MAYOR OF LONDON

London Environment Strategy

APPENDIX 2: EVIDENCE BASE

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Air Quality

Impacts of air quality on health
Evidence for the impacts of air pollution on health is extensive, and still growing: a joint review undertaken by the European Union and the World Health Organization in 2013, the Review of evidence on health aspects of air pollution (REVIHAAP) project[1] referenced around 1,000 studies in drawing its conclusions.

In the UK, the current state of knowledge on the health impacts of air pollution is kept up to date by the Committee on the Medical Effects of Air Pollutants[2], and this has been complemented by London specific studies such as those undertaken by the Institute of Medicine and King's College London. The most recent report, by King's College London[3], estimated that the equivalent of over 9,000 Londoners died prematurely from long term exposure to air pollution in 2010. This underlines the fact that air quality is the most pressing environmental threat to the future health of London.

Exposure to particulate matter (PM) can affect both the lungs and the heart, leading to variety of effects including:

- premature death in people with heart or lung disease
- heart attacks
- irregular heartbeat
- aggravated asthma
- decreased lung function
- increased respiratory symptoms, such as irritation of the airways, coughing or difficulty breathing

There is also growing evidence that PM emitted from different sources can have specific health effects, for instance the International Agency for Research on Cancer, a body of the World Health Organization, identified PM emitted from diesel engines as a "group I carcinogen" meaning that a causal relationship has been established between exposure to

[1] World Health Organization (2013) Review of evidence on health aspects of air pollution – REVIHAAP Project Technical Report. Accessed from: http://www.euro.who.int/en/health-topics/environment-and-health/air-quality/publications/2013/review-of-evidence-on-health-aspects-of-air-pollution-revihaap-project-final-technical-report

[2] Committee on the Medical Effects of Air Pollution (COMEAP) website. Accessed from: https://www.gov.uk/government/groups/committee-on-the-medical-effects-of-air-pollutants-comeap

[3] https://www.london.gov.uk/sites/default/files/hiainlondon_kingsreport_14072015_final.pdf

this pollutant and human cancer.[4] People with heart or lung diseases, children, and older adults are the most likely to be affected by exposure to particulate pollution.

Exposure to nitrogen dioxide (NO_2) can irritate airways in the human respiratory system. Such exposures over short periods can aggravate respiratory diseases, particularly asthma, leading to respiratory symptoms (such as coughing, wheezing or difficulty breathing) and hospital admissions. Longer exposures to elevated concentrations of NO_2 may cause reduced lung function growth, contribute to the development of asthma and potentially increase susceptibility to respiratory infections. People with asthma, as well as children and the elderly, are generally at greater risk for the health effects of NO_2.

Air quality concentration limits and guidelines

To reduce the health impacts of air pollution, legal limits for a variety of air pollutants are set out in the EU "Directive on ambient air quality and cleaner air for Europe" (Directive 2008/50/EC).[5] These limits are adopted as objectives in UK law under the Air Quality Standards Regulations 2010 (SI 2010:1001).[6] EU and UK limits and standards are set at the same concentrations.

For some pollutants, the World Health Organization also publishes "guideline values". Whilst these do not represent legal requirements, they are based on in depth research on what levels of air quality are required to protect health.[7] EU/UK concentration limits and World Health Organization (WHO) guideline values are summarised in Table 1.

Table 1: EU/UK air quality limits and WHO guideline values

Pollutant	UK objective/ EU limit	Averaging period	World Health Organization guideline
Nitrogen dioxide (NO_2)	200 µg/m^3 not to be exceeded more than 18 times a year	1-hour mean	200 µg/m^3
	40 µg/m^3	Annual mean	40 µg/m^3
Particulate Matter (PM_{10})	50 µg/m^3 not to be exceeded more than 35 times a year	24-hour mean	50 µg/m^3
	40 µg/m^3	Annual mean	20 µg/m^3

[4] International Agency for Research on Cancer (2014) Monographs vol. 105 Diesel and gasoline engine exhausts and some nitroarenes. Accessed from: http://monographs.iarc.fr/ENG/Monographs/vol105/mono105.pdf

[5] European Union Directive on ambient air quality and cleaner air for Europe (2008). Accessed from: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32008L0050&from=en

[6] Air Quality Standards Regulations 2010. Accessed from: http://www.legislation.gov.uk/uksi/2010/1001/contents/made

[7] World Health Organization (2005) WHO Air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide Global update 2005. Accessed from: http://whqlibdoc.who.int/hq/2006/WHO_SDE_PHE_OEH_06.02_eng.pdf?ua=1

Table 1: EU/UK air quality limits and WHO guideline values			
Pollutant	**UK objective/ EU limit**	**Averaging period**	**World Health Organization guideline**
Particulate Matter ($PM_{2.5}$)	25 µg/m^3 And a duty to work towards reducing emissions / concentrations of fine particulate matter ($PM_{2.5}$)	Annual mean	10 µg/m^3
Ozone (O_3)	100 µg/m^3, not to be exceeded more than 10 times a year	8-hour mean	100 µg/m^3
Sulphur dioxide (SO_2)	266 µg/m^3 not to be exceeded more than 35 times a year	15-minute mean	500 µg/m^3 (10-minute mean)
	350 µg/m^3 not to be exceeded more than 24 times a year	1-hour mean	-
	125 µg/m^3 not to be exceeded more than 3 times a year	24-hour mean	20 µg/m^3
Benzene (C_6H_6)	16.25 µg/m^3	Running annual mean	-
	5 µg/m^3	Annual mean	-
1,3-Butadiene (C_4H_6)	2.25 µg/m^3	Running annual mean	-
Carbon Monoxide (CO)	10 mg/m^3	Maximum daily running 8-hour mean	-
Lead (Pb)	0.25 µg/m^3	Annual mean	-

London, in common with most locations, meets UK and EU legal limits for ozone, sulphur dioxide, benzene, butadiene, carbon monoxide and lead.[8]

Two pollutants remain a specific concern. These are particulate matter (PM_{10}, $PM_{2.5}$ and black carbon) and nitrogen dioxide (NO_2). London is failing to meet the legal limit for NO_2. Particulate matter is damaging to health at any level and must be reduced.

Monitoring air quality

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[8]Defra (2016) Air Pollution in the UK 2015. Accessed from: https://uk-air.defra.gov.uk/library/annualreport/

Air quality is improving in London but remains at levels that are dangerous to human health.

There are two main tools for understanding current and future air quality in London. The first is a comprehensive monitoring network, combining sites maintained by the GLA, Transport for London, the London boroughs, and others.

The majority of monitoring sites in London publish their live and historic data through a single portal maintained by the Environmental Research Group at Kings College London, this is called the London Air Quality Monitoring Network (LAQN).[9] A number of London boroughs, and some other organizations publish monitoring data themselves, or use other services such as the Air Quality England website to put monitoring data on the web.[10]

The second tool is the London Atmospheric Emissions Inventory (LAEI).[11] This estimates emissions from the sources of pollution in London and makes projections about how these will change in the future. The inventory emissions for the inventory base year are validated against the monitoring network, using LAQN and other sites. The current LAEI, at the time of writing, has a base year of 2013.

Previous targets and achievements against them

It is helpful to understand the targets included in the previous Mayor's Air Quality Strategy (MAQS) and to evaluate previous policies.

The MAQS set a target of a 31 per cent reduction in PM_{10} emissions and a 35 per cent reduction in NO_x emissions by 2015 compared to 2008 levels. These reductions, combined with further action by government and others, were set to achieve compliance with legal limits (i.e. concentrations) for both PM_{10} and NO_2.

However, only a 20 per cent reduction in PM_{10} and a 25 per cent reduction in NO_x emissions were achieved. This meant the legal limits for PM_{10} were achieved but were not for NO_2.

The London Atmospheric Emissions Inventory – the evidence base for developing air quality policy

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[9] London Air Quality Network. Accessed from: https://www.londonair.org.uk/

[10] Air Quality England website. Accessed from: http://www.airqualityengland.co.uk/

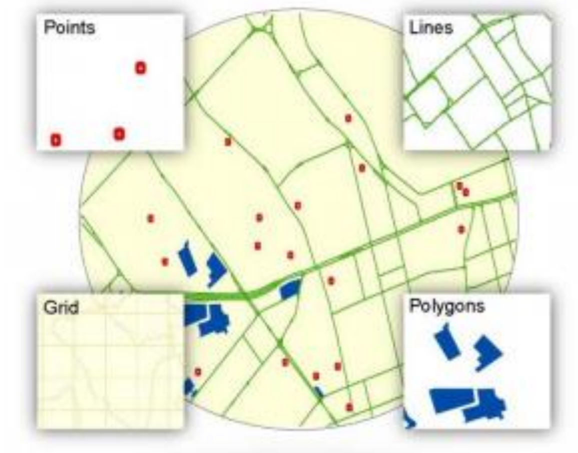
[11] London Atmospheric Emissions Inventory. Accessed from: https://data.london.gov.uk/dataset/london-atmospheric-emissions-inventory-2013

The LAEI provides an analytical evidence base, essential for strategy and policy development and planning for London. The primary functions of the inventory are strategic emissions modelling, concentrations modelling, and air quality mapping. These processes can be used to identify existing pollution hotspots in London, the contribution of different sources, and to forecast future changes to air quality.

The LAEI is a compilation of geographically referenced datasets of pollutant emissions and sources in Greater London, and up to and including the M25 motorway ring. The base year for the current LAEI is 2013, with back projections to 2008 and 2010 and forward projections to 2020, 2025 and 2030.

Wherever possible, the LAEI uses the most spatially disaggregated data on polluting activities that is readily available for each source type. Emissions are calculated by geographical source type; point, polygon, line and area/grid, as illustrated by Figure 1.

Figure 1: LAEI source geographies



The LAEI considers a wide variety of emissions sources, the main categories considered are listed in Table 2.

Table 2: Emission source categories in the LAEI

General sector	Specific sector	Activity
Industrial and commercial	Industrial processes	Large: Part A processes Small: Part B processes Non-road mobile machinery exhaust
	Heat and power generation	Solid and liquid fuel combustion Gas combustion Gas oil combustion
	Natural gas supply	Gas leakage
	Waste	Waste and waste-water handling Waste transfer Small-scale waste burning
	Construction	Non-road mobile machinery exhaust Construction and demolition dust
Domestic	Heat and power generation	Solid and liquid fuel combustion Coal combustion Gas oil combustion Gas combustion
	Machinery	Non-road mobile machinery exhaust
Transport	River	Passenger shipping Commercial shipping
	Road	Motorcycle Taxi Car - petrol, diesel, electric Vans - petrol, diesel, electric HGVs - Artic, rigid TfL buses Other bus/coaches
	Rail	Passenger Freight
	Aviation	Aircraft and airport activities
Miscellaneous	Agriculture	Combustion Livestock Other agriculture
	Forestry	Biosynthesis

The LAEI outputs include several key pollutants (Box 1), such as NO_x and particulate matter, which are related to health impacts and legal compliance. They also include subsidiary pollutants, which are either involved in atmospheric chemistry processes or are currently within legal limits (see Box 2 for a description of the difference between pollutant emissions and pollutant concentrations). Key pollutants include:

- oxides of nitrogen (NO_x), including from vehicle emissions and other combustion sources
- particulate matter with aerodynamic diameter < 10 µm (PM_{10}) including from combustion/exhaust, tyre wear, brake wear and resuspension sources
- particulate matter with aerodynamic diameter < 2.5 µm ($PM_{2.5}$) including from combustion/exhaust, tyre wear, brake wear and resuspension sources

Subsidiary pollutants include:

- 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)
- hydrogen chloride (HCl)
- carbon dioxide (CO_2). Additional energy information relating to CO_2 emissions from non-combustion sources is taken from the London Energy and Greenhouse Gas Inventory (LEGGI)

Box 1: Pollutants of concern in London
Particulate matter (PM_{10} and $PM_{2.5}$): Particulate matter (PM) is a complex mix of non-gaseous material of varied chemical composition. It is categorised by the size of the particle. For example, PM_{10} is particles with a diameter of less than ten micrometres (µm). Most PM emissions in London are caused by road traffic, with engine emission and tyre and brake wear being the main sources. Construction sites, with high volumes of dust and emissions from machinery are also major sources of local PM pollution. Other sources include wood burning stoves, accidental fires and burning of waste. However, a large proportion of PM comes from natural sources, such as sea salt, forest fires and Saharan dust. In addition, there are sources outside London caused by human activity. Small particles tend to be long-lived in the atmosphere and can be carried great distances. This imported PM forms a significant proportion of total PM in London.

Box 1: Pollutants of concern in London
Black carbon: This is a component of fine particulate matter ($PM_{2.5}$ and smaller). It is formed through the incomplete combustion of fossil fuels, biofuel, and biomass, and is emitted in both anthropogenic and naturally occurring soot. Black carbon also contributes to climate change. Black carbon warms the planet by absorbing sunlight and heating the atmosphere. **Nitrogen dioxide (NO_2):** All combustion processes produce Nitrogen Oxide (NO_x). In London, road transport and heating systems are the main sources of these emissions. NO_x is primarily made up of two pollutants - nitric oxide (NO) and nitrogen dioxide (NO_2). NO_2 is of most concern due to its impact on health. However, NO easily converts to NO_2 in the air - so to reduce concentrations of NO_2 it is essential to control emissions of NO_x.

The GLA is responsible for the LAEI and works closely with TfL, who coordinate its development on the GLA's behalf. Besides its core function of informing GLA and TfL strategy and policy development, the inventory provides evidence for the London boroughs' local air quality management planning and health functions. Boroughs are provided with a dashboard of useful data summaries and statistics, alongside access to the full inventory. The inventory air quality maps inform the declaration of air quality focus areas (see the Air Quality 'Focus Areas' in London section), where further local action is required to reduce public exposure to levels above the air quality limit values.

The inventory is publicly available, directly helping to raise awareness and understanding of London's air quality. It also informs public information systems, such as pollution forecasts. Further information about LAEI – including output emissions data, air quality maps and methodology documents – can be found via the London Datastore.[12] LAEI borough maps are also available via the London Datastore.[13] The LAEI is updated from time to time, but the latest version will always be available on the Datastore.

Box 2: What's the difference between emissions and concentrations?
London's air quality is affected by a number of factors. These include the weather, local geography and **emissions** sources from both within and outside London. Air quality is measured in **concentrations**, which are specific levels of a pollutant in a given area. Legal limits are set in relation to concentrations. Local emissions from vehicles, buildings, construction and other sources contribute significantly to air pollution in

[12] GLA, "London Atmospheric Emissions Inventory (LAEI) 2013" (2016). Accessed from: https://data.london.gov.uk/dataset/london-atmospheric-emissions-inventory-2013

[13] GLA, "LLAQM bespoke borough by borough 2013 air quality modelling and data" (2016). Accessed from: https://data.london.gov.uk/dataset/llaqm-bespoke-borough-by-borough-air-quality-modelling-and-data

London. This is what the Mayor can most directly control and influence. That means we must understand how these emissions are being reduced to understand how effective particular policies and proposals could be. However, there is rarely a direct relationship between reducing emissions within London and reducing concentrations given the other factors at play. This is why the strategy refers both to concentrations and emissions.

Trends in London's pollution concentrations

The monitoring network provides unique opportunities to understand trends in London's air quality. One way to view air quality monitoring data is to group monitors based on their location and distance from the roadside and look at the average concentrations.

Figure 2, Figure 3, and Figure 4 show the general (average) trend over the last decade or so for NO_2, PM_{10} and $PM_{2.5}$ concentrations at sites that are part of the LAQN[14], grouped by site type. Roadside monitors (RS) are within five metres of roads, while 'background sites' (BG) are located away from major sources of pollution.

Overall, there has been a gradual reduction in NO_2, PM_{10} and $PM_{2.5}$ concentrations at background sites in inner and outer London, and at outer London roadside sites. Inner London NO_2 roadside sites have shown a more variable trend but have seen a steeper decline from 2012. This decline is also reflected in the inner London PM_{10} roadside sites, whereas concentrations of $PM_{2.5}$ may be levelling off at inner London roadside sites. The trends in $PM_{2.5}$ are less certain, as there are fewer monitors available to measure this pollutant. The higher uncertainty is represented by a wider shadow around the central trend lines.

[14] The data used in these graphs is from the LAQN and processed using tools from the Openair project, an open source suite of statistical tools for analysing air quality data. Accessed from: http://www.openair-project.org/

Figure 2: Trends in NO_2 in London – 2000 to 2016 (source: the London Air Quality Network and analysis by King's College London)

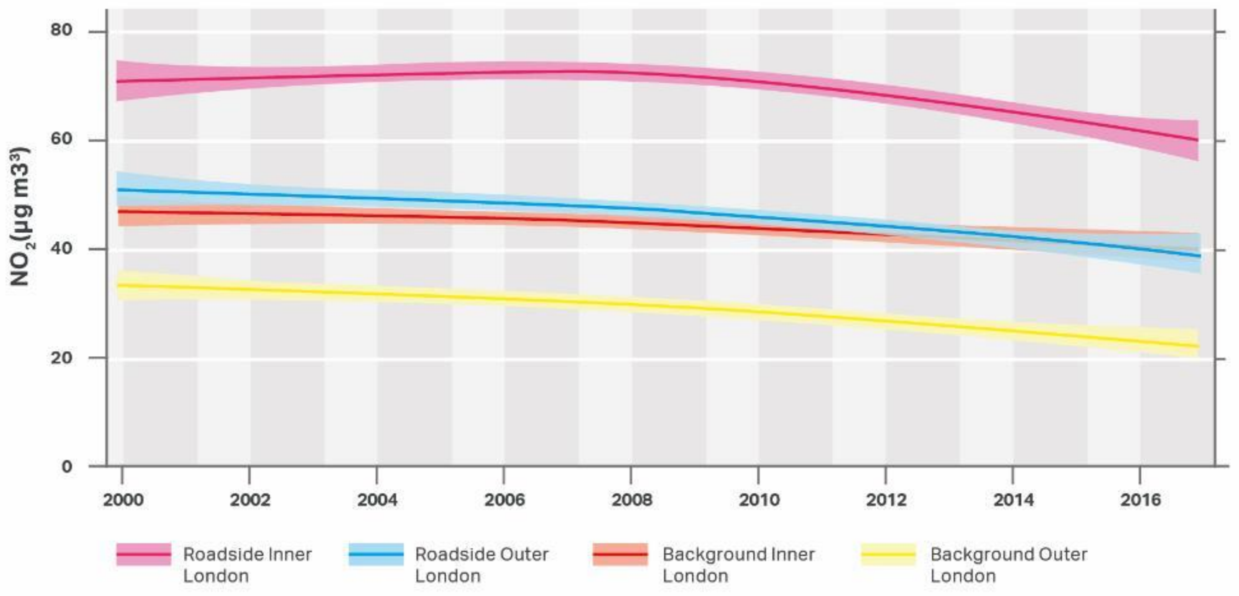


Figure 3: Trends in PM_{10} in London – 2004 to 2016 (source: the London Air Quality Network and analysis by King's College London)

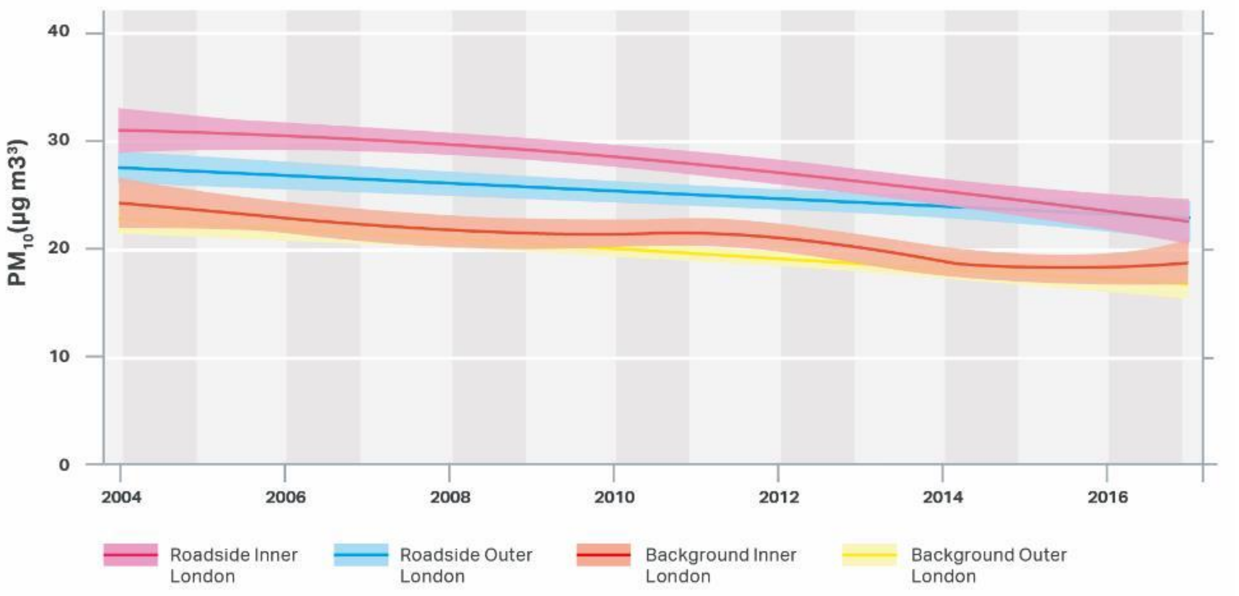
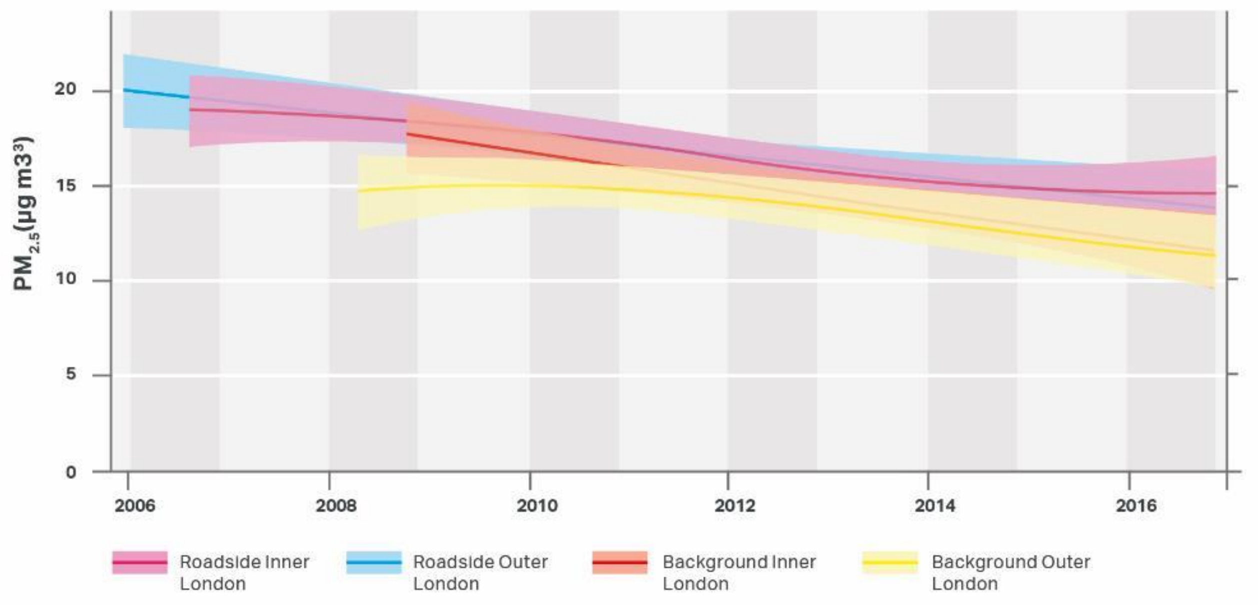


Figure 4: Trends in $PM_{2.5}$ in London – 2006 to 2016 (source: the London Air Quality Network and analysis by King's College London)



These reductions are important as they show, overall, that air quality is improving in London – albeit not quickly enough to meet legal limits. While the vast majority of roads in London met the PM_{10} EU annual mean limit value of 40 µg/m^3 in 2013, many roads still exceeded the NO_2 EU annual mean limit value of 40 µg/m^3 by a large margin.

Concentrations of $PM_{2.5}$ meet EU limits but are still well above WHO recommended limits.

This downward trajectory across London is also supported by analysis at most individual monitoring sites. The dynamic nature of air pollution and the way it is affected by multiple factors means that concentrations at some sites can go up while the overall trend across the city is improving. Factors that can influence local trends include changes in traffic volumes, the variable response of exhaust abatement in different road conditions as well as temporary changes issues like construction activity, weather, local road layouts etc. In addition, they reflect all pollution sources experienced at a monitoring site and not just locally emitted pollution or road-based pollution specifically.

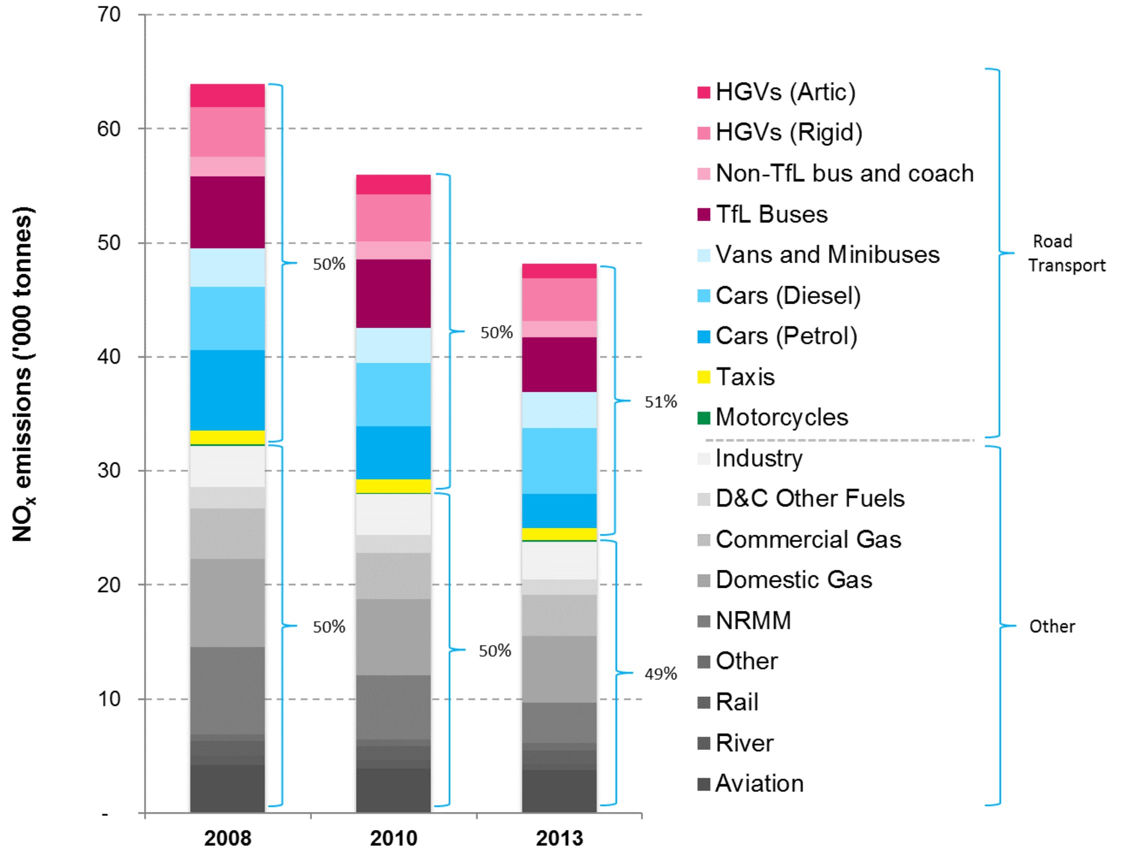
Trends in London's pollution emissions[15]

NO_x (all sources)

Currently, around half of nitrogen oxides (NO_x) emissions come from road transport sources. The other half of emissions come from non-road transport sources, including construction, domestic and commercial buildings, river, aviation and industrial emissions.

Total NO_x emissions in London fell by 25 per cent over the period 2008 to 2013, compared with a 35 per cent target to 2015 in the previous air quality strategy (Figure 5).

Figure 5: Emissions trend and main source categories – NO_x 2008-2013



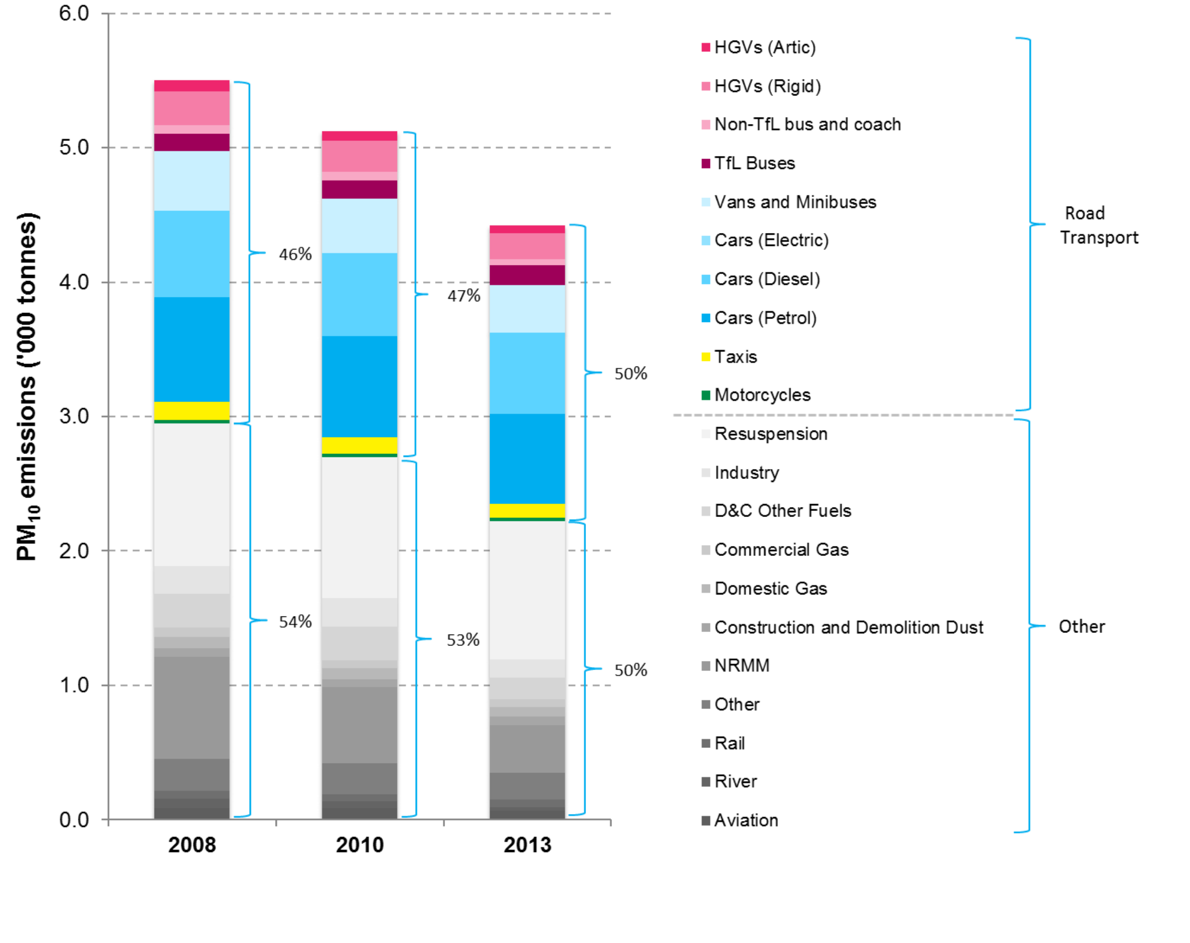
[15] Data for emissions quantities are taken from the LAEI 2013.

PM_{10} (all sources)

The source of PM_{10} emissions in London is a similar breakdown to nitrogen oxides, with around half of the emissions coming from road transport and the remainder from non-transport sources.

Total PM_{10} emissions fell by 20 per cent over the period 2008 to 2013, compared with a 31 per cent target to 2015 in the previous air quality strategy (Figure 6).

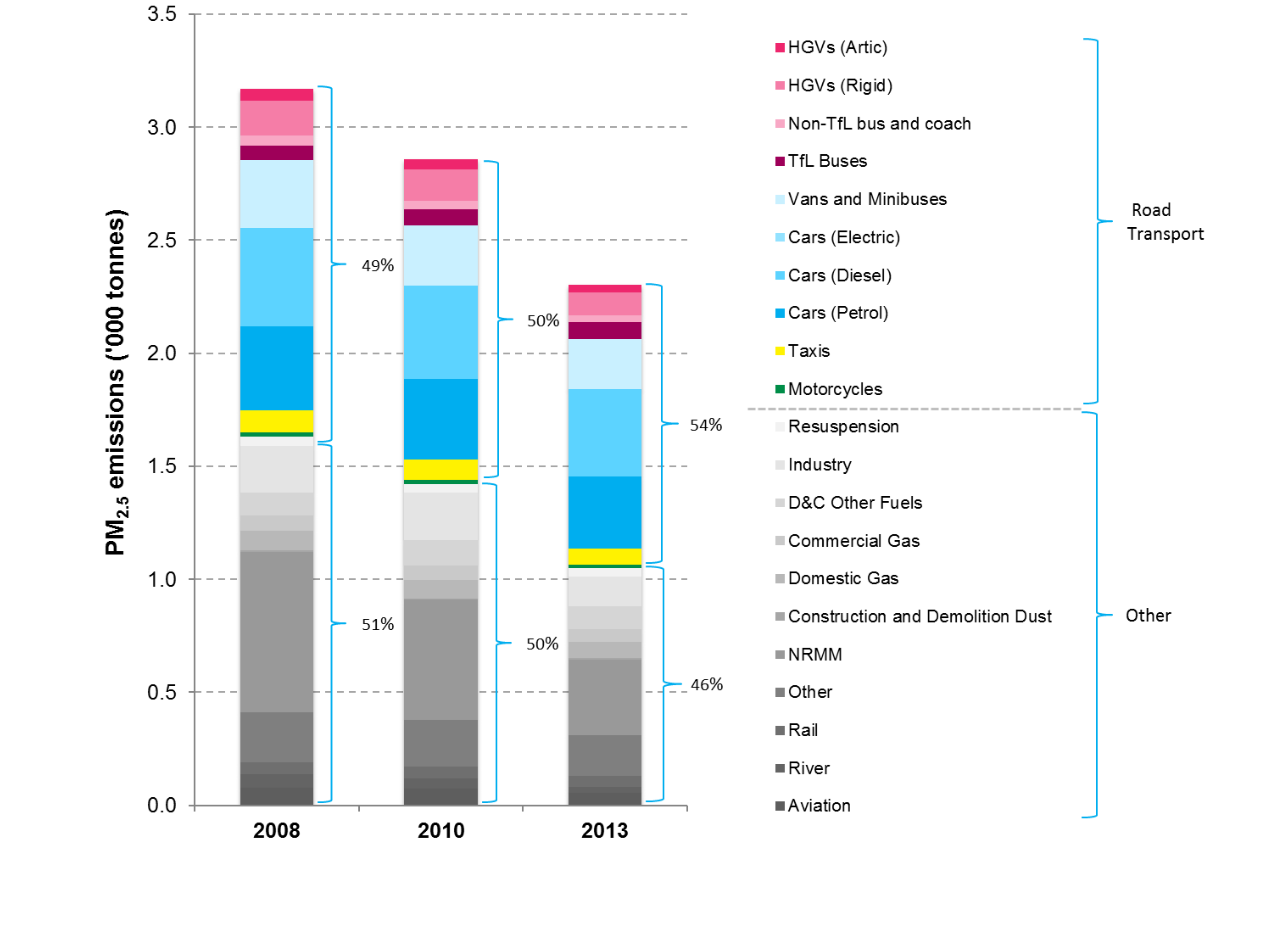
Figure 6: Emissions trend and main source categories – PM_{10} 2008-2013



$PM_{2.5}$ (all sources)

Total $PM_{2.5}$ emissions fell by 27 per cent over the period 2008 to 2013 (Figure 7). The sources of $PM_{2.5}$ emissions in London are similar to those for PM_{10} but some sources, such as tyre and brake wear are more significant (see Figure 22).

Figure 7: Emissions trend and main source categories – $PM_{2.5}$, 2008-2013



A snapshot of air pollution in London

Pollutants disperse rapidly in the atmosphere after they are emitted. This dispersion is affected by numerous factors including the weather, height, and temperature of the emission. In order to understand where pollutant concentrations are highest, information from the LAEI is used to model pollution across London at a 20-metre resolution.

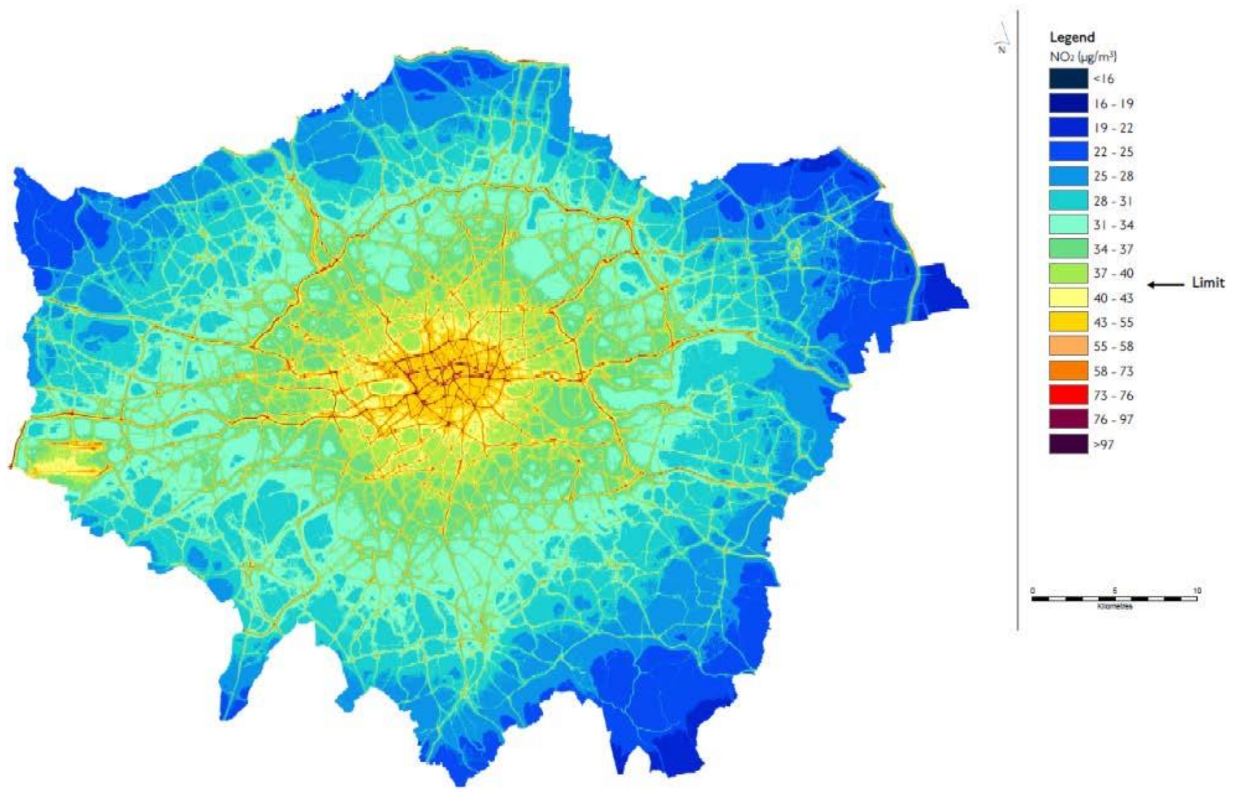
The following air quality concentration maps have been validated against real world monitoring data and indicate the geographical extent of exceedances of the limit values and can be used to determine the exposure of the local population.

This baseline ensures that policies can be set to reduce air pollution across London, as well as to ensure that measures are directed and scaled most appropriately to areas of greatest need, either in terms of particularly high concentrations or high levels of human exposure (see also the Air Quality ‘Focus Areas’ in London section). Having a robust baseline that is checked against real monitoring results also allows greater confidence in the modelling that is used for forward projections.

NO_2 concentrations

In 2013, approximately 1.9 million people in London, equating to 23 per cent of the population of London were living in areas with average NO_2 concentrations above the EU limit value, the majority in inner London. Concentrations are still higher towards central London, with its higher density of emissions sources (Figure 8). However, it must be remembered that the EU limit values do not necessarily represent a level of exposure below which there are no health effects, and reductions of pollutant concentrations below the legal limit values will be expected to produce further health benefits.

Figure 8: 2013 - Annual mean NO_2 concentrations[16]

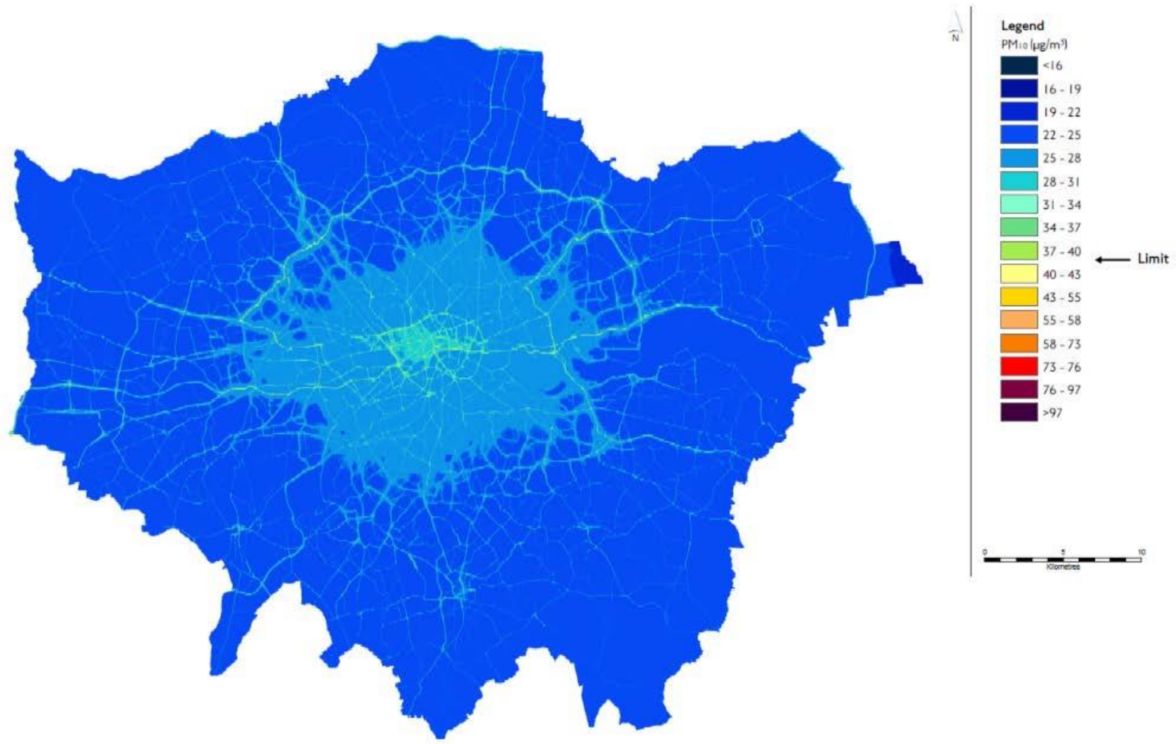


[16] GLA (2017) London Atmospheric Emissions Inventory (LAEI) 2013 Update.

PM_{10} concentrations

In 2013, annual average PM_{10} concentrations were considered within the legal limits (Figure 9). However, modelling still indicates some locations where the daily average value for PM_{10} will be exceeded (for example kerbside locations in central London, or within the road space itself, and close to some industrial sites).

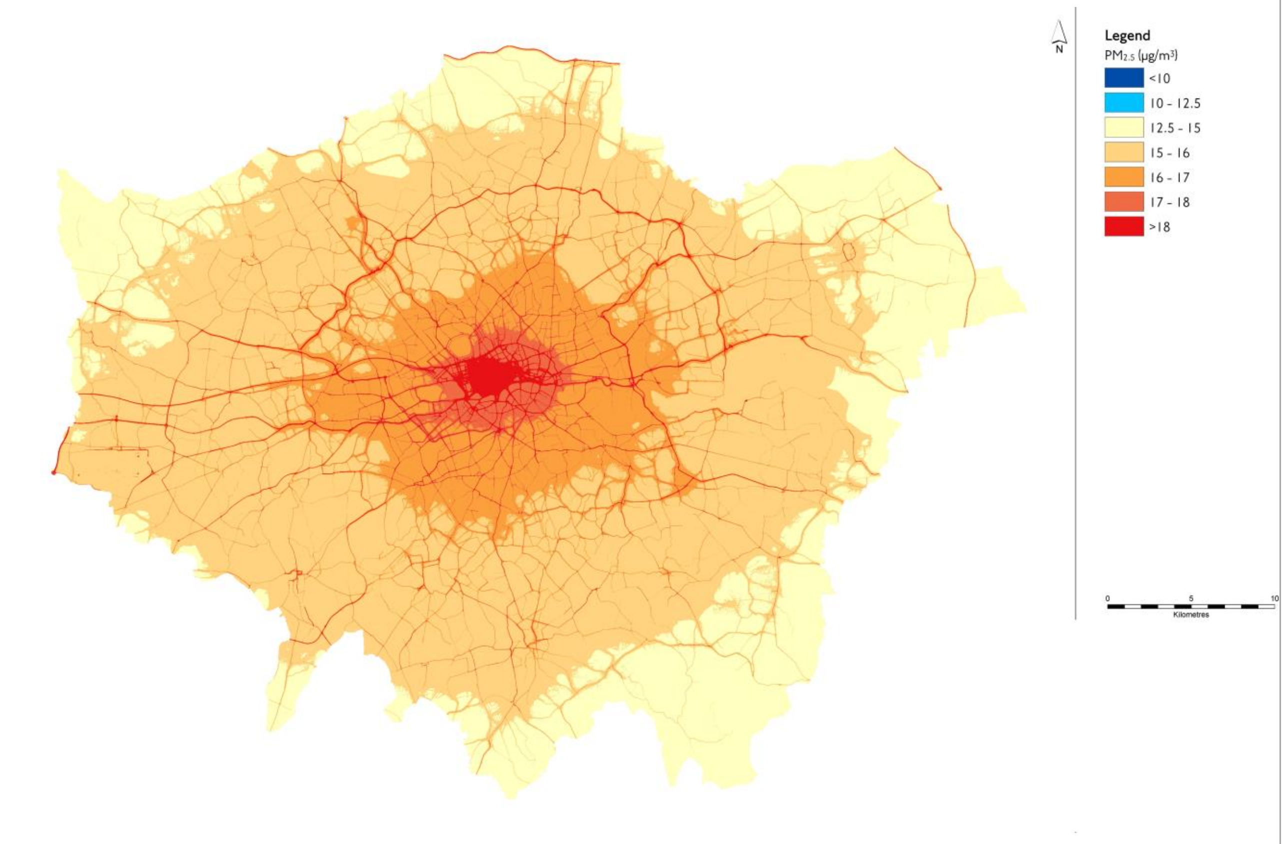
Figure 9: 2013 - Annual mean PM_{10} concentrations [16]



$PM_{2.5}$ concentrations

The EU has set a target value of no more than 25 µg/m³ of $PM_{2.5}$, and a 20 per cent reduction on 2010 levels at urban background. While London meets EU limits at most locations the WHO recommends a limit of 10 µg/m³ based on the evidence from health effects (Figure 10).

Figure 10: 2013 - Annual mean $PM_{2.5}$ concentrations[16]



Air Quality 'Focus Areas' in London

At a large scale, the baseline maps show the extensive areas of exceedance of legal air quality limits, particularly for NO_2, which demonstrates the need for large scale intervention.

The outputs of the LAEI and modelling on a smaller scale can be combined with other data sets, such as population data.[17] This means the LAEI can also be used as a tool to help ensure that measures to reduce pollution are directed and scaled most appropriately to areas of greatest need, both in terms of particularly high concentrations and high levels of human exposure. These areas are referred to as Air Quality Focus Areas (Figure 11).

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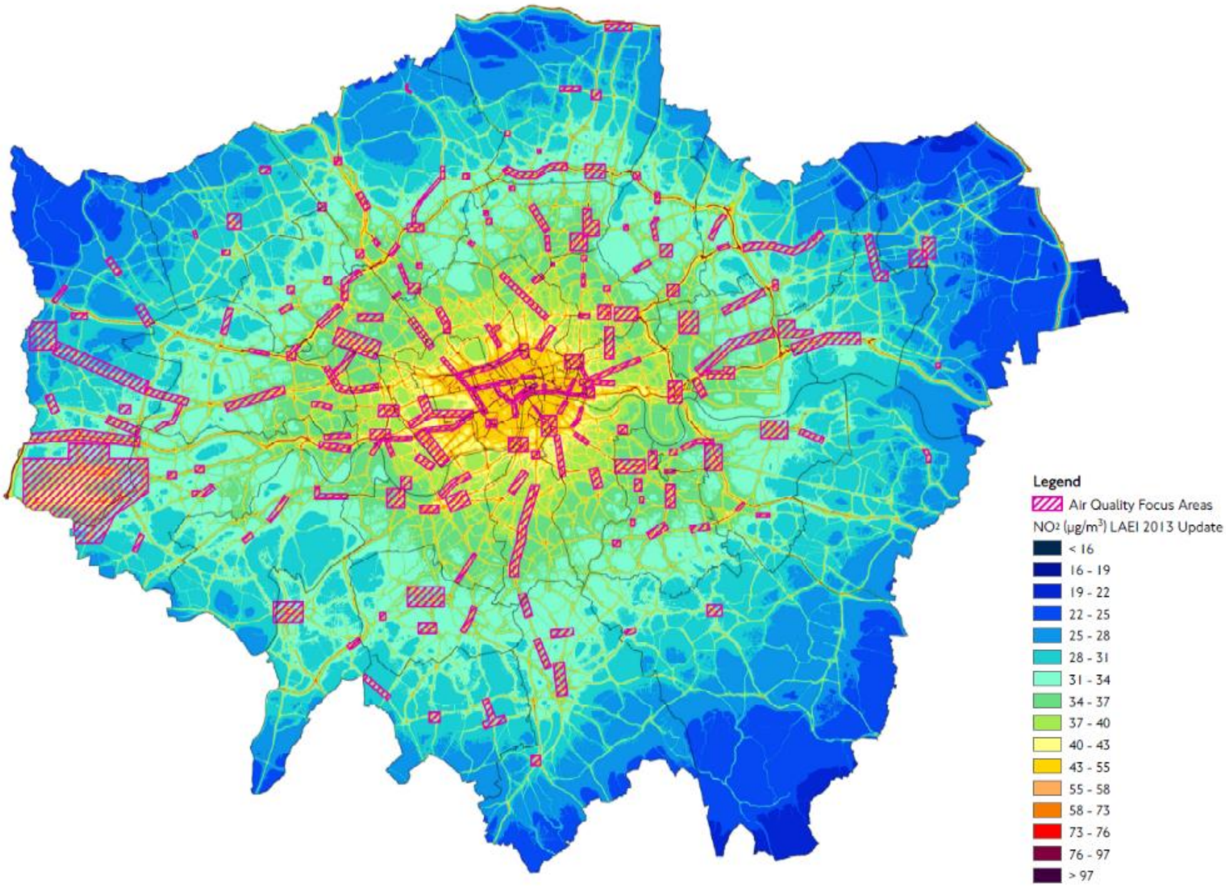
[17] GLA (2016), London Atmospheric Emissions Inventory (LAEI) 2013 Air Quality Focus Areas - December 2016 update. Accessed from: https://data.london.gov.uk/dataset/laei-2013-london-focus-areas

Figure 11: Air Quality 'Focus Areas'[17]



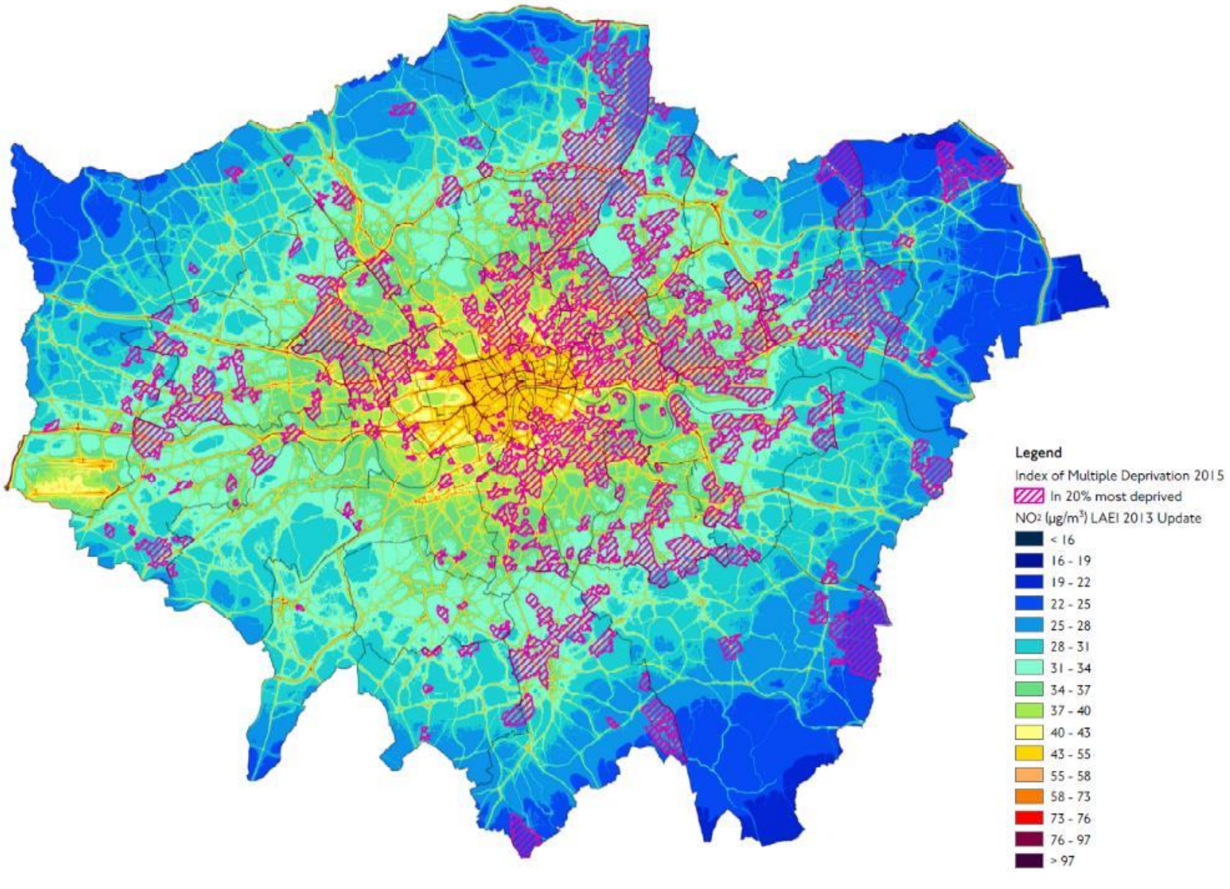
Many focus areas are located along major roads, especially where these go through town centres given the greater human exposure to pollution. Heathrow also stands out as a major focus area. In developing proposals to improve air quality, these areas are prioritised where possible. One example of this is Low Emission Bus Zones.

