London. The DECC projection factors are shown in the Appendix Table B 2 with solid fuels predicted to reduce much more rapidly than liquid fuels.

Gas consumption

Base Year 2013	• DECC sub-national gas consumption dataset at LSOA level, combined with NAEI emission factors and NOx emission factors based on the age profile of boilers in London
Future Years 2020, 2020, 2025, 2030	• Projected according to projections drivers for fuel use from the DECC Energy Projections

Significant improvements have been made to the domestic gas emissions for the 2013 update of the LAEI, with new NOx emissions factors, which reflect actual boiler stock in London, and improved mapping of consumption based on Census data. Emission estimates for NOx have increased as a result of the changes. Other emission factors have been updated based on the NAEI.

Historical emission estimates

Emissions from domestic gas consumption have been calculated based on the DECC sub-national gas consumption dataset at LSOA level[16] combined with NAEI emission factors for pollutants other than NOx. For NOx, emission factors based on the age distribution of boilers in London have been used. The NOx factors were calculated as part of an LAEI improvements study in 2014 (not yet published).

Emission factors

The NAEI emission factors for 2008, 2010 and 2012 for the sector 'Domestic combustion' have been converted to give factors appropriate to the DECC activity data which is reported in kWh. These are shown in Table B 3 in the Appendix. Emission factors for 2013 were not available from the NAEI Emission Factors database at the time the calculations were made so it was assumed that 2013 factors are the same as 2012.

Emission Factors for NOx were available from the AMEC and Aether study[17] to derive Borough specific emissions factors based on boiler age profiles and boiler emissions data by age. These factors are shown in Table B 4. The factors used in the calculations for the 2013 update of the LAEI are slightly higher than those included in the final version of the study report because of small changes resulting from final checks before submission. It was not a significant change.

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15 https://www.gov.uk/government/publications/updated-energy-and-emissions-projections-2014

16 https://www.gov.uk/government/statistics/lower-and-middle-super-output-areas-gas-consumption

17 Reducing Harmful Emissions from Buildings – Updating LAEI buildings emissions, Report to the GLA (unpublished)

Emission factors were not available for all individual Boroughs because of incomplete boiler stock data. Therefore inner and outer London average emissions factors, calculated from aggregated Borough data, were applied in Boroughs without Borough specific estimates. This gap filling is shown in Table B 5 of the Appendix.

Activity data

Further geographical disaggregation of gas consumption and hence emissions, was made through the use of 2011 Census data on the numbers of households using gas for central heating in each census output area. This data combined with the LSOA gas consumption data were used to calculate average household gas consumption and then calculate total gas consumption within each of the LAEI grid area. The same census data distribution was used for each historical year but combined with DECC data for the relevant years: 2008, 2010 and 2013.

In some cases where LSOA boundaries have changed at the 2011 census, gaps in household counts related to the LSOA data before 2011 were filled using borough level household average consumption data.

Future emissions projections

Projections of emissions from domestic gas consumption were made based on the latest Energy projections from DECC[18] . The DECC high growth scenario was used because London is likely to grow at a faster pace that the rest of the UK however within the DECC projection the impact of growth is offset by energy efficiency measures resulting in modest emissions reductions. The factors used to project forward from 2013 for all pollutants are shown in Appendix Table B 5. The distribution of emissions was also adjusted in future years by household drivers (growth factors from a 2013 base) calculated from projected numbers of households at Ward level derived from GLA data.

House and Garden Non-Road Mobile Machinery

Base Year 2013	• Proportion of NAEI emissions in London determined from CEH 2007 land cover map
Future Years 2020, 2020, 2025, 2030	• Projected from household growth forecasts at Ward level

Historic emissions estimates for the 2013 inventory have been updated based on the most up to date national totals from the NAEI. The same method has been used for mapping emissions as for the 2010 inventory.

Historical Emissions Estimates

Emissions from household and garden machinery in the LAEI are 8.12% of the UK NAEI emissions for this sector, calculated as the proportion of suburban land cover in the LAEI area based on the Centre for Ecology and Hydrology (CEH) 2007 land

[18] https://www.gov.uk/government/publications/updated-energy-and-emissions-projections-2014

cover map[19]. Within the LAEI area the emissions were distributed to each 1km grid square using the same suburban land cover dataset.

Future emissions projections

Estimates of future emissions from household and garden machinery were calculated by modifying the 2013 estimates based on geographically specific GLA forecasts of households at Ward level.

[19] http://www.ceh.ac.uk/landcovermap2007.html

Transport

River

Base Year 2013	• Emissions factors are the same as the NAEI
Future Years 2020, 2020, 2025, 2030	• Passenger shipping activity projections held constant

Emission factors

The shipping emission factors take into account revised MARPOL regulations and the European Commission's SCMFD. The revised MARPOL Annex VI Regulations entered into force on 1st July 2010. Relevant key provisions include:

- A reduction in the global limit of sulphur content in fuel to 3.5% by mass (from the current 4.5%) effective from 1st January 2012; then to 0.5%, effective from 1st January 2020 subject to a feasibility review to be completed no later than 2018);
- A reduction in sulphur limits for fuels in SO_X ECAs to 1%, beginning on 1 July 2010 (from the current 1.5%); being further reduced to 0.1%, effective from 1st January 2015;

As with the existing MARPOL Annex VI, the revised regulations allow for the use of suitable abatement equipment as an alternative to the fuel switching requirements described above on the basis that equivalent SO_X emissions are achieved on a continuous basis; and

- Tiered reductions in NO_x emissions from marine engines (with the most stringent controls on 'Tier III' engines, i.e. those installed on ships constructed on or after 1st January 2016, operating in ECAs).
- The European Commission's strategy on emission reductions from ships was the SCMFD (European Parliament and Council, 2005), which came into force on 6th July 2005, amending the existing Sulphur Content of Liquid Fuels Directive (SCLFD) (European Council, 1999). The SCMFD is linked to MARPOL Annex VI, which was used as the determinant of the maximum permissible sulphur content of marine fuels used in Sulphur Emission Control Areas (SECAs).

The main elements of the Directive include:

- A 1.5% sulphur limit for fuels used by all ships in the SECAs of the Baltic Sea, from 11th August 2006, and the North Sea and English Channel, from either 11th August 2007 or 12 months after the entry into force of the International Maritime Organisation designation, whichever is the earlier[20];
- A 1.5% sulphur limit for fuels used by passenger vessels on regular services between EU ports, from 11th August 2006; and

[20] Compliance was in fact required from 22 November 2007

- A 0.1% sulphur limit on fuel used by inland waterway vessels and by seagoing ships at berth in EU ports, from 1st January 2010.

The emission factors are the same as those used in the NAEI. The Defra emission factors include NO_X, SO_2, PM_{10} and HC. $PM_{2.5}$ emissions have been estimated as 95% of PM_{10} (based on NAEI emission factors). HC emissions are assumed to be equivalent to NMVOC. CH_4 and N_2O emissions have been calculated from NO_X emissions based on the respective NAEI emission factors.

Passenger shipping

Emissions from passenger shipping are represented as line sources, by a series of links along the river between the piers used by the largest operators, extending from Hampton Court in the west to Woolwich Arsenal in the east. Cross-river ferry services have been represented by straight line paths between ferry terminals. The River Thames is generally no more than 300m wide, but the mobile source type does not have a width attributed to it as a width is not required for the LAEI. No “in port” emissions from passenger shipping were included the LAEI 2013.

Activity data

The schedules of the major service operators (Appendix Table C 1), have been obtained by contacting River Services at TfL. The estimated hours of operation of other services have been estimated based on the likely number of journeys undertaken per day and/or week. These have been used in the bottom up calculation to derive hours of operation and hence emissions. New data on fuel consumption has been obtained from company reports where available.

Where possible, the hours of operation have been allocated to links of the river, based on knowledge of shipping routes. This is a difference compared with the LAEI 2010 where emissions were assumed to be equally distributed along the extent of the operators’ routes.

Fuel consumption data has been calculated using the same formula as used in LAEI 2010 which uses as input:

- Main engine fuel consumption rate ($l\ h^{-1}$)
- Main engine activity data ($h\ annum^{-1}$)
- Main engine load factor
- Number of main engines
- Auxiliary engine fuel consumption rate ($l\ h^{-1}$)
- Auxiliary engine activity data ($h\ annum^{-1}$)
- Auxiliary engine load factor
- Number of auxiliary engines
- Fuel density ($kg\ l^{-1}$).

Where data were not available the same assumptions made for the LAEI 2010 were used.

Back projections and future scenarios

No back projections have been calculated as the methodology is not changing. Activity is assumed to be constant in the future years in the absence of firm information concerning future activity.

Spatial information

The inventory includes all passenger shipping on the River Thames, from Hampton Court to Woolwich Arsenal. Pier locations have been obtained from OS mapping data.

Commercial shipping

Source type

In-port emissions from ports and wharves have been reported as the new polygon sources based on the extent of the ports. OS and port mapping have been used to estimate the extent of the port boundaries.

At sea emissions were represented as a mobile source (as they should have been in previous inventories) by a series of links along the river between ports and wharves.

The method used is the same as that used in the NAEI.

Activity data

Lloyds List Intelligence (LLI) provided detailed activity and vessel data for 2013 for each berth so that it was possible to update activity data. The following information was provided:

- Vessel type;
- Gross tonnage;
- Main engine power and fuel;
- Auxiliary engine power and fuel;
- Average speed when not manoeuvring; and
- Date and time of arrival and departure.

The list of berths available from Port of London Authority (PLA)[21] has been digitised and the area of each berth likely to be used by ships has been mapped using satellite imagery. The activity data and berths have been cross referenced to determine the berths that were used in 2013.

Back projections and future scenarios

The 2013 update for commercial shipping emissions has been used to provide the back projections for 2010 and 2008. As the activity data originated from 2004, activity from Thames Europort was included in the 2008 and 2010 emissions. The Thames Europort port facilities were mothballed in 2008[22], therefore activity and therefore emissions have been removed from these inventories. In addition, the assumptions regarding the time that each vessel spent in port and vessel power had previously been taken from the LAEI 2008. As more accurate data were available from the 2013 data obtained, assumptions were changed for 2008 and 2010.

The LAEI 2008 used an annual growth rate of 1% in the number of vessel calls to the Port of London (that lies within the LAEI area) for the period 2003 – 2010, as

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[21] https://www.pla.co.uk/Safety/Hydrography/Definitive-Berth-Names

[22] Dartford Borough Council (2011) Examination in Public of Dartford Core Strategy. Dartford Borough Council Statement on Matter 2: Spatial Vision - https://www.dartford.gov.uk/__data/assets/pdf_file/0010/74269/Matter-2-FINAL-inc-App-B.pdf

identified in the "Port of London Handbook 2004" and "PLA Annual Review 2003". This growth rate was used to calculate the activity rate for LAEI Revised 2010 from the 2004 activity data.

The Port of London Authority (PLA) is currently working on the *Thames Vision*[23] project to plan the future of the river. The evidence base will include a river capacity study (commissioned jointly with TfL) and economic growth forecasts. In the absence of this detailed information at present, future growth in port traffic has been approximated from the forecast Ro-Ro units in London (3.3% growth) in the *Update of UK Port Demand Forecasts to 2030 & Economic Value of Transhipment Study Final Report*[24]. This is referenced in the *International competitiveness of the UK maritime sector Final report Prepared for Department for Transport*[25] and reference is made to the view of the government that the recession will delay the traffic level by a number of years, but not ultimately reduce the eventual levels of demand for port capacity predicted in the forecasts. No growth in activity has been assumed for wharves that are likely to currently be operating at near to capacity. It was therefore decided to apply no growth to wharves receiving more than 500 vessel visits per year (Fords Jetty, Purfleet Deep Water Terminal and Vopak Terminal).

The emerging London Gateway Port[26] which will be a major container port has not been included as it is outside the LAEI domain.

Spatial information

The LAEI domain includes ports and terminals on the River Thames, starting from the breakwater at the M25 Motorway eastern boundary and then about 43 km westward towards Teddington. The berths in the LAEI area have been obtained from the Port of London Authority (PLA) Definitive Berth Names list[27].

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[23] https://pla.co.uk/About-Us/The-Thames-Vision

[24] MDS Transmodal Limited (2007) Update of UK Port Demand Forecasts to 2030 & Economic Value of Transhipment Study Final Report

[25] Oxera (2015) International competitiveness of the UK maritime sector Final report Prepared for Department for Transport

[26] http://www.londongateway.com/

[27] https://www.pla.co.uk/Safety/Hydrography/Definitive-Berth-Names

Road

Base Year 2013	• The AADT data for each road link has been calculated using manual classified count (MCC) data from both DfT and TfL where it is available and from TfL's London Highway Assignment Model (LoHAM) and LTS models for the remaing roads.
Future Years 2020, 2020, 2025, 2030	• The growth in traffic flow has been simulated using scaling factors from TfL's Business Plan and from a recent LTS model forecast, with speed data adjusted accordingly. The traffic and speed growth was implemented by road types (TLRN, motorways, local roads) and by zones (by boroughs and motorway junctions).