Air quality and deprivation

Another way to understand the impact of air pollution in London is to look at the relationship between air quality and social factors, such as indices of deprivation. There are considerable differences in average levels of exposure in 2013 between more deprived and less deprived communities, with more deprived communities experiencing higher NO_2 and PM_{10} concentrations than less deprived communities.[18]

Figure 12 shows the top 20 per cent of the most deprived areas (based on indices of multiple deprivation[19]) overlaid on the 2013 concentration map for NO_2. Bearing in mind the relatively low level of residential population in central London, it can be seen from the map that deprived areas are clustered in inner-east London, and that these areas experienced (in 2013) concentrations of NO_2 that generally exceeded the limit values.

Figure 12: Relationship between air quality and indices of multiple deprivation[18]



[18] GLA, King et al. (2017) Updated Analysis of Air Pollution Exposure in London. Accessed From: https://www.london.gov.uk/sites/default/files/aether_updated_london_air_pollution_exposure_final_20-2-17.pdf

[19] Department for Communities and Local Government (2015) English indices of deprivation 2015. Accessed from: https://www.gov.uk/government/statistics/english-indices-of-deprivation-2015

The indicators of multiple deprivation include: income deprivation, employment deprivation, health deprivation, disability, education, skills and training deprivation, barriers to housing and services, crime and living environment deprivation. People living in areas of high multiple deprivation are therefore not only more vulnerable to the effects of air pollution, but also the least able to take direct local action to improve their environment. The strong relationship between inequalities and levels of exposure in London underlines the fact that air pollution is a social justice issue as well as an environmental one.

Indoor air quality

The quality of indoor air is essential for people’s well-being, since the average person spends most of their time indoors. Indoor levels of particulate matter and NO_2 are usually dominated by pollution brought in from outside. Therefore, action to reduce ambient concentrations will have a significant impact on reducing these levels indoors as well.

Additional contributions from indoor sources of pollutants, including from some types of paints, glues and building materials and, in some cases, cooking, can lead to levels of indoor pollution exceeding those outdoors. Wood or other solid fuel burning stoves can also be a significant contributor to indoor particulate levels. Poorly maintained appliances, such as boilers and ventilation systems, can also lead to emissions or build-up of indoor generated pollutants such as carbon monoxide.

As with outdoor air pollution, one of the best ways to reduce indoor air pollution is to reduce the source. This can be done by:

- ensuring that materials used in paints, furnishings and elsewhere in the home or workplace are low in volatile compounds
- ensuring appliances that burn fuel are low emission wherever possible and are well maintained
- removing or replacing unnecessary sources of pollutants, such as solid fuel fires

Unlike outdoor pollution, indoor pollutant levels can also be reduced by using effective ventilation strategies that ensure that pollutants are effectively removed from the indoor environment and are not drawn in from inlets close to outdoor sources. Maintenance and correct use of ventilation systems is as important as design in ensuring that they are effective.

Baseline projections

This section provides baseline projections on how different sources of emissions are expected to change over time up to 2030.

It is important to note that the following baseline projections include the benefit of bringing forward the central London ULEZ in 2019, as well as many of the bus, taxi and non-transport measures being delivered through the London Environment Strategy. As a result, part of the benefits attributable to the strategy are actually captured in the baseline.

There have been minor changes to the baseline modelling for the final strategy in comparison with the draft strategy, which contained interim projections. These include minor adjustments for road transport NO_x in 2025, whereby cold start emissions have been handled differently to ensure a like-for-like comparison across the future baseline and strategy scenarios.

In addition, in the draft strategy baseline 2030 estimates were provisional and have now been updated to provide consistency with the baseline projections towards 2050. As part of this, road transport emissions are now based on updated vehicle emissions factors and growth projections have been aligned with the Mayor’s Transport Strategy reference case (updated to incorporate London Plan updates in December 2017).

Baseline 2030 emissions from non-transport sources including Non-Road Mobile Machinery (NRMM) and gas use have been updated to align housing and population forecasts with the London Plan, alongside the London Zero Carbon Model data, and to incorporate some method changes which were required to project baseline emissions out to 2050. Shipping emissions in 2030 have also been aligned to the recently released Port of London Authority emissions inventory.

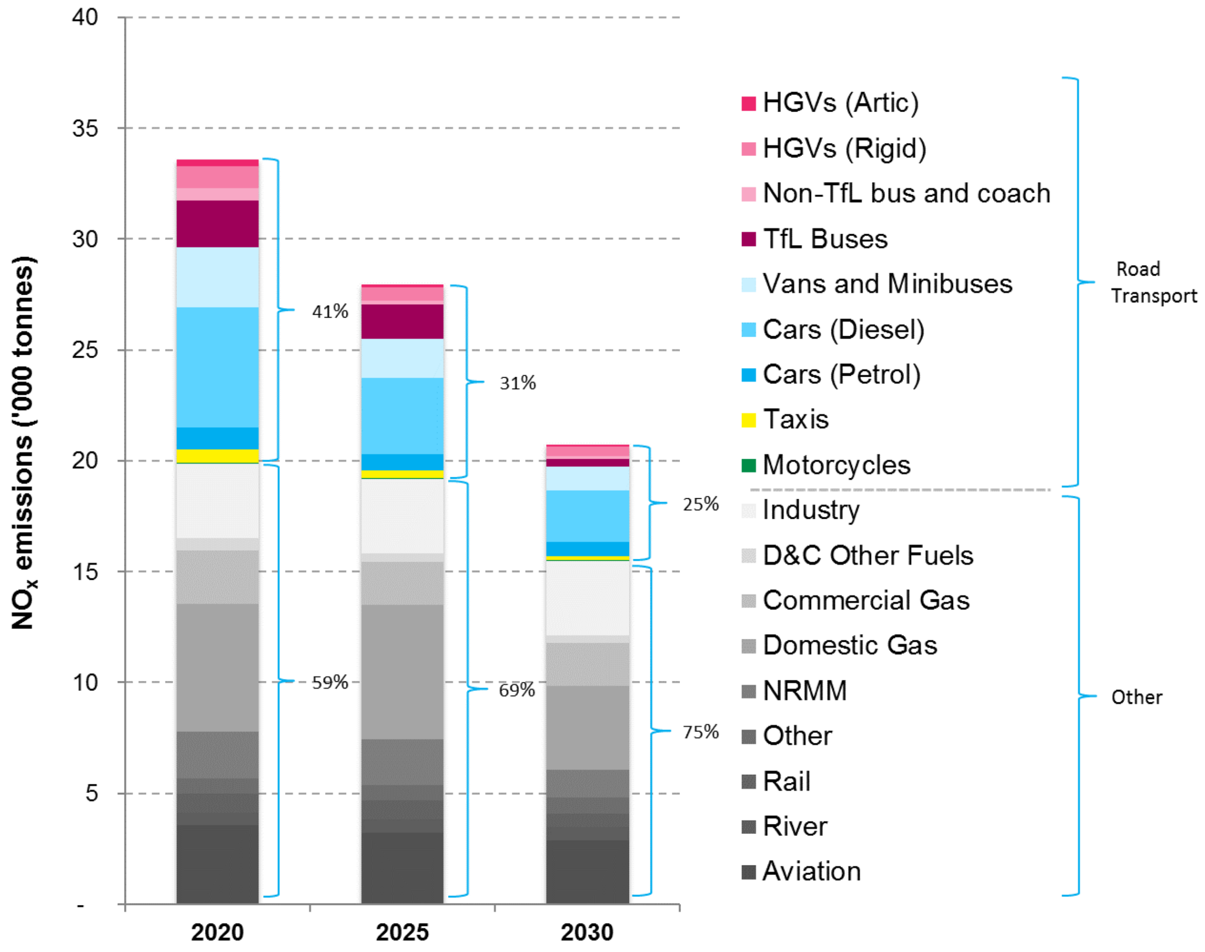
Trends in overall emissions

Total NO_x emissions

Against 2013, NO_x emissions are expected to fall by 30 per cent in 2020, 42 per cent in 2025 and 57 per cent in 2030.

Reductions in NO_x emissions are projected as the vehicle fleet in London becomes cleaner, brought about by technological advances and policies (such as the central London ULEZ, including its earlier introduction in 2019, which reduces road transport NO_x emissions by around 20 per cent) to encourage their early uptake (Figure 13).

Figure 13: Emissions trend and main source categories, 2020-2030 – NO_x[20]



Total PM_{10} emissions

Emissions of PM_{10} are expected to fall by 14 per cent (compared to 2013) up to 2020, mainly due to reductions in road transport emissions and significant reductions in NRMM emissions. Emissions are expected to fall by 17 per cent in 2025, and 22 per cent by 2030 (relative to 2013) (Figure 14).

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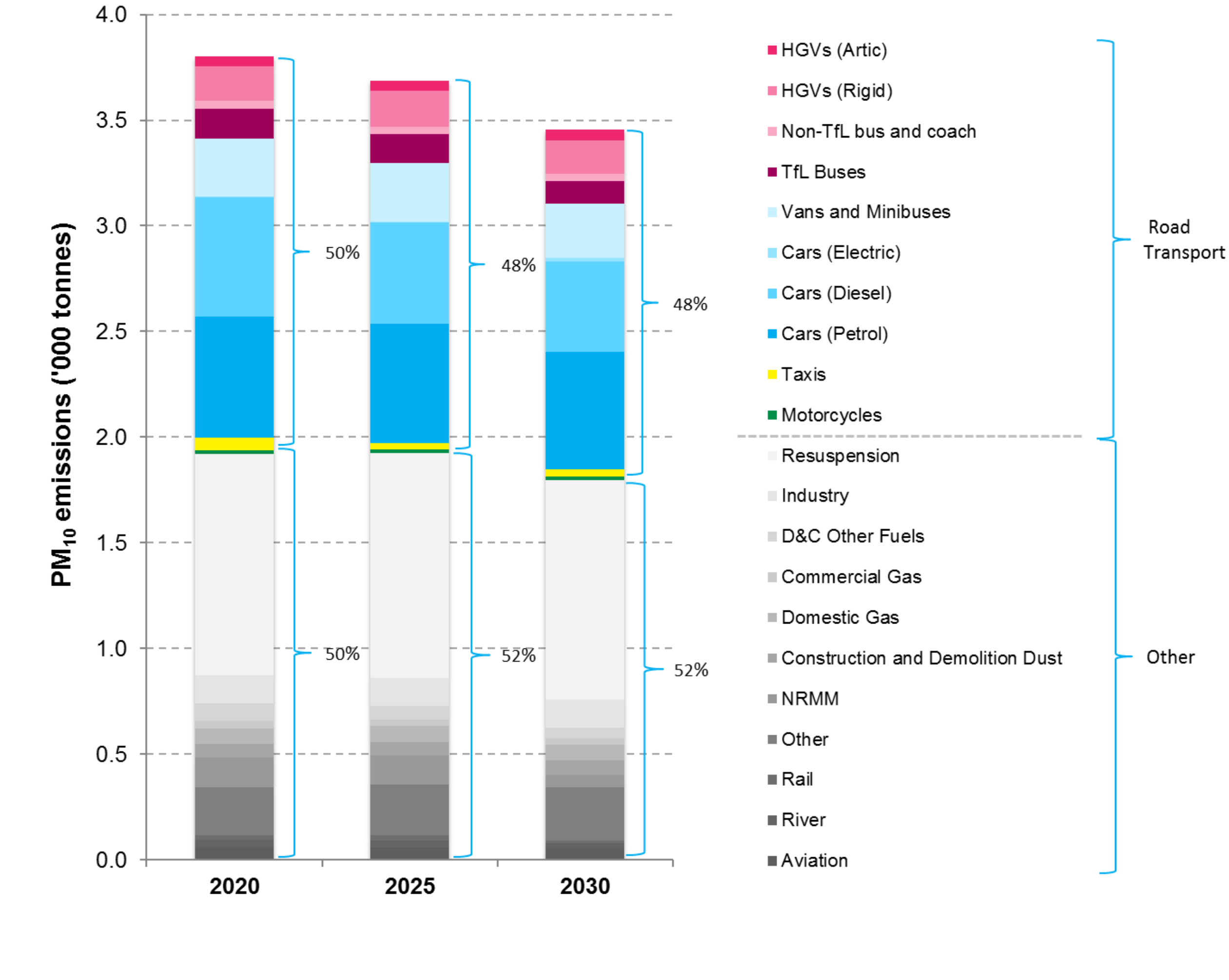
[20] GLA/TfL (2018), London Environment Strategy Modelling

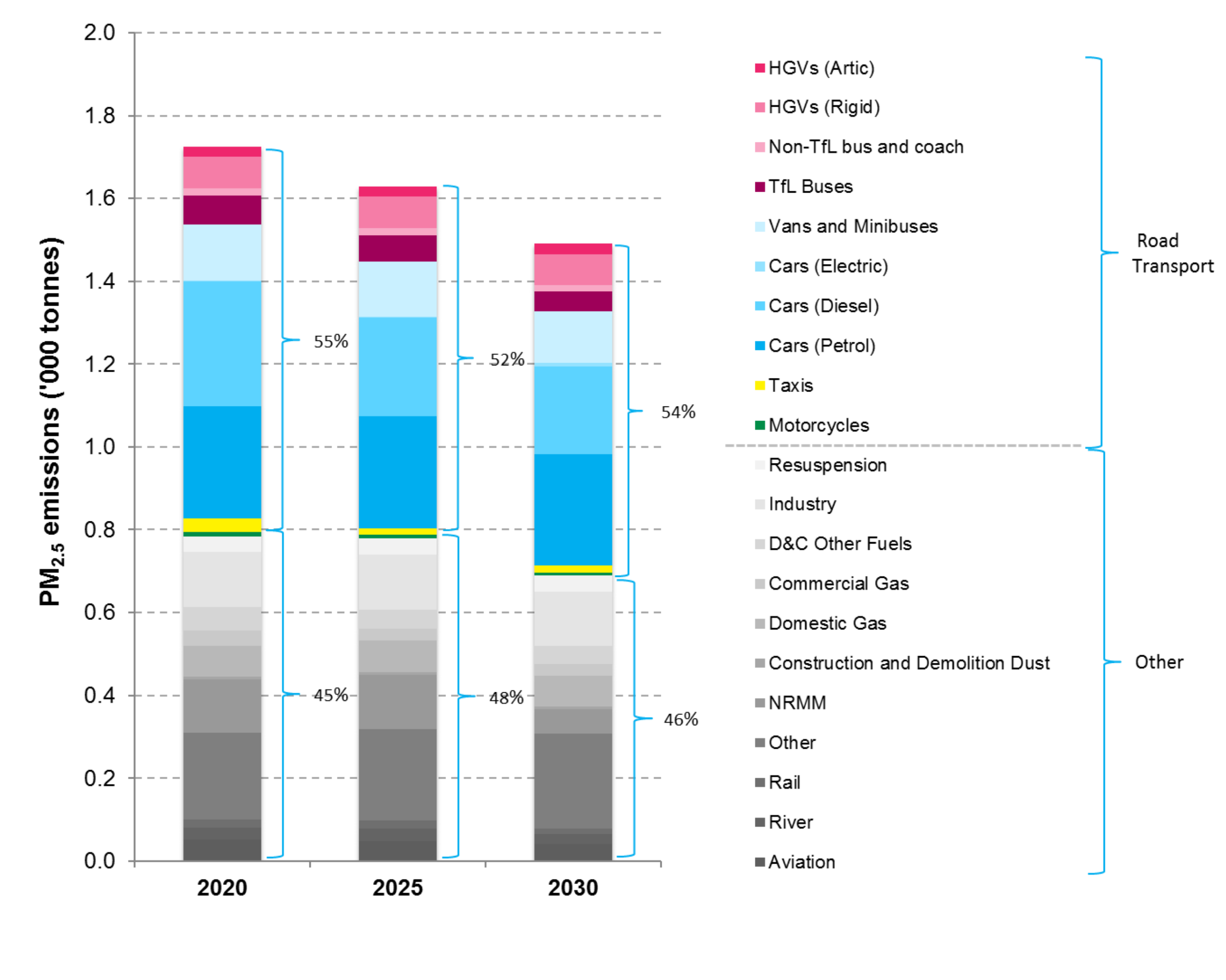
Figure 14: Emissions trend and main source categories, 2020-2030 – PM_{10}[20]



Total $PM_{2.5}$ emissions

Against 2013, $PM_{2.5}$ emissions are expected to fall by 25 per cent up in 2020. This figure is helped by significant reductions in NRMM emissions. Emissions are expected to fall by 29 per cent in 2025, and 35 per cent by 2030 (relative to 2013) (Figure 15).

Figure 15: Emissions trend and main source categories, 2020-2030 – $PM_{2.5}$[20]



Trends in emissions from road transport

In 2013, emissions from road transport comprised around 50 per cent of total NO_x and PM_{10} emissions in London. The following data show the various components of this road traffic emission in more detail.

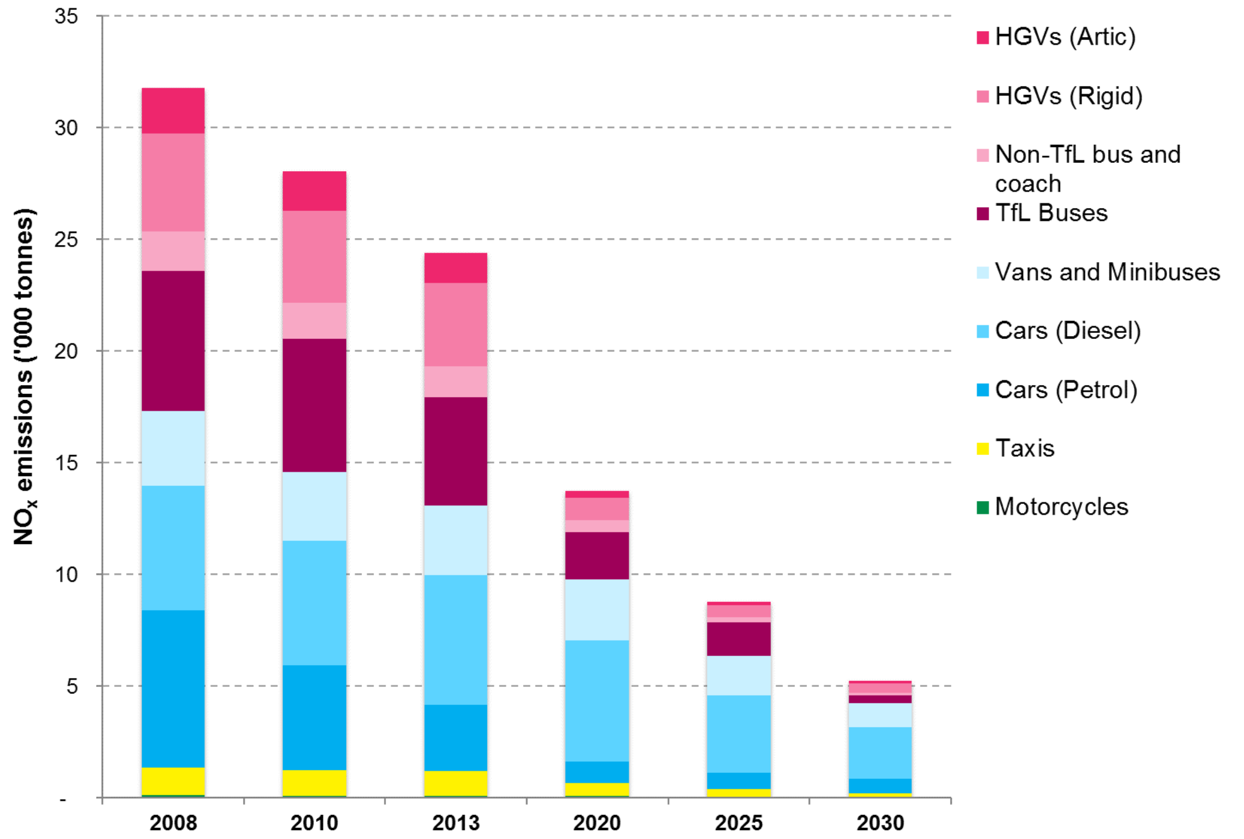
Road transport NO_x emissions

The most significant reductions in NO_x emissions are from cleaning up Transport for London buses. Bus improvements deliver significant NO_x reductions over time across London, and particularly within central London from 2020 due to the Ultra Low Emission Zone (ULEZ) package of measures which include Euro VI and hybrid buses. Significant reductions in NO_x from HGVs can also be seen in 2020 when ULEZ will be in place.

Taxi emissions are also forecast to reduce significantly between 2013 and 2020, with the introduction of the requirement that only zero emission capable taxis are licensed from 2018.

Limited reductions in emissions from cars are expected prior to the introduction of the central London ULEZ, and there was a slight increase in 2013 compared to 2010 due to the failure of European emissions standards to reduce emissions from the fleet. This is particularly pronounced in relation to diesel (Figure 16).

Figure 16: Trend in emissions from road transport and resuspension – NO_x[20]



Breaking down emissions into vehicle types in different areas of London illustrates the impact of diesel cars across Greater London, the biggest individual source of NO_x in 2013. TfL buses were the second biggest source across Greater London and biggest source in central London. However, by 2020 we expect the proportion of NO_x emissions coming from TfL buses to have fallen, being overtaken by diesel cars across Greater London, and also taxis in central London (Figure 17 and Figure 18).

Figure 17: Comparative NO_x emissions by source for 2013 – Greater London and central London compared[16]

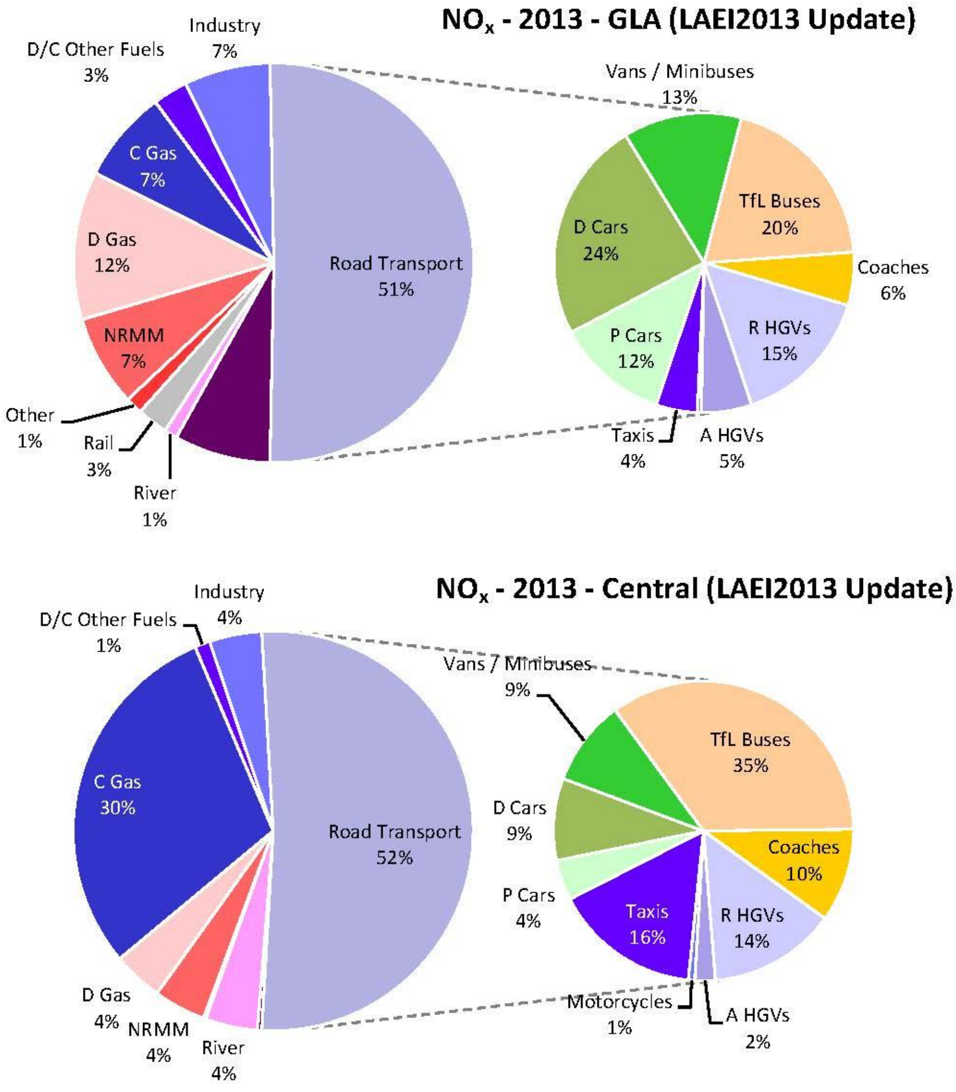
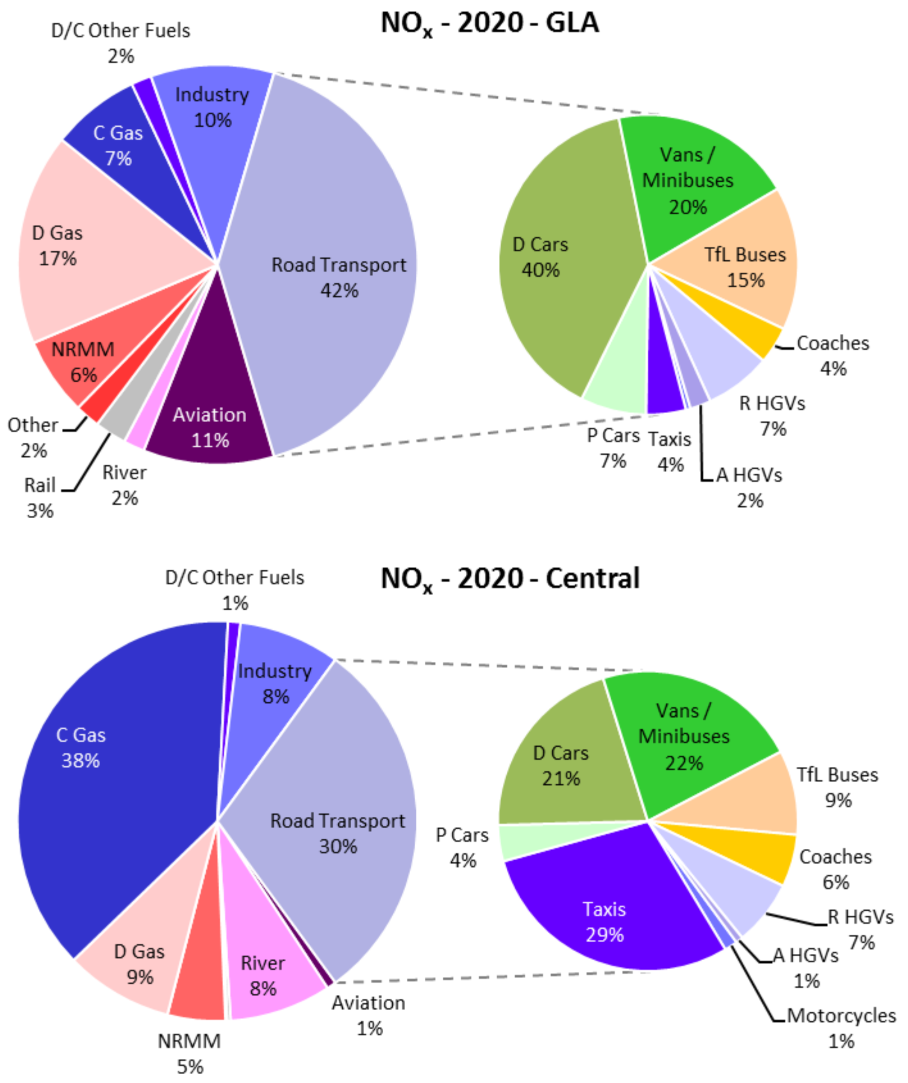


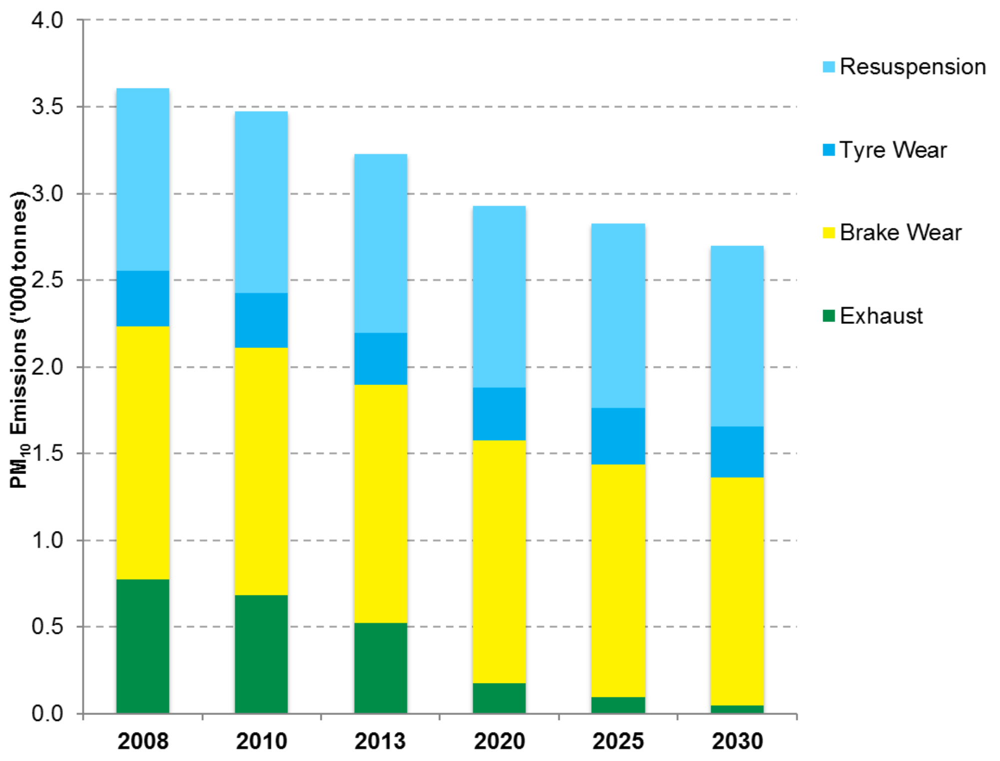
Figure 18: Comparative NO_x emissions by source for 2020 – Greater London and central London compared[20]



Road transport PM_{10} emissions

Whilst improvements to vehicle exhaust emissions and policies (particularly the existing Low Emission Zone for HGVs) have reduced PM_{10} emissions from road transport, the rate of reduction is less pronounced than NO_x, as these were put in place earlier and have already taken effect. However, tyre and brake wear, as well as resuspension components of PM_{10} remain (Figure 19).

Figure 19: Trend in emissions from road transport and resuspension – PM_{10}[20]



By 2030, PM_{10} exhaust emissions should be about 10 per cent of 2008 exhaust emissions. Currently, reductions in vehicle kilometres provide the main mechanism for reducing non-exhaust contributions over time, for example through promoting modal shift, transit-oriented development, and the move to electric or zero emission vehicles, etc.

The geographical variation in PM_{10} emissions is illustrated in Figure 20 and Figure 21. The variation in broad source categories is less distinct between central and Greater London in 2020. However, there is distinction in the contribution of vehicle types, particularly the dominance of emissions from cars across Greater London and the greater contribution of taxis in central London.

Figure 20: Comparative PM_{10} emissions by source for 2013 – Greater London and central London compared[16]

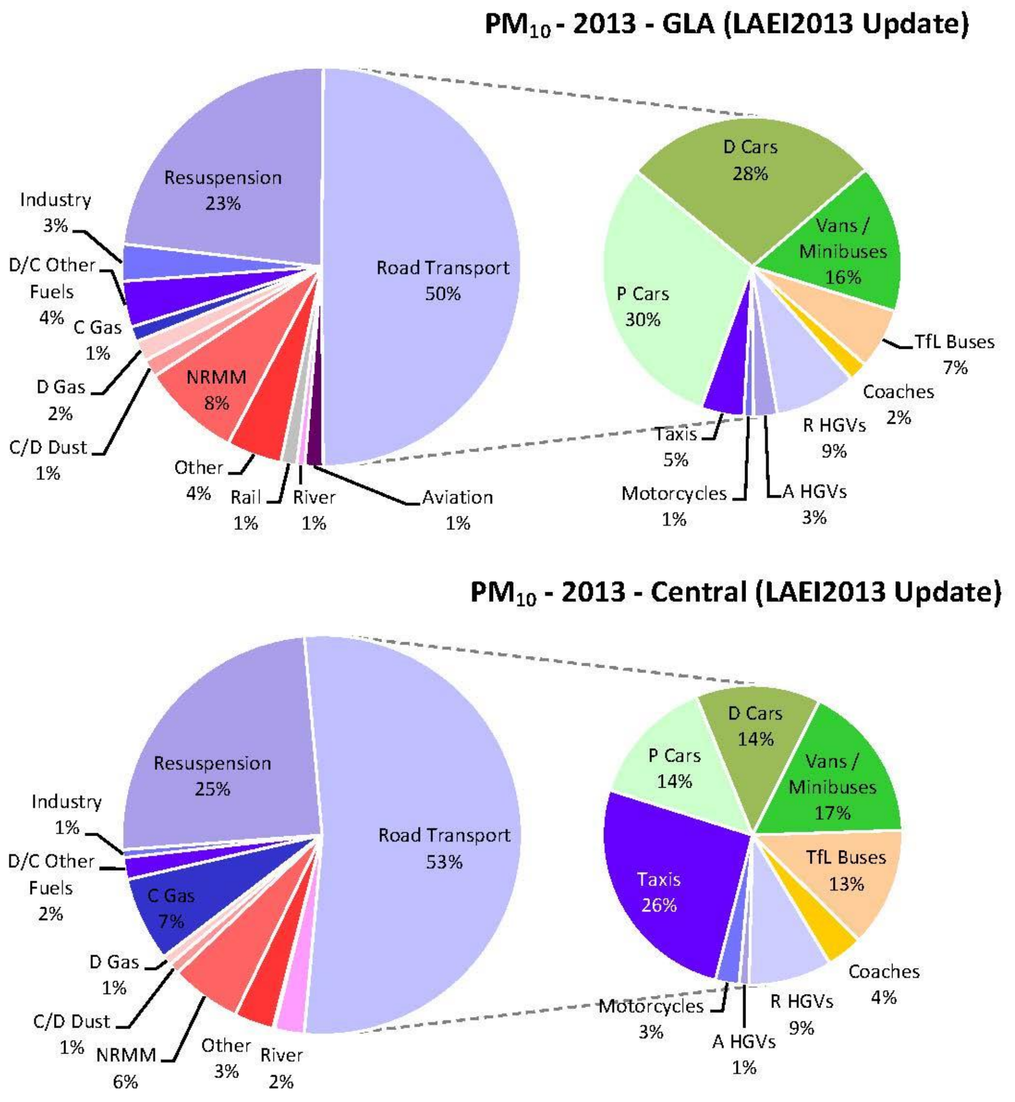
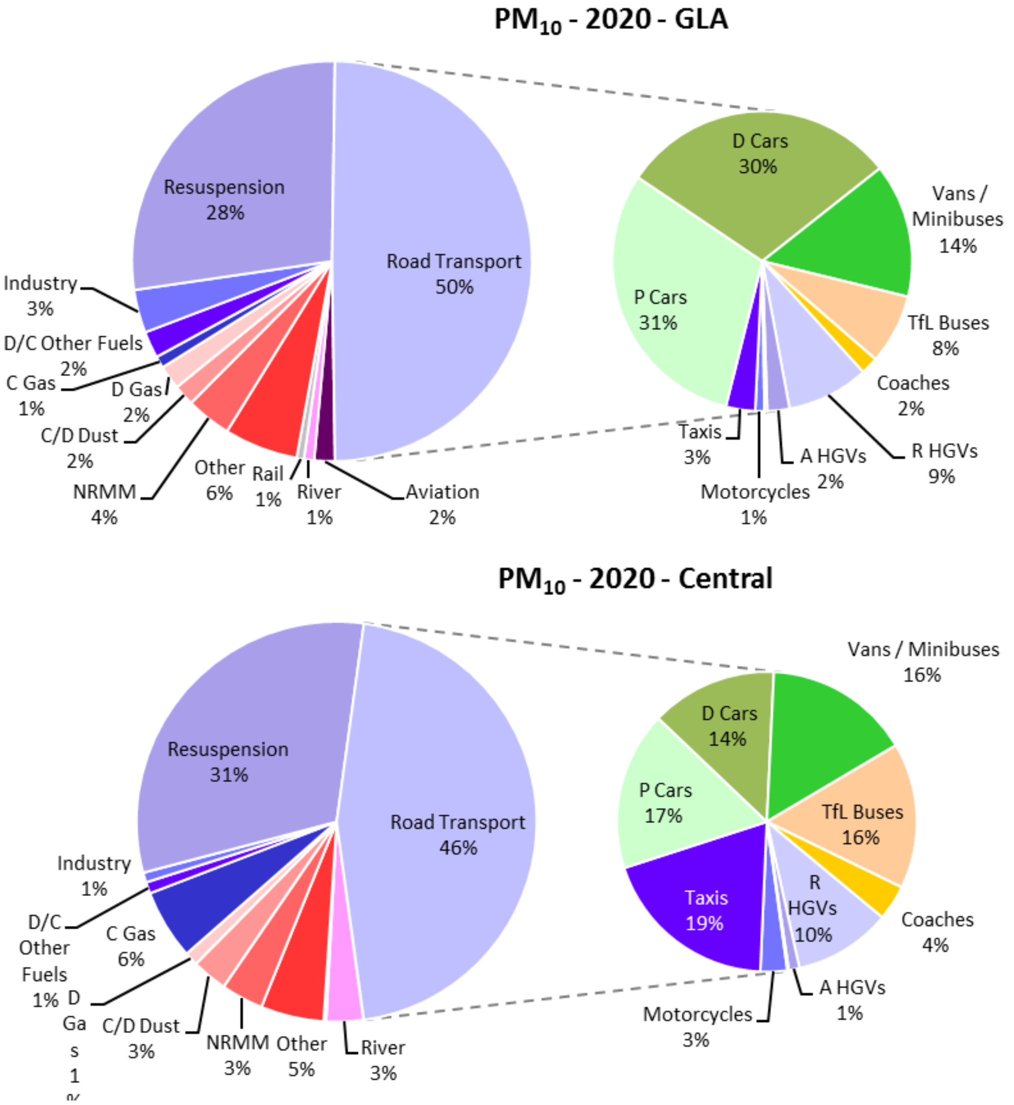


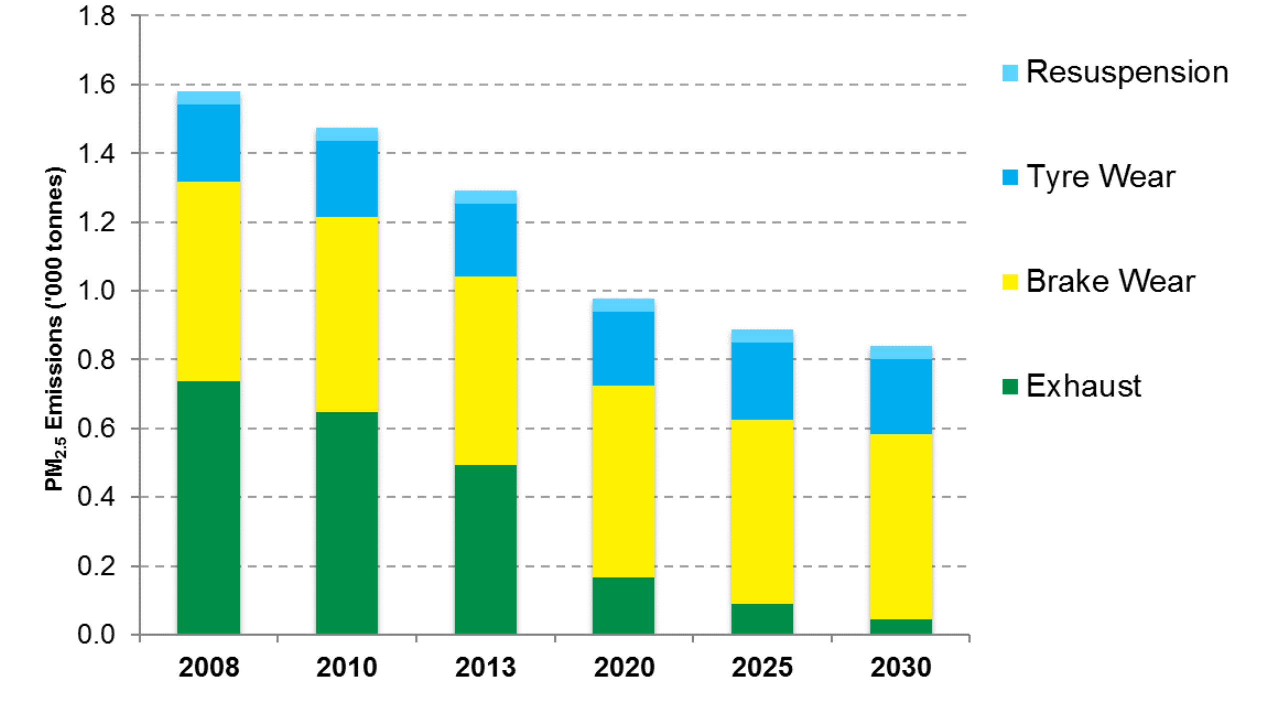
Figure 21: Comparative PM_{10} emissions by source for 2020 – Greater London and central London compared[20]



Road transport $PM_{2.5}$ emissions

As with PM_{10} projections, improvements to vehicle exhaust emissions and policies have reduced $PM_{2.5}$ emissions from road transport (Figure 22), with exhaust emissions projected to reduce by about 90 per cent between 2008 and 2030. Unlike PM_{10}, resuspension is a relatively small source of $PM_{2.5}$ and future emissions are expected to be dominated by tyre and brake wear.

Figure 22: Trend in emissions from road transport and resuspension – $PM_{2.5}$[20]



From 2025, $PM_{2.5}$ emissions should level out due to these non-exhaust contributions. The geographical variation in $PM_{2.5}$ emissions is illustrated in Figure 23 and Figure 24, and is broadly similar to the variation in PM_{10} source types.

Figure 23: Comparative $PM_{2.5}$ emissions by source for 2013 – Greater London and central London compared[16]

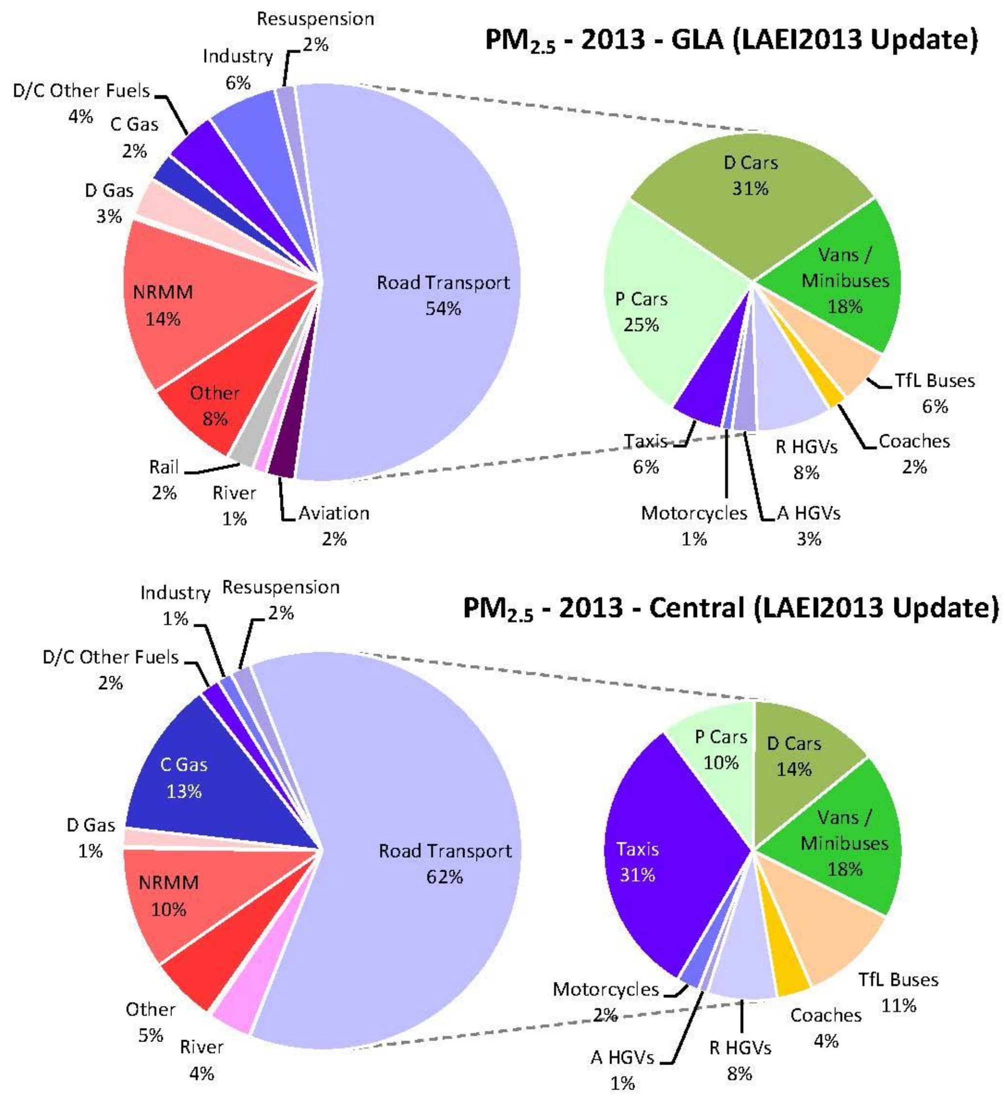
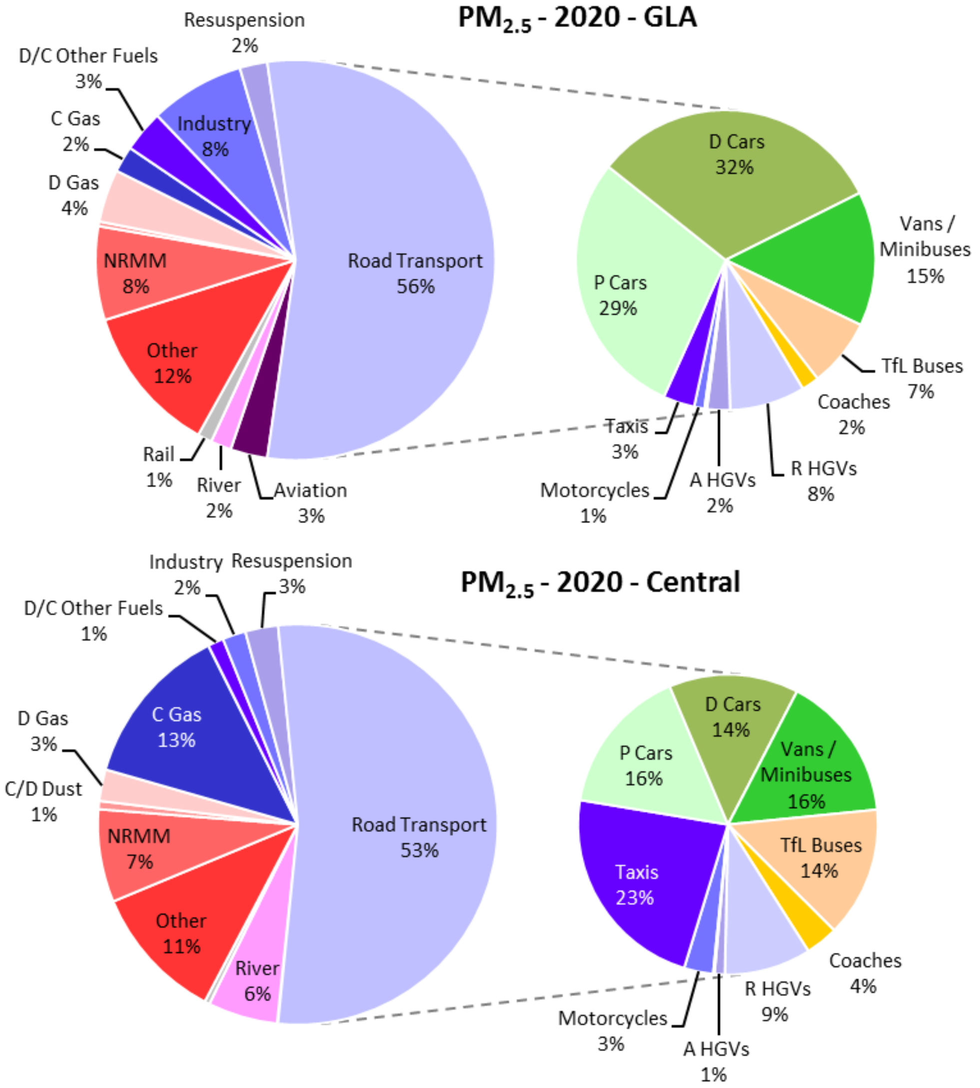


Figure 24: Comparative $PM_{2.5}$ emissions by source for 2020 – Greater London and central London compared[20]



Trends in emissions from non-road transport sources

Whilst road traffic in Greater London contributed slightly more than half of London's NO_x emissions in 2013, by 2020 it is forecast to reduce to around 41 per cent, whilst other sources make up 59 per cent of emissions (Figure 17 and Figure 18). Sources such as domestic and commercial gas are forecast to contribute around 25 per cent of London's NO_x emissions by 2020.

In central London in 2013, road traffic contributed just over 50 per cent of NO_x emissions, but this is forecast to fall to 30 per cent by 2020. However, by 2020 nearly 50 per cent of central London's NO_x emissions are from domestic and commercial gas (Figure 18). Therefore, targeted measures to reduce the contributions from these sources will be important in continuing to improve air quality in London.

As Figure 25, Figure 26 and Figure 27 show, further action is required after 2020 if a plateau in emissions reductions from non-transport sources is to be avoided.

Figure 25: Trend in emissions from non-road transport – NO_x[20]

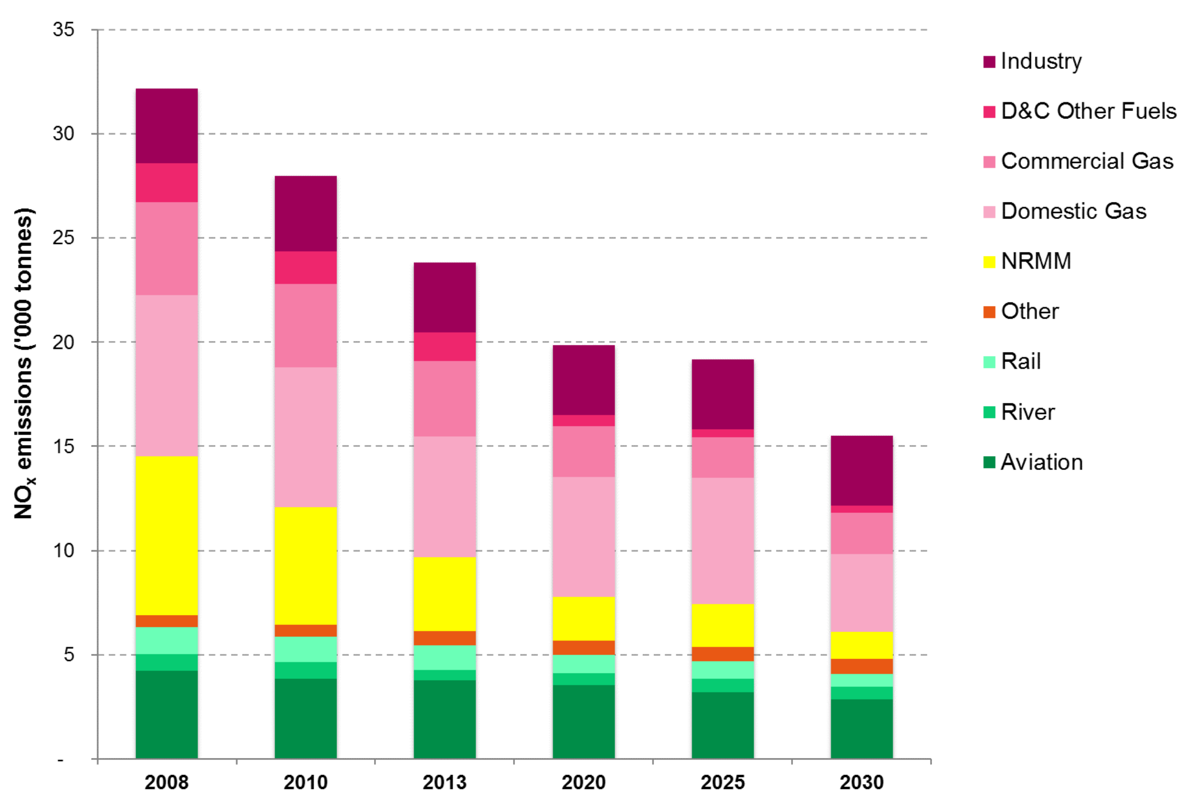


Figure 26: Trend in emissions from non-road transport – PM_{10}[20]

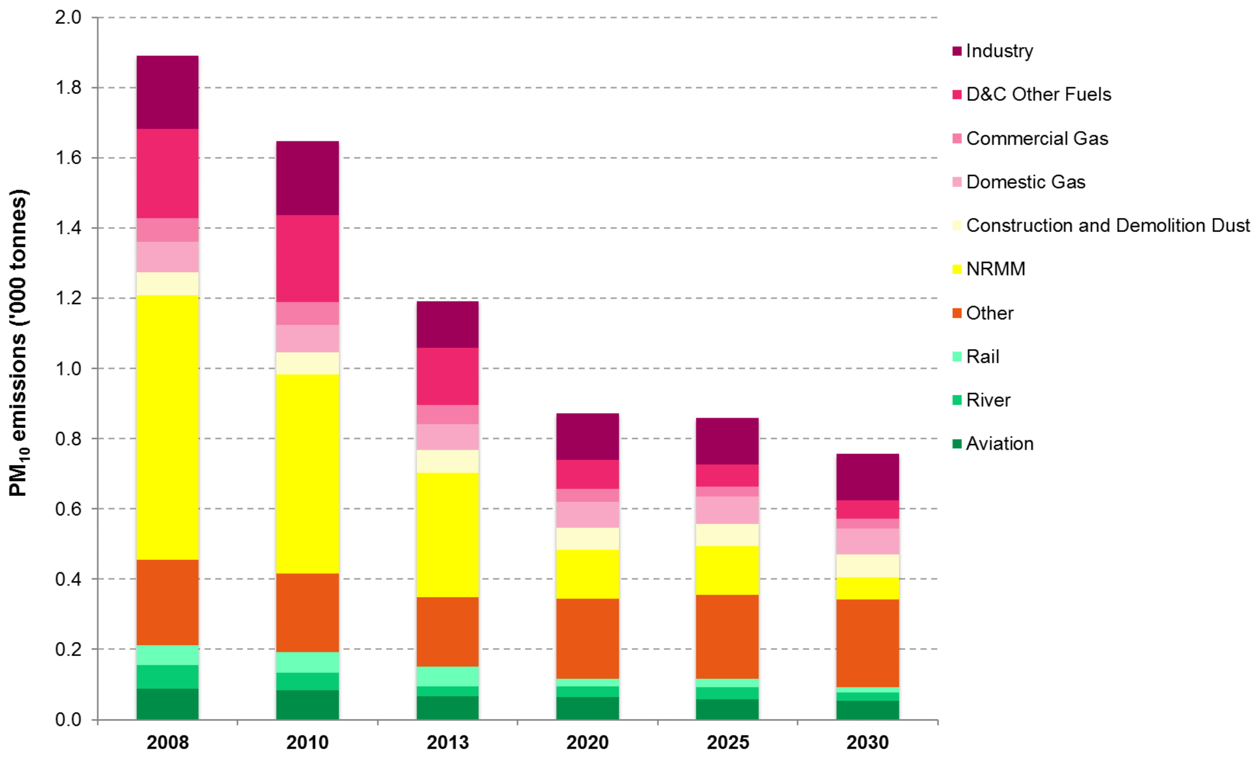
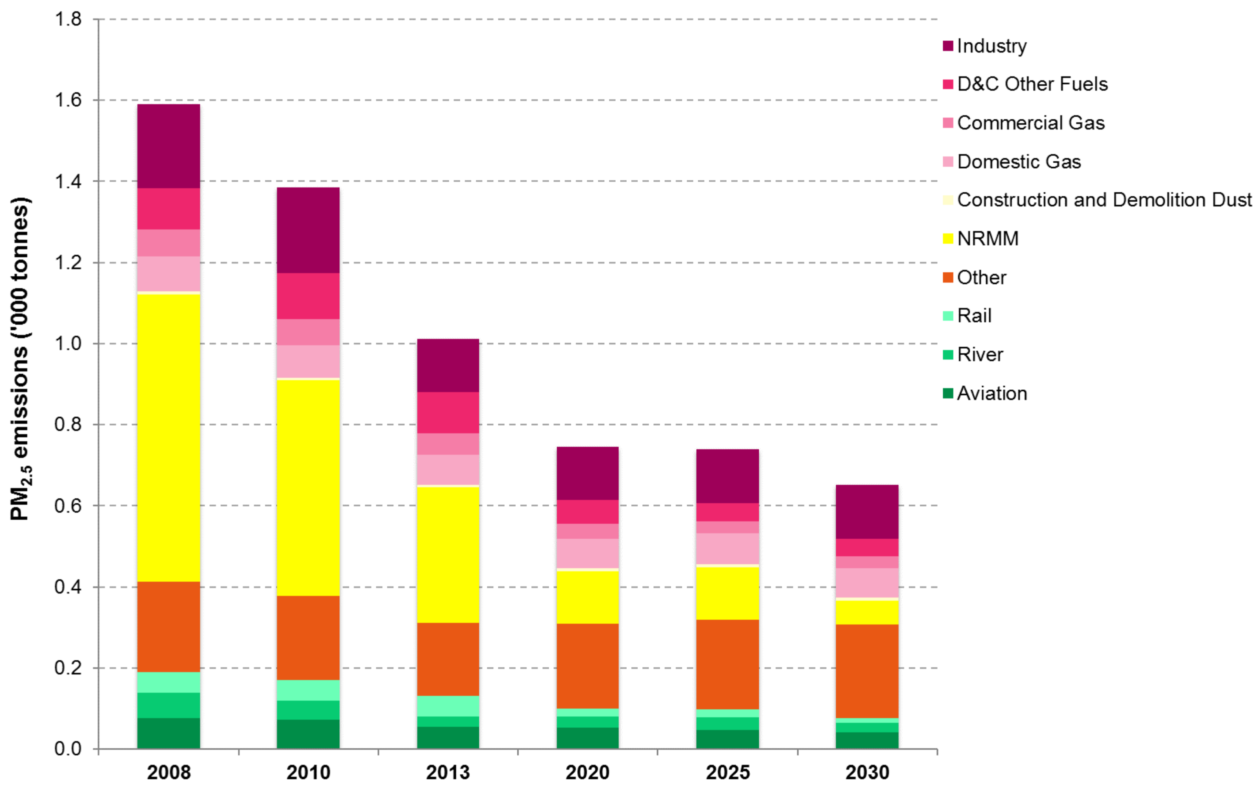


Figure 27: Trend in emissions from non-road transport – $PM_{2.5}$[20]



Strategy projections

This section presents the modelled emission and concentration reductions as a result of the policies included in the London Environment Strategy. Further interpretation of the concentration maps is included in the Strategy document.

Strategy projected NO_x emissions and concentrations

Compared to a 2013 baseline, a 40 per cent reduction in NO_x is expected by 2020, a 55 per cent reduction by 2025, a 65 per cent reduction by 2030, and an 82 per cent reduction by 2050 (Figure 28).

Figure 28: Emission trend and main source categories for London's NO_x 2013-2050, reflecting the London Environment Strategy[20]

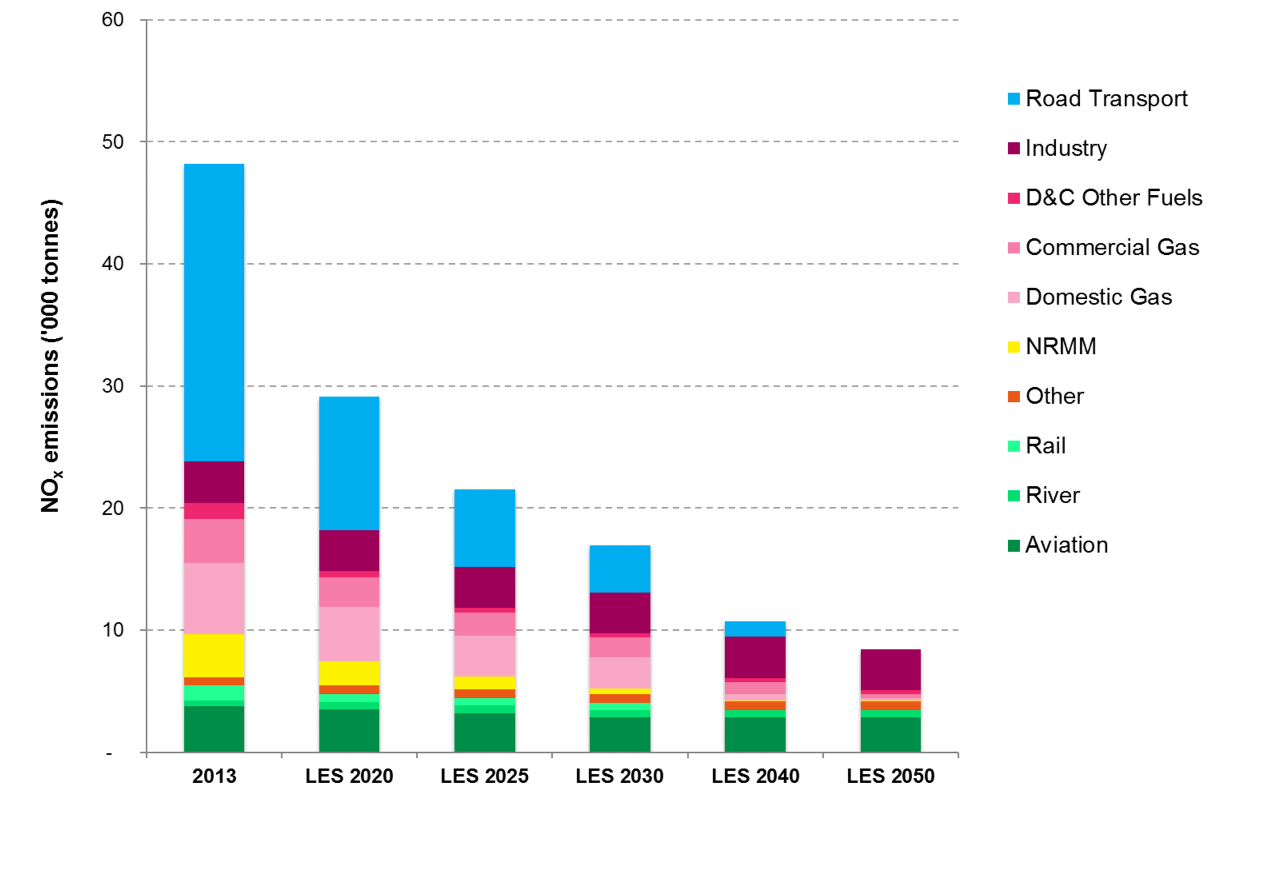
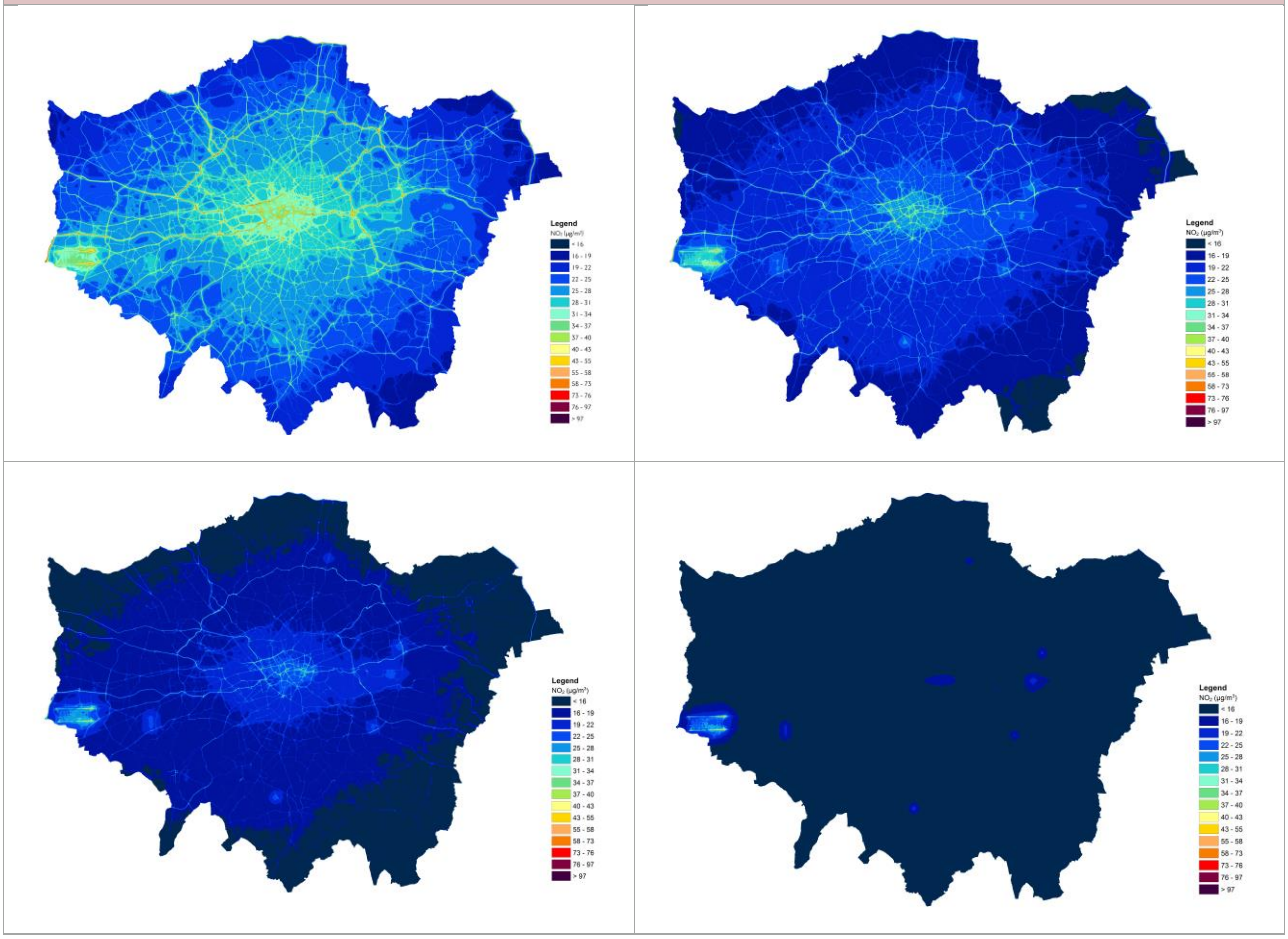


Figure 29: Projected NO_2 concentrations in 2020, 2025, 2030 and 2050 based on the Mayor's action (does not include additional requested Government measures)[20]



Strategy projected PM_{10} emissions and concentrations

Compared to a 2013 baseline, there is an expected 16 per cent reduction in PM_{10} by 2020, a 23 per cent reduction by 2025, a 28 per cent reduction by 2030, and a 38 per cent reduction by 2050 (Figure 30). These reductions should mean that legal limit values continue to be met, and further reductions that will be beneficial for health will be delivered.

Figure 30: Emission trend and main source categories for London's PM_{10} 2013-2050, reflecting London Environment Strategy[20]

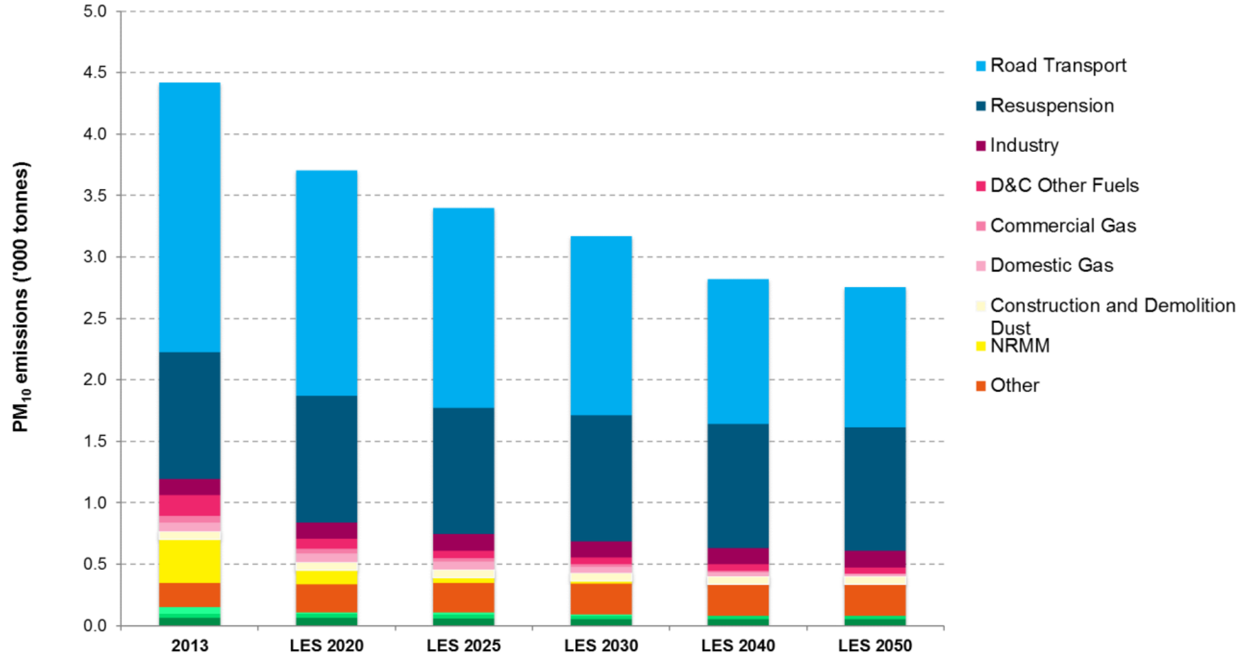
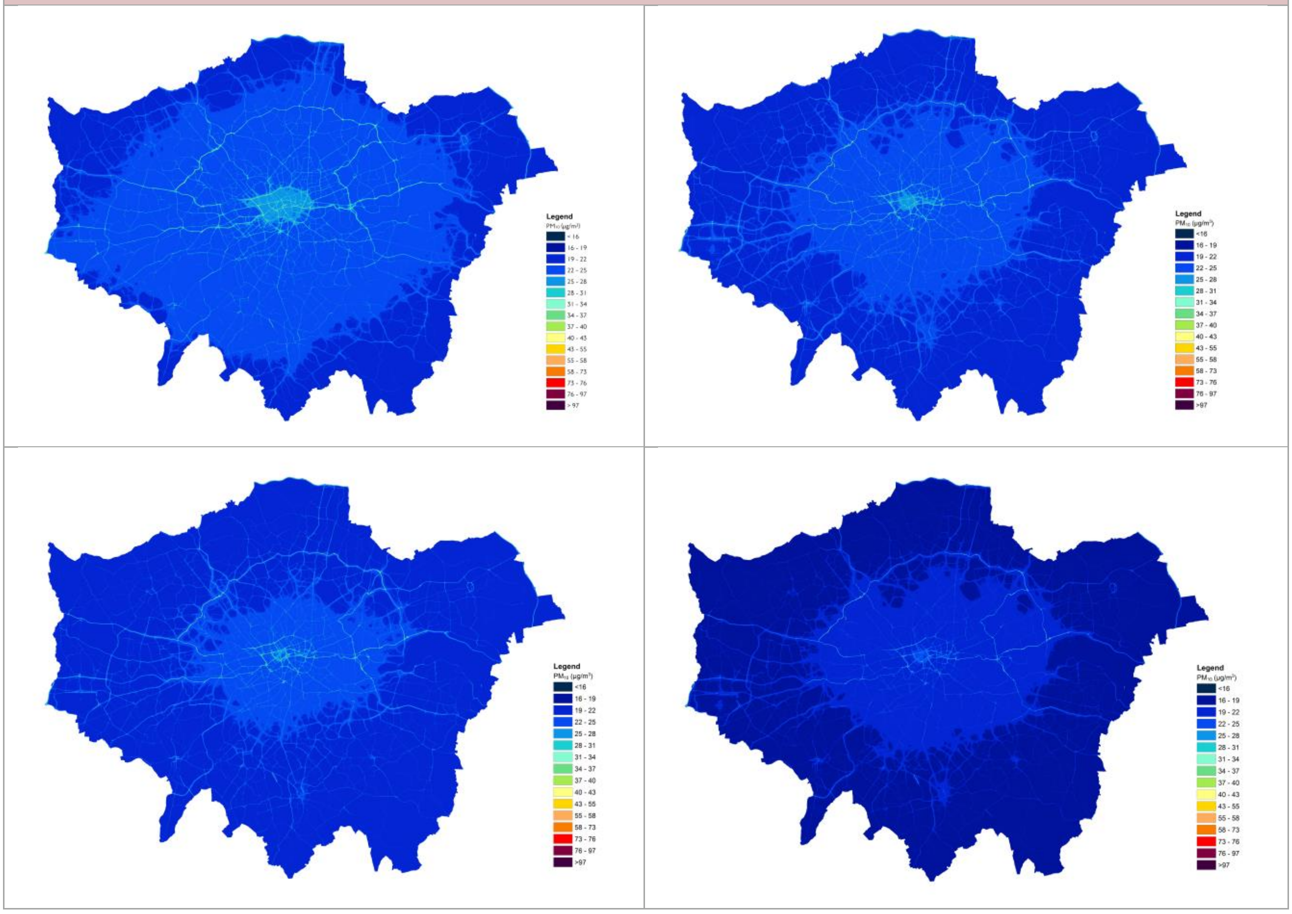


Figure 31: Projected PM_{10} concentrations in 2020, 2025, 2030 and 2050 based on the Mayor's action (does not include additional requested Government measures)[20]



Strategy projected $PM_{2.5}$ emissions and concentrations

Finally, $PM_{2.5}$compared to a 2013 baseline, a 28 per cent reduction in $PM_{2.5}$ is expected by 2020, a 37 per cent reduction by 2025, a 43 per cent reduction by 2030, and a 52 per cent reduction by 2050 (Figure 32).

Figure 32: Emission trend and main source categories for London's $PM_{2.5}$ 2013-2050, reflecting London Environment Strategy[20]

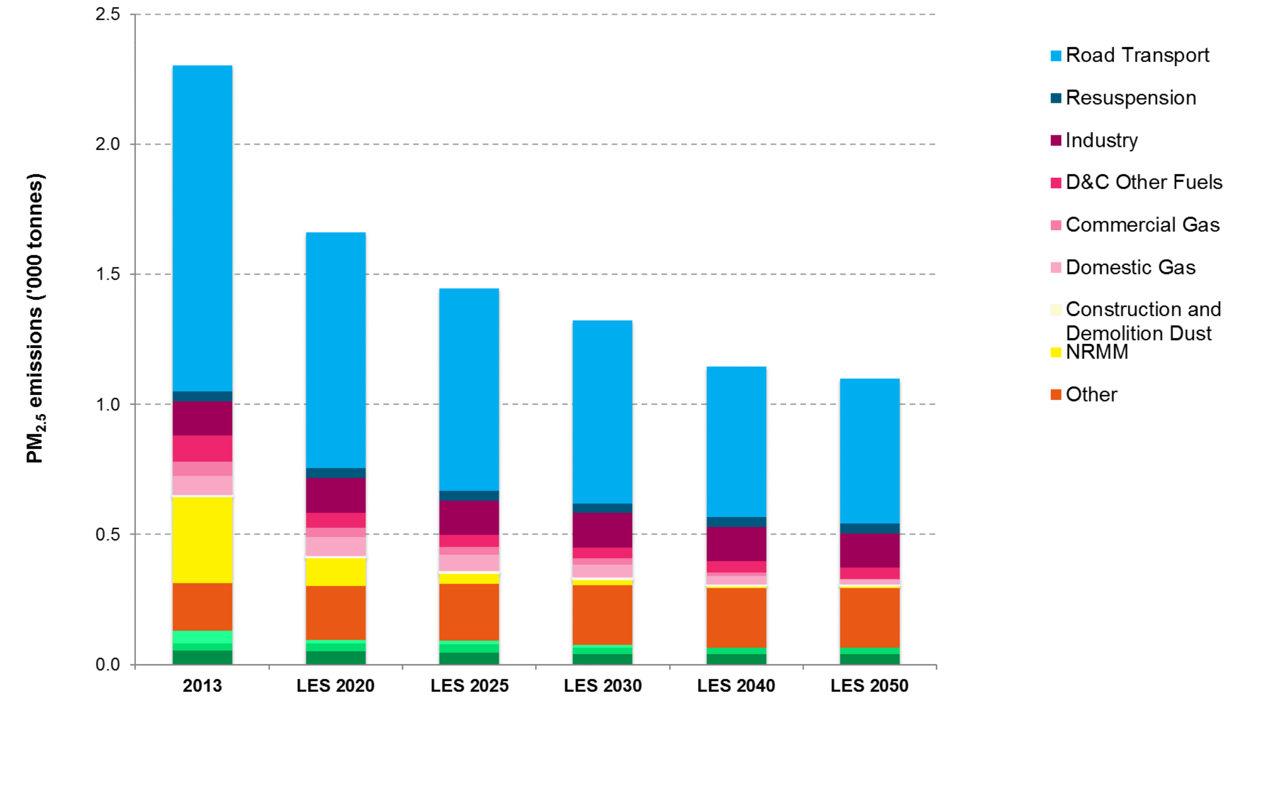
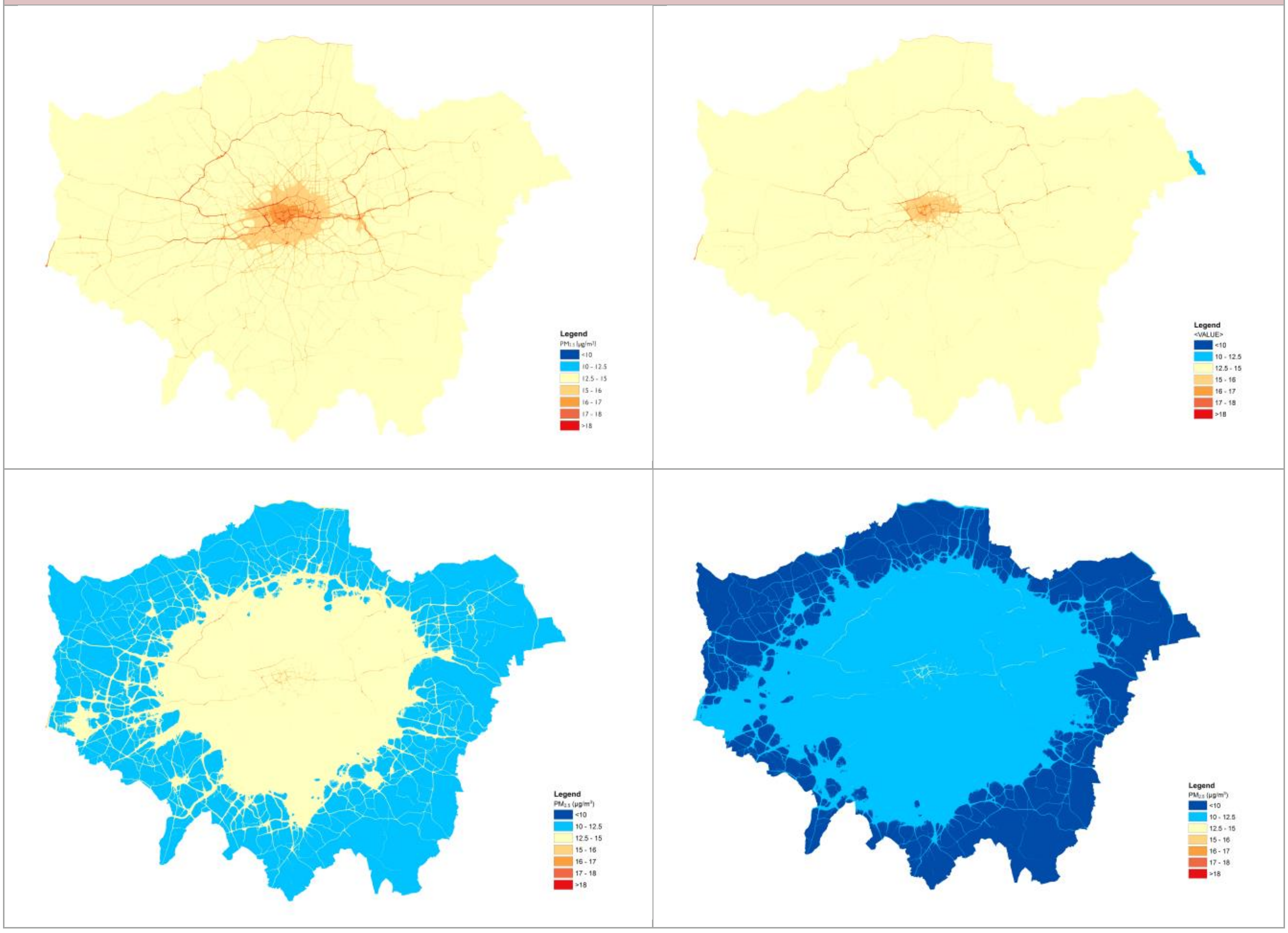
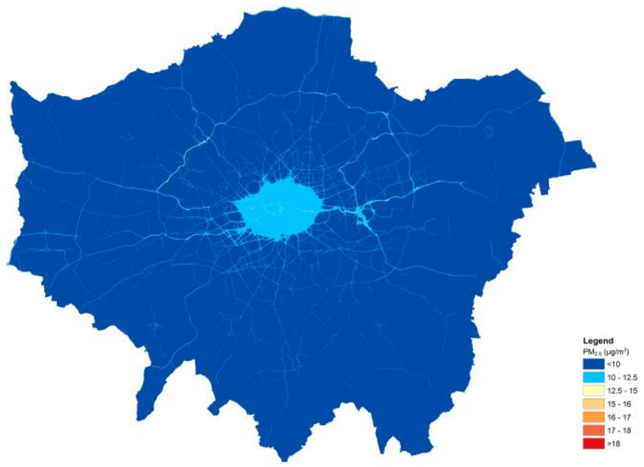


Figure 33: Projected $PM_{2.5}$ concentrations in 2020, 2025, 2030 and 2050 based on the Mayor's action (does not include additional requested Government measures)[20]



For 2050 an additional map has been included illustrate to the variation caused by the assumptions around wood burning. The 2050 map in Figure 33 above includes the concentrations attributed to wood burning. The 2050 map in Figure 34 shows the $PM_{2.5}$ concentrations in London if wood burning as a source is removed.

Figure 34: Projected $PM_{2.5}$ concentrations in 2050 based on the Mayor's action with wood burning removed (does not include additional requested Government measures)[20]



Conclusions

A review of the current baseline and evidence highlights several key issues to be addressed in the strategy:

Achieving legal compliance as quickly as possible

The last strategy did not achieve the expected emission reductions. In part, this was due to the underperformance of Euro engine emissions standards. Targets in the London Environment Strategy will need to reflect the latest evidence on vehicle emissions performance. It must set out appropriate steps by all levels of government to ensure a roadmap to compliance as quickly as possible.

Diesel vehicles, especially cars and vans

These remain the main source of road transport pollution. A comprehensive approach is required to phase out their use.

Tackling all sources of pollution

To achieve legal compliance as quickly as possible, all sources of pollution must be addressed. That means significantly increasing efforts in relation to non-transport sources. This is vital, as the proportion of total emissions from non-transport sources is expected to increase over the lifetime of this strategy as policies on transport start to have an effect.

Government action

The government controls some of the most powerful policy levers to influence air quality, including fiscal incentives such as vehicle excise duty. It alone can legislate to provide new powers to tackle non-transport emission sources. Achieving legal compliance, and going beyond these to achieve WHO recommended guidelines, is dependent on further government action and leadership.

Maximising co-benefits between air quality and climate change policies
There is a risk that unintended consequences can arise if climate and air quality policies are developed in isolation, for example, in relation to energy and planning policy or standards that promote a switch to older diesel or petrol vehicles over low emission vehicles. Conversely, integrated policy design can bring benefits for both air quality and climate change. For example, switching to zero emission vehicles can also reduce black carbon emissions.

Further reductions are needed in PM_{10} and $PM_{2.5}$, particularly from transboundary pollution, tyre and brake wear and wood burning
London is currently far from achieving WHO health-based limits for $PM_{2.5}$. It will be necessary to address wood burning-related emissions, which evidence suggests are a significant source of emissions, particularly on some of the most polluted days.

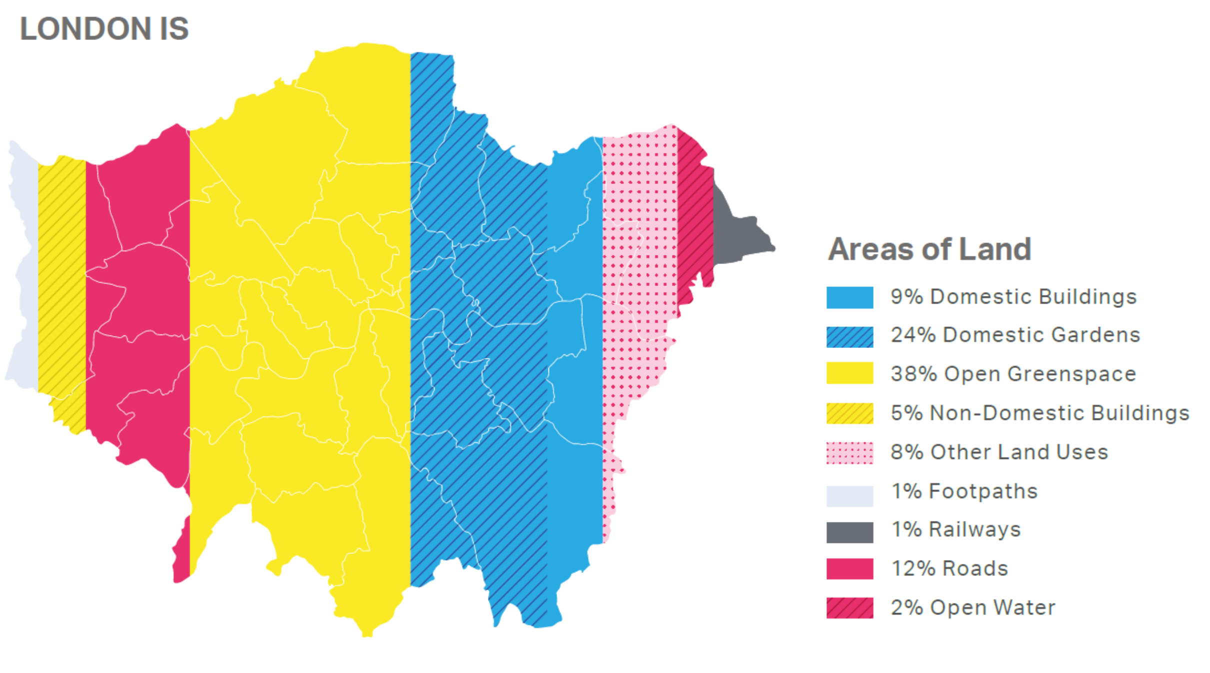
Green Infrastructure

A green city

Previous best estimates suggested that just under half of London is classified as green (or blue) open space (Figure 35):

- 33 per cent of London is green space like parks, woodland and farmland
- 14 per cent is private, vegetated domestic garden space
- 2 per cent is 'blue infrastructure' like rivers, canals and wetlands.[21]

Figure 35: Relative area of land cover in London[22]



This has stayed roughly at the same level since the assessment undertaken to inform the Mayor's Biodiversity Strategy in 2002, despite increased growth and development in

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[21] GiGL (n.d.), Key London Figures. Accessed from: http://www.gigl.org.uk/keyfigures/

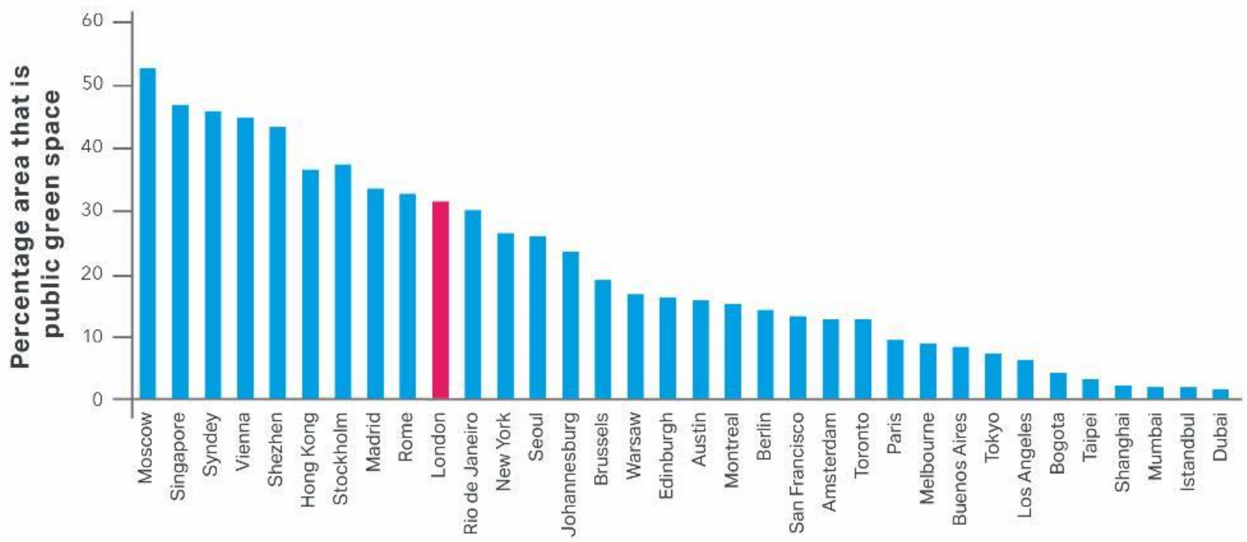
[22] From a Fatuous Maps infographic for the Greater London National Park City Initiative. N.B. the actual area of land in London which is green is 47 per cent. This is because 40 per cent of domestic garden land is paved, decked or occupied by out-buildings. Similarly, up to 5 per cent of land in parks is occupied by hard surfaces

London since then. But this overall picture masks local variations, and changes in quality, which are more difficult to track at a strategic level.

If private gardens (which make up 24 per cent of London's land area) are excluded from the calculation, London's other green spaces (parks, woodland, wetland, farmland, etc.) cover about 23 per cent of London. This is broadly comparable to other major UK cities – 24 per cent in Birmingham, and 20 per cent in Manchester.

London compares favourably with other world cities with respect to the amount of green space per head of population (Figure 36). An assessment of the amount of green space provision was undertaken for the World Cities Culture Forum. This ranked London 10th amongst 30 global cities – higher than cities with a similar urban form, such as New York, Berlin and Paris.

Figure 36: Percentage of green space in different world cities[23]



Types of green open space

Parks and public greenspace

Greater London has approximately 3,000 parks of varying sizes designated by the boroughs as 'public open space'. These cover approximately 18 per cent of Greater London (Table 3).

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[23] World Cities Culture Forum (n.d.) % of public green space (parks and gardens). Accessed from: http://www.worldcitiescultureforum.com/data/of-public-green-space-parks-and-gardens

Table 3: Public open space in London		
Public open space	**Area (ha)**	**Percentage of Greater London**
Regional parks (excluding Wandle Valley and Colne Valley)	6,755	4.24
Metropolitan parks	8,065	5.06
District parks	4,413	2.77
Local parks and open spaces	5,668	3.55
Small open spaces	804	0.5
Pocket parks	125	0.08
Linear open spaces	2,689	1.69
Total	**28,519**	**17.88**

Trees and woodlands
A number of different assessments using aerial imagery and randomised plot analysis of London's tree and woodland cover show that there are over eight million trees in London. They cover approximately 20 per cent of London's surface area. Most of these trees are in woodlands, parks and gardens. A significant number (about 500,000) are the trees that line London's streets.

An assessment by the London Assembly showed that the number of street trees has remained relatively stable – with around 505,000 trees in 2007 and around 497,000 in 2011.[24] The slight variation in numbers of trees or percentage of canopy cover is within any standard error caused by the assessment methodologies. A more recent exercise involving the mapping of street trees in London shows approximately 700,000 trees, although this includes some trees located in parks and opens spaces due to the way the data was collected and collated.[25]

The total area of canopy cover has remained relatively static since 2002. An assessment undertaken by Forest Research suggests that the majority of cities in the UK have 16-21 per cent canopy cover (Table 4).[26] Coastal cities tend to have a lower canopy cover. The assessment recommends that all cities should have a minimum tree canopy cover of 20 per cent. Where this minimum is achieved, cities should set a target to increase canopy cover to at least 25 per cent. This will ensure that canopy cover is always above the

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[24] London Assembly (2011) Branching out: the future for London's street trees. Accessed from: https://www.london.gov.uk/about-us/london-assembly/london-assembly-publications/branching-out-future-londons-street-trees

[25] Mayor of London (n.d.) London Tree Map. Accessed from: https://www.london.gov.uk/what-we-do/environment/parks-green-spaces-and-biodiversity/trees-and-woodlands/london-tree-map

[26] Forest Research (n.d) Urban Tree Cover. Accessed from: http://www.urbantreecover.org/

minimum threshold, allowing for tree cover to vary over time (e.g. due to tree age or disease) and to buffer climate change impacts.

Table 4: Canopy cover in major UK cities

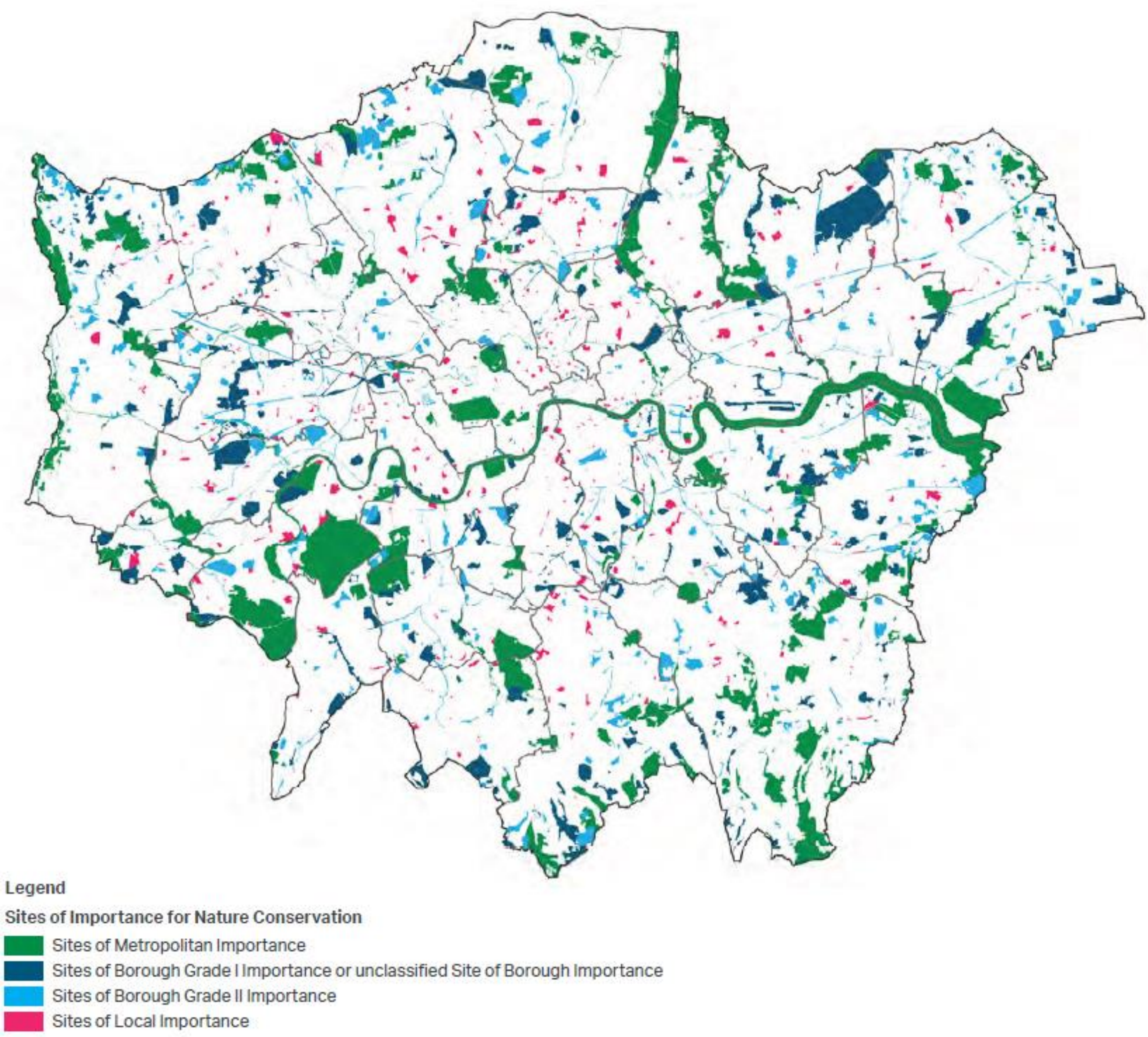
Town	Per cent tree cover (± std error, where available)	Source	Year of survey
Birmingham	19.0 (± 1.48)	i-Tree Canopy	2016
	23.0	i-Tree Canopy	2012
Brighton	14.4 (± 1.57)	i-Tree Canopy	2016
	12.0 (± 1.45)	i-Tree Canopy	2016
Bristol	18.6 (± 1.52)	i-Tree Canopy	2016
	17.0 (± 1.42)	i-Tree Canopy	2016
Cambridge	19.0 (± 1.75)	i-Tree Canopy	2016
	17.1	Proximitree	2014
Cardiff	21.0 (± 1.44)	i-Tree Canopy	2016
Coventry	20.6 (± 1.81)	i-Tree Canopy	2016
	12.8 (± 1.49)	i-Tree Canopy	2016
Edinburgh	19.6 (± 1.26)	i-Tree Canopy	2015
	17.0	i-Tree Eco	2015
Glasgow	14.9 (± 1.13)	i-Tree Canopy	2015
	13.5 (± 1.40)	i-Tree Canopy	2016
London	19.6 (± 0.72)	i-Tree Canopy	2016
	21.9	LTOA Canopy	2012
Hull	13.4 (± 1.53)	i-Tree Canopy	2016
	9.0 (± 1.28)	i-Tree Canopy	2016
Leeds	17.4 (± 1.20)	i-Tree Canopy	2016
Liverpool	16.2 (± 1.17)	i-Tree Canopy	2016
	12.2 (± 1.46)	i-Tree Canopy	2016
Manchester	21.1 (± 1.30)	i-Tree Canopy	2016
	17.0 (± 1.42)	i-Tree Canopy	2016
Newcastle	10.6 (± 1.38)	i-Tree Canopy	2016
	10.4 (± 1.37)	i-Tree Canopy	2016
Norwich	18.6 (± 1.74)	i-Tree Canopy	2016
Nottingham	15.2 (± 1.61)	i-Tree Canopy	2016
	14.0 (± 1.42)	i-Tree Canopy	2016
Portsmouth	8.0 (± 1.21)	i-Tree Canopy	2016
	8.0 (± 1.21)	i-Tree Canopy	2016

Table 4: Canopy cover in major UK cities			
Town	**Per cent tree cover (± std error, where available)**	**Source**	**Year of survey**
Sheffield	16.2 (± 1.25)	i-Tree Canopy	2016
York	9.8 (± 1.33)	i-Tree Canopy	2016

European and national nature conservation designations
London's most important sites for nature conservation have been recognised at the European and national levels and consequently have been given statutory designations. They include two Special Protection Areas (SPAs), three Special Areas of Conservation (SACs), two National Nature Reserves (NNRs), and 37 Sites of Special Scientific Interest (SSSIs).

Sites of Importance for Nature Conservation
Important wildlife sites in Greater London are identified as Sites of Importance for Nature Conservation (SINCs). SINCs are a land use planning policy 'designation' conferred through London Plan policy. Consequently, SINCs receive a significant degree of protection through the planning process. Almost 20 per cent of Greater London's land area is identified as a SINC, variously graded as Metropolitan, Borough, or Local depending upon the relative importance and value of the SINC (Figure 37). The total area of SINCs has increased slightly since 2002,from 29,855 hectares to 30,679 hectares.

Figure 37: Distribution of SINCs in London



Procedures and criteria for the identification of SINCs can be used by boroughs to identify SINCs in their Local Plans and give strong protection to SINCs in accordance with policies in the London Plan.

London's semi-natural habitats
London's SINCs, and the extent to which they are under appropriate management, provides the core framework necessary to conserve London's biodiversity. Since 2000,

almost 39,000 hectares have been reported as having been enhanced in London, and over 18,000 hectares have been restored.[27]

Examples include the creation of over 600 hectares of new woodland in Thames Chase on London's eastern fringe, the creation of reed beds in the central London Royal Parks, the expansion of 3.5 hectares of heathland at Mitcham and West Wickham Commons, and the creation of 45 hectares of various biodiversity action plan habitats in the Queen Elizabeth Olympic Park.

It is not feasible to undertake a direct, like-for-like comparison between the figures for land cover types published in the 2002 Biodiversity Strategy and current figures for land cover types. Current data would need to be derived from multiple (not fully compatible) datasets. Nevertheless, we can compare data on land cover and habitats where there is comparable data (Table 5). These figures suggest that despite the reduction of the total amount of green space in London this has not resulted in a significant adverse impact on the amount of semi-natural wildlife habitats.