Activity data

Major road links

The methodology used to update major road traffic data is in accordance with that used in the LAEI 2010[28]. There are a total of 2009 MCC traffic count sites within the LAEI area used to allocate traffic to the network. Not all sites are counted each year, and of the 2009, 649 were counted in 2013 (links updated are indicated in red in Figure 2). The MCC data are based upon only one day of observations, so to minimise the effect of specific local events introducing outliers into the dataset, the 2013 data were added to a series of MCC data (extending back to 1999). For each site separately, and using all traffic counts from 1999 to 2013, the MCC data has been smoothed using a LOESS smoothing function. Furthermore, as the MCC data only cover a 12-hour weekday period (7am to 7pm), these data were then expanded to provide counts for each hour of each day in 2013 (including weekends and overnight hours), using hourly average automatic traffic counts (ATC). The taxi to car ratio has been updated using MCC data in 2013 by location and time (see summary of changes in the Appendix Table C 2 Taxi/(taxi+car) ratio by location (average of MCC hourly data)Table C 2. The resulting annual hourly dataset was then averaged by link to provide the AADT data (by 11 vehicle types) for each major road. Road traffic data was manually checked versus TfL's traffic Surveys Unit data for a list of hotspot road links (e.g. Oxford Street, Regent Street, Brixton High Street, Putney High Street, Marylebone Road, A13 at Silvertown Way and A12 Blackwall Tunnel).

Modelled (LTS) road links

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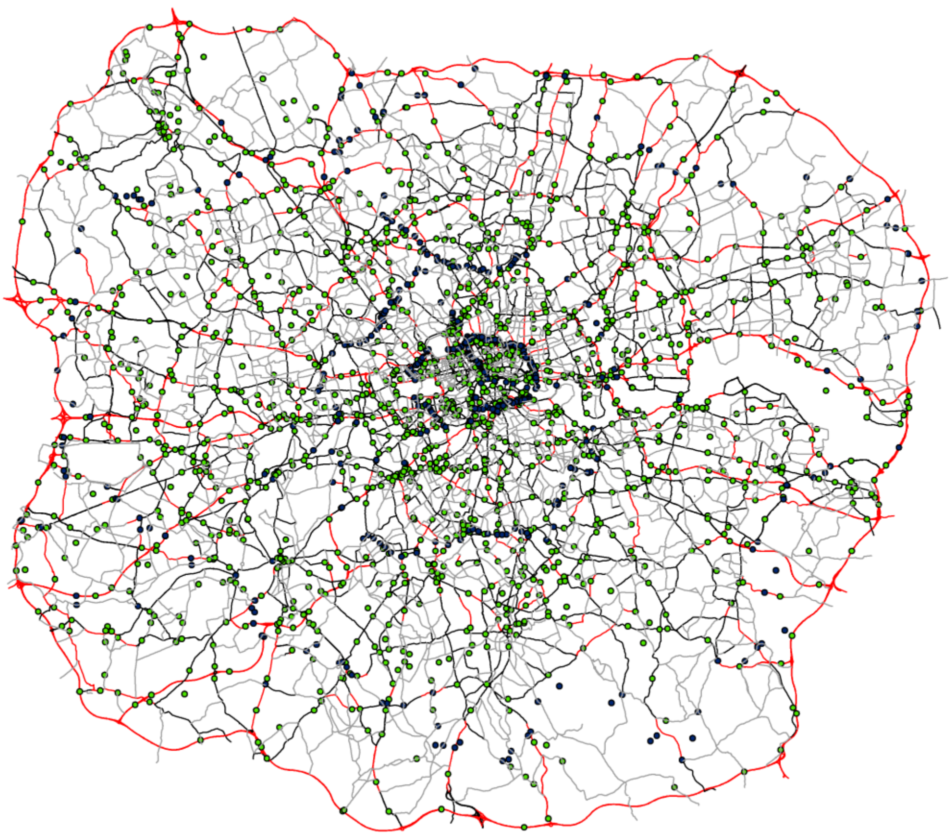
[28] https://files.datapress.com/london/dataset/london-atmospheric-emissions-inventory-2010/0-Documentation.zip

For the LTS links, traffic flow has been based upon TfL's LoHAM data for 2009 and 2012. The matched links (745 LTS links out of a total of 4,265, or 17.5%) had their count data scaled from 2009/2012 to 2008, 2010 and 2013; for any unmatched links (82.5%), the LAEI 2010 data were retained and further scaled from 2010 to 2013 (all data were scaled using Table C 3).

Minor road links

Finally, minor road traffic has previously been expressed as annual vehicle km travelled in each of the 2,466 km^2 grids of the LAEI. In this LAEI, the 2,466 km^2 was further divided into 3,355 polygons to account for the new grid exact cut of locations and boroughs.

Figure 2 The LAEI 2013 road network. Major road links are in black, LTS road links are in grey. Circles represent the manual classified count (MCC) sites used to determine major road traffic; green circles are for DfT count sites and navy ones for TfL. Major road links updated with 2013 data are highlighted in red.



DfT data indicates that 30.3, 29.7 and 28.8 billion vehicle km (bvkm) were driven on all roads in the GLA in 2008, 2010 and 2013, respectively. The bvkm travelled on major and LTS roads (Table C 4) were calculated and the remaining vehicle km were attributed to minor roads, at 1km^2 grid resolution or finer, if the km^2 grids are divided by borough or Central/Inner/Outer location boundaries. Equation (1) was used for the calculation of bvkm on major roads:

$$bvkm=\frac{(flow \times 365 \times L_{road} \times M)}{(1\times 10^{12})} \qquad (1)$$

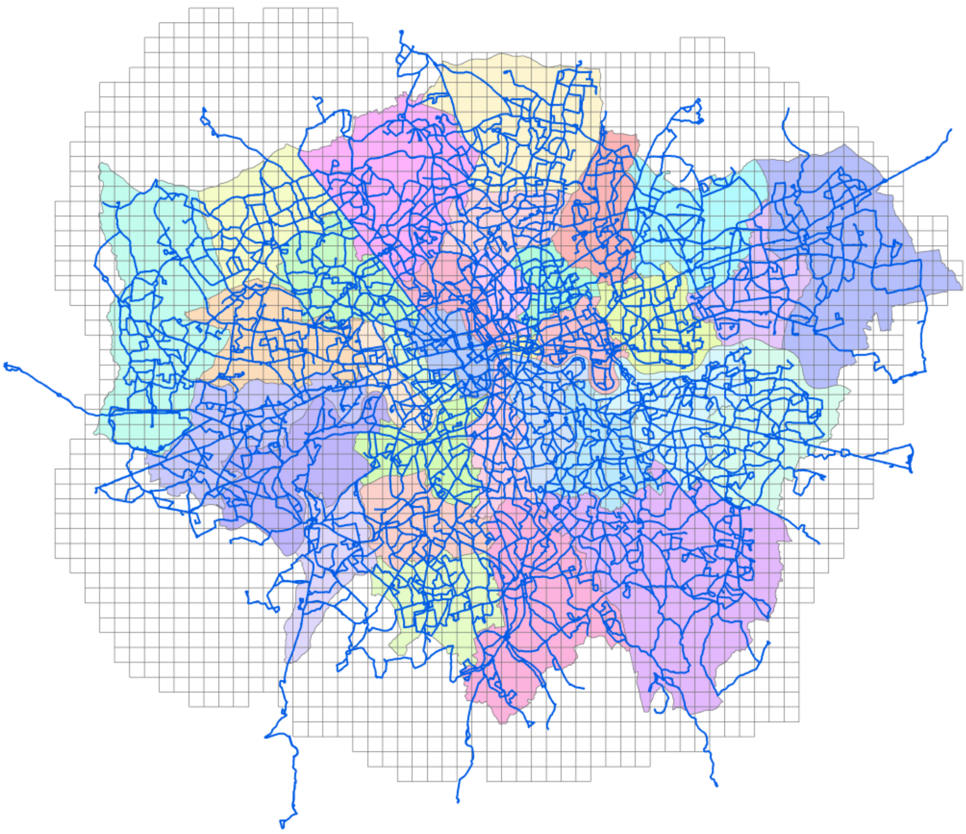
where: bvkm = billion vehicle km; flow = 24 hour road traffic flow; Lroad = road link length (m) and M = a link specific multiplier – typically M = 0 for slip roads, 0.5 for dual carriageways and roundabouts, and 1 for single roads. Complex road junctions are assigned M values manually. The vehicle km driven in the GLA area, split by vehicle type, are provided in Table C 5.

Bus Network data

A major method development in this LAEI was the inclusion of iBus data to improve the estimations of speed and flows of TfL Buses at TOID link level.

A GIS layer of TfL Bus routes was intersected with the major road network in London. The TfL Bus routes are shown in Figure 3. Data sets were also provided by TfL of scheduled bus stopping times on each route and direction, through each stop on that route, for a typical weekday, Saturday and Sunday from March 2013. The data sets included the vehicle registration numbers, which could be matched to the vehicle size and technology via an inventory also provided by TfL.

Figure 3 Map of the TfL Bus network used to implement iBus data in the LAEI. Routes are shown superposed on a map of London boroughs and the LAEI grid



The location of the bus stops on each route, and the time the buses were scheduled to arrive at these stops, were used to derive an average speed by hour and location (ULEZ/Inner/Outer/External) for each bus route and direction. This resulted in a significant reduction in the average TfL Bus speeds relative to previous speed estimates, as shown in Appendix Table C 6.

The flow of buses (by size and technology) on each route, direction, hour and location, was also calculated for each data set. A weighted average of flows and speeds was then calculated over the weekly period, using the weekday, Saturday and Sunday. The data were scaled further to account for public holidays.

An estimation of the % of vehicle km associated with out-of-service buses from each bus route was provided by TfL. In the absence of further detailed information, it was assumed that these buses travelled along the same roads as the route itself, and the TfL Bus flows were scaled accordingly. Over the whole network, the out-of-service buses covered approximately 11% of the distance of the in-service buses.

Once a data set had been generated for an average day in 2013, the counts (and speed) per hour of each technology/bus type on each route and direction were joined to the list of TOID links intersected with the bus routes. The vehicle km from TfL Buses on each major road or LTS link were then calculated relative to the total "Bus + Coach" flow obtained from MCC and modelled data. The total "Bus + Coach" flow was reduced accordingly to represent coaches alone. The previous method had been to assume an 80:20 split of TfL Buses to coaches on all links. Because of many areas where the new TfL Bus flow exceeded the old figure, this process resulted in an increase in both bus and coach vehicle km, as shown in Appendix Table C 7.

In each of the 3,355 polygons of the LAEI, the length of each route/direction, and the length of the intersect of these routes/directions with the major road network (discussed above), could be calculated. The minor road vehicle km were thus calculated by multiplying the difference between these two lengths by the known traffic flow on each route/direction, then summing over all routes and directions. The results of these updates on iBus vehicle km on all roads in 2013 are summarised in Appendix Table C 7.

The iBus minor road vehicle km were used, in conjunction with the iBus fleet composition calculated by zone (using the major road data) to estimate emissions from TfL Buses on minor roads.

The overall process of including iBus data resulted in large changes in the emissions calculated; both vehicle flow updates, and speed updates played a part in this. Since the processes above were all carried out using the 2013 data sets, previous years (2008 and 2010) also had to be estimated. The flows were scaled using ratios of operated figures to 2013 derived from TfL's Travel in London report 7[29].

In projecting the iBus flows and speeds in future years (2020, 2025 and 2030), growth factors were applied at bus route level (as opposed to road link level like other traffic). Growth factors were generated by vehicle type, road type and borough for each period of the day. For each bus route, the proportion of its distance in each road type and borough was used to produce a weighted average growth factor for flows and speed to each of the future years, using the growth factors already derived for buses. The central estimate (between low and high growth assumptions) was used in each case.

Information on past and future fleet compositions by route was provided by TfL and this was used to allocate the correct number of trips on each route to each bus size and technology.

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[29] https://tfl.gov.uk/corporate/publications-and-reports/travel-in-london-reports

Speed update using TrafficMaster GPS speed

Vehicle speeds for the major road network in the LAEI 2010 were based upon a combination of TrafficMaster GPS derived and Moving Car Observer (MCO) speeds. For LAEI 2013, new speed data derived from a GPS-based vehicle tracking system were supplied by TfL from 2010/2011, 2011/2012 and 2012/2013 observations, and averaged by AM (07:00 – 10:00), inter (10:00 – 16:00), PM (16:00 – 19:00) and evening (19:00 – 22:00) peak periods. Data from 2012/2013 were given priority over data from 2011/2012 or 2010/2011 and represented 98% of the update. Data were averaged at TOID link level, and were available for approximately 63 % of the LAEI 2013 major road links. For the remaining road links, where TrafficMaster data were not available, the LAEI 2010 speed data were retained.

Model input/output data location update

The London Emissions Toolkit (LET) is used to calculate the LAEI emissions. For the LAEI2013 the LET was modified so that it can now incorporate input data by

- Zone (ULEZ, IRR, INNER, OUTER, EXTERNAL)
- Borough
- TLRN (TfL Road Network) links split by borough
- M25 and other motorways (including A282) split between junctions

The compiled output tool was also improved to be fully consistent with the format of the input data. A sensitivity test was performed using LEGGI2013 inputs expanded to have the 3,355 polygons instead of the 2,466 km2 grids. All pollutants' totals over the LAEI area changed by < 0.01% (varies by zone) owing to this update.

Back projections and future scenarios

TfL forecasts of traffic and speed changes beyond 2013 were based on the LTS traffic model (version 7.0) and have been used to calculate traffic flows and speed for 2020, 2025 and 2030 (Table C 8 and Table C9). The traffic and speed change data are consistent with TfL's Business Plan and disaggregated by:

- Road types (TLRN, motorways, local roads)
- Location (by boroughs, external area, by motorway junctions)
- Vehicle types (cars, LGVs, Taxi, bus, HGVs)
- Time of the day: AM, Inter and PM periods and Overnight (weighted average of AM, Inter and PM)
- Low and high growth assumptions (a central estimate was used assuming that both low and high scenario are equally likely)

Vehicle fleet compositions and petrol/diesel proportions using ANPR data

The vehicle fleet composition data used in the LAEI 2013 have been provided by TfL and are based upon a combination of UK National Atmospheric Emissions Inventory (NAEI) and TfL's London-specific fleet composition data. These data fully incorporate the effects of the Mayor's Air Quality Strategy such as the ULEZ (Ultra Low Emissions Zone) from 2020. The new fleet composition used in the LAEI 2013 has been improved and now includes:

- Additional vehicle types (hybrid cars and hybrid LGVs; electric cars and electric LGVs; SCR fail cars and SCR fail LGVs; low-emissions ZEC (Zero Emission Capable) taxis; Euro 4/5 motorcycles)

- Fleet composition by location (ULEZ, IRR, INNER, OUTER, EXTERNAL)

In addition, a revision has been made to the petrol/diesel split of the car and LGV fleets to include the electric vehicles (EVs) mentioned above. As shown in Table C10 and Table C11 in the Appendix, there is a significant decrease in the proportion of diesel vehicles (cars in particular) by 2020 relative to the last LAEI.