Table 5: Land use and habitat change (sources: data collected for the Mayor's Biodiversity Strategy and more recent data from Greenspace Information for Greater London

Habitat or land use	Area of habitat or land use (ha)		
	Biodiversity Strategy (2002)	GiGL data	2016 baseline[28]
Gardens	34,584 (total area)	22,000 (vegetated area)	N/A
SINC	29,855	30,679 (2013 data)	N/A
Woodland	7,200	7,500 (2009-10 data)	7,477
Chalk grassland	300	300 (2009-10 data)	336
Reedbed	125	140 (2009-10 data)	144
Acid grassland	1300	1,450 (2009-10 data)	1,523
Heathland	80	55[29] (2009-10 data)	56

[27] Mayor of London, Environment Agency, *et al*. (2013) London's Environment Revealed. Accessed from: https://files.datapress.com/london/dataset/state-environment-report-london/SOE-2013-report.pdf

[28] Estimated as a result of research conducted by London Wildlife Trust and GiGL into habitat targets for the drat London Plan. LWT & GiGL (2017) The London Plan habitat targets: a review of progress and forward recommendations. Accessed from: https://www.london.gov.uk/what-we-do/planning/london-plan/new-london-plan/evidence-base

[29] There appears to be a 25ha reduction in heathland; but this is likely to be an anomaly in the data, as there is no suggestion that large areas of heathland have been lost in London. Indeed, there have been heathland restoration projects undertaken in recent years. The anomaly is likely to be a consequence of errors in habitat description between acid grassland, which the data suggests has increased by almost 200ha, and heathland.

Gardens

Domestic gardens provide many people with daily contact with nature and form a pleasant component of residential areas. In total, they comprise about 38,000 hectares of land, or 24 per cent of the land area of London. However, not all gardens comprise the classic combination of lawns, flowers beds, shrubs and trees. Many now include extensive areas of decking and paving. Consequently, only about 60 per cent of land in London's gardens is green, or 14 per cent of London's land area.

To inform policy formulation for the London Plan of 2011, the Greater London Authority (GLA) commissioned London Wildlife Trust and Greenspace Information for Greater London to undertake a study into changes to London's domestic gardens.[30] The study shows that between 1999 and 2007:

- the amount of hard surfacing in London's gardens increased by 26 per cent or 2,600 hectares
- the area of garden buildings (sheds etc.) increased by 55 per cent or 1,000 hectares
- the amount of garden lawn decreased by 16 per cent or 2,200 hectares

The changes in garden cover are primarily due to many small changes to individual gardens as part of their management and use by homeowners. This is rather than large scale changes or housing development on garden land (although this can result in significant loss of garden land at a local level).

Green roofs

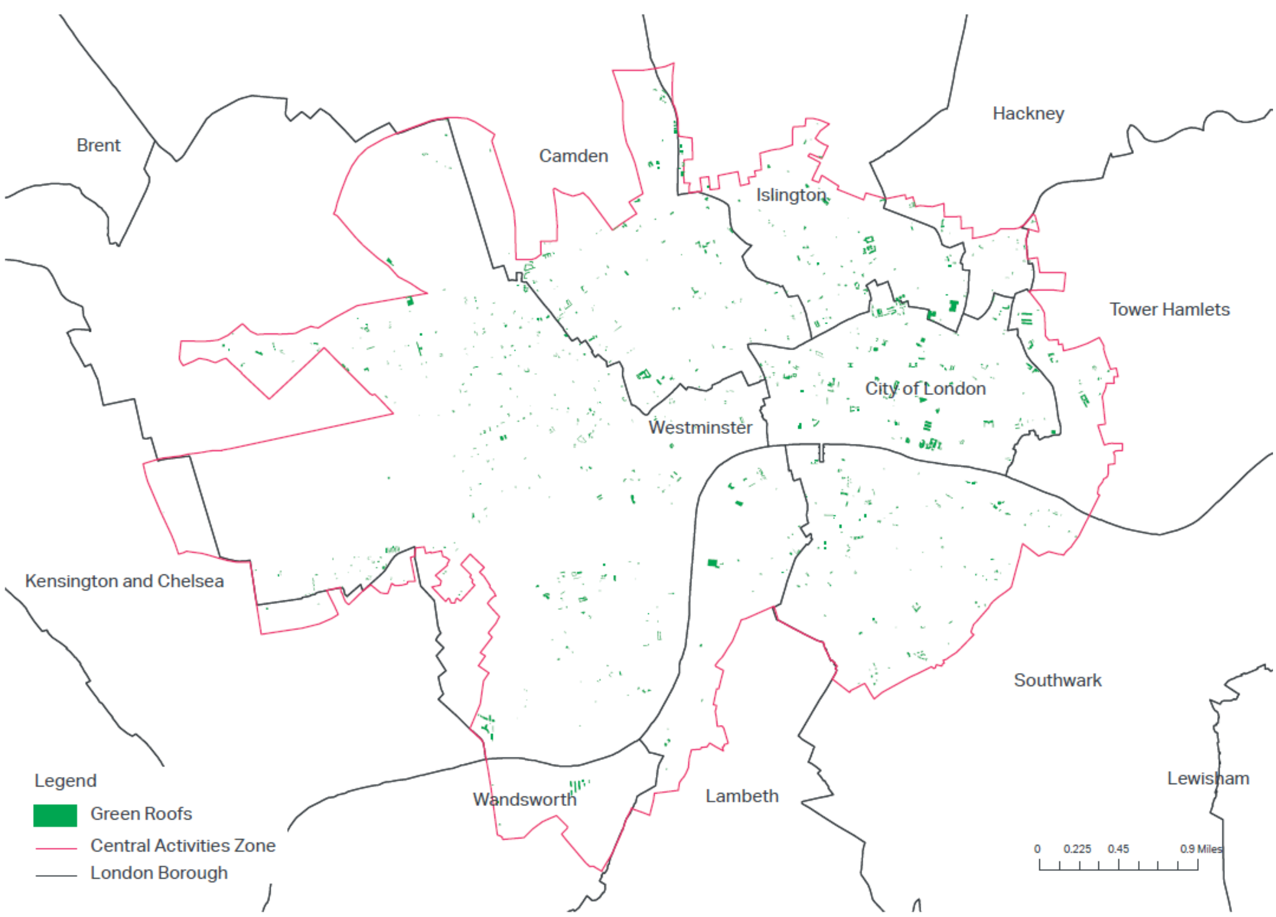
There has been a significant increase in the installation of green roofs (and other green infrastructure integrated into the built environment, such as green walls and rain gardens) in recent years. Across London there are now thought to be over one million m^2 (100 hectares) of green roofs installed.

A survey undertaken by the GLA highlighted that that there are now over 700 green roofs just in London's Central Activities Zone (CAZ). This is the area including the City of London, the West End and the South Bank (Figure 38). Green roofs here cover an area of almost 20 hectares, the same size as Green Park. Most of these have been installed since 2008, when the London Plan included a policy to promote them.

An assessment undertaken for the GLA to assess the potential for green roofs in the CAZ indicates that there are 140 hectares of existing flat roofs that could be retrofitted to be a green roof, an area equivalent to the size of Hyde Park.

[30] Greenspace Information for Greater London et al (2010). London: Garden City? Accessed from: http://www.gigl.org.uk/partnershipcasestudy/garden-research/

Figure 38: Green roofs in the Central Activities Zone

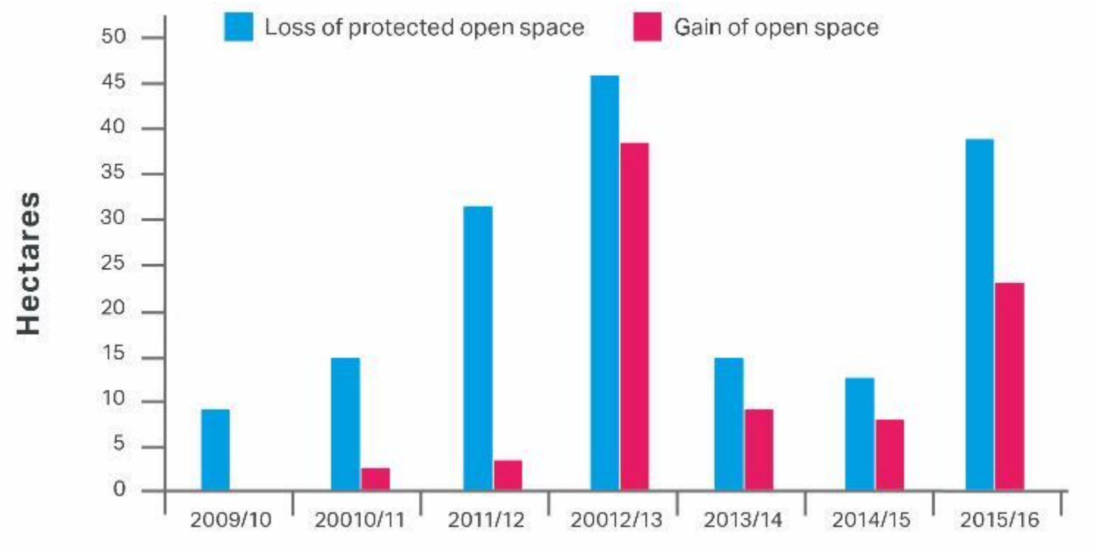


Changes in green space and biodiversity

Loss of green space

Despite the extensive nature of London's green cover, and the increasing number of new developments being greened, there is still a net loss of green space to new development, such as housing, schools, industrial premises or transport infrastructure (Figure 39). The losses are relatively small overall, with an average net loss of 10-15 hectares per annum. But over time, these can begin to erode and further fragment the green infrastructure network.

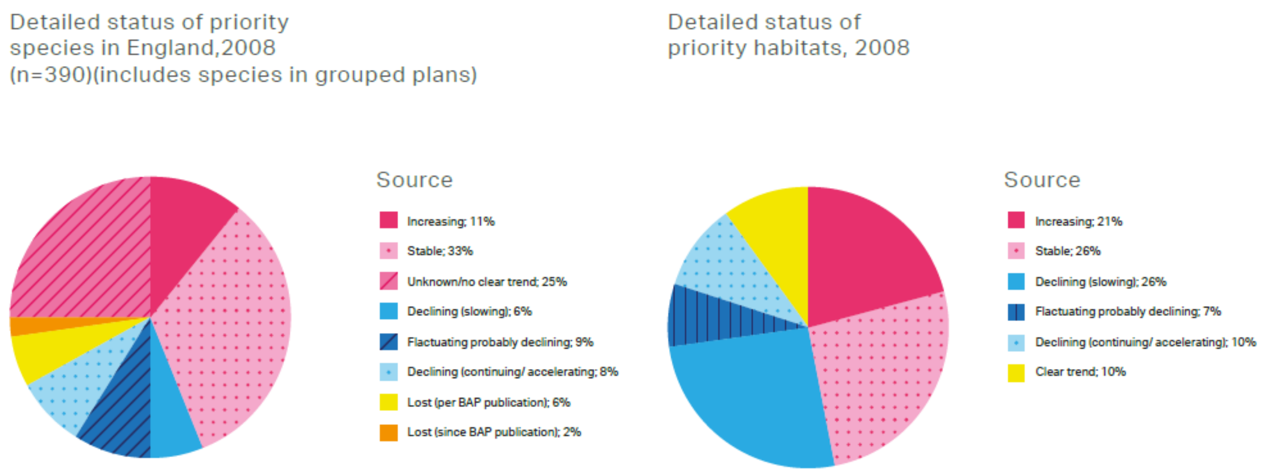
Figure 39: Losses and re-provision of protected open space



National decline in biodiversity

Overall, biodiversity and ecological resilience has been in decline over the past 50 years, largely due to agricultural intensification and urbanisation. National data demonstrates that, despite the programmes and initiatives instigated through the UK Biodiversity Action Plan, the majority of species and habitats are still in decline (Figure 40).

Figure 40: Trends and status of priority habitats and species (source: Biodiversity 2020: A strategy for England's wildlife and ecosystem services (Defra 2011))



The State of Nature 2016 (England)[31] report's key statistics show that, over the long term:

- 60 per cent of plant species declined and 40 per cent increased
- 62 per cent of butterfly species declined and 38 per cent increased
- bird species as a whole have declined by six per cent, but farmland bird species have fallen by 56 per cent
- 12 per cent of rare species are at risk of extinction from the UK

Trends in breeding bird numbers present a mixed picture with some species (such as goldfinch, cormorant and peregrine falcon) doing well, with others (such as house sparrow, mistle thrush and swift) experiencing significant declines. Of greater concern are the declines in both the number and diversity of wildflowers and insects such as butterflies.

In common with nationwide trends, there is a long term decline in the diversity of London's wildlife and natural habitats. The exception is where land is specifically managed to protect and conserve wildlife. In London, the main causes of biodiversity decline include:

- habitat fragmentation caused by urbanisation
- increasing recreational pressure on green space
- diffuse pollution (especially of rivers and waterbodies)
- declines in sympathetic management practices, such as grazing of flower-rich grasslands, or traditional woodland management

London's bird populations

The British Trust for Ornithology calculated trends for 33 species for the period 1994-2011. Over that period, 21 of the 33 species increased significantly in Greater London (blackcap, blue tit, Canada goose, carrion crow, chaffinch, chiffchaff, collared dove, cormorant, goldfinch, great spotted woodpecker, great tit, green woodpecker, greenfinch, magpie, moorhen, pied wagtail, ring-necked parakeet, robin, whitethroat, woodpigeon and wren).

Seven species declined significantly in the Greater London region during this same period; blackbird, grey heron, house sparrow, mistle thrush, song thrush, starling and swift (Figure 41).

The new London Bird Atlas, published in 2017, confirms this overall picture and also shows that some once rare species such as peregrine falcon, Cetti's warbler and little egret have increased as national populations have expanded; but the populations of other

[31] RSPB, *et al*. (2016) State of Nature (England). Accessed from: https://www.rspb.org.uk/our-work/conservation/projects/state-of-nature-reporting

species such as spotted flycatcher, turtle dove, tree sparrow are now almost absent from London as national populations have crashed.[32]

Despite the declines in species such as house sparrow, blackbird and swift, which are particularly apparent in London because these species were previously common, the population trends largely mirror national trends. Whilst the actual causes for declines are undetermined, loss of nest sites in buildings (resulting from the trend to seal buildings for energy efficiency reasons), the loss of vegetated areas in gardens, and differing responses to climate change may well be a reason for variation in the fortunes of different species.

Figure 41: Blackbird, house sparrow, goldfinch and robin population trends (1994-2015)

32 London Natural History Society (2017). The London Bird Atlas.

London's butterfly populations

The London Natural History Society is working on the London Butterfly Atlas Project, which will provide updated distribution maps of butterfly species in London.[33] Preliminary data suggests that grassland butterflies, such as large skipper and common blue, are in decline, though these could recover with sympathetic grassland management. More generalist species, such as speckled wood and gatekeeper, are holding their own or increasing (Figure 42).

Figure 42: Trends in British butterfly populations between 1995 and 2016

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[33] London Natural History Society (n.d.) London Butterfly Atlas project. Accessed from: http://www.lnhs.org.uk/index.php/about-us/recording/london-butterfly-atlas-project

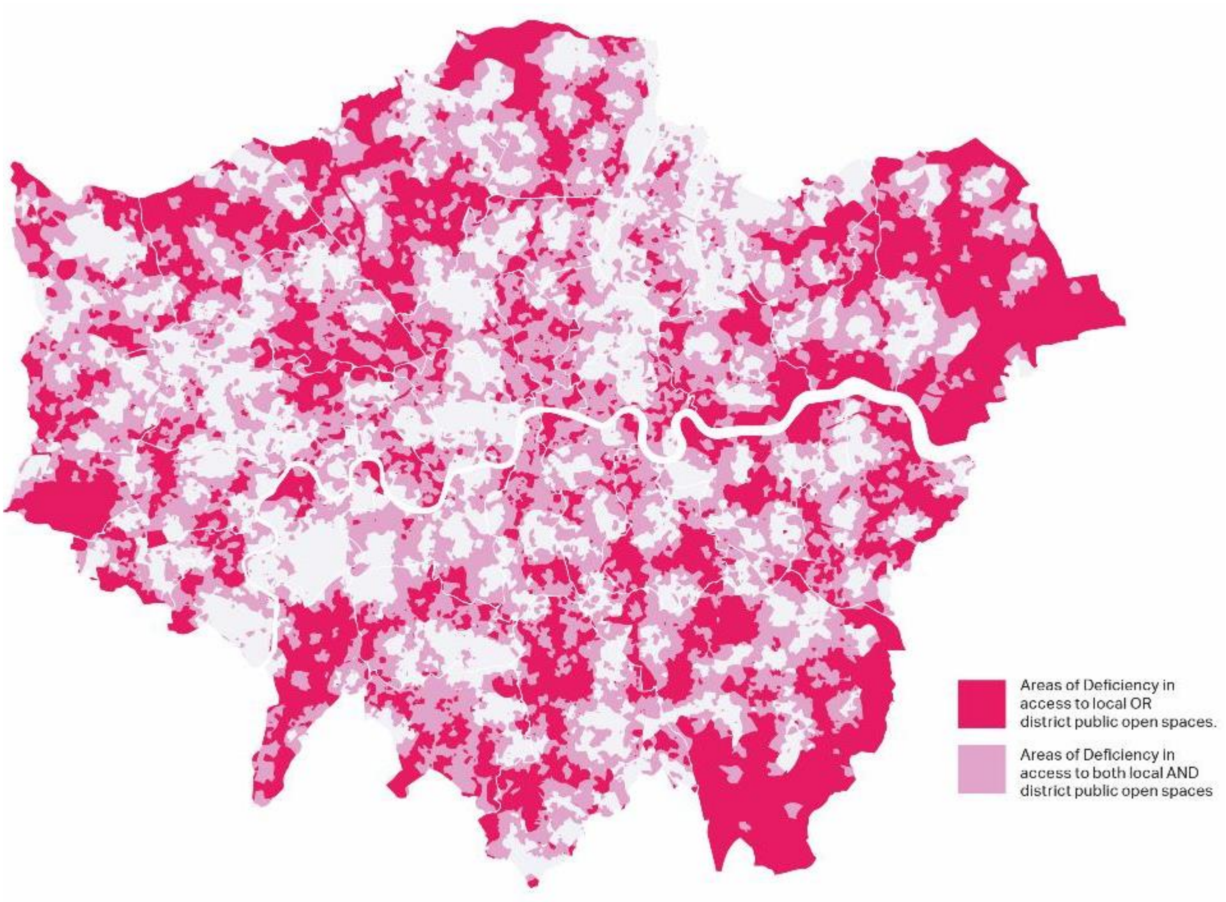
Usage and feedback from stakeholders

Access to good quality green space is valued by most Londoners. The following headline results are from an analysis of the Monitor of Engagement with the Natural Environment (MENE) survey funded by Natural England, with support from Defra and the Forestry Commission. Data collected between March 2009 and February 2012 showed that:

- only 45 per cent of Londoners visit an outdoor green space frequently (at least once a week) compared to 54 per cent of the national population
- Londoners take over 80 per cent of their outdoor visits within Greater London
- parks are of fundamental importance, accounting for nearly 62 per cent of all outdoor visits
- visits to green space in London are motivated by a social purpose that is not as strong outside of London
- 29 per cent of outdoor visits are taken for health and exercise, much lower than England as a whole (38 per cent)
- 91 per cent of Londoners agree that spending time in a green space make them feel calm and relaxed
- 82 per cent of Londoners feel that spending time out of doors (including their own garden) is an important part of their life
- nine out of ten Londoners think that a green space close to home is important
- the main barrier to spending more time in a green space was being too busy at work or at home

Despite the amount of green space in London, there are parts of the city where Londoners have limited access to publicly accessible open space (Figure 43). This is because some areas of green space are privately owned (e.g. private gardens and farmland), inaccessible (e.g. railway linesides) or with only limited access (e.g. reservoirs). The area of deficiency in access to public space has been reduced in recent years. Nevertheless, a significant number of Londoners do not have access to local or district parks.

Figure 43: Areas of Deficiency in Access to Public Open Space



Lack of accessible green space can have a marked effect on people's ability to enjoy the health and well-being benefits of being outdoors. A more focused study was undertaken as part of the MENE survey to identify the use of green space in parts of East London.[34] This demonstrated that there was a link between the availability of greenspace and frequency of visits - on average, people living in the boroughs with most accessible green space made more frequent visits than those in boroughs with the least.

[34] Natural England (2015). Visits to the natural environment in East London. Accessed from: http://publications.naturalengland.org.uk/publication/5400445944070144?category=47018

It also found that:

- adults living in East London were much less likely to visit the natural environment at least once a week – just 37% in East London, versus 45% for the rest of London and 54% for the England average
- within East London, levels of physical activity were also lowest in boroughs with the least accessible green space

Measuring green space - the Green Space Factor

The Green Space Factor is a tool that has been applied to new developments in Malmö, Sweden, such as Augustenborg and Western Harbour.[35] It can be used to secure a certain amount of green cover in every development, and to minimise the degree of sealed or paved surfaces in the development. The system was adapted from Germany, where it is used in Berlin and Hamburg among other cities. Other cities, including Seattle, USA and Southampton, UK have adapted it for their own planning needs.

A Green Space Factor aims to not only ensure a certain proportion of a development is green but also to ensure the green features provided are contributing to ecosystem function through, for example, stormwater drainage or habitat provision. Surfaces such as grass, gravel, vegetation, and green roofs are assigned a factor, based on how much they contribute to ecosystem function.

For example, a surface of concrete or asphalt would have a score of 0.0, whilst a green roof would have a score of 0.7, and a natural surface covered with vegetation would have the highest score of 1.0. These factors are then multiplied by the total area of the development that those features cover. These are added up and divided by the total area of the development to give a final Urban Greening Factor score.

$$\text{GSF score} = \frac{(\text{area A} \times \text{factor A}) + (\text{area B} \times \text{factor B}) + (\text{area C} \times \text{factor C}) + \text{etc.}}{\text{total development footprint}}$$

[35] TCPA (2011) GRaBS Expert Paper 6. Accessed from: http://www.xn--malm-8qa.se/download/18.d8bc6b31373089f7d980008924/1491301018437/greenspacefactor_greenpoints_grabs.pdf

Measuring value

The UK National Ecosystem Assessment (UKNEA) assessed the status and trends of the UK's ecosystems and the services they provide at multiple spatial scales from country to catchment levels. It described the key drivers of change affecting the UK's ecosystems, including changes in land use, infrastructure development, pollution and climate change. It also valued the contribution of ecosystem services to human well-being through economic and non-economic analyses.

The UKNEA included an assessment of the urban environment, which concluded that:

- the ecosystem goods and services that could potentially be derived from urban green infrastructure are substantial, though previously not appreciated and their potential not realised
- access to urban green space is essential for good mental and physical health, childhood development, and social cohesion. About 80 per cent of England's population live in urban areas, with average accessible green space of two hectares per 1,000 people. Deprived areas tend to fare worse in terms of quantity and/or quality of green space
- it is not just the limited extent and variable quality of green spaces, but also their spatial distribution, connectivity, functionality and accessibility that currently create barriers to their optimisation
- urban ecosystem services could be significantly enhanced to improve climate mitigation and adaptation, with consequent impacts on human health (e.g. by reducing the risk of overheating)
- developing the business case for investment in green infrastructure is dependent on good quality data for function and use, but the green infrastructure within urban areas is not systematically monitored. Responsibilities are spread across a range of organisations that collect extensive amounts of information, but often using inconsistent typology at different temporal and spatial scales

A study undertaken by Natural England estimated that the savings to the NHS through having increased access to green space for every household in England equated to £2.1bn per annum. Access to green space has considerable distributional effects for households and land owners, with previous analysis from GLA Economics modelling that house prices within 600 metres of a regional or metropolitan park were between 1.9 per cent and 2.9 per cent higher. In London, there has been some quantification of the ecosystem services value of some of the components of the city's natural capital.

The London i-Tree Eco assessment[36] quantified the benefits and services provided by London's urban forest. This demonstrated that London's approximately eight million trees

[36] Treeconomics London (2015) Valuing London's urban forest. Accessed from: https://www.forestry.gov.uk/london-itree

provide at least £133m of benefits each year by removing pollutants, sequestering carbon, and reducing surface water flooding.

A natural capital account for Beam Valley Parklands, in Dagenham, East London[37] indicates that this space (which has been designed to provide flood storage in addition to a healthy space for play and recreation) has a net natural capital asset value of approximately £42m in present value terms. It also provides £591,000 per annum in flood prevention benefits and £770,000 per annum in community benefits, largely related to improved health and well-being.

A natural capital account for London's public open spaces[38] revealed that:

- London's public green space have a gross asset value in excess of £91 billion, providing services valued at £5 billion per year
- for each £1 spent by local authorities and their partners on public green space, Londoners enjoy at least £27 in value
- Londoners avoid £950 million per year in health costs due to public green space.
- the value of recreational activities is estimated to be £926 million per year
- for the average household in London, the monetary value of being in close proximity to a green space is over £900 per year.

Delivering value for money from new woodland planting – understanding the economic benefits of natural capital

Two approaches for determining where new forests should be established were examined by the government appointed Natural Capital Committee[39]. The first of these only considered the market values (timber value benefits and costs to agriculture in the form of forgone production) associated with planting. As agricultural losses exceed the market value of timber, this leads to new forests being confined to those areas where such losses are lowest; mainly in the uplands (including peatlands which release carbon dioxide when drained for planting trees) and away from major population centres. For Great Britain as a whole, this produces overall losses in excess of £65m per annum.

A second approach was to consider both these market values and a range of non-market values (including recreation and impacts on greenhouse gases). This analysis suggested that woodlands should be planted around the periphery of major towns and cities across

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[37] eftec (2015) Beam Parklands natural capital account. Accessed from: https://www.london.gov.uk/WHAT-WE-DO/environment/environment-publications/green-infrastructure-task-force-report

[38] Vivid Economics (2017) Natural capital accounts for public green space in London. Accessed from: https://www.london.gov.uk/what-we-do/environment/parks-green-spaces-and-biodiversity/green-infrastructure/natural-capital

[39] Natural Capital Committee (2014) The State of Natural Capital: Restoring our Natural Assets. Accessed form: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/516698/ncc-state-natural-capital-second-report.pdf

the country generating high recreation benefits and away from peatlands to ensure a net contribution to cutting emissions of greenhouse gases. This would deliver net economic benefits of nearly £550m per annum across Great Britain. Within England, this yields benefit cost ratios of 5:1 using lower bound carbon values, and nearly 6:1 using higher values.

Funding

The State of UK Public Parks report[40] provides an assessment of the funding and investment in the UK's public parks and green spaces (Table 6). The research undertaken for the report demonstrated that no local authority (including all London boroughs) expects to increase their parks budgets in the period to 2020. Indeed, most expect to cut budgets, with the highest level of cuts being faced by urban authorities. This is on top of budget reductions that have been ongoing since 2010. Three-quarters of London boroughs expect further reductions of 10-20 per cent or more up to 2020.

Table 6: Anticipated levels of budgetary change in local authority parks budgets

Type of Authority	No of LAs	No of responses	Budget increased	Budget not changed	Decreased by less than 10%	Decreased between 10% - 20%	Decreased by more 20%
District	201	562	0.0%	5.4%	28.6%	53.6%	12.5%
Unitary	56	31	0.0%	3.2%	9.7%	71.0%	16.1%
Metropolitan	36	27	0.0%	0.0%	7.4%	44.4%	48.1%
London borough[41]	33	17	0.0%	11.8%	11.8%	70.6%	5.9%
County council	27	6[42]	0.0%	0.0%	0.0%	50.0%	50.0%
Northern Ireland Unitary	11	4	0.0%	50.0%	0.0%	0.0%	50.0%
Scotland Unitary	32	22	0.0%	4.5%	36.4%	59.1%	0.0%
Wales Unitary	22	10	0.0%	0.0%	20.0%	30.0%	50.0%
Averages	**418**	**173**	**0.0%**	**5.2%**	**19.1%**	**54.9%**	**20.8%**

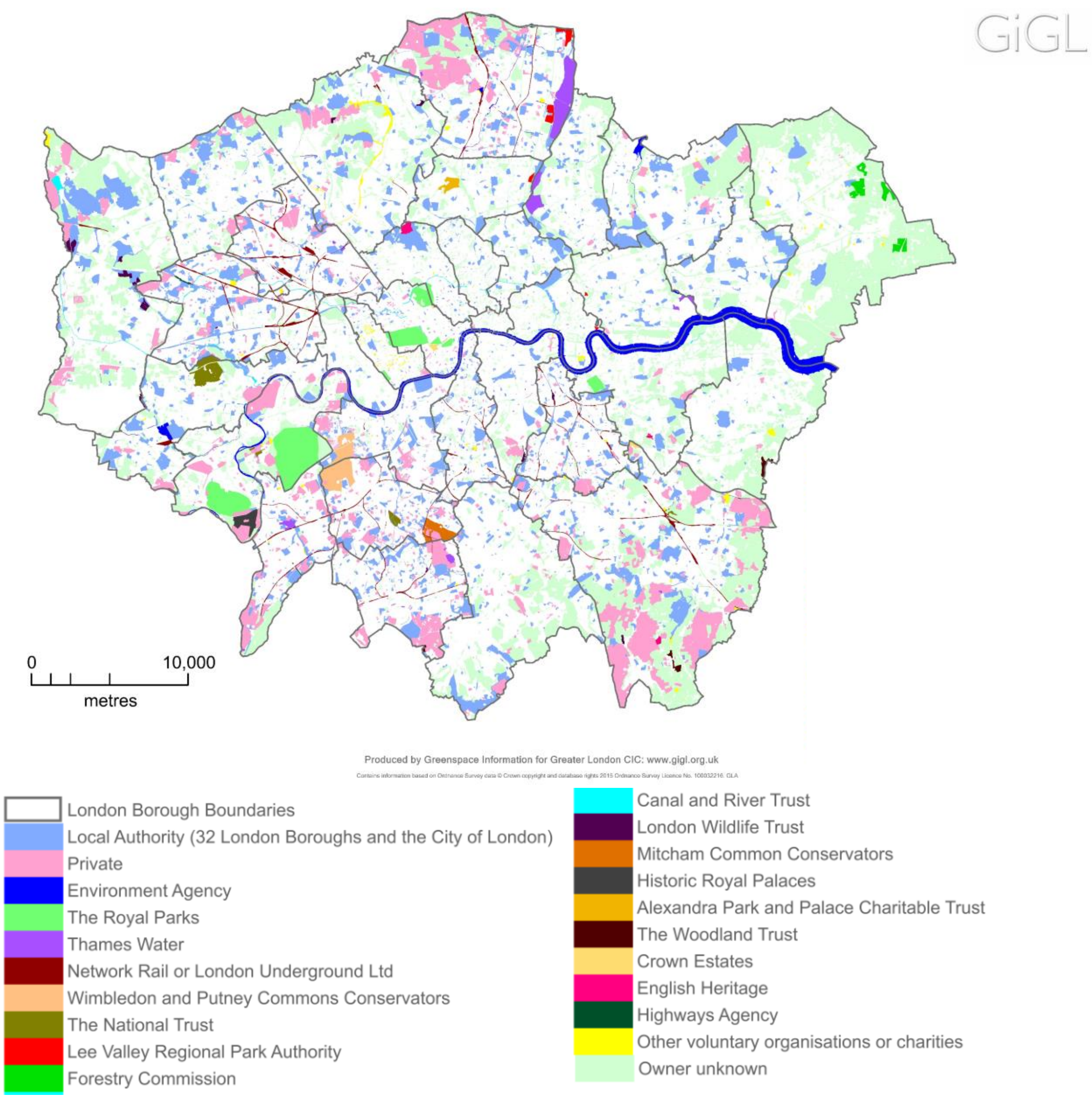
40 HLF (2016) State of UK Public Parks 2016. Accessed from: https://www.hlf.org.uk/state-uk-public-parks-2016

41 The City of London Corporation is included within the list of London Boroughs

42 The sample size for this type of authority is below 30 per cent

Not all of London's green infrastructure is managed by local authorities. About half is owned and managed by charitable organisations, government agencies, social housing providers, private and public utility providers, sports and leisure companies and other private landowners (farmland, for example). The complexity of ownership and the variety of management objectives results in green infrastructure that is not always planned, designed and managed to improve the benefits it can provide (Figure 44).

Figure 44: Ownership of green and open space across London



Climate Change Mitigation and Energy

Climate change and the need for action

If the world continues emitting greenhouse gases (GHGs) at today's levels, average global temperatures could rise by up to 5ºC by the end of this century.[43] Temperature increases of this scale would have a significant negative impact on London, the UK and the wider global economy. Extreme weather events, such as flooding, storms and heatwaves are likely to become more frequent and damaging (see the Adapting to Climate Change chapter).

The 2006 Stern Report[44] found that the economic damage caused by climate change has the potential to account for between five and ten per cent of global GDP each year, but cutting carbon emissions would reduce this to one per cent. Over a decade has passed since the Stern Report but the costs of not acting to mitigate climate change have risen while the costs of cutting carbon have fallen.

The UN Paris Climate Agreement, signed in December 2015, includes 195 countries (including the UK) who committed to limit the global average temperature increase to well below 2°C above pre-industrial levels. The same signatories agreed to pursue efforts to limit the temperature increase to 1.5°C, recognising that this would significantly reduce the risks and impacts of climate change. Reducing the risk of climate change will require a focus not just on reduction targets set in the future, but a minimisation of cumulative emissions. Cities like London will need to ensure they achieve a steady decline of GHG emissions out to 2050[45].

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[43] IPCC AR5 range for BaU is 2.6 to 4.8 by 2100 (https://www.ipcc.ch/report/ar5/)

[44] Stern (2006). The Economics of Climate Change

[45] C40, Deadline 2020, http://www.c40.org/researches/deadline-2020

The importance of national action

Supporting the implementation of the Paris Agreement, both in London and at a national level, requires the UK government to set new policies to cut GHG emissions. As there is national control for many mitigation measures, including UK building regulations and performance standards, financial support for renewables and decarbonisation of the national energy grids, much of London's emissions reductions remain outside the direct control of the Mayor.

At a national level, GHG emissions in 2016 were 42 per cent below 1990 levels[46], within the limits of the UK carbon budget (31 per cent reduction in the 2013 to 2017 period). The UK government's Clean Growth Strategy was published in autumn 2017 with the aim of setting out policies and proposals to deliver increased economic growth and decreased greenhouse gas emissions. Current national policies are not sufficient to enable both the UK and London to meet their carbon targets over the medium and long term[47]. To achieve this will require government to meet UK electricity grid decarbonisation projections out to 2022, and urgently clarify the actions that will be required to meet the objectives of the Clean Growth Strategy.

London's historic and current greenhouse gas emissions and energy use

Overall emissions and energy use

In 2015, London's greenhouse gas emissions were estimated at around 34 $MtCO_2e$ (million tonnes of carbon dioxide equivalent). This represents seven per cent of the UK's total emissions. London's emissions have fallen by 25 per cent since 1990, despite population growth (Figure 45). Emissions peaked in 2000 but have been declining since then, with GHG emissions in 2015 around 32 per cent lower than this peak. With the population of the capital now over 8.5 million – a 26 per cent increase since 1990 – London's 2015 per capita emissions (3.9 tCO_2) were the lowest of any region in the UK.

London's GHG emissions are dominated by buildings and transport. In 2015, it is estimated that 36 per cent of emissions were generated from London's homes, 40 per cent from workplaces, and 24 per cent from transport.

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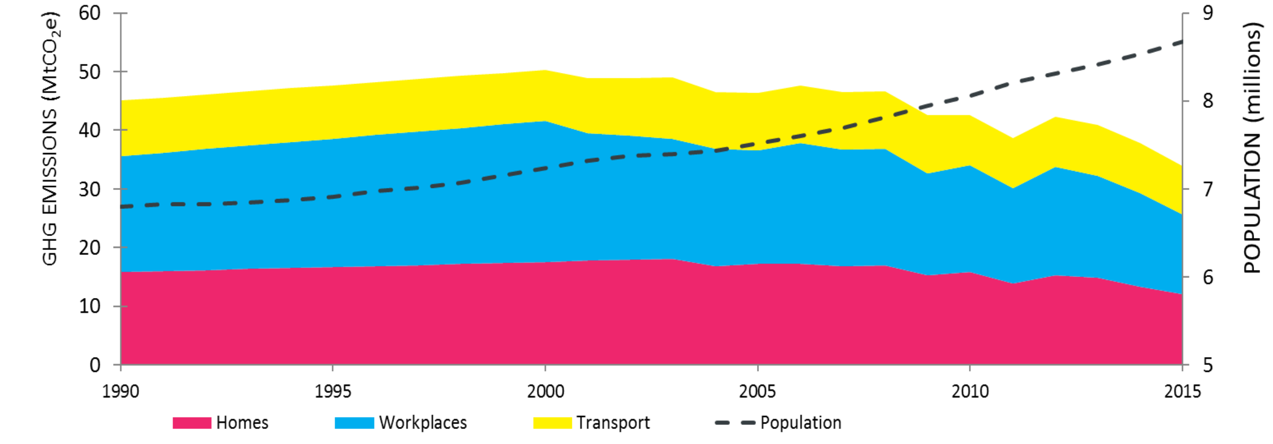
[46] BEIS (2017) Provisional UK greenhouse gas emissions national statistics 2016. Provisional statistics for 2016 are not yet available for London.

[47] Committee on Climate Change (2018) An independent assessment of the UK's Clean Growth Strategy: From ambition to action. Accessed from: https://www.theccc.org.uk/publication/independent-assessment-uks-clean-growth-strategy-ambition-action/

Figure 45: London's historic emissions[48]



Box 3: The London Energy and Greenhouse Gas Inventory

The London Energy and Greenhouse Gas Inventory (LEGGI) is a dataset of London's greenhouse gas emissions and energy consumption covering almost a quarter of a century, with the most detailed information available since 2000.

The LEGGI shows estimates of energy consumption and carbon dioxide equivalent (CO_2e) emissions from homes, workplaces and transport within the Greater London area. It is produced by the Greater London Authority on an annual basis to measure carbon reduction progress. The LEGGI uses sub-regional energy (electricity, gas and other fuels) and CO_2e data published by UK government for homes and workplaces, and data from the London Atmospheric Emissions Inventory (LAEI) for energy and CO_2e data for transport, including road, shipping, railways and the take-off and landing of aircraft from airports in London.

To allow for the necessary lag in the recording, analysis and publication of energy data used in LEGGI, datasets report on the evidence from two years prior to the assessment date. All energy statistics presented in the Environment Strategy are based on the 2017 LEGGI assessment, reporting on 2015 emissions. Both current and historic LEGGI assessments can be accessed at London's Datastore.[49]

Energy is consumed through day to day activities in the home and workplace and in transportation and industry. Consumption of energy can vary from year to year, depending

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[48] Figures pre-2000 are extrapolated from 1990 levels and sourced from LEGGI (Box 3**Error! Reference source not found.**) and the Office for National Statistics (ONS)

[49] https://data.london.gov.uk/dataset/leggi

on external factors including the weather conditions experienced. As a result, a long term trend is the most effective method of discerning meaningful changes in energy use.

London used an estimated 130 terawatt hours (TWh) of energy in 2015. This represents a reduction of 19 per cent on 1990 levels of energy use, despite a population increase of over 25 per cent over this time period.[50] Around half of London's energy demand is met through gas, whereas electricity provides around 30 per cent of London's total energy needs. The remainder is predominantly comprised of fuels used in transport (such as petrol and diesel for road vehicles).

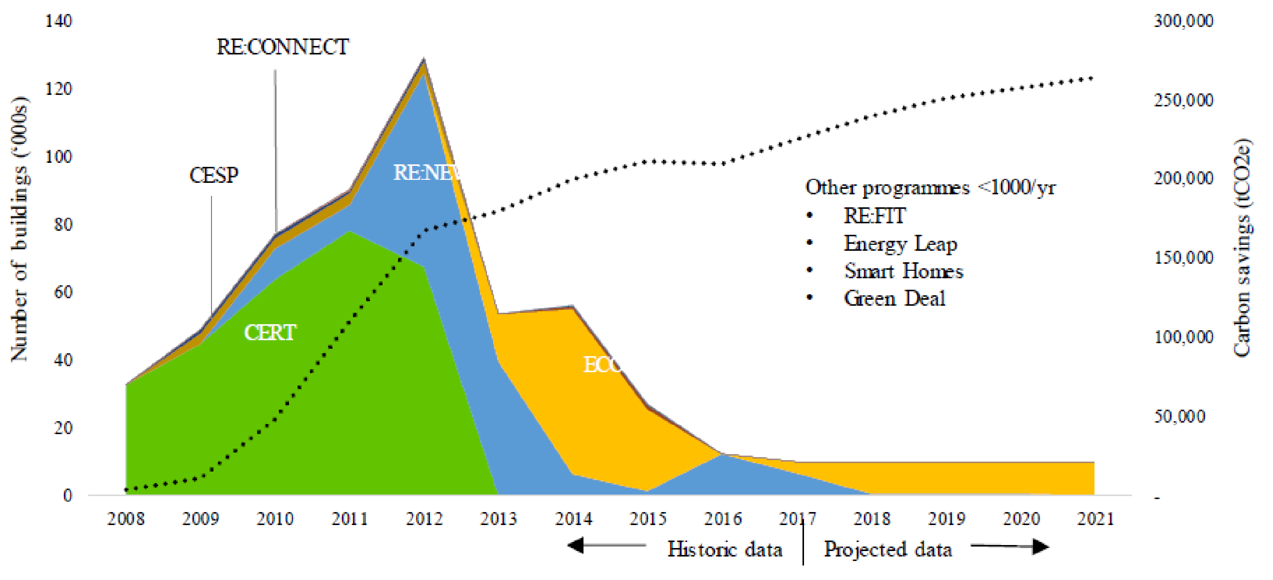
Emissions and energy use from homes and workplaces
London is home to buildings of all ages, and their energy efficiency varies considerably. More energy is used to heat and power our buildings in London than for anything else. Buildings are responsible for around four-fifths of London's total GHG emissions and 70 per cent of final energy use. In 2017 over £7bn was spent on heating and powering our buildings across London.

Through the previous Mayor's energy efficiency programmes, savings of 670,000 tonnes of CO_2 were achieved in 2015. Though significant at a local level, this represents only two per cent of London's total energy demand, and half of the targeted savings for Mayoral actions in the 2011 Climate Change Mitigation and Energy Strategy.

Additionally, although national retrofit programmes have increased the average savings per measure, there has been a significant reduction in the number of energy efficiency retrofits in recent years (Figure 46).

[50] See Appendix 1 General Assessment for further information.

Figure 46: Estimate of historic number of buildings in London retrofitted with energy efficiency measures



Emissions and energy use from gas
Gas use in London represents around half of total energy consumption, contributing 30 per cent of London's total emissions. Most of this gas is used for heating in buildings.

Gas demand in London has been reducing in recent years, partly due to more efficient gas heating systems, increased energy efficiency measures, and reduced industrial emissions as our economy has become increasingly service orientated. Part of this reduction is also associated with relatively warmer winters in recent years. Projected milder winters resulting from climate change could see this trend continue; conversely warmer summers could bring rising energy demand for mechanical cooling. Since peak energy use and emissions in 2000, GHG emissions from gas used in London are estimated to have reduced by over a third.

Emissions and energy use from national grid electricity
In London, electricity demand accounts for almost half of the total CO_2 emissions. This fraction has been decreasing rapidly in recent years due to decarbonisation of the national electricity grid. Low carbon generation (from nuclear and renewable sources) comprised more than half of UK generation for the first time in 2017. Total UK renewable electricity generation has increased to record levels of around 29 per cent in 2017, up from 19 per

cent in 2014, while coal generation has dramatically fallen from 30 per cent of generation in 2014 to 7 per cent in 2017.[51]

Electricity demand has remained steady in London since 2000, despite population growth, and is being decarbonised rapidly through the increase of renewable energy supplied through the national electricity grid. As a result, emissions from electricity used in London, though predominantly generated outside the city, have decreased by over one third since 2000.

Emissions and energy use from decentralised energy

London's decentralised energy sources provide approximately six per cent (6,000 GWh per year) of London's energy demand, an increase from three per cent in 2010. Of this, district heating networks and renewable energy supply approximately two per cent of total demand (with around 4 per cent met from gas turbine power stations in London).

Solar energy

In 2015 there were over 21,000 solar photovoltaic (PV) installations in London, generating an estimated 70 gigawatt hours (GWh) of electricity. This was 0.2 per cent of the capital's total power demand. More recent figures from Ofgem suggest London now has nearer 95 megawatts (MW) of installed solar PV capacity, with almost three-quarters of this capacity installed on residential roofs.

In comparison, London's solar thermal resource is lower, but remains a growing industry, with 252 installations providing hot water to homes across the city. As a dense urban environment, London will never be self-sufficient though solar power alone, but it remains an important resource in providing local solutions, developing community energy initiatives and decoupling energy costs from the national grid.

Heat networks

District heating (or heat networks) is the provision of hot water from a central energy centre to a network of buildings via an underground pipe network. District heating is flexible to changes in supply technologies over time, using gas or electricity to create and distribute hot water. It requires system upgrades at the central energy centre(s) only and encourages the aggregation of demand to connect to large low carbon low cost energy sources. Heat networks are also typically buried underground, and provide a more

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[51] Business, Energy and Industrial Strategy (BEIS) 2018. Energy Trends: electricity (provisional 2017 data). Accessed from: https://www.gov.uk/government/statistics/electricity-section-5-energy-trends

appropriate solution in urban areas where there is insufficient space to accommodate a large number of individual heat pumps.

London is the UK's leader on the long-term planning and delivery of district heating networks, currently supplying approximately 1,600 GWh of energy a year, almost two per cent of London's total energy demand. A map showing the location of existing networks and future opportunities is available through the London Heat Map.[52]

London's zero carbon modelling

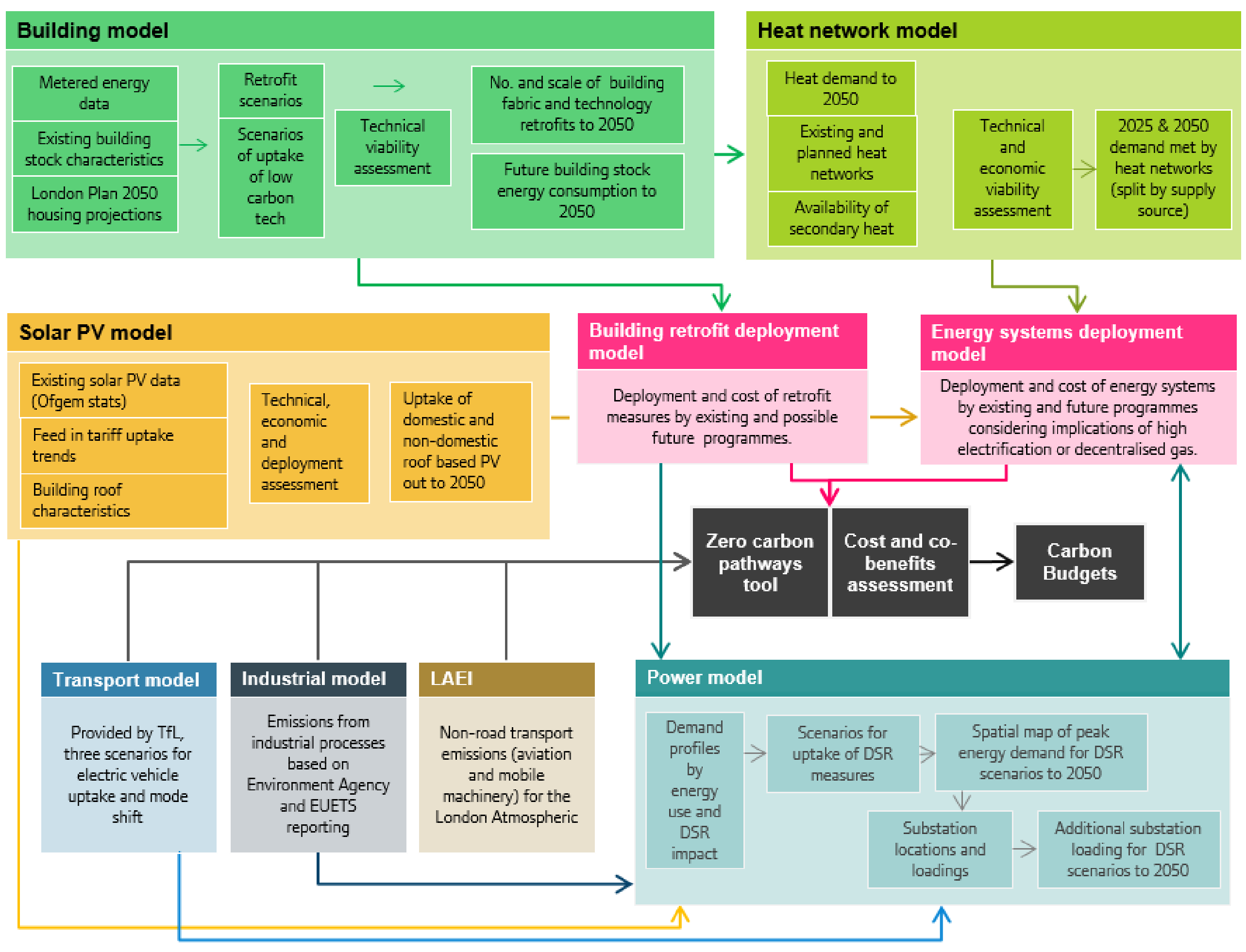
The zero carbon pathways tool and input data

London has currently reduced its emissions by 25 per cent on its 1990 baseline. The Mayor has set an ambition for London to become zero carbon by 2050, and further activity is required to achieve this. The GLA has undertaken modelling of the measures required to make London zero carbon by 2050, developing a Zero Carbon Pathways Tool. This combines datasets collected by the GLA over the past five years under one modelling framework (Figure 47) and illustrates the different routes to a zero carbon city. The model was used to test the effect of actions to cut carbon emissions, and provides a detailed spatial analysis of London's carbon emissions and energy use between now and 2050.

As a tool for stakeholders, the models continue to provide a focus point for aligning energy and carbon strategies across the city, and the development of 2050 climate plans for London's 32 boroughs. The interactive tool and associated datasets are available at https://maps.london.gov.uk/zerocarbon/.

[52] GLA (2016), London Heat Map. Accessed from: https://www.london.gov.uk/what-we-do/environment/energy/london-heat-map

Figure 47: GLA zero carbon modelling architecture



A number of existing studies, as well as new studies were commissioned to inform the modelling in the Zero Carbon Pathways Tool. These were also part of the GLA's collaboration with C40's Climate Action Plan programme to demonstrate a climate action plan that was compliant with international goals to keep global climate warming below 1.5 degrees. Studies include:

- **Building Retrofit Programme Assessment**: assessment of the impact of a suite of existing and prospective building retrofit programmes, including timelines, capital costs and emission savings. This focused on the period to 2030, where retrofit is most needed

- **Zero Carbon Energy Systems:** assessment of scenarios for zero carbon energy infrastructure out to 2050, the consideration of divergent scenarios and the impact for decision making in the next decade to prepare for later deployment
- **Co benefits assessment:** review of the wider social, economic and environmental benefits of London's climate actions, to prioritise actions and support the business case for delivery

Reports relating to these studies will be made available on the GLA website. Updates to the zero carbon pathway modelling since the draft London Environment Strategy reflect the analysis and findings of these studies.

Box 4: C40 Climate Action Plan Framework
The C40 Cities Climate Leadership Group (C40) connects 90 of the world's greatest cities, representing over 650 million people and one quarter of the global economy. London is one of eight pilot cities working with C40 to align its climate strategy with the objectives of the Paris Agreement. The lessons learnt throughout this collaboration have in turn helped the development of C40's Climate Action Plan Framework, built around the three core principles of commitment & collaboration, challenges & opportunities and acceleration & implementation. The Climate Action Plan Framework is a way of aligning the goals and ambitions of all other member cities with the transformational action needed to keep the world within 1.5 degrees Celsius of pre-industrial temperature levels. For London, our Climate Action Plan is more than a single document. It encompasses Mayoral strategies and their linkages, evidence based target setting and commitments to resource, review and implement the promises made. Where the Mayor does not have the power to deliver the transformational action needed, the plan considers the governance and coordination of relevant stakeholders who can. A summary of all London's evidence against the C40 Action Plan Framework will be available in the London Datastore.

In addition to in-house models, the underlying datasets include scenarios and projections developed through research programmes (Table 7).

Table 7: Research programmes contributing scenario and projection data

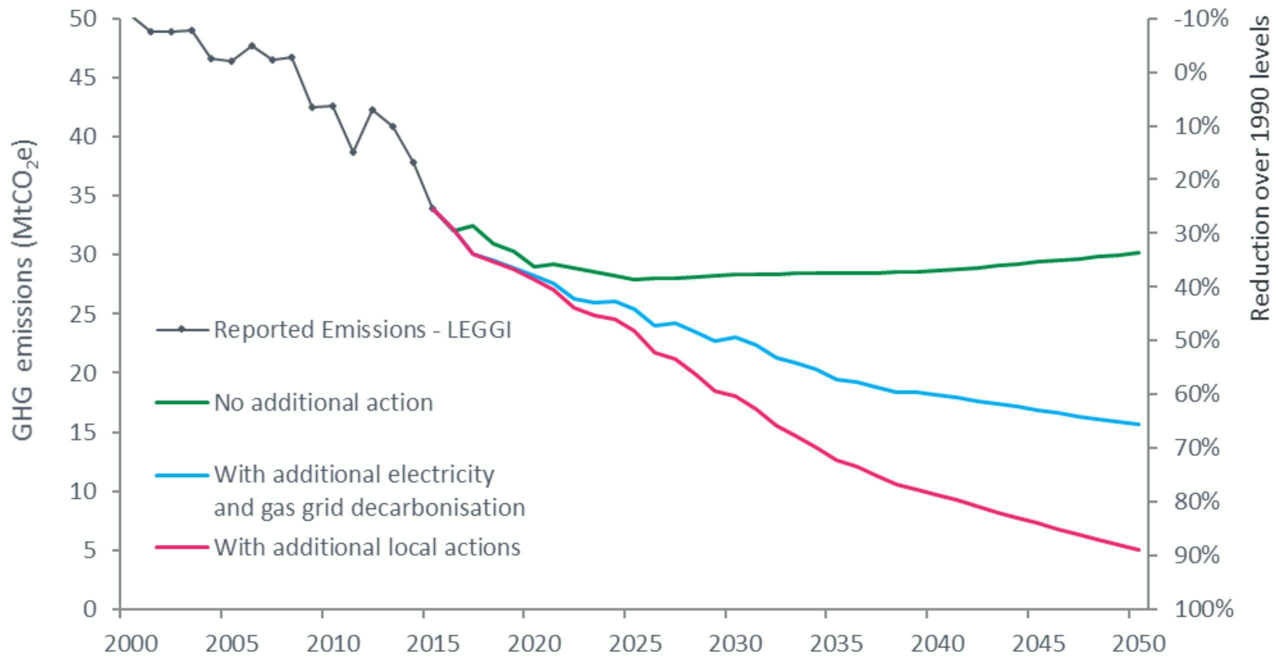
Research	URL	Details
Decentralised Energy Capacity Study (published 2011)	https://www.london.gov.uk/WHAT-WE-DO/environment/environment-publications/decentralised-energy-capacity-study-0	The London Decentralised Energy Capacity Study presents the findings of a regional assessment of the potential for renewable and low carbon energy in Greater London.

Table 7: Research programmes contributing scenario and projection data		
Research	**URL**	**Details**
Secondary Heat Study (published 2012)	https://www.london.gov.uk/WHAT-WE-DO/environment/environment-publications/secondary-heat-study-londons-zero-carbon-energy	The study examines the availability, cost and energy utilisation considerations of secondary heat sources in London, and issues associated with their integration with heat networks and with the London building stock.
ULEZ and mode shift transport models (2017)	https://www.london.gov.uk/what-we-do/transport/our-vision-transport	TfL modelling scenarios in support of the draft Mayor's Transport Strategy.
Industrial Emission Review (2017)	Unpublished – forms part of zero carbon pathways modelling	Ricardo AEA commissioned study to review and update London's industrial emissions baseline.
London Energy and Greenhouse Gas Inventory (2014)	https://data.london.gov.uk/dataset/interim-london-energy-and-greenhouse-gas-inventory--leggi--2014	Estimates of key pollutants (NO_x, PM_{10}, $PM_{2.5}$ and CO_2) in London for 2014 and projected forward to 2020, 2025, and 2030.

Reaching the zero carbon target

The Mayor's current powers will not be enough to meet London's carbon budgets. Using the zero carbon pathway tool, the GLA modelled what measures would be required to meet the 2050 zero carbon target (Figure 48), focusing on what existing policy could deliver (business as usual), what further action was required at the national level, and what would be required at the London-level (through a mix of action from national, regional and local government, dependent on powers).

Figure 48: London's GHG emissions trajectory to zero carbon



The 'no additional action' projection takes account of expected new development and population increases in London. It included no further development of heat networks, heat pumps or energy efficiency measures, beyond that which is already installed. It uses a baseline electricity grid decarbonisation trajectory which considers only low risk national policies and is derived in part from Committee on Climate Change analysis. Under this projection, London would reach a 35 per cent reduction on 1990 levels by 2050.

On top of this, an extra 30 per cent reduction could be achieved by government undertaking further decarbonisation of energy systems at a UK level in line with policies and proposals to achieve UK carbon budgets (based on the Department for Energy and Industrial Strategy (BEIS) Green Book projections of electricity grid decarbonisation).

This therefore leaves a further 35 per cent reduction that would need to be met through increased action within London's boundaries. This could be through a number of measures, including retrofitting buildings to make them more energy efficient, installing heat pumps or other decentralised energy solutions. The drivers for this London based action would be split across national, regional and local actors, dependent on their powers.

Although an ambitious task, zero carbon by 2050 can technically be achieved under a range of scenarios, but requires new policies and powers at a national and local level. The underlying actions needed to achieve this pathway have been assessed in detail through the Building Retrofit Assessment and Energy System Assessment reports. Further detail on this research is included on the GLA website. This research builds on existing work to further explore the possible reduction pathways in buildings and across the wider energy system and the associated costs, in order to set carbon budgets that minimise costs and cumulative carbon emissions.

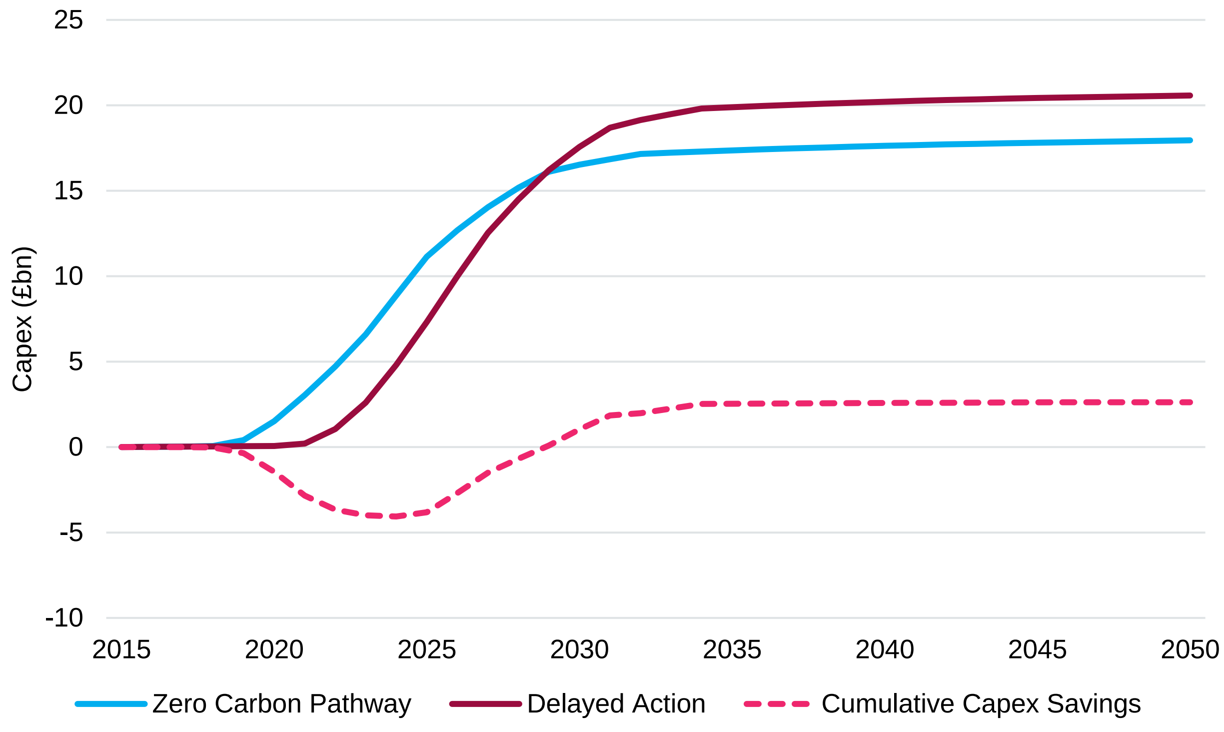
Buildings

Previous GLA modelling produced a comprehensive spatial picture of energy demand from London's workplaces and homes. By 2050, some 1.3 million new homes and over ten million square metres of new schools, hospitals and workplaces are needed in London. This will lock in emission patterns for 60-120 years (the average building and infrastructure lifespan). By 2050 the emissions footprint of London's buildings will need to be close to zero.

An assessment of future programmes that could deliver the scale of action needed is set out in the associated Building Retrofit Programme Assessment, considering 26 possible delivery mechanisms. This modelling shows that early uptake of retrofit measures is the most cost-effective way to achieve carbon savings. Later retrofits will result in smaller carbon savings if decarbonisation of the grid has progressed. The analysis shows that more buildings retrofits, at a higher total cost, will have to be undertaken, to achieve the same cumulative emissions if undertaken at a later date. The total cost of retrofitting properties, if started after 2022, to achieve the same total emissions as an immediate program could be £2.5bn higher (Figure 49). The zero carbon pathway therefore assumes early action on building energy efficiency.

It should be noted that current government policy on retrofitting buildings will not be sufficient to meet this, and further action is required. While the Mayor has some control over delivering the scale of change required, government-led, wide-reaching programs, such as minimum energy efficiency standards for buildings are vital.

Figure 49: Cost of zero carbon pathway compared to action taken after 2022[53]



Energy Systems
To scope the range of options for decarbonising heat and likely timescales, a detailed assessment of future infrastructure deployment and costs was undertaken, taking account of stakeholder input from across the electricity and gas industry.

Two of the main options to decarbonise heat are greater electrification and use of hydrogen in the gas grid. The use of hydrogen for heating at scale depends on emerging technologies (like Carbon Capture and Storage) and is unlikely to have a significant impact on carbon emissions in London until after 2035, due to limits in the speed at which the necessary infrastructure could be deployed. An electrification route involves proven technologies that could be deployed at scale and deliver significant carbon emissions reductions well in advance of 2035.

Delaying decarbonisation in anticipation of hydrogen development would result in higher cumulative emissions to 2050. Even delaying action until 2025 would roughly double the rates of reduction needed in the 2030s and 2040s to reach the same cumulative

53 Based on GLA modelling (2018)

emissions. This would likely require significant contribution from unproven negative emission technologies (such as direct CO_2 air capture) in the second half of the century.

A lower risk, more measured pathway to zero carbon London relies on the deployment of proven decarbonisation technologies, particularly heat pumps and district heat networks. Potential rates of deployments for these technologies have been assessed by looking at international examples. The first three carbon budgets therefore assume that there is a high level of deployment of heat pumps and heat networks, reaching around 10% of heat demand by 2030.

Additional research on zero carbon infrastructure for London will be available on the GLA website.

Other sectors

Transport

Transport accounts for around one fifth of London's GHG emissions, the majority arising from road transport. Measures for reducing greenhouse gas emissions from transport in London are predominantly addressed in the Mayor's Transport Strategy.[54] The MTS targets a 100 per cent zero carbon fleet of road vehicles by 2050. It also includes electrification of rail and decarbonisation of river transport. Aviation is perhaps the most difficult transport sector to decarbonise, due to a lack of alternative fuels, and currently contributes to around 2.5 per cent of London's total GHG emissions.

Waste

Greenhouse gas emissions from London's waste activities are set out in the Waste Chapter. Accounting of waste emissions is discrete from other emissions accounting in this chapter as these consider full lifecycle emissions (scope 1, 2 and 3). London has developed two methodologies, estimating both the total emissions from London's waste activities as well as the carbon intensity of energy generated from residual waste. Even with zero waste direct to landfill, landfill sites serving London will continue to emit greenhouse gases, especially methane. The London Atmospheric Emissions Inventory (LAEI)[55] projects these emissions to decrease to 76ktonnes by 2030, after which a linear reduction to zero carbon in 2050 is required.

Industry and power generation

The industrial sector (including light and heavy industry) represents five per cent of London's emissions today but its contribution could double by 2050 as it struggles to decarbonise at the pace of other sectors. Around 90 per cent of industrial emissions are from primary gas consumption and consequently this sector sees little benefit from a

[54] Mayor of London (2018) Mayor's Transport Strategy. Accessed from: https://www.london.gov.uk/what-we-do/transport/our-vision-transport/mayors-transport-strategy-2018

[55] https://data.london.gov.uk/dataset/london-atmospheric-emissions-inventory-2013

decarbonised electricity grid. As many heavy industrial processes cannot currently be switched to electric systems, their decarbonisation pathway will require future process efficiencies and the conversion to alternative gas fuels such as hydrogen and bio-gas. No reduction in the energy required for industry is assumed in the 2050 modelling beyond known plant closures. Further decarbonisation of industry through changes to fuel supplies are also explored as part of the energy systems scenarios research described above.

Residual emissions

Some emissions from energy grids, historic building stock, aviation and some industry will not be able to be reduced to zero directly. The zero carbon pathway models 10% residual emissions. This could be reduced slightly if hydrogen becomes available to decarbonise industrial processes which cannot be electrified.

At this point these remaining residual emissions can be addressed through offsetting schemes, providing the investment required to support the national infrastructure in delivering zero, and potentially negative emissions technologies needed for London to reach the balance of zero carbon by 2050. The development of negative emissions technologies, such as carbon capture and storage (CCS) is an emerging field not yet well understood in terms of cost and impact.

London's zero carbon pathway and carbon budgets

The Mayor has adopted the system of carbon budgets to provide greater clarity and certainty for London (and the UK) to effectively plan for, and invest in, a low carbon economy. Carbon budgets offer the flexibility in a budget period to respond to external factors (such as the weather, legislation, global fuel markets, and energy prices) if necessary, and reduces the risk of 'lock in' to carbon intensive patterns of production and consumption. The zero carbon modelling described above has been used to set carbon budgets which minimise cumulative carbon emissions, manage costs and reduce delivery risk.

Carbon budgets have been set so that the midpoints of each budget period fit with the zero carbon pathway out to 2032, providing some flexibility in the 4 year period around each mid-point.

Figure 50 shows the zero carbon pathway and carbon budgets.

Figure 50: London's carbon budgets[56]

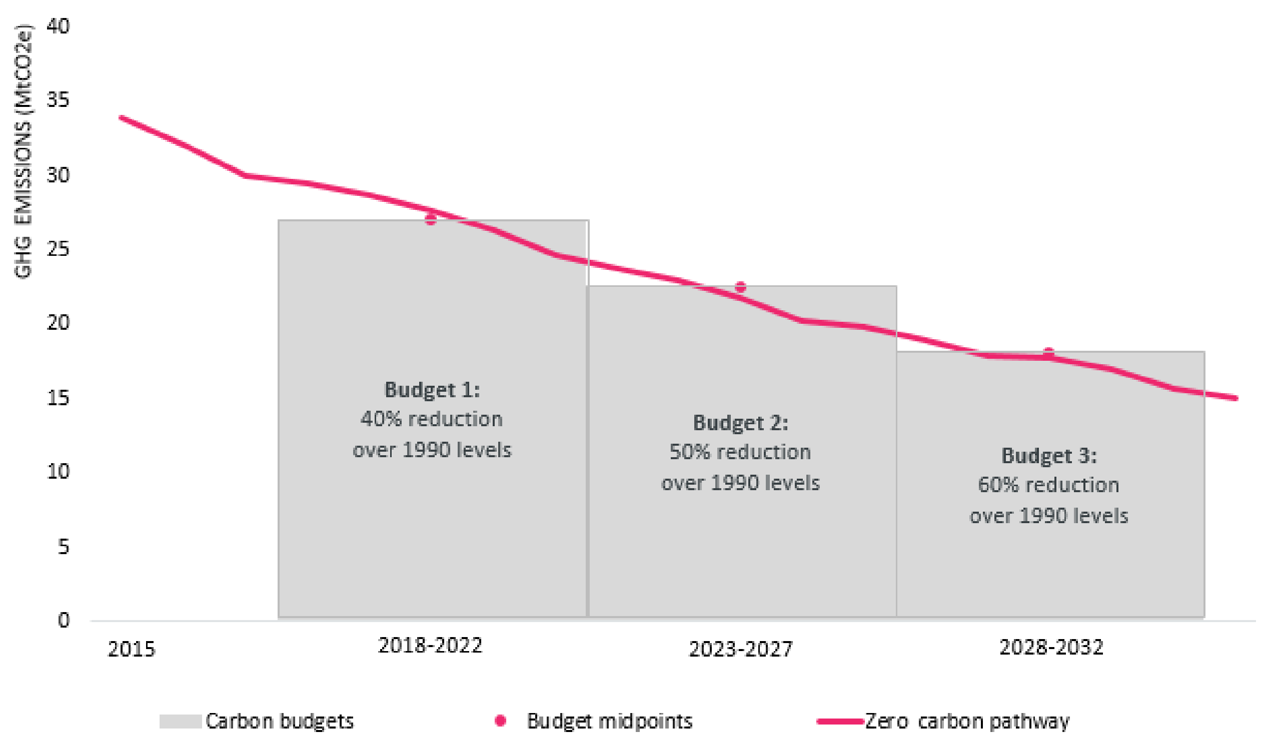


Figure 51 shows the indicative trajectory for each sector to achieve the zero carbon pathway.

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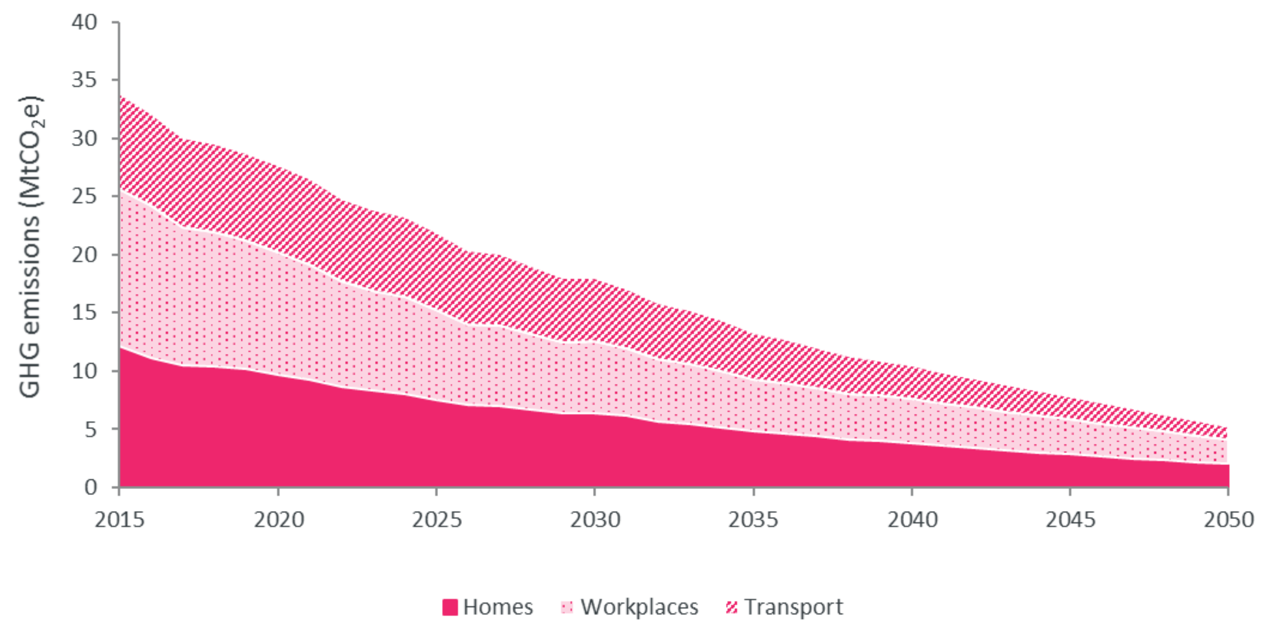
[56] Based on GLA modelling (2018)

Figure 51: Zero carbon pathway breakdown by sector[57]



As outlined earlier, the Mayor's current powers will not be enough to meet London's carbon budgets, and so the following will be required:

- additional national policy to drive energy efficiency in the form of greater regulation, i.e. minimum energy efficiency standards properly enforced and applied to a wider range of buildings and new fiscal incentives introduced by 2020, with building retrofit rates peaking in 2025
- a widespread move away from natural gas in new developments by 2020 and 10% of heat demand in existing buildings met by low carbon district heat or building level heat pumps by 2025
- UK government to meets their electricity grid decarbonisation trajectory as a minimum

GLA group carbon budgets

The London Environment Strategy commits the GLA Group to a 60 per cent reduction in carbon by 2025. Carbon budgets for the GLA group have been set to meet this target.

For consistency, this target is based on 1990 levels, although it is noted that most GLA functional bodies were not in operation in 1990. Due to the decarbonisation of the

[57] Based on GLA (2018) Zero Carbon Pathways Tool

electricity grid since 1990, this target is considered to be equivalent to a 50 per cent reduction in GLA group emissions over 2005 levels. The scope for GLA group emissions reporting is set out in Table 8.

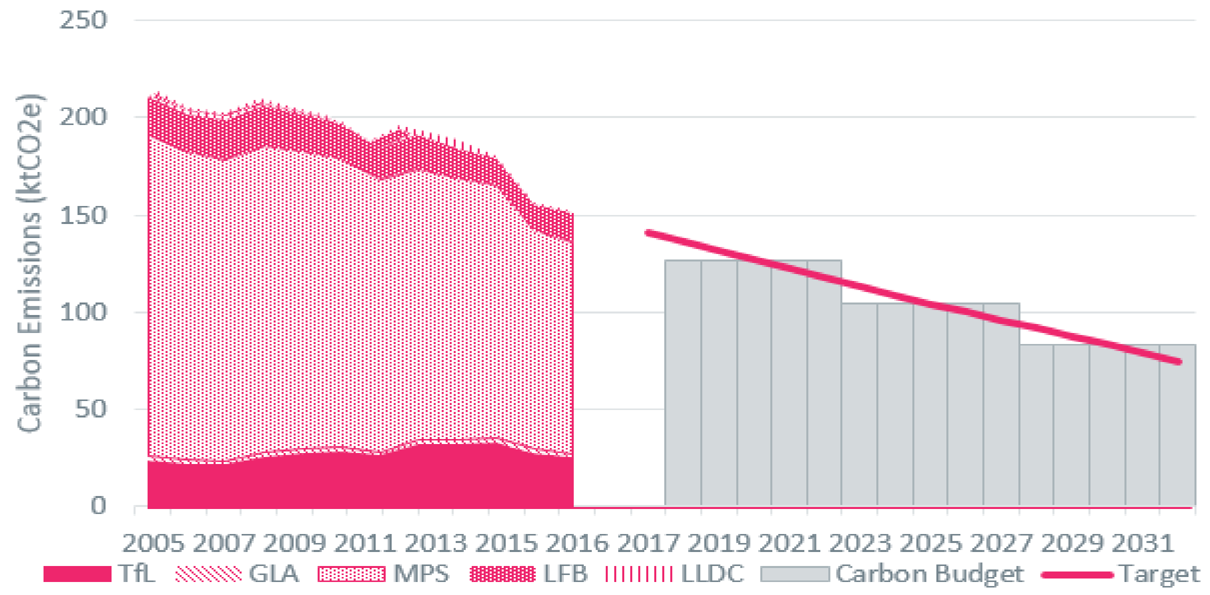
Table 8: Scope for GLA group emissions reporting

Functional body	Scope of emissions for reporting
TfL	Head Offices, Support Fleet, Staff Air Travel, London Transport Museum
GLA	City Hall, Trafalgar Square, Support Fleet, Staff Air Travel
LFB	Head Offices, Support Fleet, Staff Air Travel
MPS	Head Offices, Support Fleet, Staff Air Travel
LLDC	Head Offices, Support Fleet, Staff Air Travel
TfL, additional energy	Energy from operational buildings and infrastructure, including a proportion of rail electricity estimated to be used for running of stations, depots and other sites. This is kept separate due to the lower quality of the data and changes in TfL's estate since 2005

The GLA group carbon budgets require sustained reduction against 2005 levels (Figure 52). This does not include emissions from additional TfL sources, including non-traction bulk supply.[58]

[58] These emissions will also be monitored by TfL and have a target carbon budget, based on TfL's target reduction from 2016-17 to 2025. This has been kept separate for several reasons. It includes data on further TfL services that were not operational or did not have sufficient data in 2005 and it includes an estimate of electricity imported through bulk supply points which may in future be refined due to more granular metering.

Figure 52: GLA group carbon budgets[59]



59 CCMES report (2017)

Waste

London's waste performance - where we are and why

In London, almost seven million tonnes of waste are produced each year from our homes and public buildings (household waste), and from businesses. Local authorities only deal with about half of this waste (3.7 million tonnes); the rest is dealt with by the private sector. Figure 53 shows how London's local authority collected waste (LACW) is managed.

Figure 53: LACW management methods 2016/17. Total = 3.7 million tonnes[60]

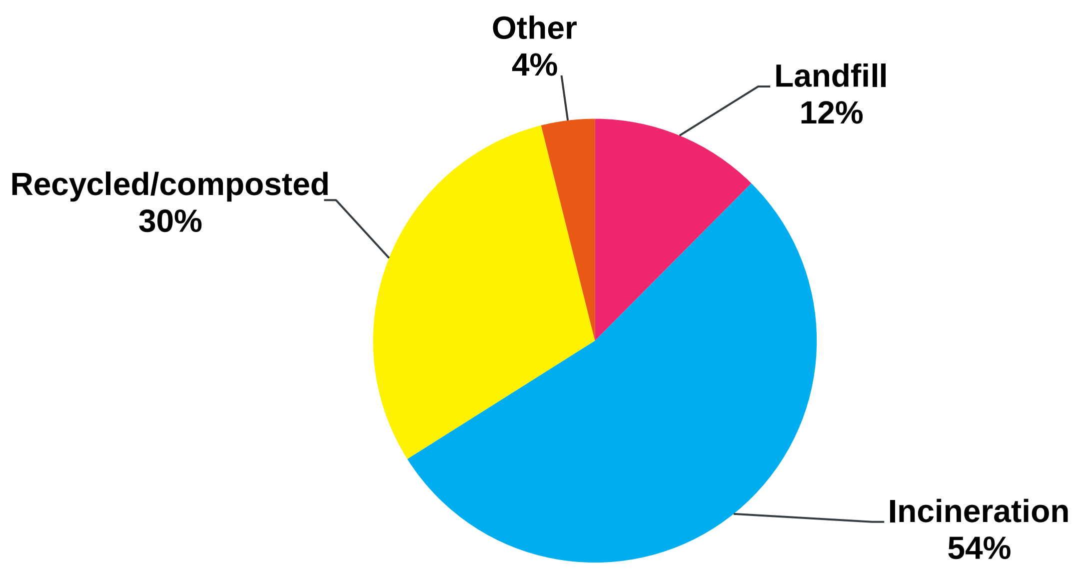
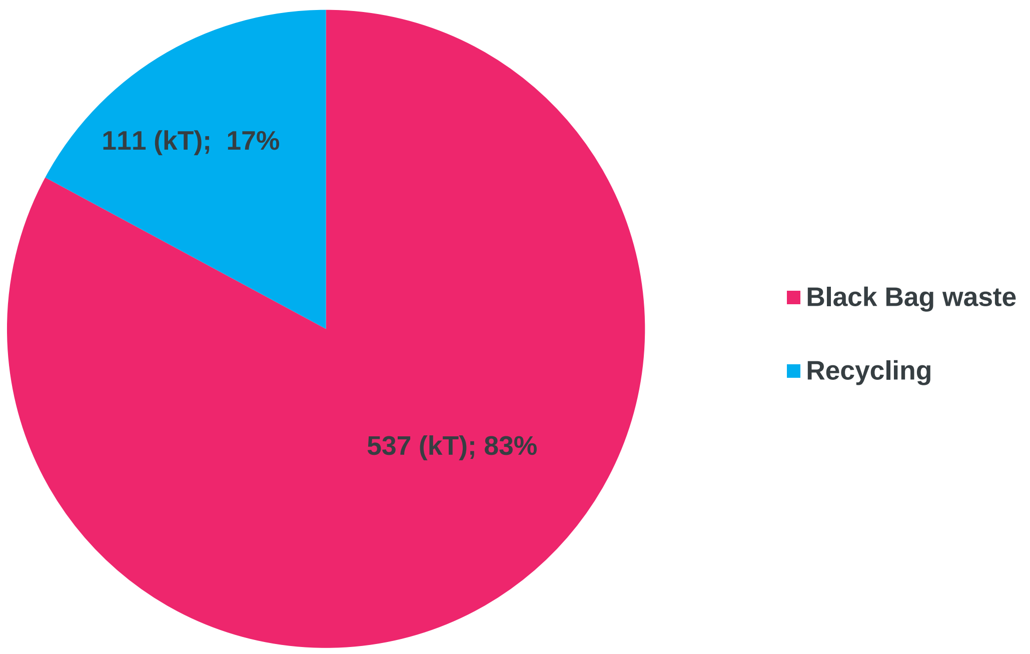


Figure 54 shows the amount of business waste collected by local authorities, the majority of which is black bag waste going to incineration or landfill.

60 Defra (2017) LACW statistics 2016/17. Accessed from: https://www.gov.uk/government/statistical-data-sets/env18-local-authority-collected-waste-annual-results-tables

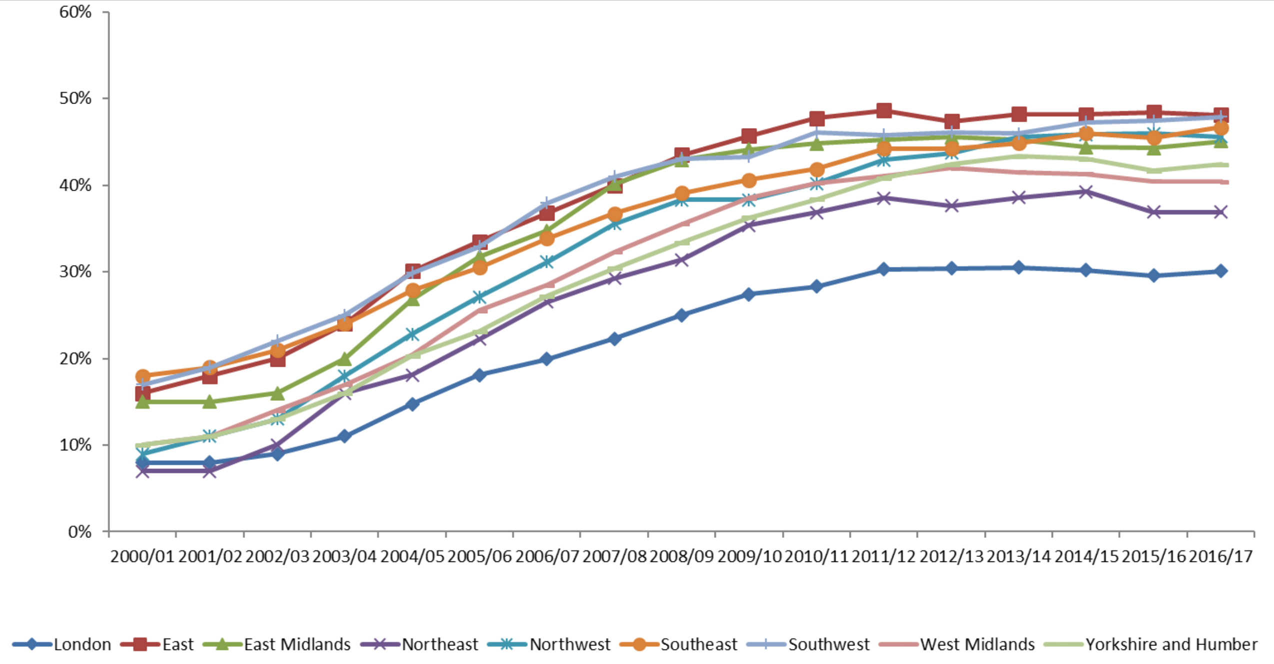
Figure 54: Management method for Local authority collected business waste[60]



Between 2003 and 2010, London significantly improved how it managed its waste. London's LACW recycling rate went from eight to 30 per cent. Landfill rates have gone down from 70 per cent in 2003 to 12 per cent in 2016/17. This improvement was largely due to the EU Landfill Directive. This restricts the amount of biodegradable waste that Member States can send to landfill by 50 per cent by 2013, and 65 per cent by 2020. The UK government has implemented this by imposing a landfill tax that incentivised more cost effective waste management alternatives.

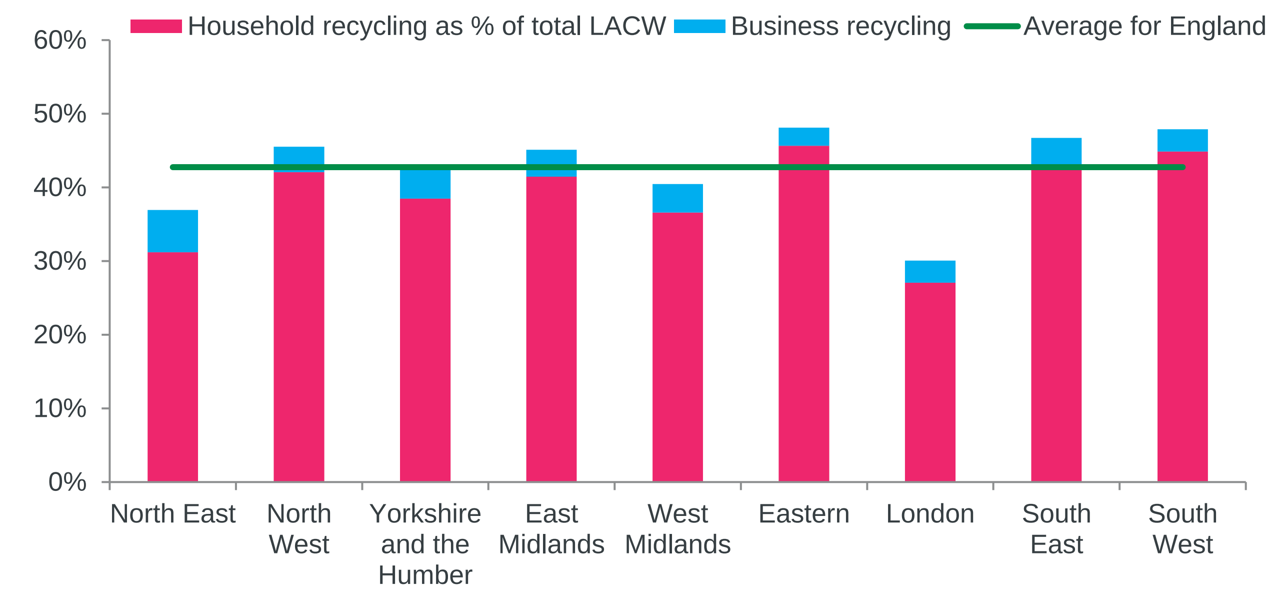
Figure 55 shows London's LACW recycling performance against other UK regions since 2001. Despite improvements in recycling performance, London continues to be the lowest performing region. Since 2011, regional recycling rates have stalled, with London's performance levelling off at 30 per cent.

Figure 55: Regional LACW Recycling performance 2001 – 2017[60]



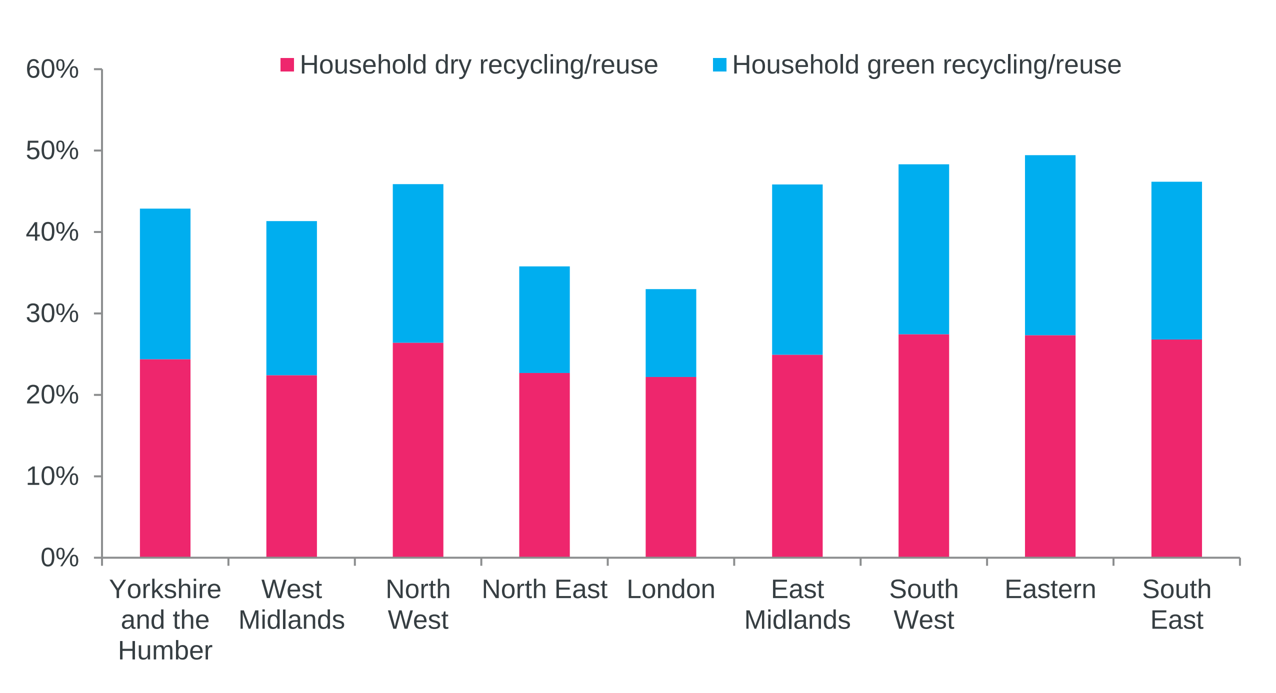
London has always performed poorly compared to other UK regions, and is sitting well below the national average recycling rate of 43 per cent in 2016 (Figure 56).

Figure 56: Regional LACW recycling rates 2016/17[60]



The government has set a national household waste recycling target of 50 per cent by 2020. Recycling targets are currently weight-based, so regions that collect denser waste are at an advantage. London is highly urbanised and produces far less dense green garden waste for composting (Figure 57), which makes it more difficult to perform against the UK recycling weight-based targets.

Figure 57: Regional household dry recycling and composting rates 2016/17[61]



There are several other possible reasons for the lack of improvement in recycling over the last seven years, including the recession in 2008. Commodity prices crashed in 2009 and, despite a small recovery in the next few years, declined again from 2011 to 2015. This meant that the price differential between recycled materials and virgin material reduced significantly, resulting in little incentive to use recycled materials. In addition, the waste processing costs for recyclable materials increased. This resulted in the liquidation of a number of small recycling facilities, including three plastics recycling plants in London.

The 2008 recession also led to a period of public sector austerity that saw local authority budgets decline significantly. Local authorities had to consider how they could meet their

[61] Defra (2017) Local authority collected waste generation from April 2000 to March 2017 (England and regions) Local authority data April 2016 to March 2017

statutory requirements with decreased budget. This led to a reduction in some non-statutory functions, such as local recycling.

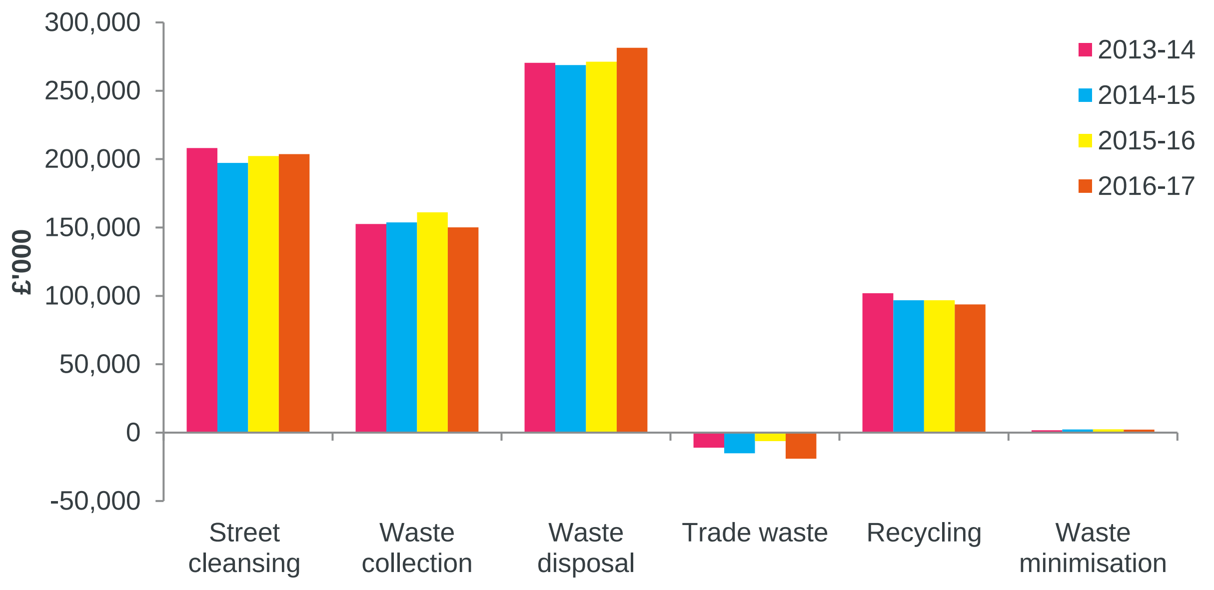
Finally, during this time London's LACW sent to incineration more than doubled from 900,000 tonnes (24 per cent) in 2011, to 2 million tonnes (54 per cent) in 2016/17. London now has the highest incineration rate across the UK (ahead of the North East at 53 per cent)

WRAP estimate that around 80 per cent of municipal waste is recyclable. This is despite changes in waste composition over recent years, including a reduction in paper and a growth in electronic devices and light weighting of plastic packaging, which can be poor quality and not easily recycled. The increase in the use of incineration without ensuring that only residual waste is processed (i.e. as much waste that can be recycled has been removed) appears to have also contributed to a low recycling rate.

The costs of Local Authority Collected Waste

Figure 58 shows London's local authority waste management costs over the past three years. Waste disposal (incineration and landfill) is the greatest area of spend (£280m), followed by street cleansing and waste collection.

Figure 58: LACW net expenditure on waste services 2016/17[62]



Waste disposal costs have largely stayed the same, whilst waste collection costs have slightly increased. However, over the same period recycling costs have been coming down

[62] DCLG (2017) Local authority revenue expenditure and financing England. Accessed from: https://www.gov.uk/government/collections/local-authority-revenue-expenditure-and-financing#2016-to-2017

and are a third cheaper than waste disposal in relative terms. A significant part of the cost are the fees that waste authorities have to pay for waste that is not reused, recycled or composted to be accepted at landfill sites or incinerators (landfill and incineration gate fees). A tax has also then been applied to waste disposed to landfill – £89 per tonne from April 2018. The cost differential between recycling and incineration or landfill is wide, ranging from £24 per tonne for recycling to £100 - £102 per tonne for incineration and landfill. Reducing waste and moving to a higher reuse and recycling based approach should bring savings to local authorities.

In addition, there is income to be secured. Materials sent for recycling have a market value that boroughs can share in, depending on their waste arrangements and contracts with external service providers. For example, local authorities providing trade (commercial) waste collection services can generate a net income, which reached a high of £19m in 2016/17. Increasingly, more London waste authorities have revenue share agreements in place, as the value of recycling has become better understood.

Reducing LACW waste arisings by just one per cent and achieving a 50 per cent LACW recycling rate could help reduce London's LACW waste disposal costs by £78m per year.[63]

London's waste governance arrangements

London's fragmented waste governance can make it confusing for residents to know what and how they can recycle. Figure 59 shows the wide variation in the number and types of recycling collection systems provided, their frequency, and the types of containers that residents use to recycle.

Around two-thirds of London boroughs offer separate collection of food waste to achieve higher recycling rates. Although not shown in the figure, there is also significant variation across boroughs in the number and types of materials that residents can recycle, especially between properties with a kerbside collection and flats.

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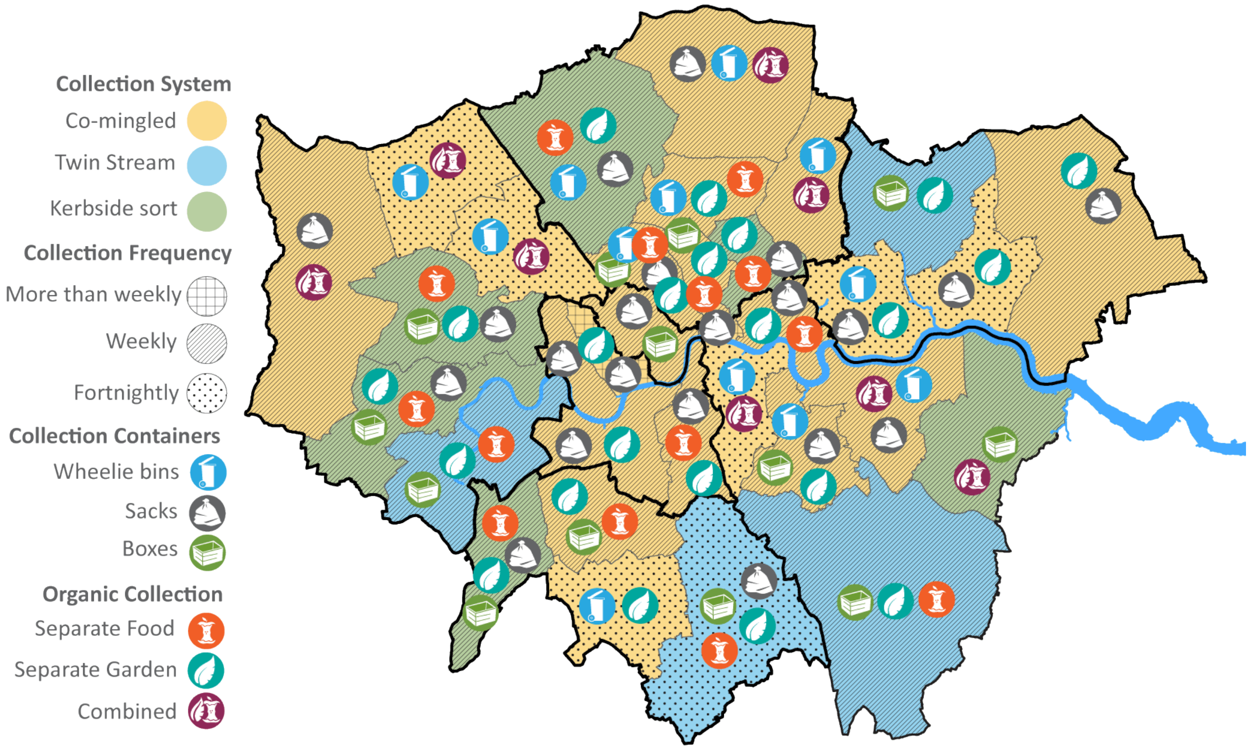
[63] Assumes 1 per cent or 37,000 tonnes of London's LACW 2016/17 arisings (3.7 million tonnes). Waste cost source: WRAP Gatefees report 2016. Assumes average avoided disposal costs of £100 per tonne moving from a 30 per cent to a 50 per cent LAWC recycling rate. Additional collection costs and savings or revenue from sale of recyclables not included.

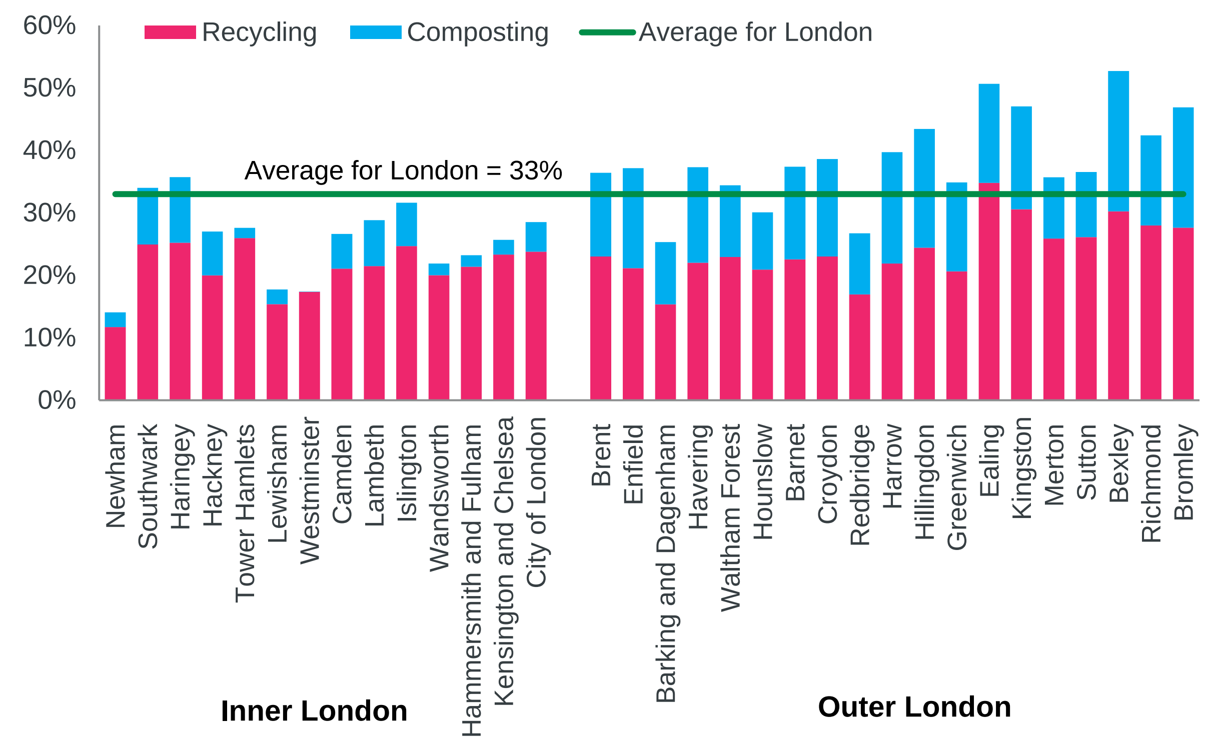
Figure 59: Local Authority waste collection services[64]



Furthermore, 24 of the 33 boroughs have private contracts in place to operate their waste collection. Authorities can be locked into a particular collection, treatment and disposal contract for over ten years (sometimes as long as 25 years), which can restrict opportunities to adapt, change and optimise recycling services. These arrangements have further contributed to London's varied service provision and recycling performance. Figure 60 shows that, on average, the recycling rate is higher for outer boroughs, mostly as a result of higher composting rates. However, there is no similar relationship between inner and outer London boroughs for dry recycling performance (paper, glass, plastics and metals).

[64] Resource London Partnership (2016) N.B. Based on best available information; some services may have changed. Service descriptions: Co-mingled – materials for recycling collected in a single container/sack and sorted at a recycling facility; Twin stream – materials collected for recycling using two separate containers; Kerbside sort – materials for recycling are placed in a variety of bins or bags and sorted at the kerbside into a collection vehicle.