Emissions control technology assumptions

Relative to the LAEI 2010, a number of vehicles have updated control technology assumptions for the emissions of certain pollutants, including the vehicle categories that did not exist in the LAEI 2010. These scaling factors are applied on top of the updated emissions functions. The updates are summarised in Table C12.

Emission factors and emission degradation factors

All pollutants' exhaust emissions (other than CO_2) in the LAEI 2013 have been calculated using a combination of COPERT 4v10 and v11 emission factors, as recommended by Defra. The most up-to-date factors were used for each vehicle type and pollutant. CO_2 emissions and fuel use were calculated using the same DFT/TRL factors as used in the LAEI2010. Primary NO_2 factors were taken from COPERT 4v10, other than for TfL Buses, where factors were provided directly by TfL. The percentage of PM_{10} mass from exhausts assumed to be $PM_{2.5}$ was 95% for all vehicles, in line with the assumption in Defra's Emissions Factor Toolkit v6.0.2.

Additionally, for pollutants whose emissions factors were calculated using COPERT, emission degradation factors were updated to reflect the relationship between accumulated mileage and the emission factors used in the COPERT methodology.

The inclusion of estimates of CO, Exhaust PM and hydrocarbons using COPERT 4v10 and v11 functions marks a change from the LAEI 2010, as estimates were previously made then using the DfT/TRL functions.

Non-exhaust PM emissions have been estimated in the same way as in the LAEI 2010.

Coldstarts and Evaporative Emissions

Improvements were made to the methods to estimate coldstart emissions in the LAEI2013. These are now calculated after deriving the number of trip origins of passenger cars, LGVs and taxis in each LAEI polygon, using data provided by TfL from the LoHAM model. The data was for 2012, so for the years 2008, 2010 and 2013, the 2012 data was multiplied by the observed zonal vehicle km ratios, as in Table C 3.

Future years' cold start data were derived by applying the same growth factors to 2013 local roads at borough level, as for major roads.

Average trip lengths were derived in each year for cars, LGVs and taxis separately using the total vehicle km for each of these vehicle types and the total number of starts in the Greater London area. Average annual temperature was also used on a yearly basis.

The inclusion of start data, average yearly temperature, and the recalculation of average trip lengths, marked an improvement on previous LAEIs, where one set of coldstart data existed.

The updated trip start data, along with petrol car and LGV proportions by location, were also used to estimate evaporative emissions of NMVOCs in this LAEI. The Tier I method from the latest EMEP/EEA emission inventory guidebook was used, along with weightings for each temperature range derived from meteorological data collected at Heathrow for 2008, 2010 and 2013 (2013 data was used for future years).

Spatial information

The LAEI road network, used to spatially represent emissions in London, is based upon the current OS MasterMap Integrated Transport Network (ITN) Layer[30].

Rail

Base Year 2013	• Freight-Rail activity data was sourced from Network Rail and emission factors from the NAEI. DfT's Rail Emissions Model provided both activity and emissions data for Passenger-Rail.
Future Years 2020, 2020, 2025, 2030	• Projections from the same sources as the 2013 base year data.

Diesel rail emissions are lower than LAEI 2010 due to a combination of the use of different emission factors and different assumptions on baseline activity and approach to calculations. Electric passenger-rail emissions are also lower than in LAEI 2010 due differing assumptions and approaches to calculation of energy use. Electric freight-rail emissions were not provided in the previous LAEI, and while considered in this LAEI, CO_2 emissions are low, as would be expected. For the London Underground, London Tramlink and the Dockland Light Rail, similar levels of CO_2 emissions were calculated in this update and the 2010 LAEI.

Activity Data

Freight-Rail

Activity data related to freight-rail was obtained from Network Rail. The data was provided for the purposes of this analysis and was sourced from a combination of Network Rail's Track Access Billing System and the ACTRAFF (ACtual TRAFFic) system. Information included: route descriptions; section names; section lengths; train kms; energy use and type of freight moved. The data allowed the calculation of emissions across London based routes taking into account density of train movements along the relevant links. Data was provided for 2014 and 2020, with the 2014 data used as an approximation for 2013.

The dataset was adjusted, based on expert judgement, to ensure that relevant freight movements were captured. This resulted in sections with less than 1.5 train km movements per week and routes with only engineering haulage being removed from the dataset.

Where a year of data has not been provided by Network Rail, assumptions have been made based on Office of Rail and Road and National Atmospheric Emissions

[30] ITN Road Network Theme - http://www.ordnancesurvey.co.uk/oswebsite/support/products/os-mastermap/itn-layer-technical-specification/road-network-theme.html

Inventory (NAEI) data. For 2008 a 6% increase in diesel freight train km versus 2013 is assumed; while for 2010, a 4% decrease versus 2013 is considered. This was based on analysis of NAEI and ORR data and discussions with TfL

For 2020 a 10% increase in diesel freight train km is assumed, based on analysis of NAEI and ORR data. For 2020 it is assumed that electrification does not impact on freight diesel from Paddington i.e. diesel freight trains will still run on this line in 2020 and onwards

Electric freight movements were assumed to remain the same in all years.

Passenger-Rail

Data on passenger movements were obtained from the Department for Transport's Rail Emission Model (REM). This included data for 2008, 2010, 2014 and 2019. The 2014 data was used as an approximation for 2013 and 2019 data for 2020. This is thought to be reasonable due to the small annual variation in passenger rail activity. Data on routes and the journey distance was provided in REM for each timetabled rail journey in the UK. Those journeys relevant to the LAEI were extracted. This included: routes starting and ending in London and journeys passing through London. Data was available on train km which allowed the apportionment of emissions along London specific sections of route. For diesel trains, information on diesel fuel use was also provided from the DfT REM. For diesel train km it was assumed that the same levels of train km occurred in 2008 and 2010 as were in 2013.

Data on Eurostar movements and energy consumption (kWh) were also added to the dataset. Assumptions for the introduction of High Speed rail and Crossrail are discussed under future projections.

Data on kWh use for the London Underground, London Tramlink and the Docklands Light Rail were obtained from a mixture London Energy and Greenhouse Gas Inventory data and forecast data for the Greater London Authority. Both datasets were provided by TfL. For London Underground and DLR, energy consumption data (kWh) was apportioned using the same method used in the previous LAEI in relation to train moments. For Tramlink the total energy consumption on that part of the network was split based on link length. DLR and Tramlink, data took into account the introduction of routes over the 2008 to 2013 period. For example for Tramlink the Elmers end extension was introduced in 2012 and was therefore not included in the 2008 and 2010 calculations. Routes and associated energy consumption data were also adjusted to take into account the phased introduction of the London Overground, over the period 2008 to 2013.

Emissions Factors

Diesel Rail

Diesel freight-rail emission estimates are based on emission factors from the NAEI for 2013 and adjusted for other years in line with assumptions used in the NAEI. Data is provided in the Appendix Table C 13.

For diesel passenger-rail, the results from the DfT REM model were applied as detailed data on emissions for each route was available. This data takes into account the electrification of the Great Western main line out of Paddington and the subsequent impact this would have on relevant diesel routes. For SO_2 emissions the

NAEI data was used instead or REM (for all relevant years). This reflected the introduction of a maximum sulphur content (of 10ppm) for diesel trains from 2012, which was required under the EU Fuel Quality Directive (2009/30/EC).

Electric Rail

For electric freight rail, only CO_2 emission estimates have been provided. The emission factors used were obtained from DEFRA / DECC UK Government Conversion Factors for Greenhouse Gas Emissions and are presented in Appendix Table C 14.

For electric passenger rail future projections took into account the introduction of Crossrail and the incorporation of High Speed rail links. These were based on the REM dataset and discussions with TfL.

Reductions in CO_2 emissions occur over time because of the increasing decarbonisation of the UK's electricity mix. For 2020, 2025, and 2030 it is assumed that the UK Government target of 100 g of CO_2 per KwH is achieved in 2030. It is anticipated that 20% of the move towards this will occur by 2020 with the remainder by 2030. As such a greater level of decarbonisation is assumed over the period 2020 to 2030 than in the period 2013 to 2020. CO_2 kg per KwH is presented in Table C 15.

Aviation

Base Year 2013	• Heathrow Inventory incorporated with activity data from UK Civil Aviation Authority and emissions factors from the International Civil Aviation Authority • City: Activity data from Airport Annual Performance Report 2013 • Other airports: not updated from LAEI2010 estimates
Future Years 2020, 2020, 2025, 2030	• Heathrow: incorporated inventory • City & other airports: held constant

Heathrow Airport

Aviation emissions in the LAEI 2013 are based upon the methodology described in the HAEI report[31] and include the following sources:

- Aircraft emissions (LTO (landing and take off) cycle up to 1000m height, APU (Auxiliary Power Unit), engine testing and aircraft refuelling);
- Airside vehicle emissions (road and off-road vehicles associated with aircraft turn-around);

[31] Peace, H., Walker, C.T. and Peirce, M.J. January 2015. Heathrow Airport 2013 Air Quality Assessment. Made by RICARDO-AEA to Heathrow Airport. Restricted Commercial. Ricardo-AEA/R/ED59030/Issue Number 1

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

The HAEI report is commercially restricted and as such, only a brief methodology can be provided.

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 (wheels off to throttle back - normally 305 m (1000 ft) or 457 m (1500 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 and Passenger Movement Data

Heathrow activity data for the base years 2008, 2010 and 2013 were compiled using aircraft movements from 1st January to 31st December 2008, 2010 and 2013, made available by the UK Civil Aviation Authority (CCA). The aircraft activity data included each aircraft movement by time and date, disaggregated by plane and engine type, number of engines, call sign, tail number, origin of the flight destination, operation type (arrival or departure) and runway used. The aircraft movement database is very large (>1 million records) and shows an overall aircraft movements of 472,083 in 2008, 450,735 in 2010 to 468,647 in 2013 (i.e. a reduction of 4.5% between 2008 and 2010 but an overall drop of only 0.7 % between 2008 and 2013). The total number of passengers[32] was 65.93 in 2008, 65.88 in 2010 and 72.33 million in 2013 (i.e.an overall increase of 9.7 % between 2008 and 2013). The number of aircraft movements remaining broadly constant between 2008 and 2013 reflect the fact that the airport is operating close to maximum capacity while the increase of passenger numbers can be explained by an increase of the average number of passengers per aircraft movement.

Emission Factors

To calculate aircraft emissions, the International Civil Aviation Organization (ICAO) emissions factors databank[33] was linked to the CAA aircraft movement database by engine type. The ICAO database provides jet engines certification test results of

[32] source: HAEI2013 report

[33] issue 21B released February 2015

emission factors (referred to as 'emission index' in the ICAO database), smoke number and fuel factors for every aircraft engine type. Adjustments were made to account for speed effects on stationary engine tests and engine deterioration using forward speed effect factors and degradation factors in line with recommendations from the Project for the Sustainable Development of Heathrow (PSDH)[34]. The pollutants in the ICAO database include: oxides of nitrogen, carbon monoxide and hydrocarbons by thrust setting (7 %, 30 %, 85 % and 100 %), and these have been used to represent idle, approach, climb out and take off operations. The ICAO database provides other information used in the aircraft emission calculations e.g. engine category split between TF (TurboFan) and MTF (Mixed TurboFan), bypass ratios (both used in the PM calculations) and the engine maximum rated thrust (in kilonewtons) used to estimate aircraft start-up emissions.

Thrust settings by mode

As a consequence 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. The thrust setting varied by vehicle type within each mode, ranging between: 4.5 to 6 % for taxi out, hold and taxi in modes; 70 to 100 % for take-off and initial climb; 70 to 85 % for climb out; 15 to 30 % for approach and 7 to 30 % for landing roll.

Times-in-mode

Aircraft times-in-mode have been derived from NTK (Noise and Track-Keeping) radar data and NATS (National Air Traffic Services) ground radar data and have been provided by aircraft type, NATS group, wake vortex category or runway type, and for the various LTO and APU running times. Spool up time was taken into account at the start of the take-off roll, as recommended by PSDH, to include a period during which fuel flow rates and thrust levels are significantly less than the take-off values. As part of the LAEI2013, taxi-in, taxi-out and hold durations were updated using EFPS (Electronic Flight Progress Strip) data. EFPS data were chosen over radar-based data as it was concluded that EFPS data has higher coverage and better availability and is more accurate. Approach, initial climb and climb-out were still derived using NTK data but used an updated NTK dataset in the LAEI2013. The new radar data provided more robust durations by using a much larger and better disaggregated sample size than in the LAEI2010. APU running times have been reduced in the LAEI2013 as a response to the airport Air Quality Action Plan (for example due to an increase use of PCA (Pre-Conditioned Air)).

Additional aircraft emissions

APU: Emissions factors are not included in the ICAO test results, thus emission rates were taken from the HAEI report and processed by aircraft type. 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; ECS (Environmental Control System) for air conditioning plus electrical power; and MES (main engine start) for main engine start plus electrical power.