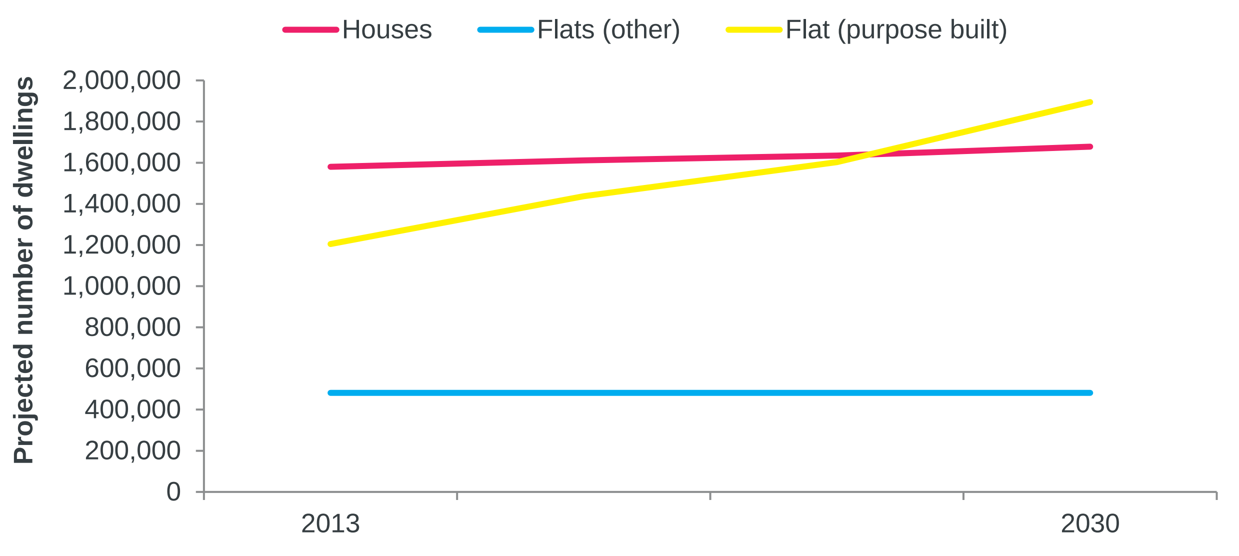
Figure 60: Household recycling performance by borough 2016/17[60]



London faces other challenges to achieving high weight based recycling performance. In addition to being highly urbanised with fewer gardens producing heavy green waste, London has a highly transient and diverse population with over 100 languages spoken. This can make communicating recycling services difficult, especially as there are 33 different collection services. On average, 50 per cent of the population live in flats, reaching 80 per cent in some boroughs. Flats often have a lack of easily accessible sufficient storage space for recycling, and can be expensive for local authorities to service.

GLA projections estimate that by 2030, 46 per cent of London properties will be purpose built flats. These projections suggest that of the properties built between now and 2030, 88 per cent of dwellings are estimated to be purpose built flats (Figure 61).

Figure 61: Projected housing stock in London[65]



Fly tipping and litter
Local authorities are responsible for enforcing and prosecuting small scale illegal dumping of waste (fly tipping), and the Environment Agency is responsible for prosecuting large scale offences. Fly tipping in London is a significant issue due to the cost of clearance and the impact on the aesthetics of the streetscape.

A legal requirement for those dealing with certain kinds of waste to take all reasonable steps to keep it safe and is set out in the Environment Protection Act (EPA). It applies to anyone who is a holder of household, industrial and commercial waste, known as the ‘Duty of Care’.

Businesses and householders have a duty of care to ensure their waste is stored and sorted safely. They also have a duty of care to ensure they only present it to a licenced waste carrier for onward treatment or disposal.

Businesses can choose whether they use waste and recycling collection services provided by their local authority (if one exists) or a private waste collection. This has led to a large number of private companies running waste operations across the capital.

[65] Resource London (2017)

In April 2017, the government published the Litter Strategy for England, identifying a number of actions to be taken nationally that could have a significant impact on litter and fly tipping in London.

Municipal waste

In 2011, Defra changed the definition of municipal waste to align with the EU definition, which defines municipal waste much more broadly to be “household waste or waste similar in composition to household waste”. This means that waste from businesses is included, whether or not it is in local authority control or possession. The change was made to make sure that the UK is correctly reporting its performance for meeting its landfill diversion targets under the European Landfill Directive.

Local authorities are required to report the waste they collect using Defra’s Waste Data Flow tool[66]. Defra publishes the waste management performance of all English waste authorities every quarter and on an annual basis.[67]

The Mayor does not have any powers over commercially collected waste, no national or regional mandatory reporting system exists, and no municipal waste reduction or recycling targets have been set by government. As such, commercially collected municipal waste including from businesses, charities, and public organisations including schools and government buildings is not required to be reported to Defra, so it is not captured in a formal way at the local or national level. Commercially collected waste performance data is collected through surveys, the most robust being in 2009[68], and by extracting data from the government’s waste interrogator tool, although this does not provide clarity on where the waste is generated from.

The GLA has estimated London’s municipal waste generation and performance by combining data from Waste Data Flow with data from the waste interrogator, Defra’s 2009 commercial and industrial waste survey, and other sources. Future waste generation is forecast out to 2030 on a waste generation per head and employee basis, using the London population and employment projections used for the London Plan.[69]

In developing the London Environment Strategy, the GLA worked with the Environment Agency and SLR Consulting to review London’s municipal waste recycling performance using new waste data from the Environment Agency’s 2016/17 Oracle Regis Appended

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[66] See http://www.wastedataflow.org/

[67] See https://www.gov.uk/government/collections/waste-and-recycling-statistics

[68]UK Commercial and Industrial waste survey 2009, May 2011. See http://webarchive.nationalarchives.gov.uk/20130125163914/http://www.defra.gov.uk/statistics/files/ci-project-report.pdf. Defra have published subsequent survey reports. However, the 2009 survey is considered the most robust baseline for estimating London’s municipal waste performance.

[69] See population and employment projections at https://www.london.gov.uk/what-we-do/planning/london-plan/new-london-plan/evidence-base

Tonnage System (ORATS) database. For the first time, ORATS combines data from the waste interrogator tool with pollution prevention and control (PPC) regulated facilities. Relevant regulated PPC facilities include municipal waste incinerators and recycling facilities handling residual waste not included in the waste interrogator.

Using the new ORATS data, London’s 2016/17 municipal waste recycling rate was estimated at 41 per cent, compared with 52 per cent using the Defra 2009 waste survey. The bulk of London’s municipal waste is sent to landfill or incineration (54 per cent, previously estimated at 37 per cent). The remaining five per cent (previously estimated at 11 per cent) is managed via other pre-treatment or unknown processes (see Figure 63). Although the ORATS database has limitations, including reliance on facility operators to submit data returns on a voluntary basis, it is considered to present a more likely recycling performance for London’s municipal waste and is supported by Defra. Therefore, a 41 per cent rate has been applied for the London Environment Strategy.

Defra has not yet estimated the UK’s municipal waste generation and performance under the revised municipal waste definition. In 2017, the GLA commissioned SLR Consulting to estimate London’s municipal business waste sources using the datasets as set out above and the government’s waste classification codes (Table 9).

Table 9: London’s municipal business waste breakdown. Estimated total = 3.8 million tonnes 2017

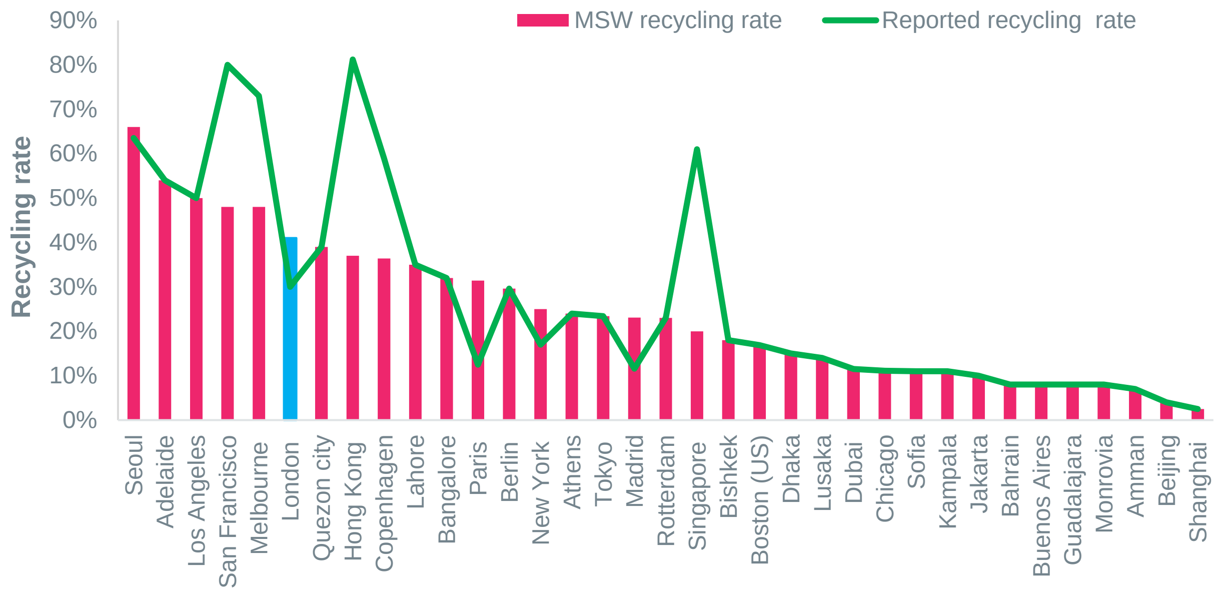
Substance Orientated Classification (SOC) group[70]	Assumed proportion classified as municipal (%)	Tonnage (000s tonnes)	Comments
Animal & vegetable wastes	90	526	Assumed largely produced by commerce. Indicatively 10% of food waste is assumed to be generated in bulk by food waste manufacturing, and therefore not comparable to household waste
Discarded equipment	100	165	Mostly waste electrical equipment Including batteries
Healthcare wastes	10	30	Includes biological waste: human and animal infectious waste). Healthcare wastes fall under European Waste Category (EWC) codes chapter 18 ('Wastes From Human or Animal Health Care and/or Related Research”)

[70] More information on SOC groups and sub groups can be found at https://naturalresources.wales/media/1996/survey-of-industrial-an-commercial-waste-generated-in-wales-2012-technical-appendices.pdf

Table 9: London's municipal business waste breakdown. Estimated total = 3.8 million tonnes 2017			
Substance Orientated Classification (SOC) group[70]	**Assumed proportion classified as municipal (%)**	**Tonnage (000s tonnes)**	**Comments**
Metallic wastes	80	227	Includes scrap metal, precious metals and common metals copper, aluminium and mixed metallic packaging waste. Assumed that this would include some bulky metal items, which would not be similar to household waste
Mineral wastes	10	20	Includes contaminated soils, dredging spoils, naturally occurring minerals and asbestos. Assumed to mostly be produced by large scale industry, and therefore differs from household waste
Non-metallic wastes	90	2,807	All other waste deemed similar in nature to household waste. Predominantly packaging materials (paper, plastic, glass) and textiles. Indicatively a 10% contribution is assumed to be generated in bulk by manufacturers, and therefore not comparable to household waste

Under the revised definition of municipal waste now used by Defra, the scope of waste in London to be managed increases significantly. However, whilst London's LACW performance is poor in the UK, it does better when compared to other global cities where waste is reported as 'municipal waste' that includes commercially collected municipal waste (mainly business waste). Rather than the current LACW rate of 30 per cent, London achieves a 41 per cent municipal waste recycling rate, sitting 6th behind Seoul (67 per cent); Adelaide (54 per cent); Los Angeles (50 per cent), San Francisco (48 per cent) and Melbourne (48 per cent). On reporting rates (the green line in Figure 62) London does less well, but this disparity reflects the number of different ways that cities report their recycling rates. For example, some include other waste sources, such as construction waste.

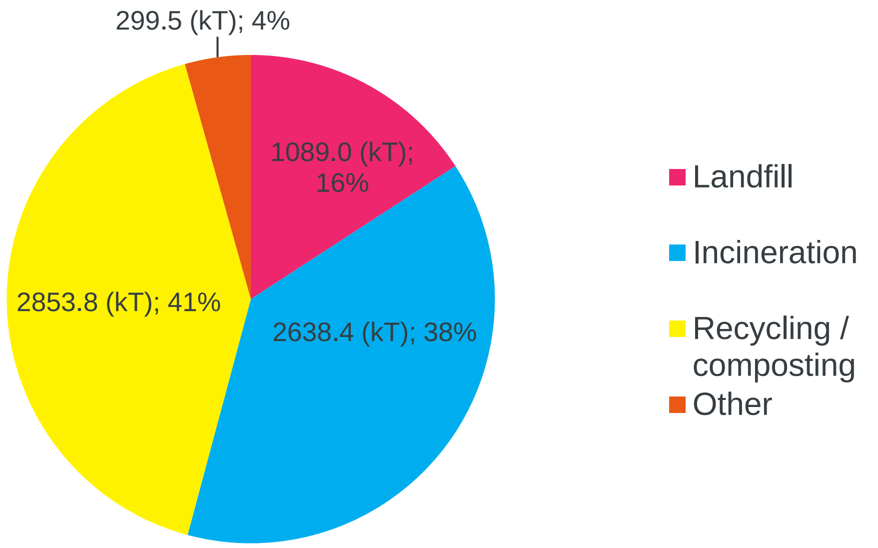
Figure 62: London's municipal waste performance in comparison with other cities (taking into account London's revised municipal waste recycling rate of 41 per cent)[71]



Applying the broader EU definition of municipal waste brings an additional 3.2 million tonnes of business waste into scope for London, giving a total of 6.9 million tonnes. Figure 63 shows London's total municipal waste management performance, combining waste from household and business sources (expressed both in tonnes and as a percentage of the total). The overall recycling performance is improved as a result of higher estimated recycling rates of business waste (around 48 per cent recycling rates compared with London's 33 per cent household waste recycling rate not shown in chart).

[71] Greenfield, D. (2016) International recycling rate comparison project. Accessed from: http://www.lwarb.gov.uk/wp-content/uploads/2016/09/LWARB-International-recycling-rate-comparison.pdf

Figure 63: London Municipal Solid Waste (MSW) arisings and management methods 2017 (in tonnes and as a percentage of the total). Total = 6.9 million tonnes 2017[72]



The opposite, however, is the case for local authority-run business waste services. Figure 55 shows that the recycling performance for business waste collected by local authorities is poor, contributing 7-18 per cent to LACW recycling performance nationally, and around ten per cent in London. It is estimated that local authorities control around a 15 per cent share of London's business waste services. Most London local authorities provide waste services to local businesses but few provide recycling collection services, with an estimated recycling rate of these services of between ten and 17 per cent.

Section 45 (1)(b) of the Environment Protection Act (EPA) 1990 requires local authorities to "arrange for the collection of commercial waste, if requested and a reasonable charge may be made for its collection". Local authority run commercial waste collection services offer two specific potential sources of competitive advantage in that no VAT applies, and there is the potential to co-collect it with the domestic waste fleet, provided that suitable waste tracking is in place.[73]

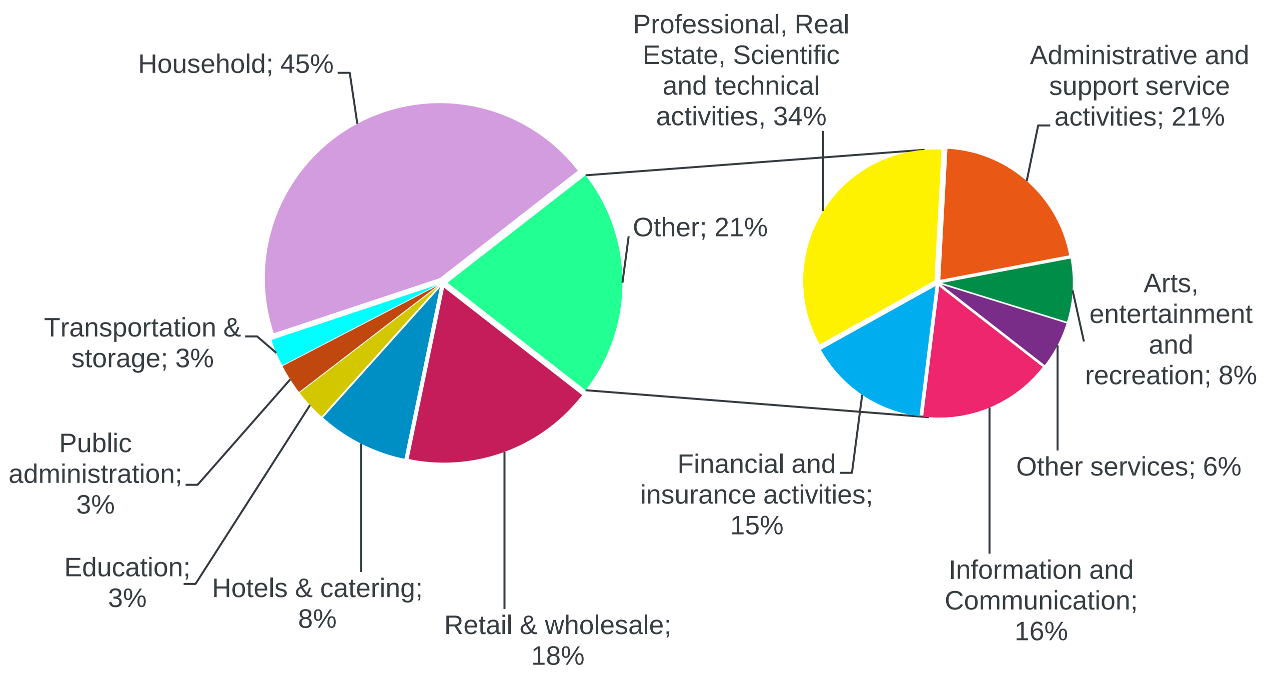
[72] N.B. given the limitations of available data on municipal business waste streams, these findings involve an element of estimation and are indicative only. 'Other' includes treatment of waste to recover recycles or to prepare a fuel.

[73] Improvement East (n.d.) Local Authority Trade Waste: Opportunity or Headache? Accessed from: http://www.eelga.gov.uk/documents/support%20services/environment/local%20authority%20trade%20waste%20-%20top%20tips.pdf

Local authorities face several challenges to boosting their business waste services in a cost effective way. One key challenge is that private waste companies attract the larger businesses that separate their recycling. Local authorities are typically left with providing services to the smaller businesses that generate less waste and can find it harder to separate their recyclable waste. Under the Environment Protection Act 1990, individual businesses and other organisations are required to find an authorised and licensed organisation to collect their waste and recycling. Private waste companies are the dominant recycling service providers for businesses in London, taking around an 85 per cent market share.

Figure 64 shows how London's municipal waste is managed (as a percentage of the total) and where it is from by sector. The bulk of London's municipal business waste (55 per cent of the total) comes from retail and wholesale activities (1.2 million tonnes, or 18 per cent) and other services (1.4 million tonnes, or 21 per cent) including administration, financial services, art and culture, collectively making up 65 per cent of total business waste.

Figure 64: London municipal waste arisings by sector 2017: total 6.9 million tonnes[74]



[74] Based on GLA waste modelling. N.B. the municipal business waste figures are estimates based on data from the 2009 Defra commercial and industrial waste survey. They should be treated with caution and not reported as official data.

Waste infrastructure

London manages around half the waste it produces. Most exported waste goes to landfill, mainly in the South East. Along with it goes the economic value of recovered materials for reuse, recycling or energy generation. Although waste to landfill has declined by 65 per cent since 2005, London still landfills around one million tonnes of municipal waste each year, costing around £100 million[75]. Landfills accepting London's waste are expected to close by 2026 and no new capacity is planned.

London exports about one million tonnes of waste per year to other countries, most of which is residual waste for incineration in continental Europe. The UK has increasingly become an attractive market place for its residual waste, particularly in the Netherlands and Germany where incineration capacity is high but local residual waste supply is low.

London has three large Energy From Waste (EFW) facilities, with a fourth being built in Sutton. Collectively, these can treat around two million tonnes of waste per year, with the potential to generate enough electricity to power 500,000 homes. At least a further 50,000 homes could be provided with heat if these facilities were upgraded to operate in combined heat and power mode.[76]

Scenario 1 (Figure 65) sets out London's estimated municipal waste management infrastructure capacity requirements[77] for achieving the Mayor's waste reduction and recycling targets by 2030, and meeting the 100 per cent net self-sufficiency target by 2026. The grey bars above zero indicate a capacity shortfall within London. Grey bars below zero indicate surplus capacity. Two other scenarios (Figure 66 and Figure 67) are also set out, applying lower waste reduction and recycling targets for comparison.

[75] GLA Waste Modelling 2018.

[76] London Energy Plan modelling: assumes London incinerators generating 1500Ghw electricity in CHP mode. Applies benchmark of a typical home energy use, i.e. 10MWh/year for domestic heat and 3.5MWh/year electricity.

[77] GLA Waste Modelling 2018

Figure 65: Scenario 1: Achieving a 50 per cent per head food waste reduction rate by 2030; 65 per cent recycling rate by 2030; 5 per cent landfill rate by 2026.

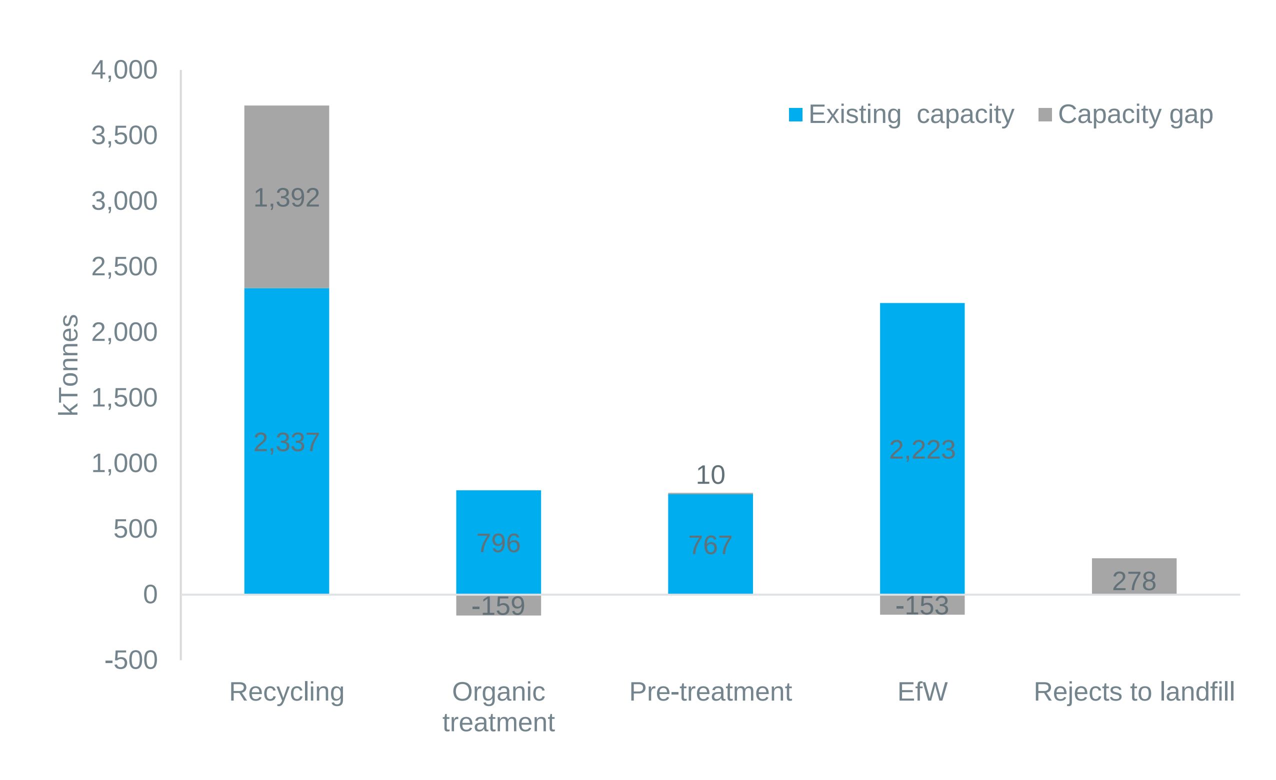


Figure 66: Scenario 2: Achieving a five per cent per head reduction rate for all waste by 2030; 65 per cent recycling rate by 2030; 5 per cent landfill rate by 2026.

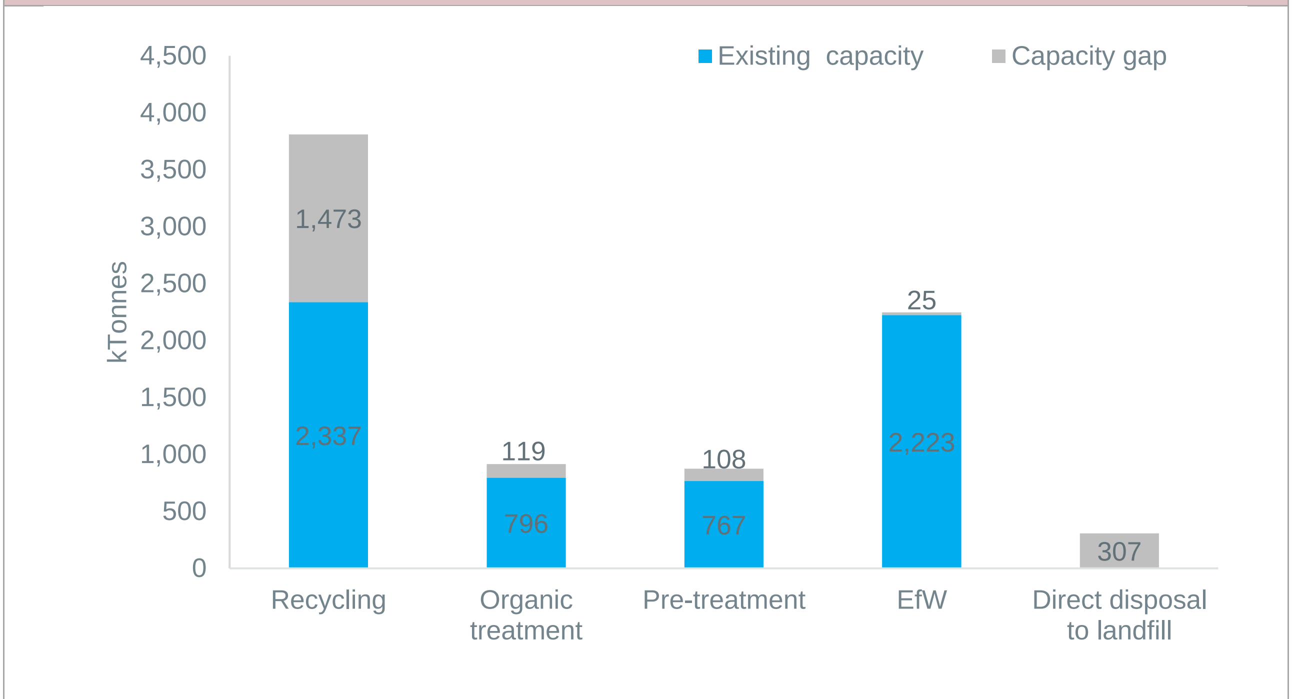
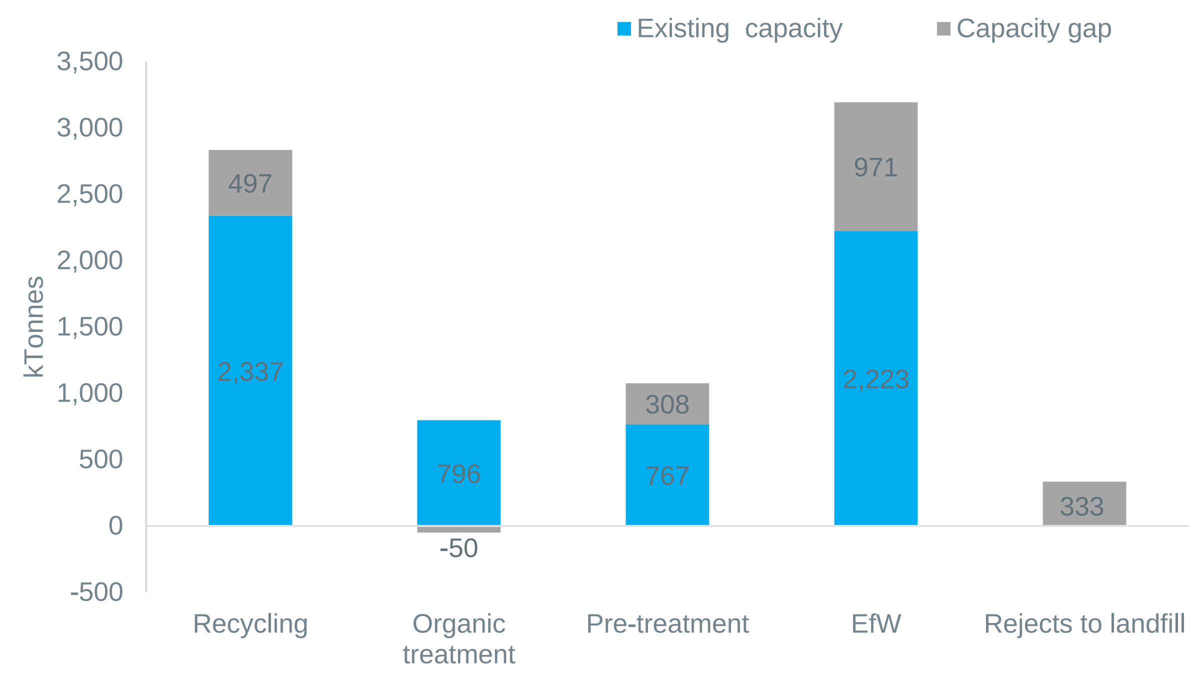


Figure 67: Scenario 3: Achieving a 20 per cent food waste reduction by 2025; 50 per cent recycling rate by 2030; five per cent landfill rate by 2026



In summary London is expected to:

- need significant additional recycling capacity (for example materials recycling facilities and sorting capacity) as recycling performance increases under all three scenarios. Under London Plan policy, new or existing recycling infrastructure managing waste from London can be located outside London to meet net regional self-sufficiency
- have surplus organic waste treatment capacity[78] in scenarios 1 and 3, and a 120,000 tonne shortfall in scenario 2. The latter is due to more food waste expected to be produced and managed via organic waste facilities to achieve the 65 per cent recycling target by 2030
- not need any additional EFW capacity[79] under scenario 1, but would need significant EFW capacity in scenario 3 where only a 20 per cent food waste reduction rate and 50 per cent recycling rate is achieved

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[78] Includes 160,000 tonnes capacity from the new RE:Food organic waste treatment facility in Dagenham that opened in July 2017.

[79] Assumed existing SELCHP (Lewisham) and RRR (Bexley) EFW facilities remain operating. Assumes planned Edmonton replacement EFW facility (780,000 tonnes per annum) operating from 2025. Assumes planned Beddington (Sutton) incinerator (280,000 tonnes) operating from 2021.

- need around 100,000 and 310,000 tonnes of pre-treatment capacity in scenarios 2 and 3, respectively, due to higher amounts of waste expected to be produced and pre-treated prior to going to EFW, recycling or landfill
- need between 270,000 – 335,000 tonnes of landfill capacity in all three scenarios to manage waste not situatable for recycling or EFW (estimated at 5 per cent of total waste produced)

The GLA has developed an interactive webmap of London's waste facilities[80]. The London waste map, updated on an annual basis, is publicly available to help London waste authorities, Mayoral Development Corporations, and waste facility operators to identify and access local waste facilities and suitable sites for new facilities.

Drivers for change – reducing waste and being more resource efficient

Food waste

City governments and large corporations around the world are taking action to cut food waste and divert materials of value of useful purposes. The Environment Food and Rural Affairs (EFRA) Committee published a report[81] recommending that the government make food waste reduction a top priority, and establish a national food waste reduction scheme to help cut food waste costs, which are estimated at £200 per person each year. The EFRA report also calls on supermarkets to publicly report the amounts of food they dispose of, and to relax rules that prevent the sale of 'wonky vegetables' that are still edible.

Single use packaging

Single use packaging materials, including coffee cups and plastic bottle waste makes up around 2 million tonnes or 30 per cent of our waste stream. This waste continues to grow, and places increasing pressure on local waste management services. Plastic packaging litters our streets and finds its way into oceans, harming wildlife and taking centuries to break down whilst releasing toxic chemicals. Single use plastic bottles form the most prevalent form of plastic packaging in our oceans and manufacturers are increasingly pressured to commit to phasing out non-recyclable plastic packaging.

A YouGov poll[82] showed that nearly two-thirds of people say they would be more likely to use a reusable water bottle if tap water refills were more freely available in widely used places, including shops, airports and parks. A similar proportion of people believed that

[80] https://maps.london.gov.uk/webmaps/waste/

[81] Environment, Food and Rural Affairs Committee (2017) Food waste in England. Accessed from: https://www.parliament.uk/business/committees/committees-a-z/commons-select/environment-food-and-rural-affairs-committee/inquiries/parliament-2015/food-waste-inquiry-16-17/

[82] See https://yougov.co.uk/news/2017/05/19/millions-brits-would-ditch-bottled-water-if-tap-wa/

businesses that serve food and/or drink should be required to provide free drinking water to the public, regardless of whether they are a customer or not.

Hugh Fearnley Whittingstall's 'war on waste' programme[83] highlighted the blight and costs of both food waste and single use packaging on UK society. The programme estimated Britons throw away around 2.5 billion coffee cups per year, with around 40 million cups in London. Coffee cups can be difficult to recycle due to the design requirement to make them durable and hot-water proof.

Re-use

Limited reported data exists on material re-use, as in most cases these materials never enter the waste stream and therefore are not reported. However, it is known that re-use activity happens through people using platforms like Ebay, Gumtree and Freecycle to get rid of their unwanted items of value. Re-use and repair provides significant employment opportunities[84], and delivers wider social benefits through the re-distribution of unwanted items to those in need. Items suitable for re-use, like furniture, fitting and electrical appliances, make up around four per cent of municipal waste, which in London is around 150,000 tonnes per year[85].

Capturing value from waste

The data in Figure 58 (LACW waste costs), Box 5 and Box 6 suggest there are significant savings to be made by reducing waste and recycling more of it, and the means to provide waste authorities with an income stream.

Box 5: Improved food waste collection[86]
Recycling rates in Ealing increased by five percentage points between April 2016 and March 2017, which saw the council introduce alternate weekly collections and wheelie bins in June 2016. Rubbish is collected one week, dry mixed recycling the next, and food waste collected every week. This service is for approximately 98,000 kerbside properties. Final statistics for 2017-18 calendar year showed recycling rates increased to 50 per cent, up from 45 per cent in 2015-16. The tonnage of food waste recycled from homes across the borough with an increase of 46-47 per cent compared to the same period last year. A total of 6,586 tonnes were recycled between 1 April and 31 March. Food waste is sent for anaerobic digestion, where it is broken down to produce biogas for electricity and biofertiliser.

[83] See https://www.bbc.co.uk/programmes/b06nzl5q.

[84] See https://www.lwarb.gov.uk/wp-content/uploads/2015/12/Employment-and-the-circular-economy-–-job-creation-through-resource-efficiency-in-London.pdf.

[85] GLA waste modelling

[86] Credit: London borough of Ealing waste services

Box 5: Improved food waste collection[86]
In total, the service change delivered an annual saving of £1.7m from operational efficiency, reduced need for street cleaning, and savings in waste disposal.

Box 6: Commercial waste recycling[87]
Westminster City Council, through its waste contractor Veolia, offers a comprehensive range of commercial waste services, including pre-paid bags, containers, compactors and balers, mixed paper/card, mixed glass, co-mingled and food waste collections to 12,000 customers. In addition, hazardous waste collection, security shredding and bulky waste collection services are offered.   In 2015/16, approximately 16,000 tonnes of commercial waste was recycled, achieving a 16 per cent recycling rate. The business unit turnover was £17m in 2016/17, generating a revenue stream for the Council that is invested back into waste services. Incentives are in place for Veolia to tackle commercial fly-tipping and grow the business by paying a share of the additional pre-paid bags sold to customers against the baseline of the previous year.   Improving air quality is a key objective of the City Council and its stakeholders. Various initiatives, including a dual fuel hydrogen and diesel system, are being trialled on commercial recycling collection vehicles in 2017/18.

Waste materials work like any other commodity as a marketable item of value meeting a demand. High value but lightweight materials commonly found in the municipal waste stream, such as aluminium, tin plastics and textiles have a high carbon intensity and typically attract higher prices than heavier materials like glass and organic waste, which are lower in carbon intensity. Typical material prices paid for recycling and their CO_2e saving performance are highlighted in Table 10.

Table 10: Average prices paid for common recyclable materials 2016[88]

Material	Price per tonne 2016	CO_2e emissions saved per tonne recycled
Aluminium cans	£687	8.70 tonnes
Textile: banks	£212	6.00 tonnes
Mixed plastic bottles	£87	1.17 tonnes
Mixed paper	£69	0.34 tonnes
Steel cans	£48	1.83 tonnes
Mixed glass	£10	0.20 tonnes

[87] London borough of Westminster services

[88] Emission factors taken from Greenhouse gas emissions performance standard for London's LACW- 2017 update - assumes materials are recycled back into their original use (i.e. plastic bottles recycled back into plastic bottles)

Price figures taken from www.letsrecycle.com/prices

There is a growing consensus amongst the waste industry, and in global commodities that a material-specific and carbon based approach would better align resource productivity with environmental goals. This was recently discussed and supported in a Policy Exchange report *Going Round in Circles*[89]. For a number of years, the government, European Commission and the waste industry have considered the use of a carbon-based metric to measure the benefits of waste management techniques like recycling, rather than using weight alone. This approach is based on the premise that focusing on the heaviest materials for recycling doesn't always deliver the greatest economic and environmental benefits. For example, it places the same nominal value on a tonne of grass cuttings as a tonne of aluminium cans.

Government, in responding to the EU Circular Economy Policy Package, has indicated it is 'less keen' on weight based recycling targets[90] and that the 65 per cent target first proposed in the EU Circular Economy Policy Package was 'too high to be achievable'[91]. The government is currently considering its position on waste and recycling policy and performance reporting in light of Brexit.

Cutting waste and creating jobs and growth – transition to a circular economy
The circular economy aims to decouple economic growth from resource use. It is regenerative by design, aiming to keep materials, products and components in use at their highest value for as long as possible (Figure 68). Waste is designed out, which can result in less land and infrastructure needed to manage waste and free up space for housing and other kinds of development. Work undertaken by ARUP[92] for the London Waste and Recycling Board (LWARB) showed the potential for a 30 per cent reduction in municipal waste by 2041 if there is a strong take up of circular economy initiatives. Such initiatives include asset sharing (e.g. car and office space sharing) and switching to lease-based models over product ownership, whereby products are serviced and maintained by the manufacturer, keeping them in use for longer and then reused or recycled at end of life.

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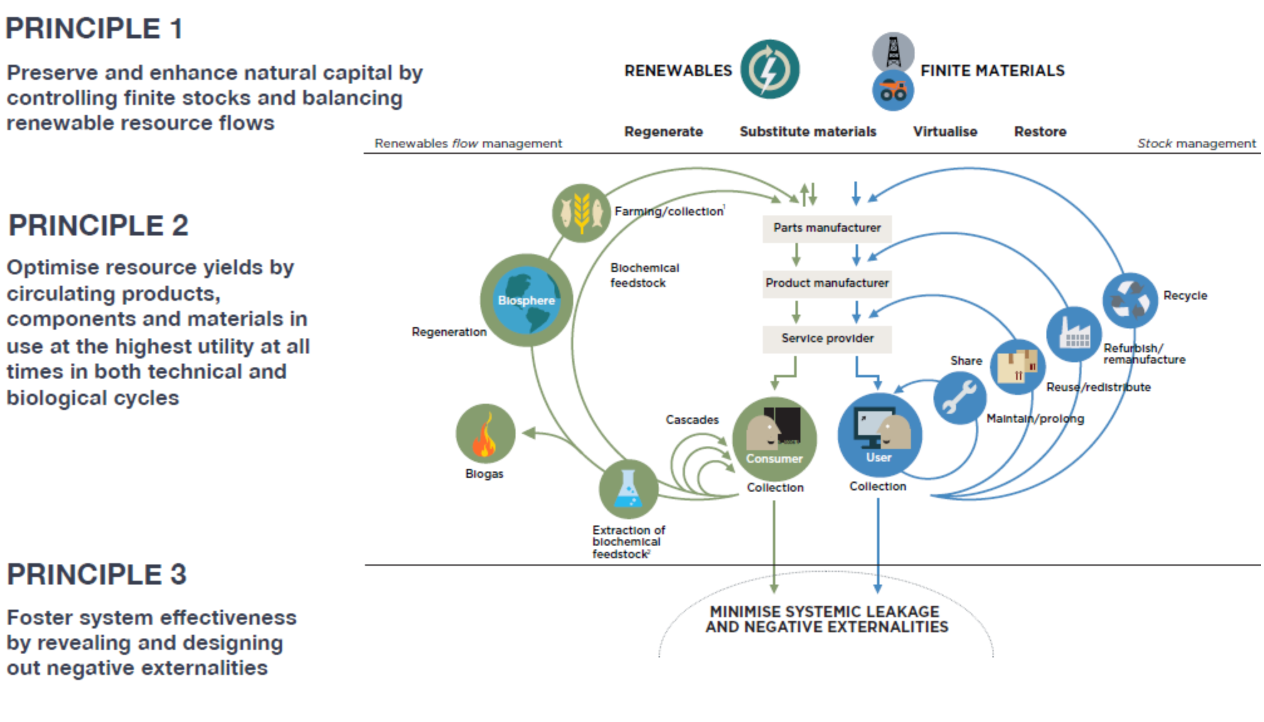
[89] Going round in circles, Policy Exchange May 2017 https://policyexchange.org.uk/publication/going-round-in-circles/. Last accessed 1 May 2018

[90] Defra Resource Minister Terese Coffey speech 31 January 2017 https://www.edie.net/news/5/Businesses-must-lead-UK-resource-efficiency-transition--says-Defra-Resource-Minister/.

[91] Terese Coffey announcement 12 October 2016 https://www.letsrecycle.com/news/latest-news/coffey-eu-recycling-target-too-high/..

[92] London Waste and Recycling Board (2017), Circular Economy effects on waste production in London.

Figure 68: The circular economy[93]



Moving waste up the waste hierarchy aligns with circular economy principles that can stimulate economic growth and generate new employment. It is estimated that moving to a circular economy could bring benefits of at least £7 billion every year by 2036[94]. Table 11 estimates employment in reuse, repair, recycling, and rental/leasing generates around 46,700 jobs.

Table 11: Employment in circular economy activities (source: ONS BRES, 2014)

Activity	Number of jobs
Recycling: waste collection, treatment, disposal and recovery of sorted materials	12,500
Recycling: wholescale of waste and scrap	1,000
Reuse: repair of metal products, machinery and equipment	6,500
Reuse: repair of computers, electronics and household goods	4,800
Reuse: retail sale of second-hand goods	4,300
Remanufacturing	0

[93] Ellen MacArthur Foundation – adapted from the cradle-to-cradle (C2C) design protocol by Braungart and McDonough
[94] GLA (2015), Towards a circular economy; GLA (2015), Employment and the circular economy – job creation through resource efficiency in London.

Table 11: Employment in circular economy activities (source: ONS BRES, 2014)	
Activity	**Number of jobs**
Rental and leasing activities	17,500
Total	**46,700**

The best performing scenario modelled for London's successful transition to a circular economy achieving high reuse and recycling rates estimated 12,000 new jobs created, the majority being low and medium skilled jobs in the reuse and recycling sector.

Improving London's recycling rate

Household waste recycling

LWARB/Resource London commissioned WRAP to model scenarios for how London's household recycling rate can be improved meeting the national 50 per cent recycling target by 2020.

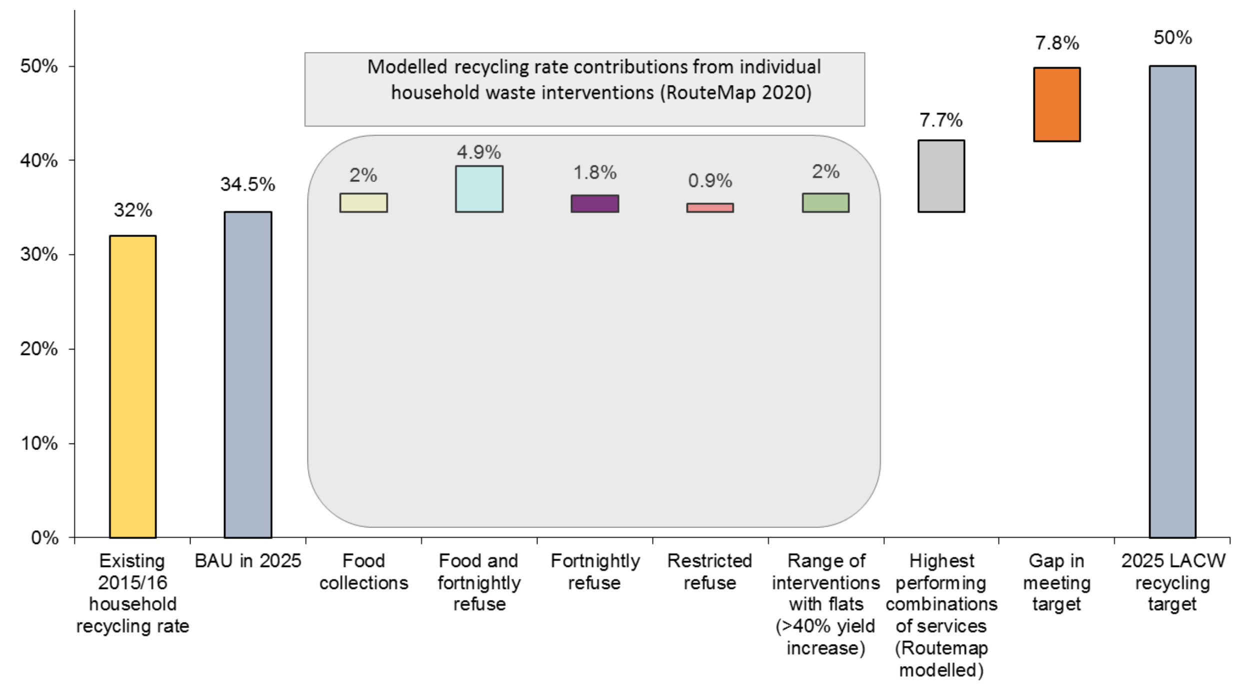
The study found that London would only be able to achieve a 42 per cent household waste recycling rate by 2022, from the 32 per cent rate achieved in 2015/16. Achieving this would require significant investment and improvements to services offered on a consistent basis across London.

Figure 69 shows the 2015/16 household recycling rate of 32 per cent, compared to 35 per cent, which is where London would be in 2025 if the current service provisions continue (a business as usual (BAU) scenario).

The modelling work commissioned by LWARB/Resource London looked at what contribution individual services could make to the recycling rate if the optimal service improvements were tailored to the different property types in the city.

The modelling then looked at a combination of individual services that would achieve the highest household recycling rate of 42 per cent by 2022. This leaves an eight per cent shortfall in reaching the national 50 per cent household recycling target. Figure 69 shows a trajectory for how London could meet a 50 per cent LACW recycling target based on the modelling work.

Figure 69: How London can meet a 50 per cent LACW recycling target by 2025[95]



The WRAP route map modelling concluded that service improvements across London could be made by 2020 with the benefits starting to take effect by 2022. The top two service combination scenarios achieving the highest recycling rates most applicable to London are summarised in Table 12.

[95] Based on WRAP and GLA modelling 2017

Table 12: Independently modelled combination scenarios				
Scenario	**Intervention for Kerbside properties (low rise)**	**Intervention for flats (high rise)**	**Maximum recycling rate achieved from combined scenario**	**Cumulative cost by 2030 (in addition to BAU)**
1b, 5a, 6c	Reduced residual and weekly separate food waste collection, adding all six dry materials to kerbside collections where not currently collected (glass, cans, paper, card, plastic bottles and household plastic packaging)	All high-rise properties receive, as a minimum, the collection of five main dry recyclable materials (glass, cans, paper, card and plastic bottles) with an expected 40 per cent performance increase	42 per cent	£129m cost
1a, 2, 5a	Weekly separate food waste collection and reduced residual waste for kerbside properties. All kerbside properties receive, as a minimum, the collection of six main dry recyclable materials (glass, cans, paper, card, plastic bottles and household plastic packaging)	No intervention (this means no additional support or increase in services to flats from what is already existing)	40 per cent	£22m saving

The results across all scenarios modelled showed that the maximum contribution to the recycling rate ranged from an almost five per cent increase from all kerbside properties having a food waste collection and fortnightly refuse collection, to just over a two per cent increase from flats having a collection of the five main dry recycling materials. The research found that the greatest opportunity for improvement to be services offered across London included:

- collection of the six main dry recycling materials mixed plastic bottles, mixed plastics (pots, tubs and trays), metals (tins and cans), paper, card, and glass to kerbside properties
- separate food waste collections and reduced residual waste
- a heavy focus on flats

Table 13 sets out the maximum household waste recycling rates that each London waste authority could realistically achieve implementing the combined scenarios, recognising local circumstances such as waste contract requirements and renewals, housing stock type and joint borough working arrangements.

Table 13: Maximum household percentage recycling rates achieved implementing each combination scenario

Waste Authority	BAU	Combined scenarios	
		1b, 5a, 6c	1a, 2, 5a
Barking and Dagenham	24	36	35
Barnet	39	44	42
Bexley	56	56	56
Brent	37	38	38
Bromley	50	51	51
Camden	27	35	33
City of London	36	51	36
Croydon	44	45	45
Ealing	40	54	53
Enfield	39	47	44
Greenwich	35	43	41
Hackney	28	36	33
Hammersmith and Fulham	21	34	31
Haringey	38	45	44
Harrow	47	49	49
Havering	33	46	45
Hillingdon	44	50	48
Hounslow	34	43	42
Islington	35	41	36
Kensington and Chelsea	25	37	34
Kingston upon Thames	47	49	47
Lambeth	28	37	33
Lewisham	19	29	26
Merton	39	44	43
Newham	17	30	28
Redbridge	28	43	41
Richmond upon Thames	43	53	51
Southwark	36	41	38
Sutton	39	50	48
Tower Hamlets	27	38	34
Waltham Forest	37	44	41

Table 13: Maximum household percentage recycling rates achieved implementing each combination scenario			
Waste Authority	**BAU**	**Combined scenarios**	
		1b, 5a, 6c	**1a, 2, 5a**
Wandsworth	20	33	30
Westminster City Council	24	35	30
Total	**35**	**42**	**40**

Table 14 shows the breakdown in costs for the service provisions for each combined scenario. The highest costs are higher for scenario 1b, 5a, 6c, mostly due to the increase in capital (bins) and operating costs in order to get an extra 40 per cent increase in recycling from flats. Significant savings in both combination scenarios are forecast to be made from reduced bulking and treatment costs (mainly landfill or incineration) and increased revenue from the sale of the additional recyclables collected.

Table 14: Cost breakdown for each combination scenario		
Cost category	**Combined scenarios**	
	1b, 5a, 6c	**1a, 2, 5a**
Container capital	£25	£8
Transition	£8	£7
Annualised vehicle	£34	£0
Annual operating and comms	£252	£92
Annual bulking and treatment (net of revenue)	-£190	-£129
Net cost difference for service	£129	-£22

In summary, the highest performing combination scenario (1b, 5a, 6c), achieving a 42 per cent household recycling rate, would bring a cumulative cost of £129m in addition to business as usual costs. The second considered scenario (1a, 2, 5a), achieving a 40 per cent household recycling rate, would present a cumulative cost saving of around £22m. The circa £150m difference for only a two per cent gain in the latter scenario provides no additional support and service improvement to flats. The full report is available online.[96]

[96] WRAP (2017) London Recycling Routemap 2020: Analysis of options to increase recycling performance in London. Accessed from: www.london.gov.uk/waste/route-map-2020

Reducing greenhouse gas emissions

Sending waste to landfill generates greenhouse gas emissions. This is particularly the case for biodegradable waste, such as food, garden waste, paper and card, which releases methane (a powerful greenhouse gas) as it decomposes. Sending high embodied carbon materials like plastics and textiles to incineration generates CO_2 emissions, whereas recycling these materials avoids CO_2 emissions.

In 2010, the GLA developed a lifecycle CO_2 equivalent (CO_2e) emissions performance standard (EPS) for activities associated with the collection, treatment, energy generation, and final disposal of London's LACW waste. This approach looked at the total combined methane (CH_4), carbon dioxide (CO_2) and nitrous oxide (N_2O) greenhouse gas emissions associated with waste products over their lifecycle, from their making through to their use and final disposal. While there are other important environmental considerations, including air quality and biodiversity, measuring CO_2e emissions has acted as a valuable proxy for determining the overall environmental impact of waste management activities.

The EPS was modelled and set broadly to align with the recycling targets in the previous municipal waste management strategy (2011). A key characteristic of the EPS is that it allows London waste authorities to balance weight based recycling targets, with a focus on materials and techniques offering the greatest economic and environmental benefits.

London's 2015/16 EPS performance resulted in an overall net annual saving of -171 ktCO_2e. This net position is a result of emissions from waste transport, landfill and incineration (377ktCO_2e) offset by emission savings from reuse, recycling and anaerobic digestion (-549ktCO_2e).

In addition to the EPS, a minimum CO_2e emissions level was set to help encourage more local heat energy generation from London's non-recycled waste. Known as the carbon intensity floor or CIF, this was set at 400 grams of CO_2 per kilowatt hour (kWh) of electricity produced. Meeting the CIF effectively rules out using traditional incineration of recyclable waste that only generates electricity, and supports efficient energy generation where both heat and power produced is used (CHP). In developing this strategy, research was undertaken to understand how London's waste incinerators currently perform against the CIF, showing a performance of around 700 grams per kWh. These facilities are considered inefficient because they don't capture and use the waste heat generated. Heat makes up two thirds of thermal treatment processes (e.g. incineration and gasification), so capturing it greatly improves plant efficiency and thus performance against the CIF.

Developing a new EPS

In developing the London Environment Strategy, the EPS has been reviewed and re-based to determine what is realistic and achievable for London, using the latest lifecycle modelling methodology and waste management performance data. The key parameters and assumption used for developing the new EPS compared to those used to develop the previous EPS are:

- London achieving a lower LACW recycling rate in 2015/16 (30 per cent) than previously forecast (45 per cent)
- London achieving a 50 per cent LACW recycling rate in 2025 instead of by 2020
- changes in waste composition of household waste, namely less paper and more food and plastic
- changes in emission factors for waste sent for landfill and incineration, which meant these activities perform worse against the EPS than before

As a result, the revised proposed EPS targets compared to the EPS targets in the previous Mayor's municipal waste strategy are set out in Table 15.

Table 15: EPS targets

Target year	Proposed EPS targets – tonnes of CO_2e per tonnes of waste managed	Previous EPS targets - tonnes of CO_2e per tonnes of waste managed
by 2020	-0.069	-0.186
by 2025	-0.084	
by 2030	-0.167	-0.243

In rebasing the EPS, there has been no less ambition to boost recycling performance and achieve the maximum GHG savings. Setting the new EPS targets is based on modelling achieving a LACW recycling rate of 50 per cent by 2025 and 60 per cent by 2030. The EPS should be easier to achieve in the short term by giving waste authorities the opportunity to implement recycling improvement measures, including from their business waste collection services.

Figure 70 shows London's current and projected performance against the new EPS in tonnes of CO_2e produced per tonne of waste managed. The bars above zero represent emissions produced from landfill and incineration. The bars beneath zero represent emission savings from recycling. An overall net position for 2015/16 and new targets set to

2030/31 are indicated by the dots. The diamonds show the previous EPS targets for comparison. More information on developing the new EPS can be found online.[97]

Figure 70: London's current and projected performance against the EPS in tonnes of CO_2e produced per tonne of waste managed

[97] Eunomia (2017) Greenhouse Gas Emissions Performance Standard for London's Local Authority Collected Waste – 2017 Update. Accessed from: www.london.gov.uk/waste/new-EPS

Adapting to Climate Change

Our changing climate
Our climate is already changing. The ten warmest years in the UK have occurred since 1990, eight of these since 2002 (Figure 71). The period since 2000 accounts for two-thirds of hot-day records and close to half of wet-day records since 1910.[98]

These changes are also seen at a local level. All regions of the UK have experienced an increase in average temperatures between 1961 and 2006 annually and for all seasons. Increases in annual average temperature are typically between 1.0 and 1.7°C, tending to be largest in the South and East of England and smallest in Scotland.

[98] Committee on Climate Change (2017) UK Climate Change Risk Assessment Evidence Report 2017: Introduction. Accessed from: https://www.theccc.org.uk/uk-climate-change-risk-assessment-2017/ccra-chapters/introduction/

Figure 71: Global annual average temperatures, ranked hottest to coldest[99]

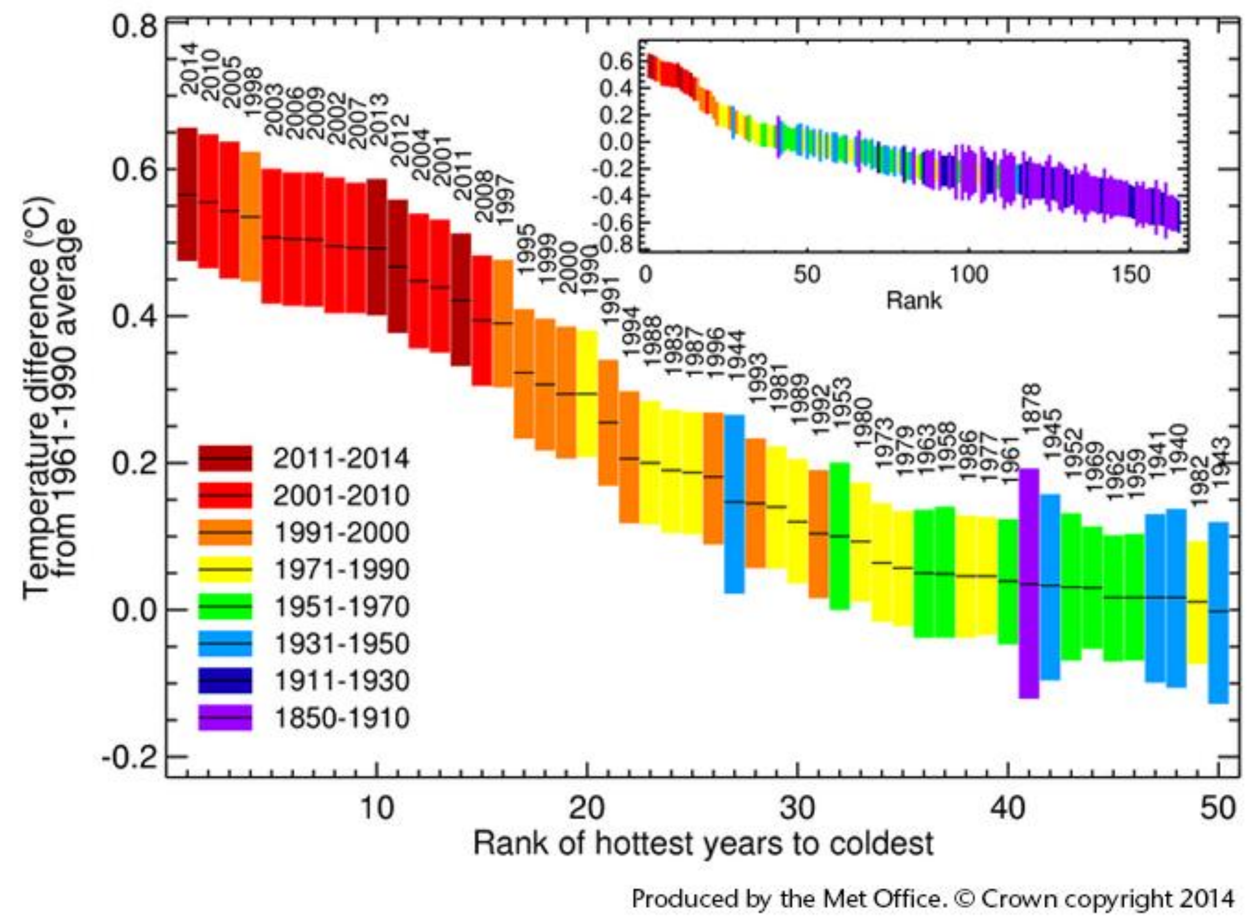


Figure 72 plots the average summer temperatures (June, July and August) in London for the period 1950-2006.[100] It can be seen that despite considerable variation from year to year, that summers have got progressively warmer, and that this rate of warming has increased over the past 30 years (dotted line), compared to the last 50 years (solid line). Average summer temperatures in London have warmed by over 2˚C over the period 1977-2006.

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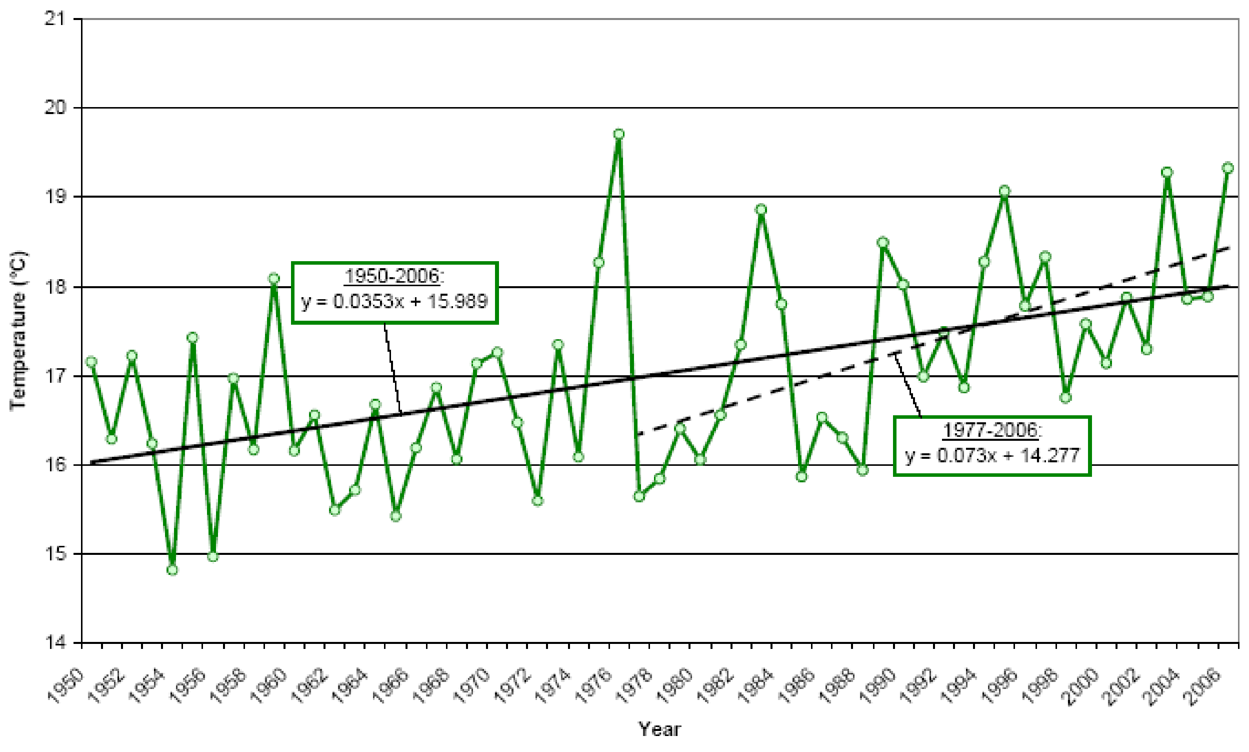
[99] Meteorological Office (2014) Human influence important factor in possible global and UK temperature records. Accessed from: https://www.metoffice.gov.uk/news/releases/2014/2014-global-temperature

[100] This is the latest data available as part of the UKCP09 trend analysis.

Figure 72: Average summer temperatures in London 1950-2006[101]



There is scientific consensus that without significant and timely global action to reduce greenhouse gas emissions, we will face changes in our climate that will have wide-ranging implications for communities, the economy, and the natural environment.[102]

[101] Based on data from the Met Office

[102] IPCC (2014) Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1132 pp

Box 7: Climate adaptation and resilience[103]

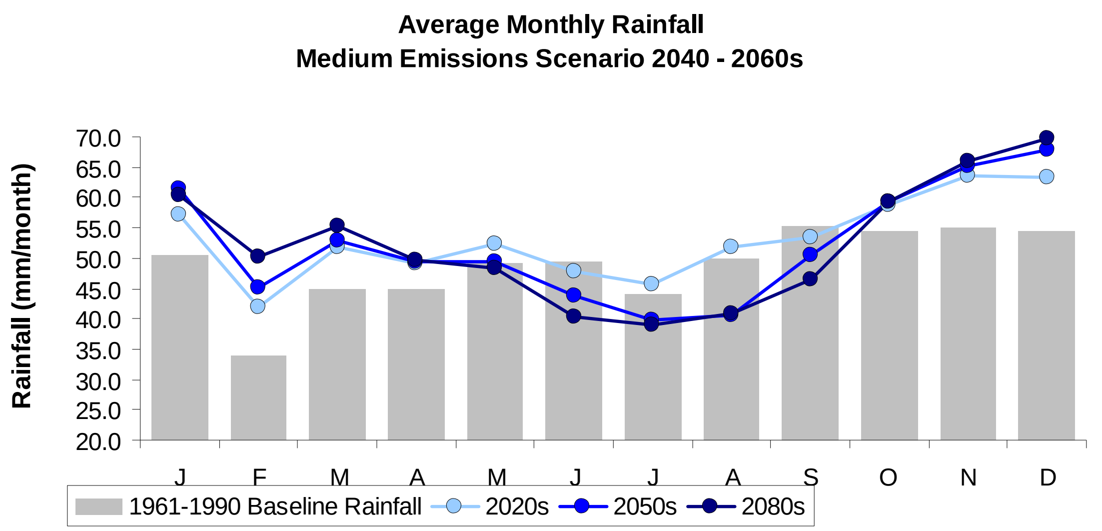
Adaptation is the process (or outcome of a process) that leads to a reduction in harm or risk of harm, or realisation of benefits associated with climate variability and climate change.

Resilience is the ability of a system to recover from the effect of an extreme load that may have caused harm.

Adaptation policies can lead to greater resilience of communities and ecosystems to climate change.

London is already vulnerable to flooding, drought, and heat. Current UK climate projections tell us that London will experience three major climate risks: flooding, drought, and heat (Figure 73 and Figure 74). With projected severe weather events like heatwaves and storms, these risks are likely to become more frequent and severe. The impacts that these events will have will also be affected by other pressures, including increasing development and population.

Figure 73: Average monthly rainfall (mm of rainfall per month) in London over the century, under a medium emissions scenario, compared to baseline period[104]

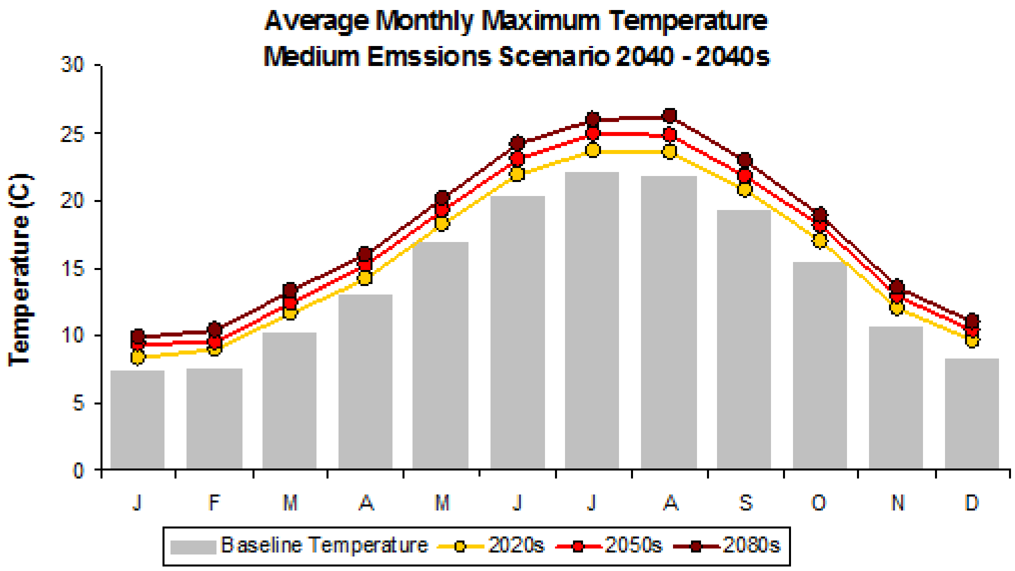


[103] UK CIP (2003) Climate adaptation: Risk, uncertainty and decision-making. Accessed from: http://www.ukcip.org.uk/wp-content/PDFs/UKCIP-Risk-framework.pdf

OECD (2006) Adaptation to Climate Change: Key Terms. Accessed from: http://www.oecd.org/env/cc/36736773.pdf

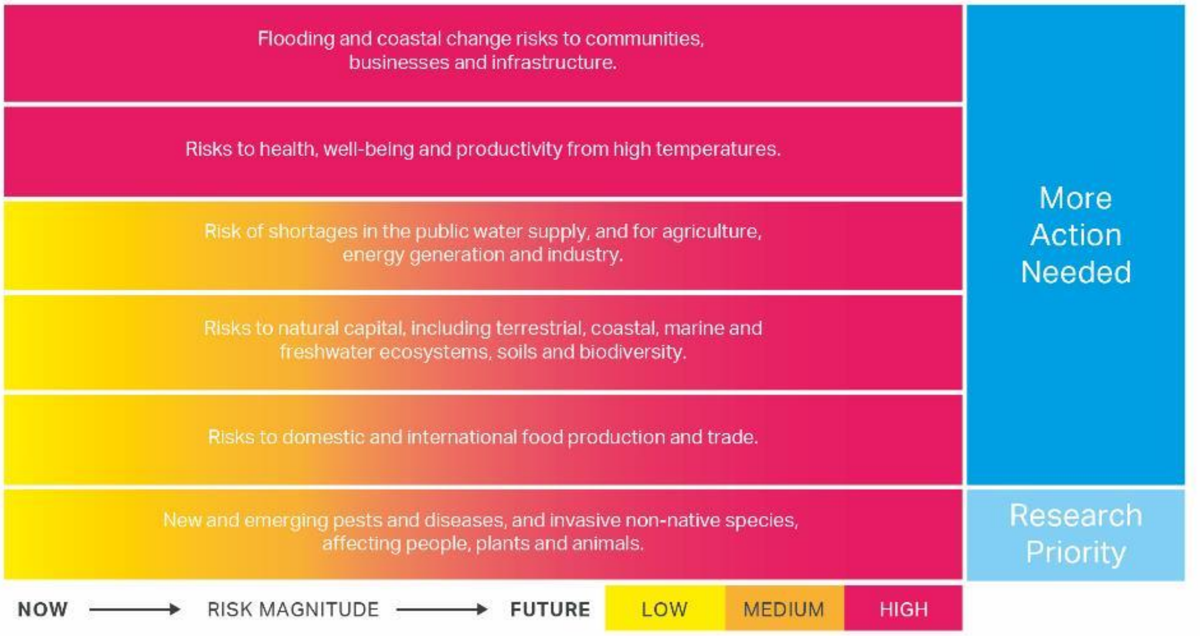
[104] UK Climate Projections (2014) Maps & Key Findings. Accessed from: http://ukclimateprojections.metoffice.gov.uk/21708

Figure 74: Average monthly maximum temperatures (ºC) in London over the century, under a medium emissions scenario, compared to baseline period[104]



The Adaptation Sub-Committee (ASC) of the Committee on Climate Change published the UK's second *Climate Change Risk Assessment* evidence report in July 2016. The assessment recognised the major risks for the UK of heat, flooding, and water scarcity, and grouped these into six categories where the climate risks pose a threat to human and ecological systems (Figure 75).

Figure 75: Top six areas of inter-related climate change risks for the United Kingdom[105]



While these broadly align with London's priority risks, these risks from climate change are locally specific and need to be understood in the context of the city's own characteristics, needs, and priorities. The ASC's description of the major risks from climate change is helpful in making the risks more specific with regard to their practical impacts and implications.

The ASC scrutinises the UK government's adaptation policies and plans, and publishes reports on the progress of adaptation in particular UK sectors every two years. Climate resilience is particularly difficult to measure given:

- the complexity of the problem
- the lack of clear ownership
- differing perceptions of what success looks like
- uncertainty around the costs and benefits of adapting

However, there have been efforts worldwide to identify useful indicators. For example, the European Environment Agency's *Climate change, impacts and vulnerability in Europe*

[105] Committee on Climate Change (2017) UK Climate Change Risk Assessment Evidence Report 2017: Introduction. Accessed from: https://www.theccc.org.uk/tackling-climate-change/preparing-for-climate-change/uk-climate-change-risk-assessment-2017/

2016: An indicator-based report presents an assessment of indicators of past and projected climate change impacts and the associated risks to ecosystems, human health, and society. Such an approach is being suggested for London, where there is currently no systematic collection of data to illustrate how well the city is adapting to the impacts of severe weather and longer-term climate change.

The following table summarises London's ability to adapt and progress made in assessing the climate change risks since 2011 (Table 16).

Table 16: London's Adaptation Scorecard

Risk	Summary	Rating
Flooding	London is well protected against tidal and reservoir flooding due to world class defences which include the Thames Barrier. The risk is much higher for flooding from its rivers and heavy rainfall. The risk from sewers and groundwater is poorly understood. Whilst actions are underway to increase our resilience to flooding, only tidal flooding has a long term plan and delivery programme	
Drought	London is resilient to all but the most severe droughts. Water companies are taking a more risk-based approach to planning for future challenges, but to offset the increase in demand significant investment in both new water resources and demand management measures will be required. Water consumption in London is 10 per cent higher than in the rest of the country and leakage rates are 25 per cent meaning more capacity is planned for than would be required if leakage rates were reduced.	
Heat	Resilience to heatwaves is improving from an emergency response perspective, but more action is needed to proactively reduce heat risk, including identifying and prioritising risk 'hotspots' based upon the urban heat island, buildings and infrastructure that are likely to overheat and heat vulnerable people and assets.	

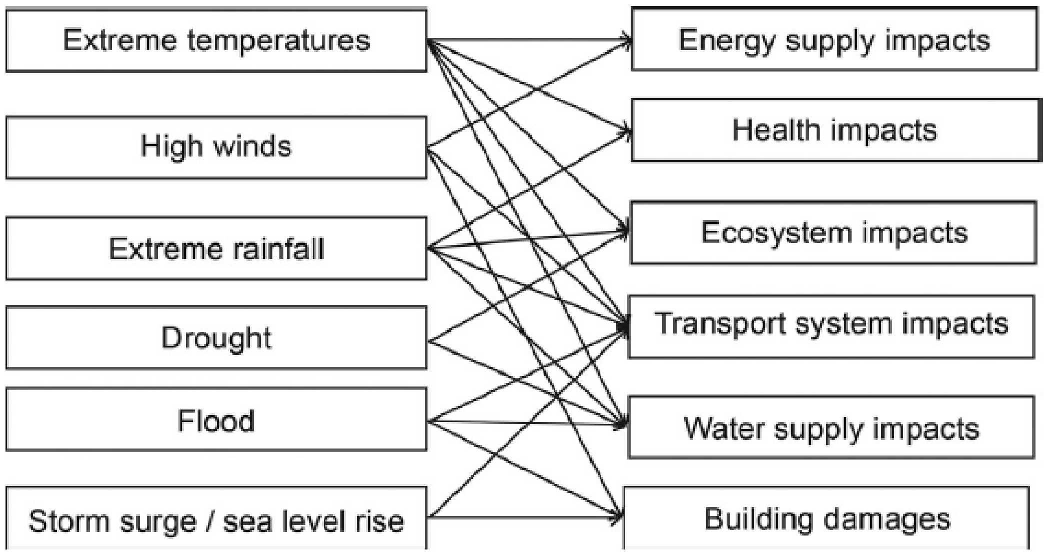
Interconnected risks and responses

Hundreds of thousands of people across England and Wales were affected by flooding during June and July 2007, the most serious inland flood since 1947. In addition to approximately 48,000 households and 7,300 businesses, the floods affected infrastructure, including water and food supply, power, telecommunications, and transportation, as well as agriculture and tourism. The Environment Agency estimated the overall costs of the flooding at £3.2 billion.

Severe weather events can not only have direct impacts (e.g. damaging homes and transport infrastructure) and indirect impacts (e.g. weaker economic growth), but impacts can also combine to cause greater issues. A particularly stark example of interdependent systems failure occurred in Hull, where pumps protecting the city were overwhelmed by volume of water, while localised power loss due to flooding led to exacerbated flooding in other locations.

Cities are complex and interdependent systems, and climate resilience will depend on anticipating the possible knock-on effects caused by climate-related impacts, in combination with other pressures and challenges, including population growth, development, and other non-climate-related risks (Figure 76).

Figure 76: Climate extremes and potential impacts on urban systems[106]



The costs of inaction

We do not have a complete understanding of the consequences of failing to address the risks from climate change. Social and environmental impacts are difficult to quantify, but given that finance is London’s largest industry, attempts by the insurance and financial sectors to measure the potential economic losses if we fail to curb greenhouse gas emissions are illustrative.

[106] Solecki, *et al*. (2015) New York City Panel on Climate Change 2015 Report Chapter 6: Indicators and Monitoring. *Annals of the New York Academy of Sciences* **1336**, 89-106

A survey of 750 experts conducted by the World Economic Forum in 2017 found extreme weather events and major natural disasters to be among the top five global risks in terms of likelihood, ahead of large-scale involuntary migration, large-scale terrorist attacks and a massive incident of data fraud/theft. Of the top five global risks in terms of impact, extreme weather events, water crises, major natural disasters and failure of climate-change mitigation and adaptation made up four of the five top risks.[107] It also recognised the strong connections between climate change and other risks, such as involuntary migration.

A Nature Climate Change study by the London School of Economics found that climate change could reduce the value of world's financial assets by £2.5 trillion, and possibly up to ten times that much in a worst case scenario. The losses would be caused by the direct destruction of assets as a result of increasingly extreme weather events, and also by a reduction in earnings for those affected by high temperatures, drought, and other climate change impacts.

The Economist Intelligence Unit (EIU) has reported that:

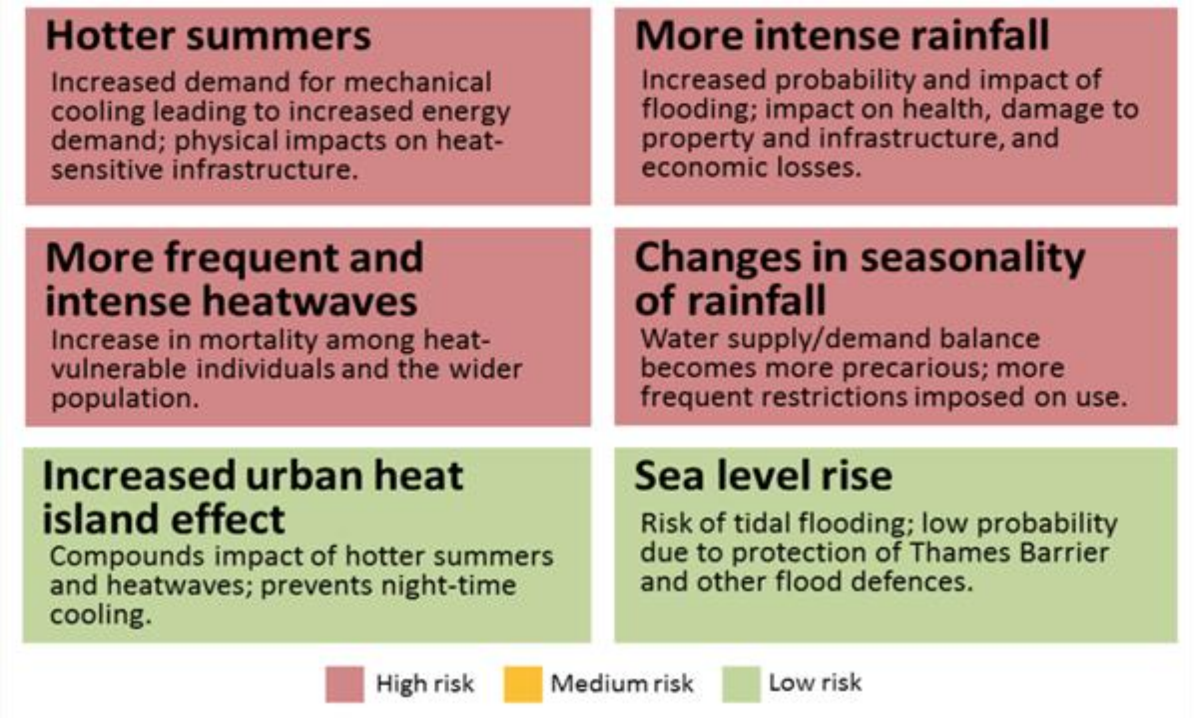
- warming of 5°C could result in $7 trillion in losses – more than the total market capitalisation of the London Stock Exchange
- 6°C of warming could lead to losses of $13.8 trillion, or roughly ten per cent of the global total of manageable financial assets

While direct impacts on physical assets or natural resources like real estate, infrastructure, and tourism are significant, the EIU found that much of the impact on future assets will be due to weaker growth and lower asset returns, which will affect the whole economy.

In 2015, the London Assembly Economy Committee highlighted the importance of the business and financial sectors in London and the physical risks to London's businesses from climate change (Figure 77).

[107] World Economic Forum (2017) Global Risks Report 2017. Accessed from: http://reports.weforum.org/global-risks-2017/

Figure 77: London businesses will see an increase in physical climate change impacts



Flood risk

Context

London's future rainfall is expected to become more seasonal, with up to 44 per cent more winter rain and up to 46 per cent less summer rain by the 2080s (Figure 78 and Figure 79). London is vulnerable to flooding from five sources: tidal, river, surface, sewer, and groundwater.[108] Wetter winters and more frequent and severe downpours, along with rising sea levels and higher tidal surges (Figure 80), are expected as climate change continues. There is a projected 0.9m rise in mean tide levels between 2000 and 2100. Left unmitigated, the tidal flood risk to London will increase over time as sea levels rise.

[108] GLA (2017) Draft London Regional Flood Risk Appraisal. Accessed from: https://www.london.gov.uk/sites/default/files/draft_regional_flood_risk_appraisal_-_dec_2017.pdf

Figure 78: Mean winter precipitation projections under a medium emissions scenario[109]

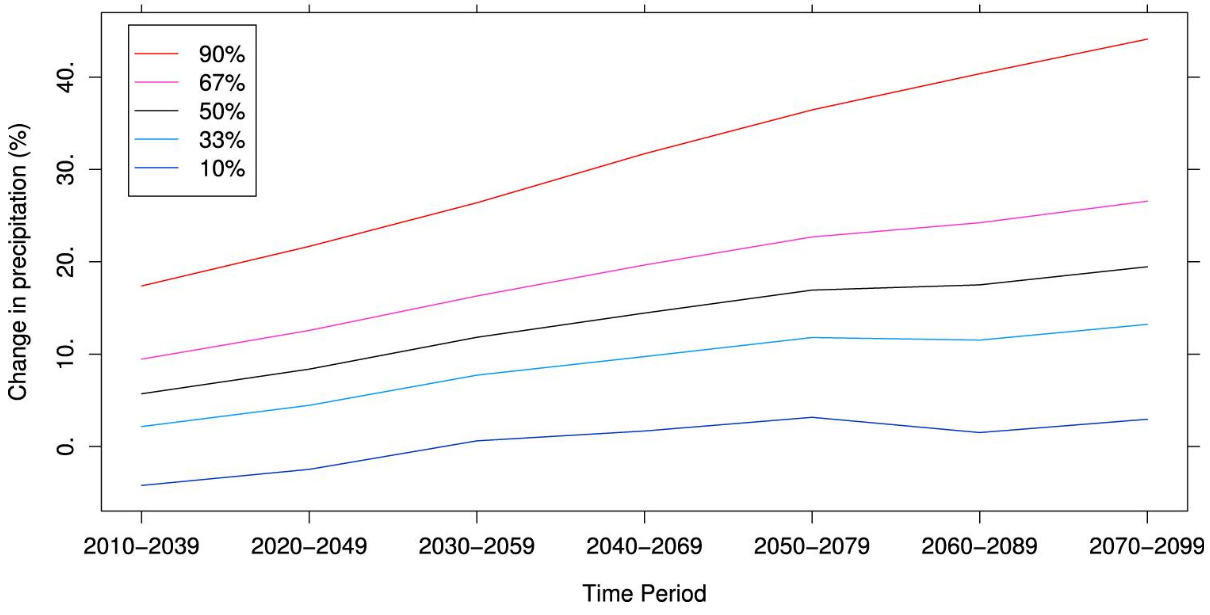
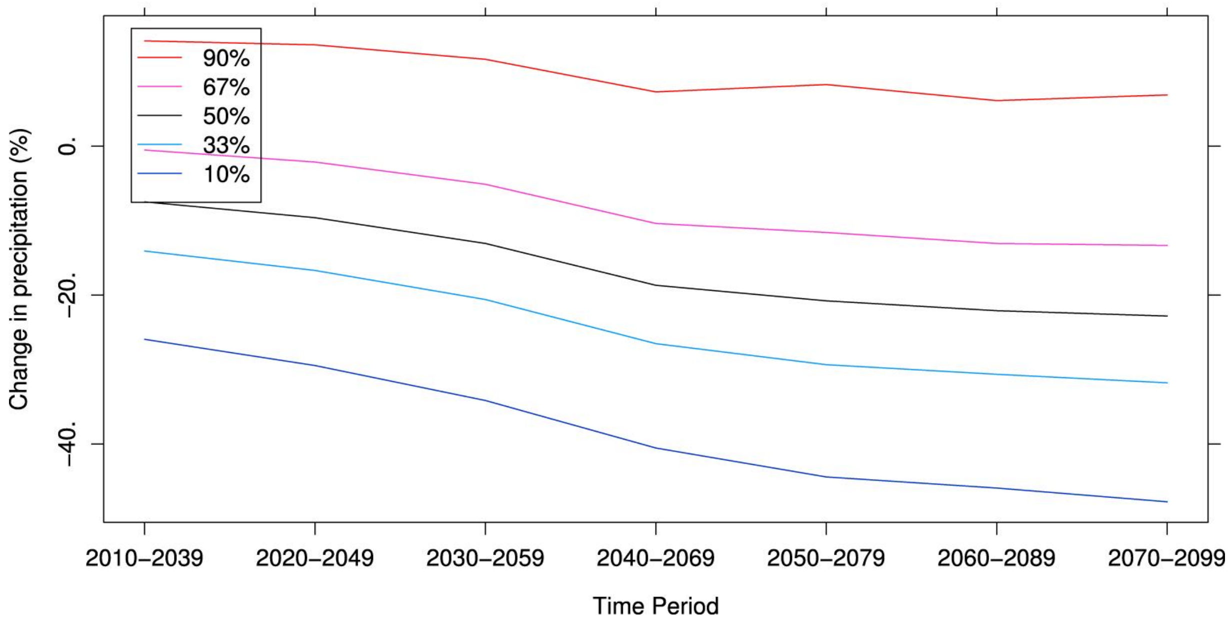
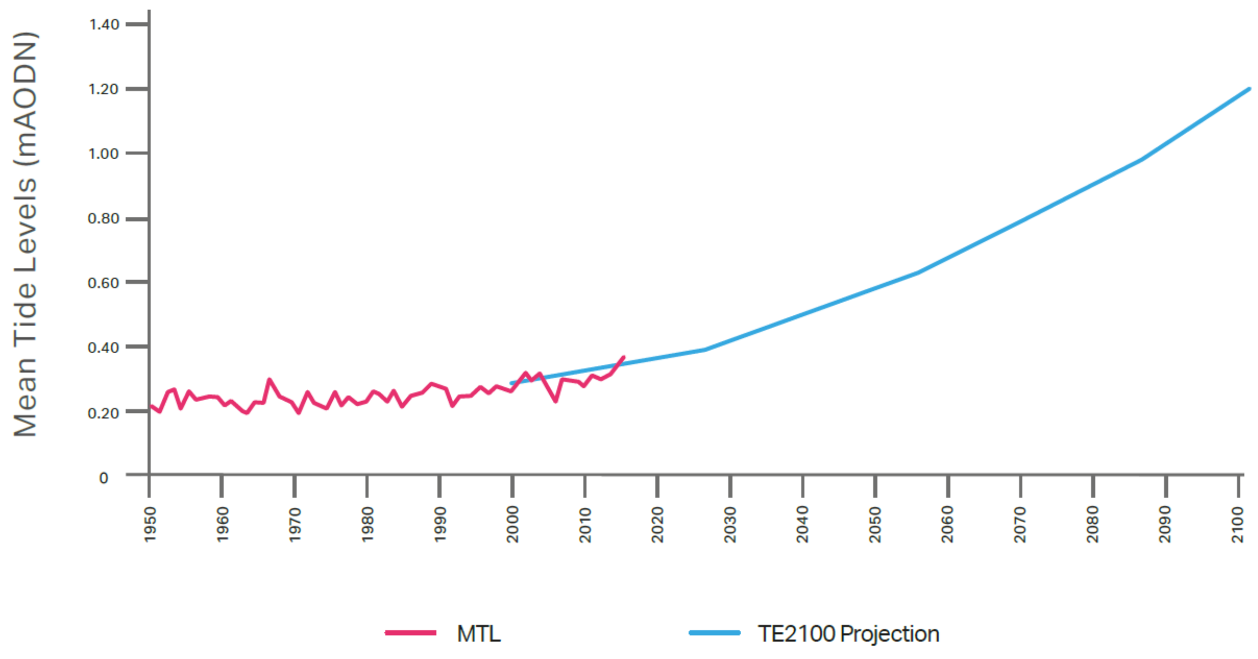


Figure 79: Mean summer precipitation projections under a medium emissions scenario[109]



[109] Met Office (2009) UK Climate Projections 2009. Accessed from: http://ukclimateprojections.metoffice.gov.uk/21708

Figure 80: Mean tide levels at Southend with climate change projections to 2100[110]



A large proportion of the city is currently potentially at risk from flooding (Figure 81). There are 37,359 existing homes at high (1:30) or medium (1:100) risk of tidal or fluvial flooding in London and 1.25m people living and working in areas of tidal and fluvial flood risk.

Growth in London can increase flood risk impacts as the city becomes more built up. Between 2001 and 2014, approximately 68,000 new homes (three per cent of all new homes in England) were built in England and Wales in areas with a 1 in 100 or greater annual chance of flooding. Of these, 23,000 were built in areas of high flood risk (a 1 in 30 or greater annual chance of flooding, even accounting for any flood defences).[111] Building on a flood plain puts these properties at higher risk, and the displaced water can exacerbate problems elsewhere.

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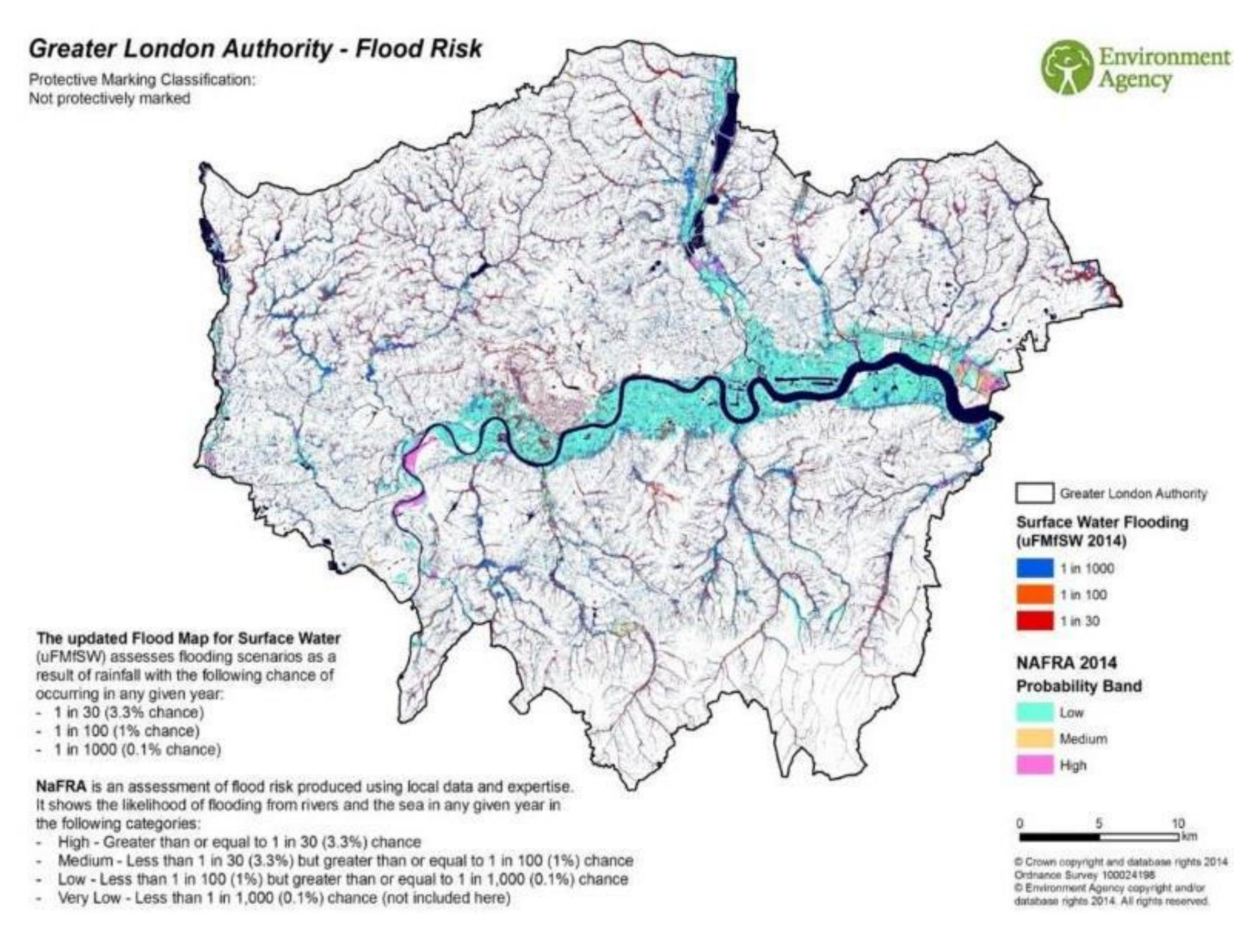
[110] Source: Environment Agency (2017)

[111] Committee on Climate Change (2015), Progress in preparing for climate change: 2015 Report to Parliament. Accessed from: https://www.theccc.org.uk/wp-content/uploads/2015/06/6.736_CCC_ASC_Adaptation-Progress-Report_2015_FINAL_WEB_250615_RFS.pdf.

Figure 81: Flood map for London showing tidal, fluvial and surface water flood risk[112]



Tidal and fluvial flood risk

The flood defences that we have in place are crucial to the functioning of the city (Figure 82 and Figure 83). While London is well-defended against tidal flooding by the Thames Barrier, standards of protection in the western Thames and its tributaries are significantly lower because they sit beyond the tidal limit and upstream of London's tidal defence system.

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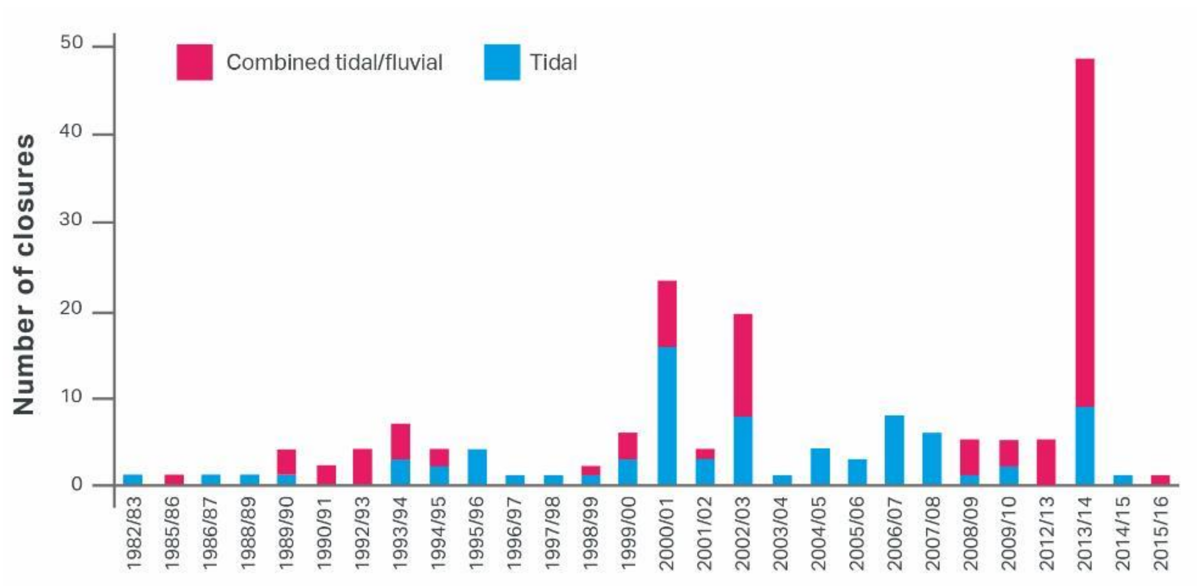
[112] Environment Agency (2014)

Figure 82: River Thames Tidal Defence System[113]

Figure 83: Number of Thames Barrier closures by season[113]



Surface water flood risk

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[113] Environment Agency (2012) Thames Estuary 2100 Plan). Accessed from: https://www.gov.uk/government/publications/thames-estuary-2100-te2100

Surface water flooding is probably the greatest short term climate risk to London. There are 68,000 properties in London at high risk of surface water flooding, including residential and commercial properties (Figure 84). Of the various forms of flooding that can affect London, the most difficult to predict and plan for is surface water flooding. Managing surface water flooding in London is complex because the drainage network is owned and maintained by many partners, and no single authority has overall responsibility for managing surface water flood risk.

There is an effective flood warning service for tidal, fluvial and groundwater flooding, where there is take-up of this service (Table 17). However, predicting when and where a heavy downpour will cause (often localised but potentially serious) surface water flooding is far more difficult. There is, therefore, no warning service for surface water flooding at present. This may change when forecasting techniques improve.

Figure 84: Number of properties at risk of surface water flooding in London[114]

Residential Properties	Commercial Properties
High (1 in 30 year event)	High (1 in 30 year event)
68,499	**12,148**
Medium (1 in 100 year event)	Medium (1 in 100 year event)
164,546	**25,623**

114 GLA modelling based on: The GeoInformation Group (2016) UKMap; and Environment Agency (2017) Risk of flooding from surface water

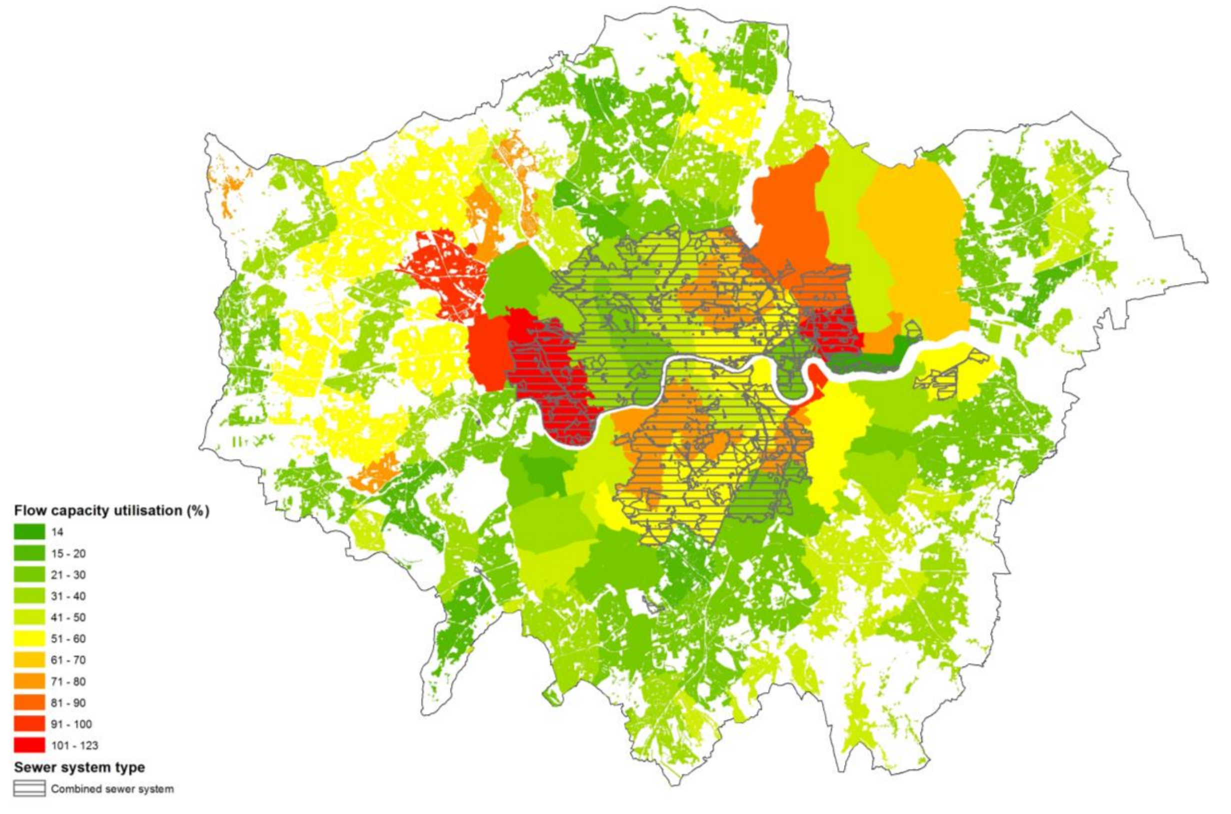
Table 17: Advance warning times for flood sources		
Flood source	**Advance warning**	**Comments**
Fluvial*	Up to 1-2 days on the Thames but as less than 2 hours on some tributaries	Suitable advance warnings are not possible on all London's rivers as some of them react much more quickly to heavy rainfall.
Surface water	Little or no warning for specific areas, but a general area warning 24 hours in advance	Thunderstorms can be difficult to predict. Poor maintenance and blockages of the storm drains will affect the ability to predict where and when flooding will occur and provide adequate warning.
Tidal[115]	2-12 hours	Tidal surges are monitored as they progress down the east coast of the UK, so advance warning is normal. The Environment Agency tests computer predictions of the surge against real-time measurements to improve their predictive capability.

Surface water drains are generally designed to cope with high-frequency, low-intensity rainfall. The current design standard is 1 in 30 years. Research by Ofwat predicts that rainfall intensity is likely to significantly increase through the century, so that what is a 1 in 30 year event today will double in frequency by 2040, and that what is a 1 in 100 year event today will become a 1 in 30 year event by the 2080s. This means that if we wish to maintain the current standard of protection, we will need to adapt to a 1 in 100-year rainfall intensity by the end of the century. There is therefore a 'gap' between what we can cope with today and what we may need to cope with in the future.

There is varying available capacity in London's drainage and sewerage network (Figure 85). In some areas, there is very limited capacity available. The map in Figure 85 reflects the current (2015) capacity. Areas in red reflect sewer systems at over 90 per cent of the flow capacity on the network. Large parts of the network with the most limited capacity are combined sewers. This means that even light rainfall can cause flooding, as there is little capacity for rainwater to drain into the sewer network.

[115] Breaches of tidal and fluvial defences, by their nature, can occur with little or no warning, though it is possible to identify locations where breaches are more likely to occur due to lower ground elevation behind the flood defences, or where poor condition of the flood defence may be identified. Overtopping of tidal defences may be forecast as much as six hours in advance.

Figure 85: Current (2015) capacity of the drainage network[116]



Water quality

The Environment Agency monitors river water quality as part of the EU Water Framework Directive (see Appendix 4 for more information on this Directive). Of the 47 river water bodies in London, three are classified as 'bad', five are 'poor', and the rest are 'moderate'; only one is currently classified as 'good'.

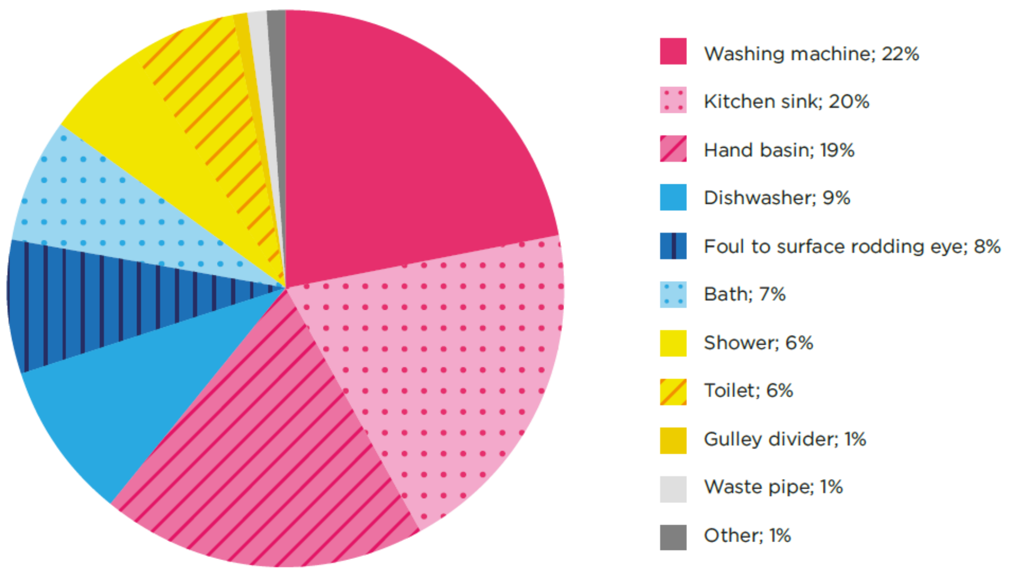
Misconnections can cause sewer flooding and lead to pollution and environmental degradation of London's tributary rivers. The problem is caused by incorrect plumbing that misconnects sewer pipes and surface water drains. (Figure 86). This can result in untreated waste water and sewage draining directly to local rivers, or sewer flooding from pipes exceeding their designed capacity According to the latest rounds of investigations as part of the water company business planning cycle, approximately 3.9 per cent of

[116] Thames Water flow capacity utilisation and sewer system type data.

properties in those drainage catchments investigated are classified as misconnected in some way.