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[34]http://webarchive.nationalarchives.gov.uk/+/http:/www.dft.gov.uk/pgr/aviation/environmentalissues/heathrowsustain/

Engine Testing Emissions: Engine testing represents a very small contribution thus the total engine testing emissions were taken directly from the HAEI report.

Refuelling Emissions: The total amount of fuel delivered to aircraft through an underground pipeline system and from individual fuel tankers was used to calculate aircraft refuelling emissions. Only fuel vapours emitted during the fuelling process and when the tankers are filled with fuel at the storage facility have been considered in the calculations. The total hydrocarbon emissions have been calculated using estimated 6 million-tonnes per annum of fuel used at Heathrow and an emission factor of 0.01 g/kg for refuelling with kerosene (or aviation turbine fuel)[35].

Start-up emissions: 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 hydrocarbon emissions have been considered. The ICCAIA (International Coordinating Council of Aerospace Industries Associations) have performed a detailed analysis of engine starting data and recommends a simple first order linear relationship between total hydrocarbons and the take-off engine thrust rating taken from the ICAO database[36]. Start-up emissions were calculated by multiplying the number of aircraft departing with the start-up hydrocarbon emissions.

Emission calculation summary for all pollutants

NO_X, CO, total hydrocarbon emissions and fuel use were calculated directly using ICAO emission factors and fuel factors. The NO_2/NO_X ratio was assumed to be 5 %[37]. CO_2 and SO_2 were derived from the fuel use, using assumed amounts of pollutant contained in aviation fuel, as given in Appendix Table C 15 alongside a list of fuel types used (by aircraft type)[38]. The fractions of total hydrocarbons used for estimating NMVOC and methane emissions were 90.43 % and 9.57 %, respectively. NMVOC was then used to calculate benzene and 1,3-butadiene emissions using factors of 0.0197 and 0.018, respectively (as given in LAEI 2008).

PM_{10} was calculated using the PSDH methodology and the ICAO smoke number, estimated by aircraft and engine type. This method is described in the LAEI 2008 methodology documents[39]. 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 were the same for this source. PM_{10} non-exhaust emissions were also included as:

[35] https://www.gov.uk/government/organisations/department-of-energy-climate-change/series/digest-of-uk-energy-statistics-dukes

[36] ICAO, First Edition 2011. Airport Air Quality Manual. Order Number: 9889, ISBN 978-92-9231-862-8

[37] AEA (June 2007). Emissions of Nitrogen Dioxide and Nitrous Acid from Road Transport and Other Sources, Report to The Department for Environment, Food and Rural Affairs, Welsh Assembly Government, the Scottish Executive and the Department of the Environment for Northern Ireland, ED05450007, Issue 1, June 2007)

[38] Watterson, J., Walker, C. and Eggleston, S. (July 2004) Revision to the Method of Estimating Emissions from Aircraft in the UK Greenhouse Gas Inventory Report to Global Atmosphere Division, DEFRA netcen/ED47052. http://naei.defra.gov.uk/reports/reports?report_id=316

[39] https://data.london.gov.uk/dataset/laei-2008

- PM_{10} brake wear emissions, estimated for each landing, using the emission factor; 2.53×10^{-7} kg PM_{10} per kg MTOW (Maximum Take Off Weight).
- PM_{10} tyre wear emissions, calculated as the amount of weight lost per landing using the emission factor; 2.23×10^{-6} kg PM_{10} per kg MRW (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.

Projected emissions

All Heathrow aircraft emissions in 2020 and 2030, except refuelling and start up, were calculated by scaling the LAEI 2013 base year 2013 data to the HAEI emissions in 2020 and 2030[40]. 2025 emissions were estimated using linear interpolation between 2020 and 2030 emissions data. Since 1950s, the Cranford Agreement applies when Heathrow is on easterly operations. Heathrow wants to end the Cranford Agreement thus all future cases assume full easterly alternation (i.e. no Cranford Agreement in place).

Refuelling and start-up projected emissions in 2020, 2025 and 2030 were scaled to Heathrow's CO_2 aircraft emissions change.

Non-aircraft emissions methodology

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

Airside vehicle sources

Airside vehicle emissions were estimated based on fuel use data combined with the latest available emission factors (COPERT 4v10) 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 (gasoil, diesel, petrol and LPG) and by airside vehicle categories such as road vehicles (car, LGV, HGV, bus) and off-road vehicles diesel (37-75 kW, 75-13 kW and 130-560 kW), petrol and LPG. Additional airside vehicle operation data such as the fraction of time idling and average speed when moving were also taken into account.

Landside vehicle sources

Landside vehicle emissions from staff car parks, taxi queues, car rental and public car parks have been estimated by combining cold-start and exhaust emissions derived from vehicle parking transaction data, total distance travelled and the emission factor by vehicle category. New emissions factors were also used based on COPERT 4v10. Emissions from taxis queuing at the terminal forecourts were estimated using the total number of taxis passing through the TFP (Taxi Feeder Park) combined with the average time spent queuing at each terminal.

Stationary sources

Heating plant emissions have been calculated by combining fuel consumption by fuel type (gas and gasoil) for each heating plant (e.g. 448, T2,T4, T5, BA Cargo, 1157 ASU) and their specific emission factors (updated with those in the NAEI). As part of

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[40] AEA-Ricardo

the LAEI2013 update, new plants have been included like the new biomass plant and some have been removed like the Thames Valley Power Combined Heat and Power (CHP) plant, which was decommissioned in 2011.

Fire-training ground emissions are very small and were estimated using the total LPG fuel consumed by the fire service at Heathrow (using new estimates for 2013) combined with emission factors from commercial boilers.

Base case and projected non-aircraft emissions

All non-aircraft Heathrow emissions in 2020 and 2030 were taken from HAEI emissions in 2020 and 2030[41]. 2025 emissions were estimated using linear interpolation between 2020 and 2030 emissions data. NO_X and PM emissions were provided in 2020 and 2030 but CO_2 was only given in 2020. CO_2 and all the other pollutants were scaled to their NO_X change between 2020 and 2030.

London City Airport

The Heathrow Airport emissions methodology has been adapted for use at 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. As a consequence, only a brief overview of the assumptions used at London City airport has been provided.

Aircraft Emissions

Aircraft activity data from London City airport have been compiled using information from the 2010 and 2013 London City Airport Annual Performance Report (APR)[42]. Aircraft movements in 2010 and 2013, by aircraft type, are summarised in Appendix Table C16.

The ICAO emission and fuel factor database has been linked to aircraft movements from the APR report using the most common engine for each aircraft type and based upon knowledge gained at Heathrow. The aircraft movements were split equally between arrival and departure[43].

Assumptions for aircraft times-in-mode (Appendix Table C17) were extracted from the 2007 Planning Application report[44] provided by London City via TfL.

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 APU's have been made using a similar approach to that used in the Heathrow Airport calculations.

At London City Airport, aircraft departing towards the west stop ascending below 1000 m altitude (near London Bridge) and maintain this altitude until clear of the London Heathrow inbound flight path, i.e. up to the LAEI boundary. When landing from the west, aircraft are not on a continuous descent profile but stay below 1000 m until commencing their final descent near London Bridge. This additional source of emissions was calculated using a low thrust of 15 %, by assuming a steady cruise-

[41] AEA-Ricardo

[42] London City Airport APR (Annual Performance Report) 2010, 2013 and 2014 released in 1 August 2011 , 8 July 2014 and 1 July 2015, respectively

[43] London City Airport

[44] http://www.londoncityairport.com/AboutAndCorporate/page/PlanningApplication

out mode (following climb out toward the west) and cruise-in mode operation (before landing from the west).

Non-aircraft emissions

All other city airport sources are considered to be small, and due to a lack of more specific information, the emissions in 2010 was taken from the LAEI2010 and growth to 2013 using the total aircraft movement changes between 2010 and 2013.

Projected emissions

London City airport projected emissions were scaled backward to 2008 based on London City Airport monthly statistics of total aircraft movements from 1998 to 2011[45] and forward to 2020, 2025 and 2030 based on extrapolating the aircraft movement changes between 2010 and 2014[46]. A summary of the total aircraft movements for all the years covered can be found in Appendix Table C18.

Other smaller airports

Because of a lack of new and reliable activity datasets for Stapleford, Denham, Elstree, Northolt, Biggin Hill, Battersea Heliport and Lippits Hill Heliport, and the relatively small contribution to total emissions from these sources, estimates of emissions for 2010 were taken directly from the LAEI 2010.

Since no published data exists for 2013 and beyond, emissions for years beyond 2010 were kept constant.

Spatial Information

The spatial representation of all the London airports has been based upon the LAEI 2010. Emission estimates were spatially analysed by source type to create geographically accurate emissions source locations for use with dispersion modelling. The source locations include:

- Point sources: hold, start up, APU, engine testing, airside vehicles, stationary sources and refuelling of aircraft;
- Line sources: taxi out, take off, initial climb, climb out, cruise-in, cruise-out, approach, landing roll and taxi in;
- Area sources: landside vehicles.
- When judged appropriate, the spatial representation was improved to give a more accurate representation of the various sources.

Heathrow Airport

Appendix Table C19 shows runway utilisation for 2013 and the assumptions used for all future years 2020, 2025 and 2030 (2020+). In 2013, very few easterly operations were taking place from 09L runway aircraft departure (0.4%) and 09R runway aircraft arrival (1.2%) due to the Cranford agreement in place (see runway 09L, 09R, 27L, 27R location in Figure 4).

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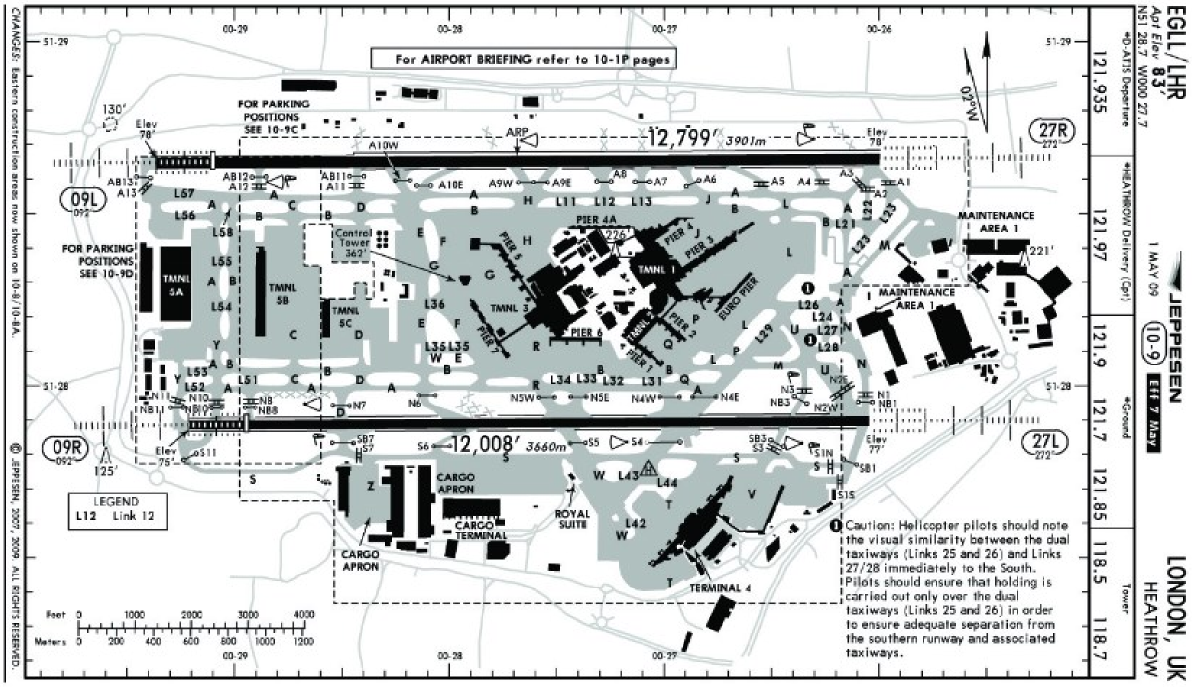
[45] http://www.lcacc.org/statistics/lcystat2.pdf

[46] London City Airport APR (Annual Performance Report) 2014 released in 1 July 2015

Figure 4 Heathrow airport diagram[47].



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. Heathrow wants to end the Cranford Agreement and believes that full easterly operation will be in place by 2020 (C, Walker (AEA-Ricardo), personal communication).

From 2020 full easterly operation has been assumed, resulting in a more even distribution of aircraft movements between the two runways (see details of runway utilisation in 2013 and beyond 2020 in Appendix Table C19). Westerly aircraft movement fraction is assumed to be unaffected and kept constant beyond 2013.

London City Airport

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. A new mode, cruising-in/cruising-out was plotted at km^2 grid level, to represent the aircraft maintaining altitude just below 1000 m until clear of the London Heathrow inbound flight path (between London Bridge and the LAEI boundary. 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)[48]

[47] http://www.nycaviation.com/spotting-guides/lhr/lhr-general-information/

[48] (London City via TfL, personal communication)

Miscellaneous

Agriculture

Combustion

Base Year 2013	• Proportion of NAEI emissions in London determined from CEH 2007 land cover map
Future Years 2020, 2020, 2025, 2030	• Projected using DECC Energy projections

The agriculture combustion sector for the LAEI includes heating of buildings using non-gas fuels and the use of off-road vehicles. The emission estimates have been updated using the same approach as in the LAEI 2010 but the total emissions covered by this sector have been updated based on the latest NAEI data. Gas emissions have been excluded because these are covered in the gas consumption estimates of the LAEI and emissions from burning straw have also been excluded because these are considered not relevant in London.

UK emissions data for air pollutants were obtained from the NAEI. The LAEI emission was calculated as a fraction of total UK emissions using CEH land cover data for 2007[49]. This data details the amount of different land cover types in each 1km grid square of the UK. The 2007 dataset is still the most recent available. Arable and improved grassland land cover types were chosen because these are most relevant for this sector. The analysis found that 0.65% of UK emissions from agriculture combustion should be allocated to the LAEI area. Emissions have been mapped within the LAEI grid using the same land cover data. The same assumptions were used for all historic years.

DECC Updated Energy Projections data for 2014 were used to derive projection factors to apply to the 2013 baseline agriculture energy consumption emissions in order to estimate emissions in future years. The High Growth DECC scenario has been chosen to apply to the LAEI emissions, specifically for the consumption of petroleum products use in Agriculture. The DECC data shows a flat projection between 2020 and 2030 at a rate of 63.7% of the 2013 consumption.

Livestock

Base Year 2013	• Proportion of NAEI emissions in London alloacted in accordance with the agricultural census.
Future Years 2020, 2020, 2025, 2030	• Future emissions have been estimated based on Non-CO_2 GHG inventory agriculture projections

[49] http://www.ceh.ac.uk/landcovermap2007.html

Emissions from animal husbandry and manure management were calculated as a fraction in the LAEI area of the UK NAEI emission. UK emissions data for air pollutants were obtained from the NAEI. The fractions of the UK emission within the LAEI area were calculated on the basis of animal numbers from the agricultural census at Local Authority level for June 2010 and 2013. This dataset was obtained from Defra[50]. Estimates for 2008 were based on 2010 data. Some manipulations of the data were necessary to match the Defra data to the London boroughs and surrounding areas because of aggregation of some boroughs in the Defra data. The calculated fractions of UK emissions by emission source are shown in Table D 1, together with notes on emission mapping methods.

Projections of emissions from livestock and other non-energy agriculture emissions (see below) were obtained from agricultural emissions projections from Rothamsted[51]. These are consistent with the NAEI data used. Projection factors were calculated based on these data to apply to the LAEI 2013 estimates for all pollutants to calculate estimates for 2020, 2025 and 2030. The projection factors are shown in Table D 3 in the Appendix.

Other Agriculture

Base Year 2013	• Proportion of NAEI emissions in London alloacted in accordance with CEH land cover maps.
Future Years 2020, 2020, 2025, 2030	• UK Agriculture GHG emissions projections

This sub-sector covers emissions from fertilisers and soils. Emissions of PM_{10} from soils were added for the 2013 LAEI as it was not included in the 2010 inventory. Emissions from synthetic nitrogen fertilizers were mapped as in the LAEI 2010, using arable land cover data. The full list of sub-sectors and fraction of UK emissions is shown in Appendix Table D 2.

Projections of emissions from non-energy agriculture emissions were obtained from agricultural emissions projections from Rothamsted[52]. These are consistent with the NAEI data used. Projection factors were calculated based on these data to apply to the LAEI 2013 estimates for all pollutants to calculate estimates for 2020, 2025 and 2030. The projection factors are shown in Appendix Table D 3.

50 https://www.gov.uk/government/statistical-data-sets/structure-of-the-agricultural-industry-in-england-and-the-uk-at-june

51 UK Agriculture GHG Emission Projections 2012-2030, Tom Misselbrook, Rothamsted Research, 30th January 2014

52 UK Agriculture GHG Emission Projections 2012-2030, Tom Misselbrook, Rothamsted Research, 30th January 2014

Accidental Fires & Bonfires

Base Year 2013	• London Fire Brigade Incidents data combined with NAEI emission factors and estimates of mass burnt
Future Years 2020, 2020, 2025, 2030	• held constant from base year

The emission estimates for accidental fires have been significantly improved through the use of a database of fire incidents combined with estimates of mass burnt and application of NAEI emission factors. Emissions estimates are broadly similar to previous estimates but the mapped historic emissions now represent actual locations of fires. Estimates for Benzo[a]pyrene and PCBs have been added for the first time.

Activity data

An improvement in methodology has been possible for this sector through the use of a detailed dataset of London Fire Brigade (LFB) Incidents[53]. This has provided a more accurate representation of the locations of emissions from accidental fires in past years. This sector is an important contributor of Persistent Organic Pollutants (POPs), which have been included in the LAEI 2013 for the first time. The dataset also includes incidents that were attended to outside the London Borough boundaries, which have provided additional data for the wider LAEI area. Illustrations of the data available are shown in the chart and map in the Appendix. For emissions mapping purposes, each incident has been allocated to the LAEI grid.

To enable emissions estimates to be made, the fire incidents property type field has been matched to the relevant NAEI sector as shown in Appendix Table D 4. Quantities of material burnt in each fire have been estimated in order to be able to apply the NAEI emission factors (see section below) to aggregated fires data and calculate emissions for each LAEI grid square.

Emissions due to accidental fires in vegetation and forest have been estimated based on area of vegetation burnt; while estimates for vehicles, dwelling, other building and straw have been estimated based on mass burnt. The quantities burnt in each fire incident have been estimated based on information in the LFB Incidents database regarding the number of pumps sent to attend the fire. Assumptions about the relationship between the number of pumps and the quantities burnt are shown in the Appendix, classified into size groups. These are based on expert judgement combined with data on combustible material presented in a room[54] from the Furniture Reuse Network publication Annex C Recycling Report FRN weights (2005)[55].

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[53] http://data.london.gov.uk/dataset/london-fire-brigade-incident-records/resource/7cd05a70-1e84-433b-847e-4e13a7f12610

[54] The average burnt material mass presented in a room, excluding bathroom, is estimated to be 250kg

[55] Published by the Furniture Reuse Network www.frn.org.uk

The LFB incidents dataset starts in 2009 and therefore data for 2009 have been used to provide an estimate for 2008, whereas actual data have been used for 2010 and 2013.

Emission factors

The emission factors used are those for 2012 for the various types of Accidental fires listed in the NAEI Emission Factors Database. Within the NAEI the emission factors do not vary by year therefore the NAEI emission factors have been applied to all years within the LAEI. The emission factors are mostly on the basis of quantity of emissions per amount of mass burnt. These have been applied to the accidental fires data in the most appropriate way possible to best match the type of material burnt in each fire type.

Within the sub-sector of LAEI Accidental fires called 'other buildings', two sets of emissions factors have been used, in order to apply the 'Small scale waste burning' emission factors to those fires that state that the material burnt was refuse rather than other types of property in this category. The Table D 7 in the Appendix presents the emission factor used for each category of accidental fires:

The emissions estimates made are broadly similar to previous estimates considering the very different approach used. Exceptions to this are a significant decrease of 60% in the estimate for CO emissions and an increase of 43% for $PM_{2.5}$. Estimates for Benzo[a]pyrene and PCBs have been added for the first time.

Future emissions estimates

The time series of the number of fires in London was considered in order to evaluate how to project emissions into the future for accidental fires related to buildings and other property. The data, in the Appendix, shows a generally downward trend in the number of fires.

The reason for the downward trend in the dwelling fires is likely due to the uptake of smoke detectors. Between 2002-03 and 2012-13, there was a significant increase in the proportion of households with at least one working smoke alarm, from 76% to 88%[56]. The UK already has fire safety regulations stricter than EU, and market penetration for smoke detectors is high. Therefore it is considered that it is unlikely that additional smoke alarms will continue to make significant difference in the number of fires in future.

The emissions estimates for accidental fires for future years have, however, been adjusted for all pollutants based on household growth forecasts derived from ward level data obtained by TfL from the GLA demand modelling team (GLA unpublished).

[56] English Housing Survey Fire and fire safety report, 2012-13 - https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/335124/Chapter_1__Smoke_alarms_and_fire_safety_measures.pdf

Forests - Biosynthesis

Base Year 2013	• Proportion of NAEI emissions in London alloacted in accordance with CEH land cover maps.
Future Years 2020, 2020, 2025, 2030	• held constant from base year

Estimates of forestry NMVOC emissions have been estimated for 2013 using the same methodology as for 2010. The LAEI fraction of the UK emission was calculated based on the fraction of UK woodland land cover that is in the LAEI area, using the CEH land cover maps. This emission estimate does not change over time within the NAEI emission methodology.

Biogenic emissions are affected by temperature and solar radiation therefore this simple method may slightly under represent actual emissions because emissions will be higher in London as it is on average warmer and sunnier then many other locations of the UK.

Appendix A: Industrial & Commercial Data Tables

Table A1 NAEI Emission Factors for Industrial and Commercial Solid and Liquid fuels (kt emission per Mt fuel)

Fuel Name	Pollutant	2008	2010	2013
Fuel oil	CO_2	3223	3223	3223
	Cd	0.000295	0.000295	0.000295
	CH_4	0.433	0.433	0.433
	CO	0.577	0.548	0.535
	Hg	0.0000147	0.0000147	0.0000147
	N_2O	0.0260	0.0260	0.0260
	NOx	7.24	7.33	7.18
	Pb	0.000522	0.000522	0.000522
	PM_{10}	0.765	0.945	0.584
	$PM_{2.5}$	0.132	0.260	0.224
	SO_2	17.7	14.3	14.2
	NMVOC	0.138	0.138	0.138
Coal	BaP	0.00000225	0.00000225	0.00000225
	Benzene	0.00189	0.00189	0.00189
	CO_2	2578	2244	2317
	Cd	0.000030	0.000030	0.000030
	CH_4	0.011	0.011	0.011
	CO	9.366	7.123	8.628
	Hg	0.00045	0.00045	0.00045
	N_2O	0.147	0.147	0.147
	NH_3	0.000279	0.000279	0.000279
	NOx	6	5	6
	Pb	0.00476	0.00476	0.00476
	PCB	0.000001	0.000001	0.000001
	PM_{10}	3.77	3.21	3.77
	$PM_{2.5}$	3.48	2.96	3.48
	SO_2	17.2	16.9	15.0
	NMVOC	0.050	0.050	0.050

Table A2 Projection factors for predicted reduction in use of solid and liquid fuels in the industrial and commercial sectors

Year	Fuel oil	Coal
2020	0.334	0.922
2025	0.216	0.866
2030	0.171	0.856

Table A3 Natural Gas Emission factors for Industrial and Commercial sector (kg emission per GWh)

Pollutant	2008	2010	2013 [2]
Benzene	0.729	0.729	0.729
CO_2 [1]	184466	184153	183806
CH_4	18.000	18.000	18.000
CO	43.7	39.3	35.8
N_2O	0.30	0.36	0.36

NO_x	204.5	196.4	182.013
PM_{10}	3.074	3.084	2.750
$PM_{2.5}$	3.073	3.083	2.750
NMVOC	8.02	8.02	8.02

1 Converted from carbon factor

2 Based on NAEI data for 2012 from the 2012 inventory dataset

Table A4 Part A1 processes which were assumed to be included in the DECC MSOA data but corresponding gas consumption double counting removed

Site Name	Operator Name	Sector	Borough
Erith Oil Works	Archer Daniels Midland Erith Ltd	Industrial	Bexley
Oakthorpe Dairy	Arla Foods Ltd	Industrial	Enfield
Greenwich Generating Station	EDF Energy Powerlink Ltd	Power generation	Greenwich
Thames Refinery	Tate & Lyle Plc	Industrial	Newham

Table A5 Part A1 processes not included in the DECC MSOA data

Site Name	Operator Name	Sector	Borough
Ford Motor Combustion Plant	Ford Motor Company Ltd	Industrial	Barking and Dagenham
Barking Power	Thames Power Services Ltd	Power generation	Barking and Dagenham
Enfield Power Station	E.ON UK PLC	Power generation	Enfield
Citigen London Ltd	Citigen UK Ltd	CHP	Islington

Table A6 Projection factors for Industrial and commercial gas consumption, applied to 2013 emissions estimates

Year	Natural gas projection factor
2020	0.628
2025	0.485
2030	0.457

Table A7 Estimated Natural gas leakage in London (GWh)

	North London (National Grid)	South London (SGN)	Total
2008	272	182	454
2010	263	171	435
2013	220	154	374

Table A8 Emission Factors for Gas Leakage from gas supply, NAEI 2013, kilotonnes per kt natural gas leaked

Pollutant	2008	2010	2013
CO_2 *	0.036	0.029	0.035
CH_4	0.790	0.801	0.799
Benzene	0.002	0.0016	0.0015
NMVOC	0.143	0.143	0.138

* Converted from Carbon in NAEI EF Database

Table A9 Future projections of gas leakage provided by National Grid for North London (GWh)

	2013	2020	2025	2030
North London	220	161	138	115
Percentage of 2013		73%	63%	52%

Table A 10 Assumed Population Growth Rates

Year	Population
2011	8,217,475
2016	8,779,641
2021	9,203,293
2026	9,543,718
2031	9,839,366
2036	10,110,876
2041	10,354,773

Table A 11 UK Emissions from Small Scale Waste Burning (obtained from NAEI)

Year	Emission Source	NOx	NMVOC	PM_{10}	$PM_{2.5}$	CO	BaP	PCB
	Units:	kt	kt	kt	kt	kt	kg	kg
2008	Open fireplaces	0.106	0.678	0.498	0.463	2.410	5.376	44.401
2008	Bonfires	0.012	0.802	1.046	0.972	3.326	3.068	3.507
2008	Other	0.102	0.519	0.299	0.277	1.821	5.961	33.007
2008	Total small-scale waste burning	0.220	1.999	1.843	1.712	7.556	14.406	80.915
2010	Open fireplaces	0.106	0.678	0.498	0.463	2.410	5.376	44.401
2010	Bonfires	0.012	0.814	1.062	0.987	3.377	3.116	3.561
2010	Other	0.102	0.519	0.299	0.277	1.821	5.961	33.007
2010	Total small-scale waste burning	0.221	2.011	1.859	1.727	7.608	14.453	80.969
2013	Open fireplaces	0.106	0.678	0.498	0.463	2.410	5.376	44.401
2013	Bonfires	0.013	0.837	1.092	1.015	3.473	3.204	3.663
2013	Other	0.102	0.519	0.299	0.277	1.821	5.961	33.007
2013	Total small-scale waste burning	0.221	2.034	1.889	1.755	7.704	14.541	81.071

Table A 12 Fraction of UK Small scale waste burning Emission in London

Emission source	Estimate of % of UK emission in London	Data used
Domestic bonfires	8.12%	Suburban land cover (CEH)
Domestic Open fireplaces	0.73%	Households reporting solid fuel burning in 2011 Census
Other (industrial and construction)	11.48%	Construction activity (as used for construction NRMM estimates)

Appendix B: Domestic Data Tables

Table B 1 NAEI Emission Factors for Domestic Solid and Liquid fuels (kt emission per Mt fuel)

Fuel Name	Pollutant	2008	2010	2013
Burning oil	Benzene	0.002	0.002	0.002
	CO_2	3150	3150	3150
	Cd	0.00001	0.00001	0.00001
	CH_4	0.462	0.462	0.462
	CO	1.848	1.848	1.848
	Hg	0.0000001	0.0000001	0.0000001
	N_2O	0.028	0.028	0.028
	NOx	3.234	3.234	3.234
	Pb	0.00009	0.00009	0.00009
	PM_{10}	0.139	0.139	0.139
	$PM_{2.5}$	0.139	0.139	0.139
	SO_2	0.592	0.506	0.672
	NMVOC	0.047	0.047	0.047
Coal	BaP	0.00003	0.00003	0.00003
	Benzene	0.075	0.075	0.075
	CO_2	3082	3082	3082
	Cd	0.00003	0.00003	0.00003
	CH_4	2.000	2.000	2.000
	CO	173.500	173.500	173.500
	Hg	0.00011	0.00011	0.00011
	N_2O	0.142	0.142	0.142
	NH_3	0.990	0.990	0.990
	NOx	3.470	3.470	3.470
	Pb	0.003	0.003	0.003
	PCB	0.000	0.000	0.000
	PM_{10}	1.150	1.150	1.150
	$PM_{2.5}$	1.133	1.133	1.133
	SO_2	15.993	15.170	15.573
	NMVOC	1.700	1.700	1.700
SSF	BaP	0.00033	0.00033	0.00033
	Benzene	0.217	0.217	0.217
	CO_2	2839	2839	2839
	Cd	0.00003	0.00003	0.00003
	CH_4	5.800	5.800	5.800
	CO	173.500	173.500	173.500
	Hg	0.00011	0.00011	0.00011
	N_2O	0.120	0.120	0.120
	NOx	3.260	3.260	3.260
	Pb	0.003	0.003	0.003
	PCB	0.000004	0.000004	0.000004
	PM_{10}	3.05	3.05	3.05
	$PM_{2.5}$	3.005	3.005	3.005
	SO_2	16.0	16.0	16.0
	NMVOC	4.9	4.9	4.9

Table B 2 Projection factors for predicted reduction in use of solid and liquid fuels in the domestic sector

Year	Burning Oil	Coal and SSF
2020	0.860	0.396
2025	0.811	0.190
2030	0.829	0.126

Table B 3 Natural Gas Emission factors for the Domestic sector

Pollutant	2008	2010	2013 [2]
Benzene	0.722	0.722	0.722
CO_2 [1]	184466	184153	183806
CO	110.9	110.9	110.9
CH_4	18	18	18
N_2O	0.360	0.360	0.360
PM_{10}	1.800	1.800	1.800
$PM_{2.5}$	1.800	1.800	1.800
NMVOC	8.020	8.020	8.020

1 Converted from carbon factor

2 Based on NAEI data for 2012 from the 2012 inventory dataset

Table B 4 NOx emission factors for domestic gas combustion, by Borough (mg/kWh)

Borough	Gap Filled using Average	2008	2010	2013	2020	2025	2030
Barking and Dagenham		160.64	152.78	143.22	111.17	92.98	92.98
Barnet	Outer	158.61	149.33	139.74	108.43	90.74	90.74
Bexley		159.41	151.24	141.51	109.49	91.84	91.84
Brent	Outer	158.61	149.33	139.74	108.43	90.74	90.74
Bromley		158.87	150.00	140.96	111.40	93.69	93.69
Camden		155.50	145.72	135.18	104.66	87.51	87.51
City of London	Inner	160.03	151.62	142.34	110.94	93.10	93.10
Croydon		161.36	153.23	144.61	113.94	95.54	95.54
Ealing	Outer	158.61	149.33	139.74	108.43	90.74	90.74
Enfield	Outer	158.61	149.33	139.74	108.43	90.74	90.74
Greenwich		159.42	150.38	140.39	108.92	91.19	91.19
Hackney		159.15	151.14	141.83	110.33	92.65	92.65
Hammersmith and Fulham		156.15	146.01	134.97	103.01	86.28	86.28
Haringey	Outer	158.61	149.33	139.74	108.43	90.74	90.74
Harrow	Outer	158.61	149.33	139.74	108.43	90.74	90.74
Havering		161.20	153.27	145.34	113.86	95.70	95.70
Hillingdon	Outer	158.61	149.33	139.74	108.43	90.74	90.74
Hounslow		158.72	149.86	139.86	106.07	89.59	89.59
Islington		160.03	151.62	142.34	110.94	93.10	93.10
Kensington and Chelsea		159.19	149.76	140.03	107.49	89.68	89.68
Kingston upon Thames		160.74	152.29	143.67	113.56	95.32	95.32

Lambeth		160.11	151.33	142.89	112.19	94.39	94.39
Lewisham	Inner	160.03	151.62	142.34	110.94	93.10	93.10
Merton		161.81	153.52	144.47	111.94	93.61	93.61
Newham		158.20	149.49	139.37	107.86	90.55	90.55
Redbridge		158.43	149.08	139.81	109.09	91.82	91.82
Richmond upon Thames		161.28	153.22	144.77	114.05	95.45	95.45
Southwark		160.48	151.83	142.67	110.70	92.75	92.75
Sutton		160.78	152.62	143.43	112.70	94.51	94.51
Tower Hamlets		156.88	146.88	137.02	104.79	88.00	88.00
Waltham Forest		158.81	150.47	139.96	107.16	89.96	89.96
Wandsworth		159.81	150.69	141.55	109.56	91.68	91.68
Westminster	Inner	160.03	151.62	142.34	110.94	93.10	93.10
Non GLA	Outer	158.61	149.33	139.74	108.43	90.74	90.74

Table B 5 Projection factors for Domestic gas consumption, applied to 2013 emissions estimates

Year	Natural gas projection factor
2020	0.869
2025	0.871
2030	0.935

Appendix C Transport Data Tables

Table C 1 Operators of scheduled and other services

Operators of scheduled services	Operators of other services
MBNA Thames Clippers	Bateaux London
City Cruises	City Cruises
Thames River Services	London RIB Voyages
Crown River Cruises	Thames RIB Experience
London Eye	Mainstream Leisure
WPSA (Westminster Passenger Service Association)	Westminster Party Boats
Turks Launches	Viscount Cruises (formerly Campion Launches)
Briggs Marine and Environmental (Woolwich Ferry)	

Table C 2 Taxi/(taxi+car) ratio by location (average of MCC hourly data)

Location	Taxi / (Taxi + Car) ratio	
	LAEI2010	LAEI 2013
ULEZ	0.211	0.310
IRR	0.139	0.216
Inner	0.066	0.121
Outer	0.027	0.028
External	0.024	0.016

Table C 3 Billion vehicle km driven in Greater London between 2008 and 2013, by area

Year	Billion vehicle km driven in the Greater London area			
	Central	Inner	Outer	Greater London area
2008	1.09	8.29	20.89	30.27
2009	1.05	8.19	20.83	30.07
2010	1.03	8.05	20.63	29.70
2011	1.01	7.82	20.28	29.10
2012	0.99	7.57	20.35	28.90
2013	0.97	7.42	20.43	28.82

Source: Department for Transport

Table C 4 Billion vehicle km driven in Greater London in 2008, 2010 and 2013, by road type

Year	Billion vehicle km driven in the Greater London area			
	Major roads	LTS roads	Minor roads	All roads
2008	20.57	5.25	4.45	30.27
2010	20.35	5.07	4.28	29.70
2013	20.35	5.07	4.28	29.70

Note that rounding of raw data means that the sum of the road types does not necessarily equal the 'All roads' value in this table.

Table C 5 Billion vehicle km driven in the GLA in 2008, 2010 and 2013, by vehicle type.

Year	Billion vehicle km driven in the Greater London area							
	Motorcycles	Taxis	Cars	Buses	LGVs	Rigid HGVs	Articulated HGVs	Total
2008	0.67	1.10	23.29	0.72	3.29	0.92	0.29	30.27
2010	0.63	1.07	22.86	0.72	3.22	0.92	0.28	29.70
2013	0.61	1.01	22.13	0.72	3.18	0.89	0.28	28.82

Note that rounding of raw data means that the sum of the vehicle types does not necessarily equal the Total values in this table.

Table C 6 Weighted average TfL Bus speeds (km/h) in different locations of the LAEI in 2013, before and after the update to speeds using iBus data

	Location	Speed	
		pre update	post iBus update
Major roads	Central	18.1	11.8
	External	73.4	21.9
	Inner	24.8	14.1
	Outer	38.1	17.5
LTS Roads	Central	13.9	11. 8
	External	35.5	21.2
	Inner	24.8	14.5
	Outer	31.5	17.7

Note, the external speed prior to the update was particularly high because of the dominant effect of motorways in this area on Bus + Coach flows. These speeds (before updating with iBus data) are still used for coaches, which make up all the bus traffic on motorways.

Table C 7 Changes in vehicle km (%) as a result of updating the method for TfL Buses using iBus data (relative to the previous LAEI method)

Location	Bus + Coach	TfL Bus	Coach
Central	112.46%	112.11%	107.66%
External	101.86%	14.25%	385.96%
Inner	117.41%	122.83%	86.28%
Outer	118.60%	104.91%	151.24%
LAEI	115.81%	99.77%	158.90%
GLA	117.75%	111.70%	125.94%

Table C 8 Traffic growth by vehicle type, shown for each location (and also over the GLA and whole LAEI) as a percentage change between 2013 and each forecast year

Year	Vehicle km ratios to 2013									
	Location	MC	Taxi	Car	LGV	iBus	Coach	Rigid	Artic	Total
2020	Central	0.5%	1.5%	0.6%	7.1%	2.4%	2.5%	-0.2%	0.4%	1.7%
	External	11.1%	4.7%	11.4%	10.3%	1.7%	0.8%	1.9%	3.1%	10.6%
	Inner	2.6%	1.4%	3.4%	8.9%	2.3%	2.3%	0.7%	0.6%	3.7%
	Outer	4.7%	1.8%	4.7%	7.7%	1.9%	1.4%	0.3%	-0.7%	4.7%
	GLA	3.5%	1.6%	4.4%	8.0%	2.1%	1.7%	0.4%	-0.5%	4.4%
	LAEI	4.8%	1.8%	6.9%	8.8%	2.1%	1.4%	0.9%	1.8%	6.6%
2025	Central	0.9%	3.0%	1.1%	11.9%	2.7%	2.8%	-0.1%	-0.3%	2.9%
	External	16.1%	14.0%	16.8%	18.1%	2.0%	0.9%	4.1%	6.4%	16.1%
	Inner	4.2%	2.9%	5.3%	15.0%	2.6%	2.6%	1.2%	1.1%	6.0%
	Outer	7.5%	4.1%	7.7%	14.0%	2.1%	1.6%	1.6%	2.9%	7.9%
	GLA	5.5%	3.4%	7.1%	14.2%	2.4%	1.9%	1.4%	2.6%	7.3%
	LAEI	7.4%	4.3%	10.5%	15.6%	2.4%	1.6%	2.3%	5.1%	10.3%
2030	Central	1.4%	4.5%	1.6%	16.7%	2.7%	2.8%	0.0%	-0.3%	4.2%
	External	20.3%	24.8%	21.4%	26.0%	2.0%	0.9%	6.4%	10.1%	21.0%
	Inner	5.6%	4.5%	7.1%	21.1%	2.6%	2.6%	1.7%	1.6%	8.2%
	Outer	10.0%	6.6%	10.5%	20.5%	2.1%	1.6%	3.0%	7.6%	11.1%
	GLA	7.5%	5.4%	9.6%	20.5%	2.4%	1.9%	2.5%	6.7%	10.2%
	LAEI	9.7%	7.0%	13.8%	22.5%	2.4%	1.6%	3.8%	8.9%	13.9%

Table C9 Speed changes, expressed by location as percentage changes between 2013 and each forecast year, and after having calculated weighted average speeds over all (non-TfL Bus) vehicles

Year	Location	% change
2020	Central	1.25
	External	-4.35
	Inner	-0.91
	Outer	-1.06
2025	Central	2.23
	External	-7.34
	Inner	-1.64
	Outer	-1.80
2030	Central	3.24
	External	-10.35
	Inner	-2.39
	Outer	-2.61

Table C10 Proportions of petrol, diesel and electric cars and LGVs for each year and location in the LAEI 2013

Cars							
		2008	**2010**	**2013**	**2020**	**2025**	**2030**
ULEZ	Electric	0.00	0.00	0.00	0.01	0.02	0.03
	Petrol	0.68	0.67	0.63	0.58	0.58	0.58
	Diesel	0.32	0.33	0.37	0.42	0.40	0.39
IRR	Electric	0.00	0.00	0.00	0.01	0.02	0.03
	Petrol	0.68	0.67	0.63	0.56	0.57	0.58
	Diesel	0.32	0.33	0.37	0.44	0.41	0.39
Inner	Electric	0.00	0.00	0.00	0.01	0.02	0.03
	Petrol	0.68	0.67	0.63	0.54	0.56	0.58
	Diesel	0.32	0.33	0.37	0.45	0.42	0.39
Outer/External	Electric	0.00	0.00	0.00	0.01	0.02	0.03
	Petrol	0.68	0.67	0.63	0.54	0.56	0.58
	Diesel	0.32	0.33	0.37	0.46	0.42	0.39
LGVs							
		2008	**2010**	**2013**	**2020**	**2025**	**2030**
ULEZ	Electric	0.00	0.00	0.00	0.03	0.06	0.10
	Petrol	0.04	0.04	0.02	0.03	0.02	0.01
	Diesel	0.96	0.96	0.98	0.95	0.93	0.88
IRR	Electric	0.00	0.00	0.00	0.03	0.06	0.10
	Petrol	0.04	0.04	0.02	0.02	0.02	0.01
	Diesel	0.96	0.96	0.98	0.95	0.93	0.88
Inner	Electric	0.00	0.00	0.00	0.03	0.06	0.10
	Petrol	0.04	0.04	0.02	0.02	0.01	0.01
	Diesel	0.96	0.96	0.98	0.95	0.93	0.88
Outer/External	Electric	0.00	0.00	0.00	0.03	0.06	0.10
	Petrol	0.04	0.04	0.02	0.02	0.01	0.01
	Diesel	0.96	0.96	0.98	0.96	0.93	0.88

Table C11 Proportions of petrol and diesel cars and LGVs from the LAEI 2010, for each year that was also run in the LAEI 2013 (all locations)

Cars			
	2008	**2010**	**2020**
Petrol	0.68	0.66	0.45
Diesel	0.32	0.34	0.55
LGVs			
	2008	**2010**	**2020**
Petrol	0.06	0.04	0.02
Diesel	0.94	0.96	0.98

Table C12 Vehicles that had updated or new scaling factors for control technologies relative to the LAEI 2010

Control technology factors				
Vehicle	**Diesel/Petrol**	**NO_x and NO_2**	**PM**	**CO_2**
Car/LGV Full Hybrid E3/4/5/6	Petrol	0.5	1	0.67
Car/LGV Plug-in Hybrid E5/6	Petrol	0.1	0.1	0.3
Car/LGV Full Hybrid E5/6	Diesel	0.5	1	0.75
LGV Plug-in Hybrid E5/6	Diesel	0.5	1	0.75
Low-emissions ZEC taxi[1]	Petrol	1	1	0.25
LT bus EIV Hybrid	Diesel	0.79	1	0.7
LT bus EV Hybrid[2]	Diesel	0.79	1	0.7
LT bus EVI Hybrid	Diesel	1	1	0.7

[1] relative to a petrol E6 N1 Class III LGV
[2] relative to E5 EGR

Electric cars and LGVs have no exhaust emissions, but the same non-exhaust emissions as petrol/diesel vehicles of the same size.

Table C 13Emission Factors (g/km) for Diesel Rail

	2008	**2010**	**2013**	**2020**	**2025**	**2030**
CO	41.8	42.2	46.1	55.0	57.9	60.1
NOx	364.8	373.3	338.3	266.9	239.1	218.3
HC	21.8	22.0	19.9	15.4	13.7	12.5
NMVOC	21.0	21.2	19.1	14.8	13.2	12.0
CH_4	0.8	0.8	0.7	0.6	0.5	0.5
Benzene	0.4	0.4	0.4	0.3	0.3	0.2
1-3 butadiene	0.2	0.2	0.2	0.1	0.1	0.1
PM_{10}	5.1	5.1	4.5	3.4	2.9	2.6
CO_2	4265.1	4265.1	4265.1	4265.1	4265.1	4265.1
SO_2	8.0	7.1	0.1*	0.1	0.1	0.1

* Note the reduction in SO_2 reflects the introduction of a maximum sulphur content (of 10ppm) for diesel trains from 2012, which was required under the EU Fuel Quality Directive (2009/30/EC)

Table C 14 CO_2 kg per Kwh for Electric Rail

Year	**CO_2 kg/Kwh**
2008	0.49
2010	0.48
2013	0.44
2020	0.37
2025	0.19
2030	0.10

Table C 15 CO_2 and SO_2 emission factors

Fuel type	CO_2 (kg/tonne)	SO_2 (kg/tonne)
ATF (Aviation Turbine Fuel)	3150	0.87
AS (Aviation Spirit)	3172	0.87

Table C16 Aircraft movements (in numbers) and fraction (in percentage) in 2010 and 2013 by aircraft type

Aircraft type	Movements 2010	Fraction (%) 2010	Movements 2013	Fraction (%) 2013
Airbus A318	1,046	1.5	985	1.3
ATR-42/72	2,296	3.4	1,080	1.5
Avro RJ1H	8,696	12.8	7,670	10.4
Avro RJ85	13,683	20.2	9,985	13.6
Cessna C25A/B C510 C525 C550 C560 C56X C680	3,651	5.4	2,269	3.1
Dash DH8C DH8D	2,883	4.2	2,726	3.7
Dassault Falcon F900 FA10 FA50 FA7X	945	1.4	897	1.2
Dornier D328	5,077	7.5	4,882	6.6
Embraer E135	648	1.0	100	0.1
Embraer E170	7,943	11.7	9,206	12.5
Embraer E190	4,991	7.4	16,036	21.8
Fokker F50	13,115	19.3	13,901	18.9
Hawker H25B	1,750	2.6	1,416	1.9
Saab 2000 SB20	-	-	1,772	2.4
Others	1,147	1.7	725	1.0
Totals	67,871	100	73,640	100

Table C17 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
APU narrow bodied	1974

Table C18 London City total aircraft movements by year

Year	2008	2010	2013	2014	2020	2025	2030
Total aircraft movements	94,763	67,871	73,640	75,600	86,940	96,440	105,940

Table C19 Fraction (in percentage) of aircraft movements in 2013 and 2020+ by runway and operations type A (Arrival) and D (Departure)

Runway	Operations	Fraction (%) 2013	Fraction (%) 2020+
09L	A	15.6%	7.8%
09L	D	0.4%	8.5%
09R	A	1.2%	9.0%
09R	D	16.3%	8.2%
27L	A	16.9%	16.9%
27L	D	15.8%	15.8%
27R	A	16.6%	16.6%
27R	D	17.2%	17.2%

Appendix D: Miscellaneous Data Tables

Table D 1 Agriculture types used to calculate fraction of UK emission and the LAEI distribution

Emission source	% of UK emission assigned to the LAEI	Notes on GIS distribution for pattern of emissions within LAEI area
Dairy and Non-dairy cattle	0.12%	Number of cattle distributed by improved grassland land cover
Sheep	0.07%	Number of sheep distributed by improved grassland land cover
Horses	0.89%	Improved grassland (there were no data on horses numbers)
Swine	0.12%	Number of pigs distributed by arable and improved grassland land cover (as a proxy for relevant agricultural areas)
Poultry	0.06%	Number of poultry distributed by arable and improved grassland land cover (as a proxy for relevant agricultural areas)
Manure management	0.12%	Used the same distribution as cattle, this is emissions from waste mainly associated with cattle

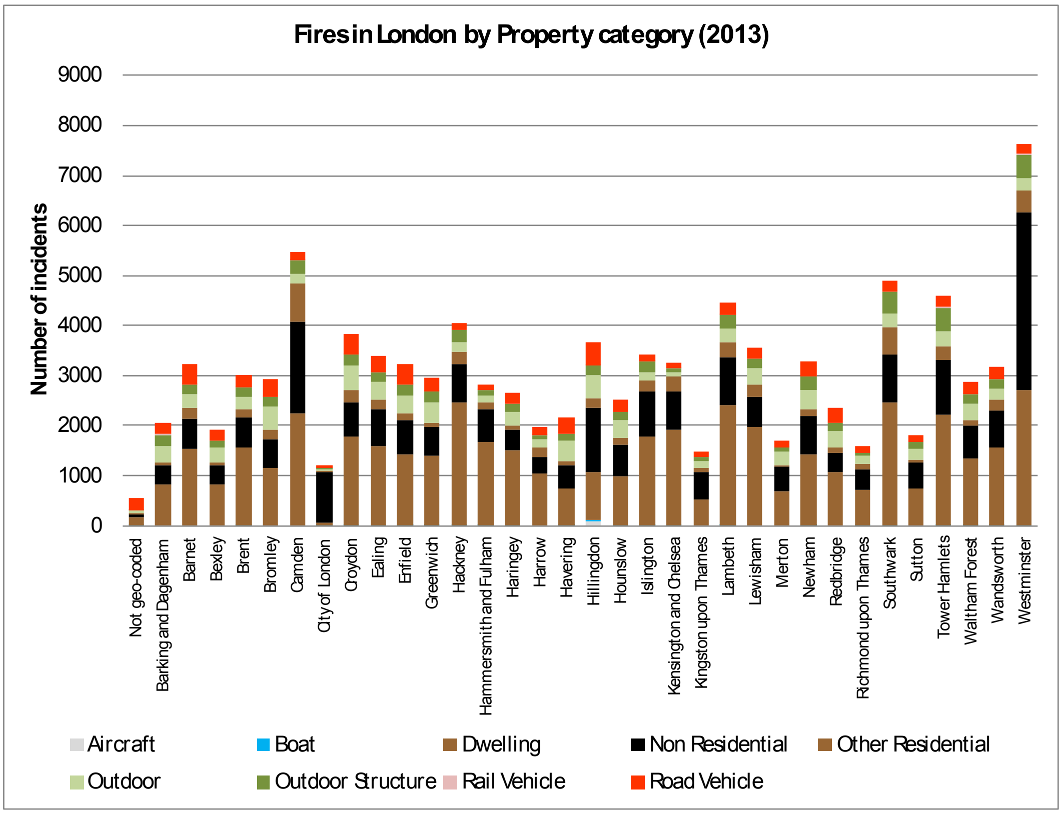
Table D 2 Land cover types used to calculate fraction of UK emission and the LAEI distribution

Emission source	% of UK emission assigned to LAEI	Land cover type used to distribute emission
Agricultural soils	0.41%	arable and improved grassland
Synthetic N-fertilizers	0.41%	arable
Fertiliser use	0.65%	arable and improved grassland
N-excretion on pasture range and paddock unspecified	0.89%	improved grassland

Table D 3 Projection Factors used to calculation future emissions for Agriculture (applied to the 2013 baseline)

Emission source	Projection Factor		
	2020	2025	2030
Dairy and Non-dairy cattle	0.99	0.98	0.98
Sheep	0.96	0.95	0.95
Horses	1.00	1.00	1.00
Swine	1.01	1.00	1.00
Poultry	1.03	1.03	1.03
Manure management	1.00	1.00	1.00
Agricultural soils	1.02	1.01	1.01
Synthetic N-fertilizers	1.00	1.00	1.00
Fertiliser use	1.00	1.00	1.00
N-excretion on pasture range and paddock unspecified	1.00	1.00	1.00

Figure D 1 London Fire Brigade dataset



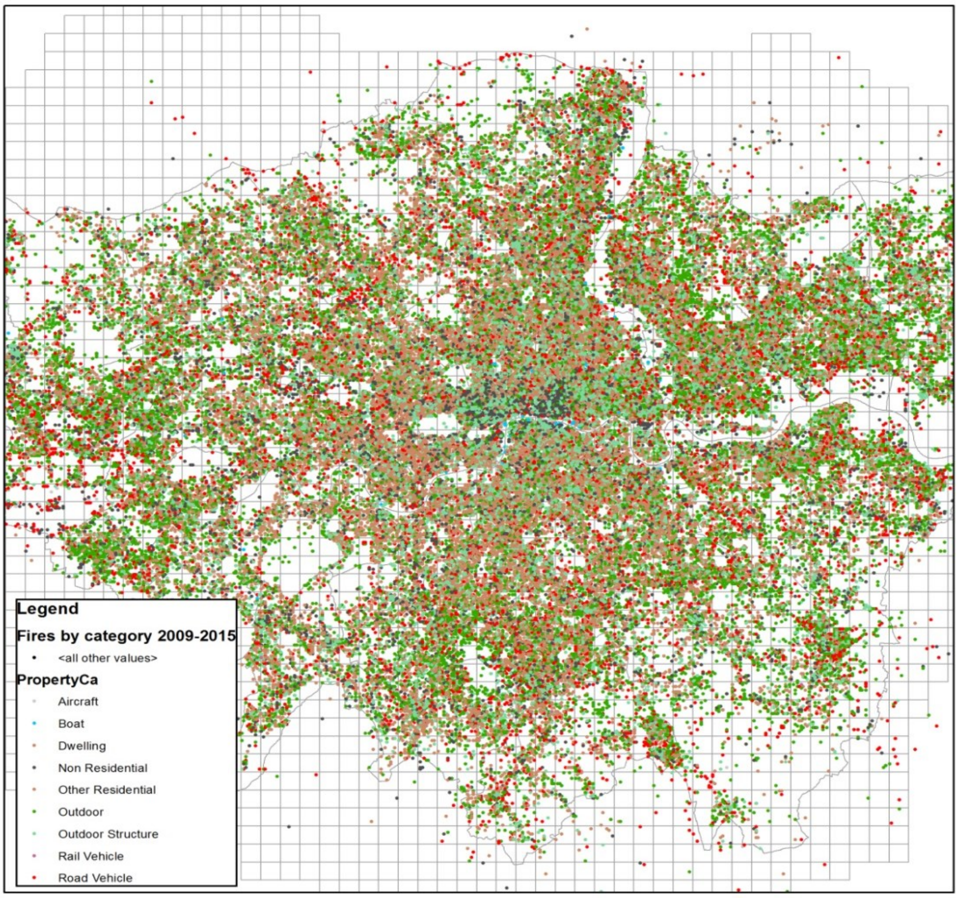


Table D 4 Mapping of LFB incident categories and NAEI emission sector

Fire database property types	NAEI sector	Units for activity
Road vehicle	Accidental fires – vehicles	mass burnt
Dwellings and other residential	Accidental fires – dwellings	mass burnt
Non-residential and outdoor structure and outdoor refuse related types	Accidental fires - other buildings	mass burnt
Outdoor (Straw/stubble burning)	Accidental fires – straw	mass burnt
Part of outdoor category (not including refuse burning)	Accidental fires – vegetation	area burnt
Part of outdoor category (Woodland/forest - broadleaf/hardwood Woodland/forest - conifers/softwood)	Accidental fires – forests	area burnt

Table D 5 Accidental fires: vehicles, dwelling, other buildings and straw. Size classification of accidental fires and mass burnt associated

Size of Fire	Number of pumps attending	Assumed average mass burnt (kg)
Very small	0	62.5
Small	1	250
Medium	2-3	500
Big	4-8	750
Very big	>8	1500

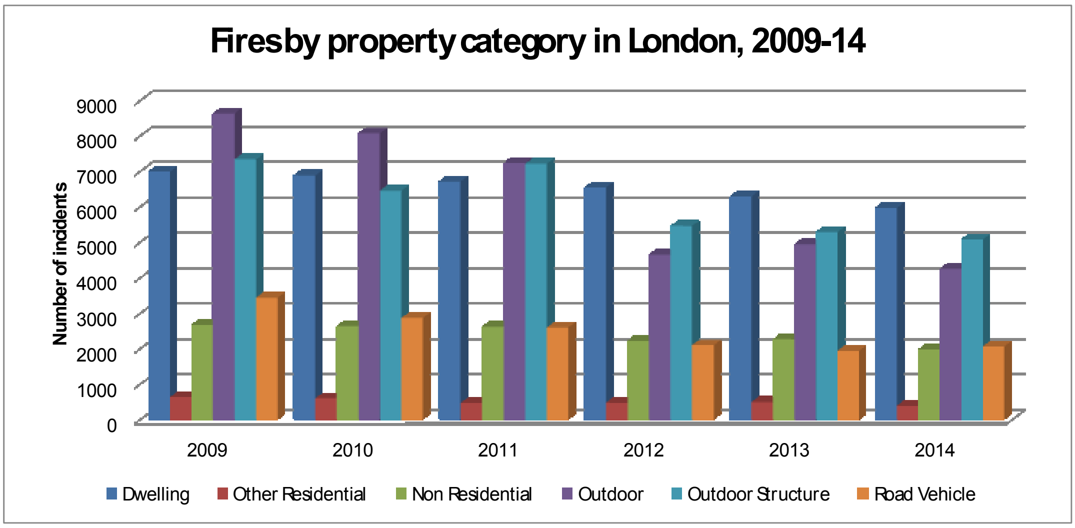
Table D 6 Accidental fires: vegetation and forest. Size classification of fires and area burnt associated

Size of Fire	Number of pumps attending	Assumed average area burnt (ha)
Very small	0	0.0025
Small	1	0.005
Small-medium	2-3	0.01
Medium	4-5	0.02
Medium-big	6-7	0.2
Big	8-9	0.5
Very big	>9	1

Table D 7 Emission Factors for Accidental fires, g/kg mass burnt

Accidental Fires Type	CO	CH_4	NOx	NMVOC	PM_{10}	$PM_{2.5}$	PCB	BaP
Dwellings	42.0	6.5	3.0	15.0	8.0	7.4	0.00051	0.0012
Vehicles	63.0	5.0	2.0	8.5	50.0	46.5	0.02550	0.0012
Other buildings	42.0	6.5	3.0	15.0	8.0	7.4	0.00051	0.0012
Refuse	52.4		1.5	13.8	12.8	11.9	0.00056	0.00010
Straw	58.0	2.7	2.3	9.0	11.0	9.0		
Forests	5400	357	190	500	324	265		
Vegetation	1436	94	51	132	21.6	17.6		

Figure D 2 Fires by property in London 2009-2014



Appendix E: Detailed Description of Construction Emission Estimates

The SPG outlines criteria for a NRMM Ultra Low Emission Zone. Estimates of future emissions from NRMM have been be improved for the LAEI 2013 based on emission limit values for key machine types (EC Directive 97/68/EC) combined with details of the emissions requirements in the Supplementary Planning Guidance.

From 1st September 2015 NRMM of net power between 37kW and 560kW used in London is required to meet strict engine standards. This applies to both variable and constant speed engines for both NO_x and PM. These will be based upon engine emissions standards set in EU Directive 97/68/EC[57] and its subsequent amendments. An illustration of the impacts of the new standards is shown in Table E 1 below.

From 1st September 2015:

- NRMM used on the site of any major development[58] within Greater London will be required to meet **Stage IIIA** of the Directive as a minimum;
- NRMM used on any site within the Central Activity Zone or Canary Wharf will be required to meet **Stage IIIB** of the Directive as a minimum.
- From 1st September 2020:
- NRMM used on any site within Greater London will be required to meet **Stage IIIB** of the EU Directive as a minimum.
- NRMM used on any site within the Central Activity Zone or Canary Wharf will be required to meet **Stage IV** of the Directive as a minimum.

Table E 1 Illustration of reductions in emission limits for an average sized item of NRMM equipment (37 ≤ kW < 75)

Emission standards	Stage II (g/kWh)	Stage IIIA (g/kWh)	% reduction from Stage II	Stage IIIB (g/kWh)	% reduction from Stage II	Stage IV (g/kWh)	% reduction from Stage II
NOx	7	4.7	33%	3.3	53%	0.4	94%
PM10	0.4	0.4	0%	0.025	94%	0.025	94%

If Stage IIIA equipment is not available, the requirement may be met using the following techniques,:

- Reorganisation of NRMM fleet;

[57] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CONSLEG:1997L0068:20070101:en:PDF
[58] Major developments are defined in the London Plan as those:

- For dwellings: where 10 or more are to be constructed (or if number not given, area is more than 0.5 hectares); and
- For all other uses: where the floor space will be 1000 sq metres or more (or the site area is 1 hectare or more). The site area is that directly involved in some aspect of the development. Floor space is defined as the sum of floor area within the building measured externally to the external wall faces at each level. Basement car parks, rooftop plant rooms, caretakers' flats etc. should be included in the floor space figure.

- Replacing equipment (with new or second hand equipment which meets the policy);
- Retrofit abatement technologies; and
- Re-engining.

There are also some exemptions allowed where machinery is not available, in short supply or used for less than 30 days.

A new method for estimating change in construction NRMM emissions has been developed based on data on estimated NRMM fleet mix combined with estimates for the split of activity across machinery of different ages (stages) and data on European Limit Values for these stages.

The data on the fleet mix originates from a 2004 study[59]. There are no more recent data available. This data provides estimates of the sizes, populations and hours usage for various construction machinery. Based on the power ratings data, emission limits have been assigned to the different machinery types and weighted average emission factors calculated for the fleet according to age (stage).

The estimates of activity data by stage have been calculated from NAEI projected fuel consumption by stage obtained from the NAEI team, with assumptions made to calculate equivalent data for the 2013 baseline based on the years that each Stage start. The consumption data has been used to calculate percentage contributions of fuel consumption by machines in each stage and this has been combined with weighted average emission factors by stage for 2013 to calculate percentage savings in these emission factors from 2013 to 2020 and 2025.

To reflect the variation in regulations in the SPG, different weighted average emission factors have been calculated for the Central Activity Zone and Canary Wharf, where the regulations are stricter. This has been done by varying the fractions of fuel consumption by Stage as machinery is upgraded from Stage IIIA to IIIB to IV. It has been assumed that there is an average of 80% compliance in the Central Activity Zone/Canary Wharf and 50% compliance in the rest of London.

Finally, emissions savings in future years have been applied to the baseline 2013 emissions (see above) with greater savings rates applied to emissions in the Central Activity and Canary Wharf zones. Emissions savings rates calculated for PM_{10} have been applied to emissions of PM_{10} and $PM_{2.5}$. NOx emissions savings have been applied to all other pollutants.

[59] Table 3.1 from report to DfT Non-Road Mobile Machinery Usage, Life and Correction Factors http://uk-air.defra.gov.uk/assets/documents/reports/cat15/0502141215_NRMM_report_Final_November_2004_3.pdf

Table E 2 Emission factors and Projection Factors for Construction NRMM

Weighted average emission factors (g/kWh)						
	NOx			PM		
Year	National average	London average	Central zone	National average	London average	Central zone
2013	6.13			0.45		
2015	5.57	5.29	3.95	0.40	0.37	0.10
2020	4.46	3.69	1.21	0.32	0.17	0.07
2025	4.35	3.59	1.19	0.32	0.17	0.07
Projection factors (Fraction of 2013 emission)						
	NOx*			PM_{10} and $PM_{2.5}$		
2015	0.91	0.86	0.64	0.89	0.83	0.22
2020	0.73	0.60	0.20	0.72	0.39	0.17
2025	0.71	0.58	0.19	0.72	0.38	0.17

* NOx projection factors applied to all other pollutants except PM_{10} and $PM_{2.5}$

The SPG also requires that for all developments an inventory of all NRMM should be kept on-site stating the emission limits for all equipment. This documentation should be made available to local authority officers as required. Kings College London has developed an online database[60] to enable this reporting to be made to a central database for London. This data should enable a bottom-up estimate of NRMM emissions to be made for the next LAEI update.

Mapping future emissions

Future emissions distributions were calculated based on the London Plan 2011 maps[61] and not using site specific data. There are no comprehensive data available on specific locations of construction sites in future years but the maps that form part of the London Plan 2011 provide indications of the locations where development is expected in future. These locations are classified into various types of development, illustrated below:

- Areas of Regeneration,
- Areas for Intensification,
- Opportunity areas,
- Strategic Industrial Locations, and
- Town Centres,
- The Central Activities Zone.

For simplicity and because there is no data to assign weightings to different land use types, it was assumed that development will be evenly distributed across the six development land types but excluding areas of green space (as defined by the locations of Green Belt, Metropolitan Open Land, Regional Parks and Metropolitan Parks, shown in green on the map above). The resulting map shows land areas that are likely to contain development over the next 10 years.

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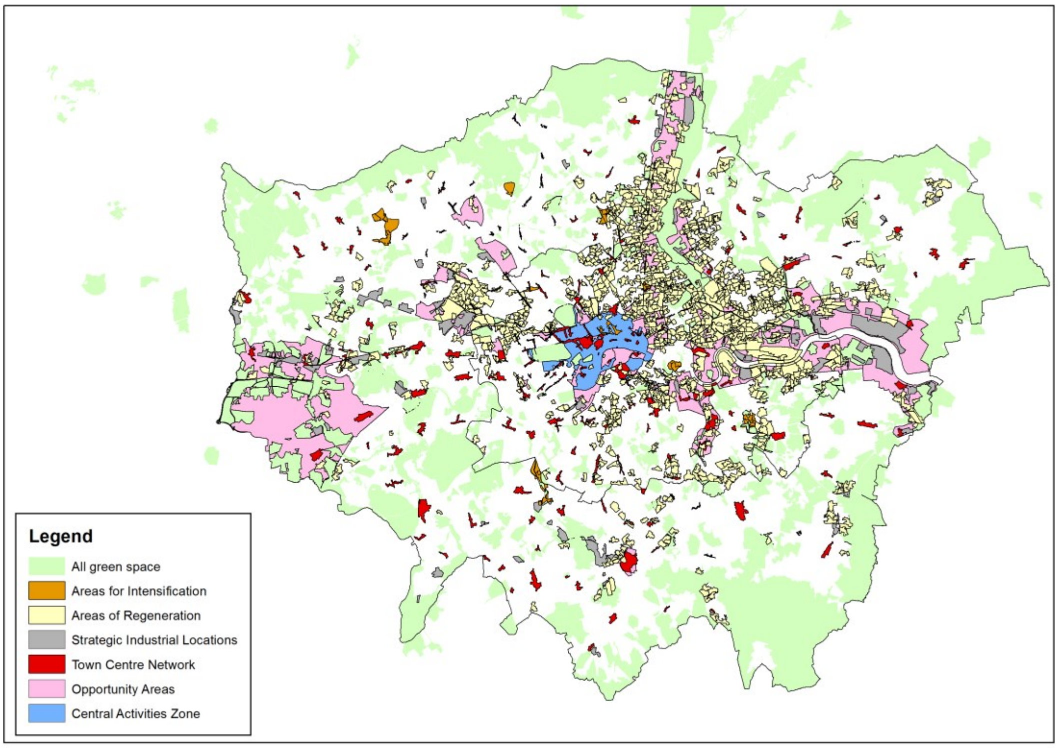
60 https://nrmm.london/

61 London Plan 2011 Chapter 2 London's Places http://www.london.gov.uk/sites/default/files/LP2011%20Chapter%202.pdf

Figure E 1 Development Areas defined in the London Plan 2011



The map above was combined with the LAEI grid to calculate for each LAEI grid the amount of land covered by the six types of development area identified in the map (and excluding the green space). The emissions estimates for future years (calculated as described above) were then distributed in proportion to the combined map of development land area per 1km^2. The same spatial distribution was used for all future years.