In November 2017, the Zoological Society of London (ZSL) with their partners, including the Environment Agency, Thames Water, Thames21 and Catchment Partnerships in London, released a report assessing the state of London's river water quality.[117] Approximately 600km of rivers and streams flow through Greater London into the Tidal Thames. With the help of more than 100 trained volunteers and a targeted survey method, they assessed 142 km of river and 1,177 outfalls for signs of contamination. The surveying efforts found that 356 outfalls showed signs of pollution and 269 of those indicated reasonable confidence of a pollution issue.

Figure 86: Misconnections



Drought

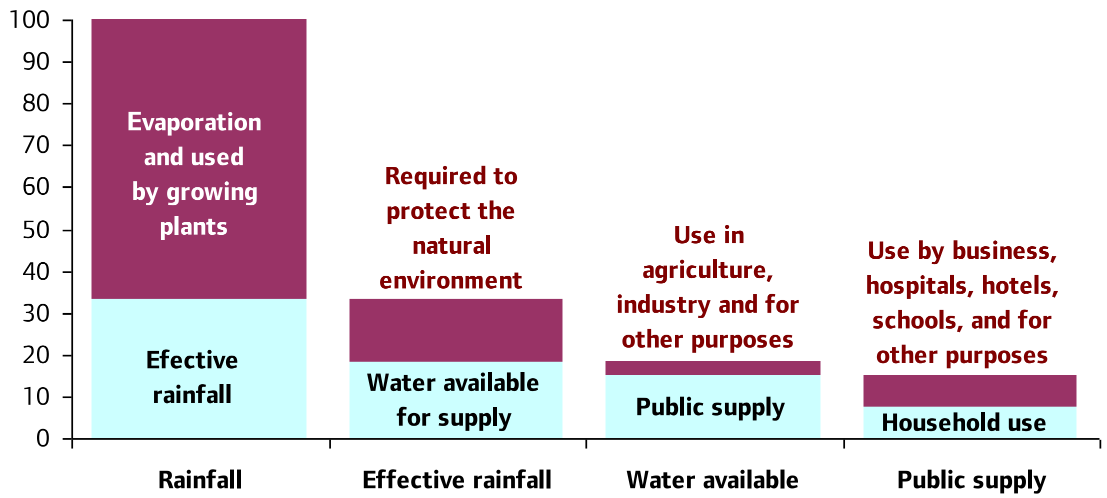
Drought is caused by lack of sufficient rainfall. Droughts can be short and sharp, as experienced in the hot summer of 2003, or prolonged, such as the dry winters experienced in 2004-06 and 2010-12. However, how water is managed can affect the way a drought impacts upon us and on the environment. If demands for water are high, a lack of water supplies increases the likelihood and frequency of drought management measures, such as restrictions on water use.

[117] The Zoological Society of London (2017). Tackling Pollution in London's Rivers. Accessed from: https://www.zsl.org/sites/default/files/media/2017-12/1710_CP_OutfallReport_Final.pdf.

Eighty per cent of London's water comes from the Thames and the River Lee and is stored in reservoirs around London. Most of the remaining 20 per cent is groundwater, pumped from the chalk aquifer that lies underneath London. Both the rivers and the aquifer are fed by rainfall. Winter rainfall is particularly important, because it is over the winter months that rainfall replenishes groundwater stores, and it is these stores that help maintain river flows and abstractions in the spring and summer. Reservoirs are also filled over the winter.

Two-thirds of annual average rainfall is lost through evaporation, or used by plants. Fifty-five per cent of this remaining portion is then abstracted, leaving approximately 45 per cent of the 'effective' rainfall to feed our rivers and wetlands (Figure 87) This means that only 18 per cent of the original rainfall forms part of our water supply. South east England's large population, combined with the relatively low level of rainfall, means the amount of water available per person is very low in comparison to many hotter, drier countries.

Figure 87: What happens to rainfall in the Thames catchment?



Four water companies supply London with water. Table 18 shows the proportion of London's population served by each water company and the amount of water supplied by each company to its London consumers.

Table 18: Water company supply statistics for London	
Water company	**Proportion of London's population served (%)**
Thames Water	78.25
Affinity Water	12.91
Essex and Suffolk	5.34
SES Water	3.5

Table 19 shows that the average household water consumption in London is 149 litres per person per day and the average leakage rate in London is 24.4 per cent. This shows the dual pressure on water use in London. Potential water shortages present a threat to people and industries, especially when combined with other pressures, including increasing development and population.

Water efficiency is a key strategy for addressing water scarcity and can act as a short term solution in coordination with medium- and long term increases in water supply. In June 2017, Waterwise released a Water Efficiency Strategy for the UK, outlining key actions for water companies, regulators, industry bodies, local authorities, academia and others to coordinate efforts on water demand reduction, water efficiency communications and engagement and integration with sustainable drainage.[118] They note that in an international assessment of major cities around the world and their efforts on water efficiency, London ranked 34 out of 50.

London's water distribution network is ageing and this can cause problems in addressing leakage as the network is difficult and expensive to upgrade. This is due to three reasons:

- much of London's mains water network dates back to the Victorian era. Thames Water estimates that nearly a third of the water pipes making up its network are over 150 years old, and about half of them are over 100 years old
- a large proportion of London is built on clay, deposited on the former floodplain of the Thames. This clay is prone to shrinking and swelling in response to changes in soil moisture content (respectively known as subsidence and heave). This movement causes the pipes and joints to break
- London clay is particularly corrosive and weakens the pipes, increasing the risk of breakage due to subsidence and heave and vibrations from construction and transport

In addition, it is estimated that a third of leakage is on the customer side of the network. To address these leaks requires access to homes and also new technology such as smart meters to effectively locate these leaks.

[118] Waterwise (2017). Water Efficiency Strategy for the UK. Accessed from: http://www.waterwise.org.uk/wp-content/uploads/2018/02/Waterwise-National-water-strategy-report.pdf.

Table 19: Household consumption and leakage rates in London[119]

Water company	Area covered	No. of households supplied	No. of non-households supplied	Average daily household consumption l/p/d (2016/17)			Total non-household consumption Ml/d (2016/17)		Average leakage (2016/17)	
				Measured	Unmeasured	Average	Measured	Unmeasured	Amount (Ml/d)	Rate (% of supply)
Thames Water	London WRZ	912,337 measured 1,817,250 unmeasured 2,729,587 total	115,290 measured 33,635 unmeasured 148,925 total	119.5	158.6	146.4	351.3	15.0	579.3	26.5
Affinity Water	Pinn WRZ	450,201	20,138	149.7	172.3	164.8	36.9	3.4	45.8	18.0

[119] Affinity Water numbers of properties are based on London-specific, while consumption and leakage figures are based on the Pinn WRZ, which is not perfectly aligned with Affinity's London service area

Essex & Suffolk Water measured vs. unmeasured properties derived from a percentage measured figure provided by Essex & Suffolk

Essex & Suffolk Water non-household water consumption calculated as a proportion of the Essex WRZ consumption rather than actual measured consumption

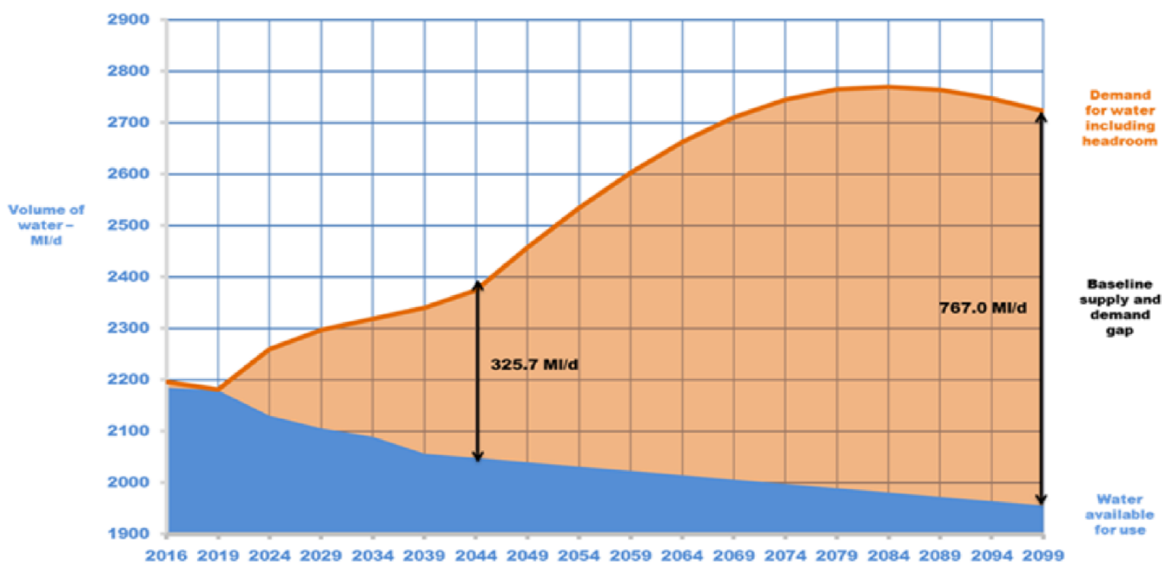
Measured vs. unmeasured household consumption and non-household consumption for the London portion of the SES Water service area were not available at the time of printing

Table 19: Household consumption and leakage rates in London[119]										
Water company	**Area covered**	**No. of households supplied**	**No. of non-households supplied**	**Average daily household consumption l/p/d (2016/17)**			**Total non-household consumption Ml/d (2016/17)**		**Average leakage (2016/17)**	
				Measured	**Unmeasured**	**Average**	**Measured**	**Unmeasured**	**Amount (Ml/d)**	**Rate (% of supply)**
Essex & Suffolk Water	London portion of service area	109,850 measured 76,336 unmeasured 186,186 total	8,932 measured 570 unmeasured 9,502 total	148.9	160.3	154.6	17.3	1.1	23.5	16.0
SES Water	London portion of service area	122,140	5,219			164.8			10.2	14.1
Total		3,488,114	183,784							

Water companies must produce Water Resources Management Plans (WRMP) detailing how they intend to provide sufficient water to meet demands and protect the environment over the next 25 years. These WRMPs are approved by the Environment Agency and are reviewed every year and updated every five years. In a parallel process, water companies must submit their business plans on how the WRMPs will be funded to their financial regulator, Ofwat.

Figure 88 shows that Thames Water forecast a water resource deficit of over 100 Ml per day by 2024, rising to a deficit of 325.7 Ml per day by 2044. This is equivalent to the water needed by around two million people.

Figure 88: Water deficit projections, Thames Water[120]



Currently Thames Water, which supplies 78 per cent of London's water customers, is looking at a range of water resource options for their Water Resource Management Plan (WRMP). Thames Water provides their preferred plan as evidence for addressing the supply-demand deficit. This includes measures in the short term to increase demand management measures; in the medium term measures to achieve 75% meter penetration, further reduce leakage, abstract from the Thames at Teddington and develop a new

[120] Draft baseline supply demand balance for London Water Resource Zone (draft WRMP, February 2018) – Thames Water

reservoir near Oxford; and in the long term options to transfer water from Oxford, reuse effluent at the Beckton Treatment Works and do aquifer storage and recharge

How will climate change affect the risk of drought?[121]
Climate change is expected to affect water availability by:

- reducing river flows
- reducing groundwater replenishment (‘recharge’)
- increasing evaporation
- increasing loss from broken water mains due to increasing subsidence
- increasing demand for water from people and wildlife.

Reducing river flows

Climate change is not projected to alter the total amount of rain that falls in a year, but it will affect when rain falls, and how heavily it falls. Drier summers will mean that rivers will receive a reduced contribution in the amount of rainfall that can prevent low flow rates. Heavier winter rainfall will mean that a greater proportion of the rain runs off the ground into rivers, increasing flood risk, rather than being absorbed and adding to the groundwater that provides the baseflow for the following year.

In drought periods, more than 75 per cent of the freshwater flows in the Thames can be abstracted, reducing the normal flow of the river. In a severe drought, emergency legislation can allow further abstraction, reducing freshwater flows in the Thames to ten per cent of normal flows. Lower river levels mean that pollution becomes more concentrated, so has a greater effect on wildlife.

Reducing groundwater recharge

In the South East, the amount of groundwater present during the summer and early autumn generally governs whether drought restrictions will be experienced. The level of winter rainfall in turn determines the groundwater levels. Climate change will reduce summer rainfall and therefore reduce the minimal summer groundwater replenishment (‘recharge’), while the heavier winter rainfall may run off into the rivers before it is able to be absorbed into the ground to recharge the aquifers.

Increasing evaporation

Two-thirds of rainfall in the Thames catchment is lost to evaporation or used by plants. Hotter summers and more cloud-free days will increase the rate of evaporation even further, leaving less ‘effective rainfall’.

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[121] Greater London Authority (2011). Managing Risks and Increasing Resilience: The Mayor’s climate change adaptation strategy. Accessed from: https://www.london.gov.uk/sites/default/files/gla_migrate_files_destination/Adaptation-oct11.pdf.

Increasing losses from broken water mains due to increasing subsidence

The combination of a very old distribution network, corrosive soils, and ground movement means that London experiences the highest levels of leakage in the UK. More seasonal rainfall will cause soil moisture levels to fluctuate more dramatically, increasing the amount of subsidence and heave, resulting in more damage to the mains distribution network. However, warmer winters with less snow and frost will reduce the amount of water lost through frozen pipes and frozen ground.

Increased demand for water from people and plants

In hot weather, demand for water increases. This increased demand comes from the need to water gardens, use of paddling pools and people washing more frequently. Analysis suggests that the peak demand in London in 2006 (a drought year) was nearly double that in 2007 (a comparatively cool and wet summer).[122]

Hotter, drier summers will increase the rate of transpiration in plants, drawing more water from the soils. This transpiration has the benefit of providing evaporative cooling, helping to reduce London’s temperatures, but can add to the subsidence in soils, contributing to the damage of buildings and infrastructure. Warmer winters will lengthen the growing season, increasing the demand for water from vegetation, and also reduce the winter recharge period for aquifers.

Heat risk

Context

‘Overheating’ is a term used to describe when temperatures rise to a point where they affect the health and comfort of Londoners. High temperatures also have an impact on London’s infrastructure, buckling railway lines, melting road surfaces, making travel in the capital uncomfortable, and increasing water usage and energy demand for cooling.

Figure 89 shows the projected increase in average monthly temperatures in London until 2050 under a medium greenhouse gas emissions scenario, which would require significant reductions in emissions:

- average summer days will be 2.7°C warmer
- very hot days will be 6.5°C warmer than the baseline average
- average winter days will be 2.2°C warmer
- a very warm winter day will be 3.5°C above the baseline
- extremely cold winters will still occur, but less frequently

[122] Environment Agency, personal communications

London's average summer temperatures are expected to keep rising, so that by the middle of this century we can expect what are now heatwave temperatures to occur in most summers. This will increase the likelihood of temperature thresholds being breached more frequently and impacting health, infrastructure, comfort and operation of the city:

- the threshold temperature for housing is 28°C for living areas and 26°C for bedrooms
- the 'warm' temperature threshold for offices, schools and living areas is 25°C
- the 'hot' temperature threshold for offices, schools and living areas is 28°C[123]

Figure 89: Average monthly temperatures (ºC) in London over the century, under a medium emissions scenario, compared to baseline period (UKCP09)[124]

Urban heat island effect

The 'urban heat island' (UHI) describes the warmth of the surfaces and atmosphere that urban areas often experience in comparison to the rural areas that surround them. This warmth can be seen in the way that trees come into leaf earlier in the spring in cities than in rural areas, and the reduced number of nights with frost.

London generates its own microclimate, which can result in the centre of London being up to 10°C warmer than the rural areas around the city. On an average summer morning, the centre of London is slightly cooler than rural areas, as the urban fabric absorbs solar

[123] London Climate Change Partnership & Environment Agency (2012), Heat Thresholds Project: Final report. Accessed from: http://climatelondon.org.uk/wp-content/uploads/2013/01/LCCP_HeatThresholds_final-report-PUBLIC.pdf

[124] UK Climate Projections (2014) Maps & Key Findings. Accessed from: http://ukclimateprojections.metoffice.gov.uk/21708

energy. During the day, rural and urban areas are approximately the same temperature. After sunset, rural areas quickly cool off, whereas in urban areas the greater amount of absorbed heat escapes less quickly, trapped in the urban atmosphere and in street canyons. This relatively slower rate of cooling off compared to rural areas is known as the 'urban heat island effect'. Figure 90 shows night-time temperature across the city, with clear 'hot spots' in more densely developed inner London, compared with outer London.

Figure 90: Mean midnight temperature (˚C), May-September 2011[125]

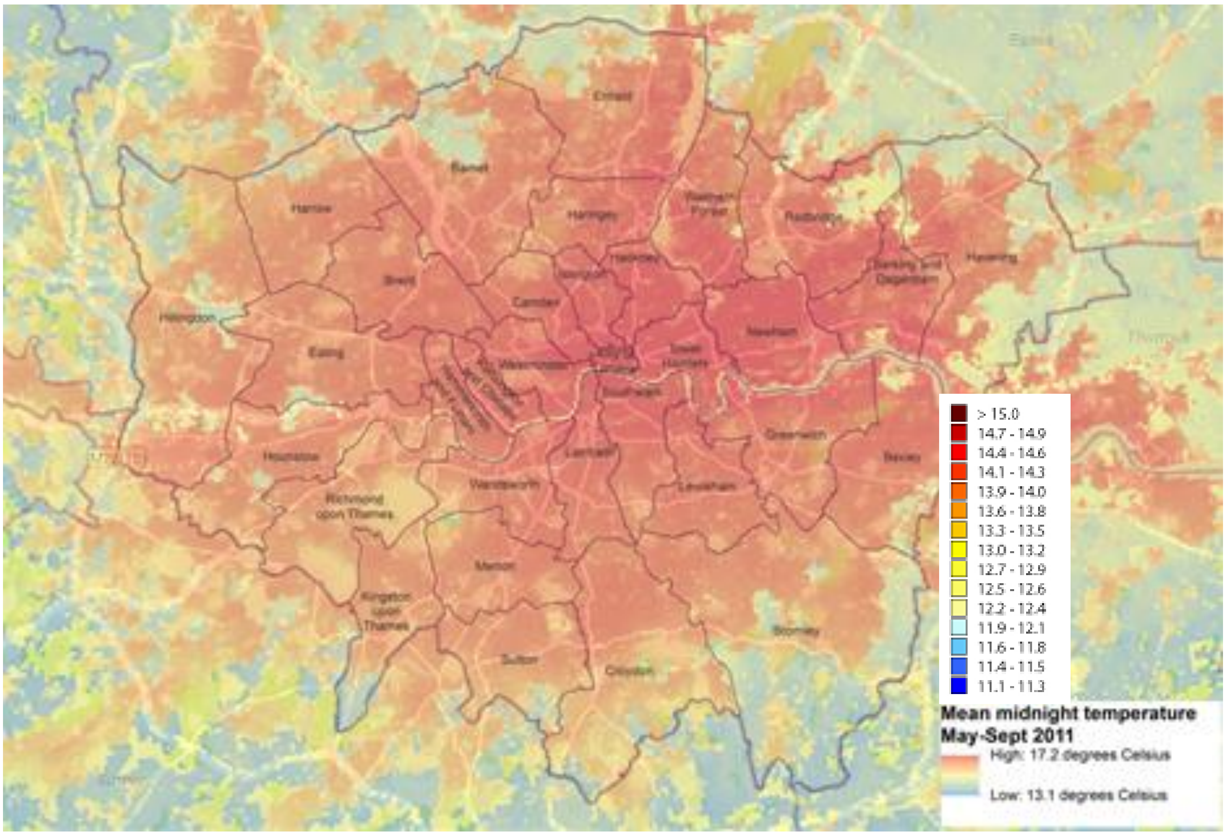

Figure 91 provides a simplified diagram of an UHI. It shows how the UHI varies across a typical city, highlighting how temperatures generally rise from the rural fringe towards the city centre. The profile also demonstrates how temperatures can vary across a city depending on the nature of the land cover, such that urban parks are cooler than adjacent areas covered by buildings, and high-density areas are hotter still. It should be noted that even moderate wind speeds can shift this temperature pattern downwind.

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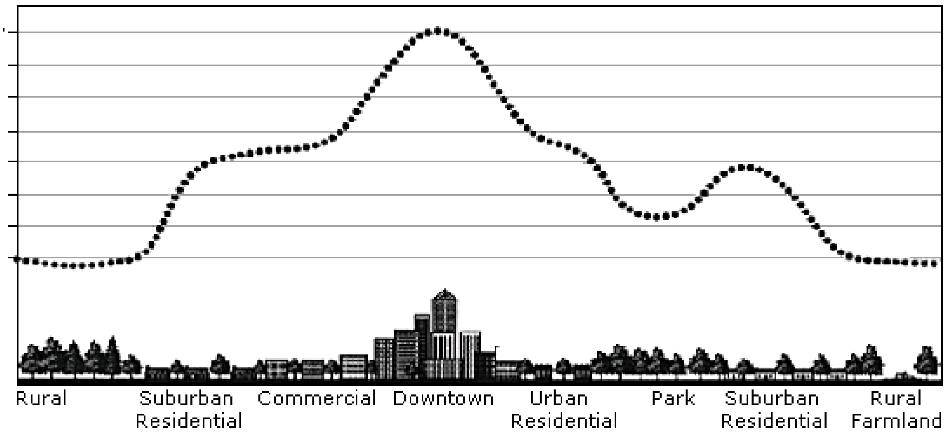
[125] GLA (2017) London's Urban Heat Island - Average Summer. Accessed from: https://data.london.gov.uk/dataset/london-s-urban-heat-island---average-summer

Figure 91: Simplified temperature profile of a typical urban heat island



The UHI effect varies from day to day in London but, in general, peaks after sunset when air temperatures in the warmest parts of the city can typically be 3-4°C warmer than outlying rural areas.

Cloudy, windy, or rainy days limit the intensity of the UHI by either preventing the urban fabric from absorbing as much solar energy, or by mixing the warm air with cooler, fresher air from outside the city.

The heat generated in the city by traffic, air conditioning systems and other energy uses also acts to raise temperatures. This 'anthropogenic' (man-made) contribution to the UHI can have significant local impact in high-density areas, raising summer air temperatures by a further 2ºC.[126] If the use of air conditioning were to become more widespread, the area affected by a significant anthropogenic contribution would increase.

The amplified night-time temperatures are important during hot weather because:

- cool nights help people recover from the heat of the day. Hot nights therefore limit recuperation and may contribute to deaths associated with prolonged hot weather (especially for the ill and the elderly)
- hot nights prevent the city from cooling off and so reduce the amount of natural night-time cooling in buildings. This increases the demand for cooling the following day (leading to a feedback loop of increased waste heat and rising demand for cooling)

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[126] Hamilton I., Davies M., Steadman P., Stone A., Ridley I., and Evans S. (2009) The significance of the anthropogenic heat emissions of London's buildings: A comparison against captured shortwave radiation. *Building and Environment* **44**(4), 807-817

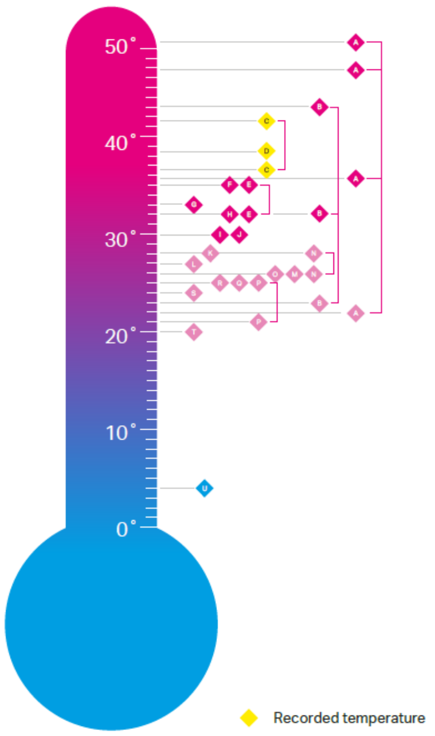
- hot nights can affect people's sleep, resulting in a negative effect on the economy, education and quality of life

Heat thresholds in London
Summer heatwaves may make our homes, workplaces, and public transport uncomfortable, and can have consequences for public health, particularly of vulnerable people. As demand for cooling increases, there may be stress on power supply networks, with increasing energy demand threatening London's sustainability.

Figure 92 identifies some of the main thresholds for heat in London when services are disrupted and Londoners are affected. These include:

- 24°C – London Underground puts in place overheating plans including public health communications and measures to prevent tracks from buckling
- 24.7°C – over two days leads to greater incidences of morbidity, mortality and hospital admissions in London
- 33°C – softening of tarmac, asphalt and bitumen road surface generally begins to occur
- 36°C – power sources begin overheating, extreme precautions may need to be introduced to prevent rail lines buckling, such as speed restrictions[123]

Figure 92: Heat thresholds in London[127]



	Temp
A	36°C External air temperature which results in rail track temperatures of 48°C-52°C. Extreme precautions, such as temporary speed restrictions, taken by Network Rail at this air temperature to avoid buckling of power sources. 22°C Network Rail begin to implement staged preventative measures at this air temperature.
B	43°C Maximum internal air temperature advised for server rooms. 32°C Maximum internal air temperature advised for computer rooms. 23°C maximum internal air temperature advised for IT equipment room.
C	41.5°C and 36.2°C Air temperatures recorded on the tube and on the platforms respectively during the 2003 heatwave in London.
D	38.5°C Highest daytime temperature recorded in the UK (at Gravesend, Kent).
E	32°C and 35°C Internal air temperature thresholds to which Crossrail rolling stock and stations respectively are designed not to exceed.
F	35°C Heat stress risk for healthy adults begins at the internal air temperature combined with a relative humidity level of 50%.
G	33°C Softening of tarmac, asphalt and bitumen road surfaces generally begins to occur but is also dependent on direct solar exposure.
H	32°C The highest estimate for summar mean daily maximum temperatures by the 20%.
I	30°C Vulnerability of commercial buildings to power outages increases when external air temperatures exceed this.
J	30°C Overhead power lines begin to experience a reduced rating factor above this air temperature.
K	28.1°C The highest estimate for summer mean daily maximum temperature by the 2050s.
L	27°C Threshold temperature specified for over-heating in well insultated housing.
M	26.2°C The cental estimate for summer mean daily maximum temperatures by the 2080s.

	Temp
N	28°C Current CIBSE temperature threshold for living areas. If 1% of annual occupied hours exceed this temperature, internal spaces in a building have technically overheated. 26°C Current CIBSE temperature threshold for bedrooms.
O	26°C Threshold for air temperatures of internal cool areas required to be provided by hospitals
P	25°C Suggested 'hot' temperature threshold for bedrooms. 21°C Suggested 'warm' temperature threshold for bedrooms.
Q	24.8°C the central estimate for summer mean daily maximum temperature by the 2050s.
R	24.7°C over 2 days leads to greater incidences of morbidity, mortality and hospital admissions in London.
S	24°C London Underground implement overheating plans including public health communications and mesures to prevent non-pre-stressed railtracks from buckling.
T	20°C Legionella bacteria begin to develop in potable water supplies (both stored and piped) if water temperature exceeds this.
U	4°C to 60°C Bacterial growth on food encouraged between these temperature. Likelihoog of food home diseases increase by 4.5% for every 1oC increase in air temperature.

[127] LCCP & Environment Agency (2012) Heat Thresholds Project. Accessed from: http://climatelondon.org/publications/overheating-thresholds-report/

Extreme weather events

A heatwave refers to a prolonged period of unusually hot weather. While there is no standard definition of a heatwave in England, the Met Office uses the World Meteorological Organization definition of a heatwave, which is "when the daily maximum temperature of more than five consecutive days exceeds the average maximum temperature by 5°C, the normal period being 1961-1990".[128] They are common in the northern and southern hemisphere during summer, and have historically been associated with health problems and an increase in mortality.

Urban heat island and heatwave maps were produced using LondUM, a specific set-up of the Met Office Unified Model version 6.1 for London. It uses the Met Office Reading Surface Exchange Scheme (MORUSES), as well as urban morphology data derived from Virtual London.[129] The model was run from May until September 2006 and December 2006. The maps show average surface temperatures over the summer period of 2006 at a 1km by 1km resolution. Figure 93 shows the average maximum daily temperatures for the summer of 2006, a warm London summer. Figure 94 shows the average maximum daily temperatures for the heatwave in the summer of 2006.[130]

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[128] Met Office (2016). Heatwave. Accessed from: https://www.metoffice.gov.uk/learning/learn-about-the-weather/weather-phenomena/heatwave.

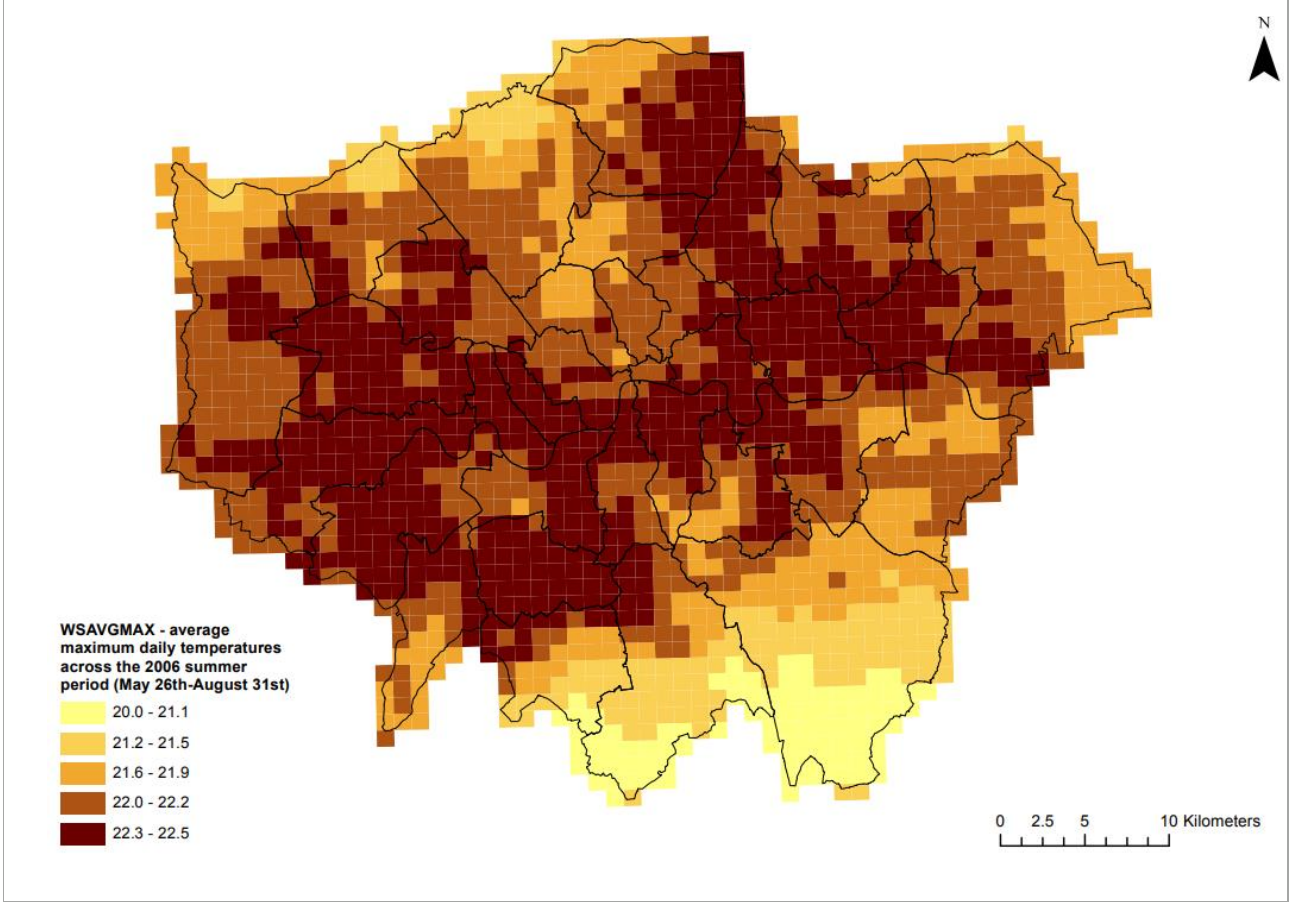
[129] *LondUM (2011). Model data generated by Sylvia I. Bohnenstengel (*), Department of Meteorology, University of Reading and data retrieved from* http://www.met.reading.ac.uk/~sws07sib/home/LondUM.html.

(*) Now at Metoffice@Reading, Email: sylvia.bohnenstengel@metoffice.gov.uk

Bohnenstengel SI, Evans S, Clark P and Belcher SeE (2011) Simulations of the London Urban Heat island. Quarterly journal of the Royal Meteorological Society, 137(659). pp. 1625-1640. ISSN 1477-870X doi 10.1002/qj.855. LondUM data (2013).

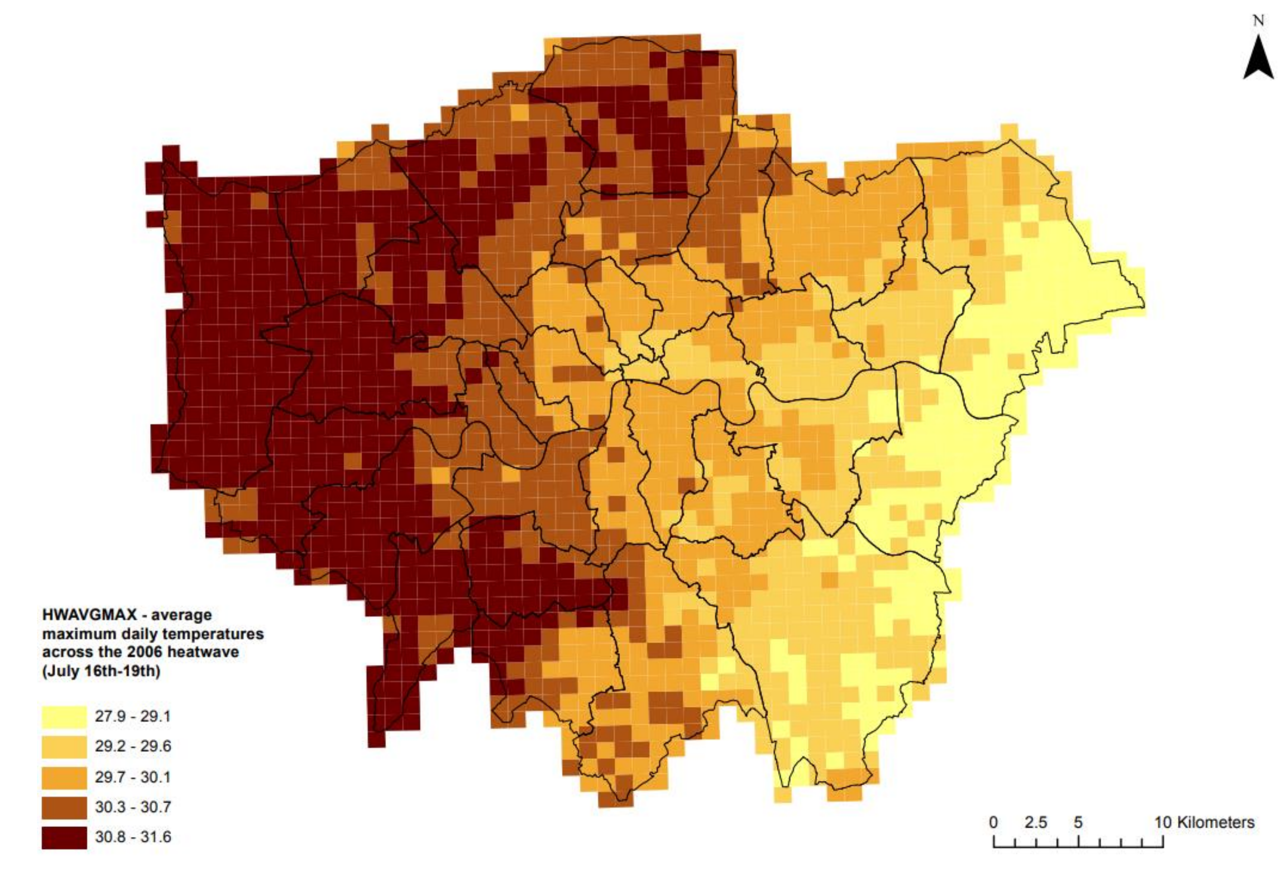
[130] The 2006 heatwave is the most recent heatwave of its kind with this level of data analysis available.

Figure 93: Average maximum daily temperatures across the summer period 2006 (May 26th-August 31st)[131]



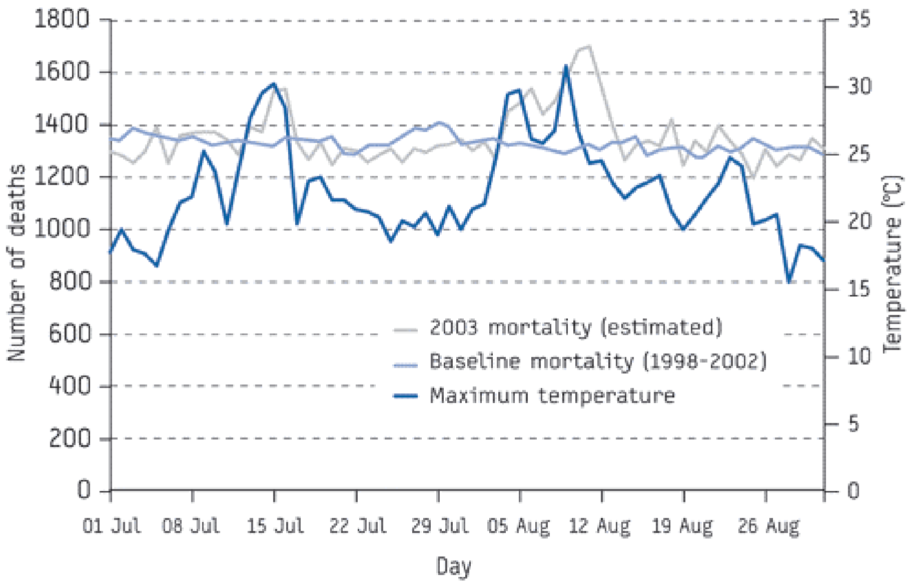
[131] GLA (2016) London's Urban Heat Island - During A Warm Summer. Accessed from: https://data.london.gov.uk/dataset/timeline/london-s-urban-heat-island

Figure 94: Average maximum daily temperatures across the 2006 heatwave (July 16-19th)[131]



In England and Wales, there were 2,139 excess deaths during the August 2003 heatwave. Figure 95 shows the number of deaths and maximum temperatures during the 2003 heatwave period. It can be seen that the number of deaths closely follows the maximum temperature.

Figure 95: Number of deaths during summer 2003[132]



The August 2003 heatwave provided a dramatic example of how vulnerable London is to heat. It is estimated that at least 600 people died in London[133] because of the heatwave. The impact of the 2003 heatwave on Londoners appears to have been greater than anywhere else in the UK.[134] An analysis of the excess deaths during the August 2003 heatwave for each UK government region shows that whilst London did not experience the highest temperatures nationally, London had the highest number of excess deaths for any region, even allowing for the size of its population.

Further research[135] suggests that the number of deaths in response to rising temperatures in London increases above 24.7°C (which is a higher threshold than in other UK regions) and that above this threshold, there is a greater increase in the number of deaths per degree Celsius rise in temperatures than in other regions with lower thresholds. The reasons for this vulnerability are that London is in the warmest part of the UK and therefore

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[132] London School of Hygiene and Tropical Medicine

[133] Office for National Statistics. Excess deaths are calculated by subtracting the number of expected deaths from the number of observed deaths. These are estimates because it is not possible to define the cause of death being due to high temperatures.

[134] Johnson H., Kovats R.S. et al (2005) The impact of the 2003 heat wave on daily mortality in England and Wales and the use of rapid weekly mortality estimates

[135] Armstrong BG, Chalabi Z, Fenn B, Hajat S, Kovats S, Milojevic A, Wilkinson P. (2010) *The association of mortality with high temperatures in a temperate climate: England and Wales.* J Epidemol Commun Health, 2010 May 3.

our thermally poor homes are more likely to overheat. Poor air quality also compounds the impact of high temperatures. It should be noted that most Londoners will acclimatise to warmer summer temperatures.

Reducing the need for cooling in buildings

Our indoor climate depends upon how much of the outdoor climate our buildings filter or transmit, and how much heat is generated internally. In 2014, the Chartered Institute of Building Services Engineers (CIBSE), working in conjunction with the GLA, published the TM49 guide.[136] This aims to provide a risk-based approach to help developers and their advisers simultaneously address the challenges of developing in an urban heat island and managing an uncertain future climate. It provides guidance to help ensure that new development is better designed for the climate it will experience over its design life.

As it is impossible to pre-judge the impact of warm weather conditions on a building in a general sense, overheating modelling is meant to be conducted using three design weather years:

- 1976: a year with a prolonged period of sustained warmth
- 1989: a moderately warm summer (current design year for London)
- 2003: a year with a very intense single warm spell

To enable the urban heat island effect in the locality of the development to be taken into account, weather year data for three different locations are used to take account of future climate effects. The most representative weather data set for the project location is generally used. For development within:

- the GLA Central Activity Zone (CAZ) and other high density urban areas (e.g. Canary Wharf): London Weather Centre data
- lower density urban and suburban areas: London Heathrow airport data
- rural and peri-urban areas around the edge of London: Gatwick Airport data

The CIBSE guide TM52 contains additional guidance on the limits of thermal comfort[137] and provides guidance on predicting overheating in buildings. It is intended to inform designers, developers and others responsible for defining the indoor environment in buildings.

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[136] CIBSE (2014). TM49: Design Summer Years for London. Accessed from: https://www.cibse.org/Knowledge/knowledge-items/detail?id=a0q20000008I6yFAAS.

[137] CIBSE (2013). TM52: The Limits of Thermal Comfort: Avoiding Overheating in European Buildings. Accessed from: https://www.cibse.org/Knowledge/knowledge-items/detail?id=a0q20000008I7f5AAC.

Ambient Noise

Noise as an environmental health risk

The World Health Organization (WHO) recognises environmental noise as having a number of adverse health effects, and has listed it as the second largest environmental health risk in Western Europe behind air quality. This has acted as the catalyst for the Environmental Noise Directive (Noise Directive). The Noise Directive requires EU Member States to produce noise maps and action plans every five years. These help transport authorities better identify and prioritise relevant local action on noise (see Appendix 4 for more information on legislative and policy background).

Box 8: Guidelines on noise

The WHO has developed recommended daytime noise guidelines. To avoid serious annoyance, outdoor sound levels should not exceed 55dB from steady continuous noise sources. Long term average exposure to levels above 55dB can trigger elevated blood pressure and heart attacks.[138]

Night time noise guidelines established by the WHO for Europe recommend a level of 40dB for annual average night exposure. This corresponds to the sound of a quiet street in a residential area, and prolonged exposure to levels over this amount can result in sleep disturbance and insomnia.[138]

Decibels in context

A decibel (dB) is a measure of the intensity of sound. The quietest sound audible to a healthy human ear is 0dB. Decibels are on a logarithmic scale, so every 3dB increase in sound is equivalent to a doubling of sound intensity. Likewise, every 3dB decrease is equivalent to halving the sound intensity.

However, sound intensity and our perception of sound differ greatly. For example, a change of 5dB is the level needed before most people report a noticeable or significant change in noise level. Even though only a 3dB change is required to double sound intensity, a change of 10dB is required before a listener perceives a doubling of sound.

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[138] WHO Europe (2009). Night Noise Guidelines for Europe. Accessed from: http://www.euro.who.int/__data/assets/pdf_file/0017/43316/E92845.pdf

Box 8: Guidelines on noise

How loud are everyday sounds?	
Whisper	30dB
Normal conversation	50-65dB
City traffic noise	80dB
Train	100dB
Jet flyover at 100ft	103dB
Jackhammer	110dB
Fireworks	145dB

LAeq Definition

LAeq is the A-weighted equivalent continuous sound level for a specified time period (e.g. 8 hours or 16 hours). This is a preferred method for describing sound levels that vary over time.

Noise can have a big impact on our quality of life, our health and the economy. However, we do not have a complete understanding of the consequences of failing to address the risks of noise. It is estimated by the WHO, that at least one million healthy life years[139] are lost every year from traffic related noise in the western part of Europe,[140] while 903,000 healthy life years are estimated to be lost due to noise related sleep disturbance.

Road traffic noise

Road traffic is the largest single cause of noise pollution in London (Table 20). Typically noise levels from road traffic increase with higher traffic volumes and speeds. Because the road network is so extensive and spread throughout London, road traffic noise is likely to affect the most people. In the Greater London Urban Area, noise exposure data shows that almost 2.4 million people are exposed to noise levels from road traffic that exceed the levels provided as a guideline by the WHO (55dB).

[139] Using disability adjusted life years (DALYs), which are the potential years of life lost due to premature death and the equivalent years of "healthy" life lost by virtue of being in states of poor health or disability.

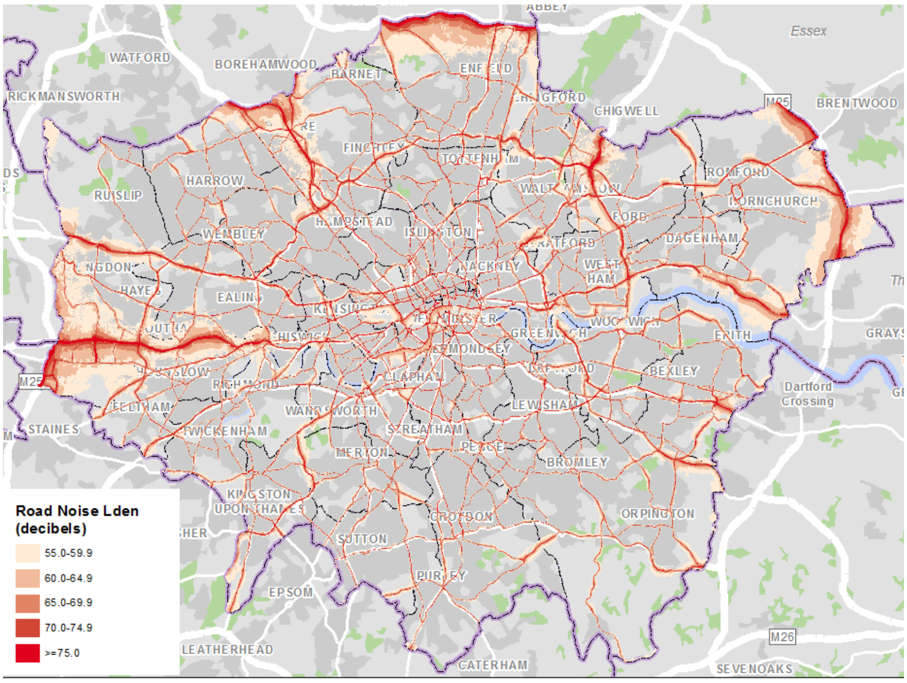
[140] World Health Organization (2011), Burden of disease from environmental noise, accessed via: http://www.euro.who.int/__data/assets/pdf_file/0008/136466/e94888.pdf?ua=1

Table 20: Number of people affected by road traffic, rail and industrial noise in the Greater London Urban Area, 2011 (Based on an annual average 24 hour period for 2011)[141]			
L_{den} dB	Road	Rail	Industry
≥ 55dB	2,387,200	525,200	23,600
≥ 60dB	1,426,100	308,500	13,000
≥ 65dB	1,027,200	158,100	7,500
≥ 70dB	597,800	59,800	4,600
≥ 75dB	99,200	15,200	3,000

Noise maps show the geographic dispersal of estimated levels of road traffic noise along major transport routes (Figure 96). Major Roads are defined as regional or national roads which have three million or more vehicle passages per year. The Major Roads were identified using the Department for Transport's (DfT) Transport Statistics Major Roads data from 2010. The highest levels of road noise are seen where the GLA boundary intersects with the M25, and on motorways into London.

[141] Defra (2014), Noise exposure data – England. Accessed from: https://data.gov.uk/dataset/noise-exposure-data-england

Figure 96: Noise map of estimated L_{DEN} road traffic noise levels across London[142]



Rail traffic noise

London is more dependent on rail than any other city in the UK, with 70 per cent of all rail travel (including Tube journeys) in the UK being to, from, or within London.

Rail transport has a number of noise implications for the city through train operation, maintenance, freight loading and station operation. However, the effects are usually more concentrated than for road noise and are therefore somewhat easier to mitigate. This is reflected in phone interviews with London residents (March 2016, n=1004),[143] where only 8 per cent of respondents felt that rail or underground noise was a problem.

When looking at the number of people in Greater London who are exposed to noise levels above those recommended by the WHO, Table 20 above shows that much fewer people are exposed to rail noise above 55dB, than their counterparts under road noise.

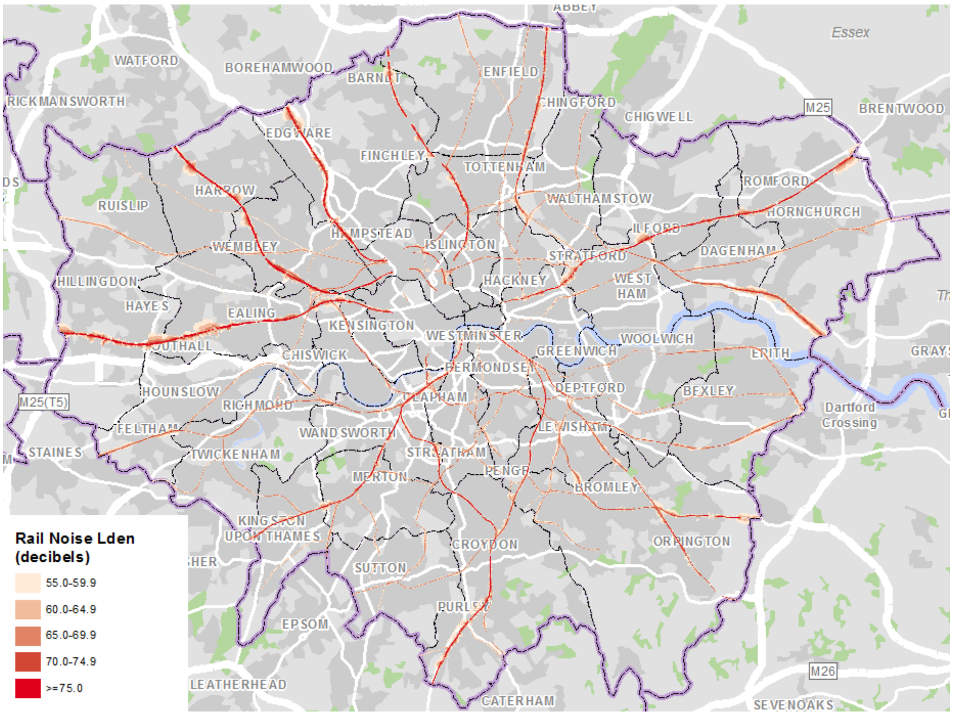
Noise maps show the geographic dispersal of estimated levels of rail traffic noise along major transport routes (Figure 97). Major Railways are defined as sections of rail route that

[142] Defra (2016), Road Noise – Lden – England Round 2. Accessed from: https://data.gov.uk/dataset/road-noise-lden-england-round-21

[143] Greater London Authority (2016) March 2016 – congestion, night-tube, noise, volunteering and growth. Accessed from: https://data.london.gov.uk/dataset/gla-poll-results

have over 30,000 train passages each year. The Major Railways were identified using Network Rail's Actual Traffic (ACTRAFF) database for the year to September 2011. As rail-based modes of travel, including the Tube, make up 80 per cent of the 1.3 million trips to central London in an average weekday morning peak period, it is important to understand the implications of all available rail systems on noise.

Figure 97: Noise maps of estimated L_{DEN} rail traffic noise levels across London[144]

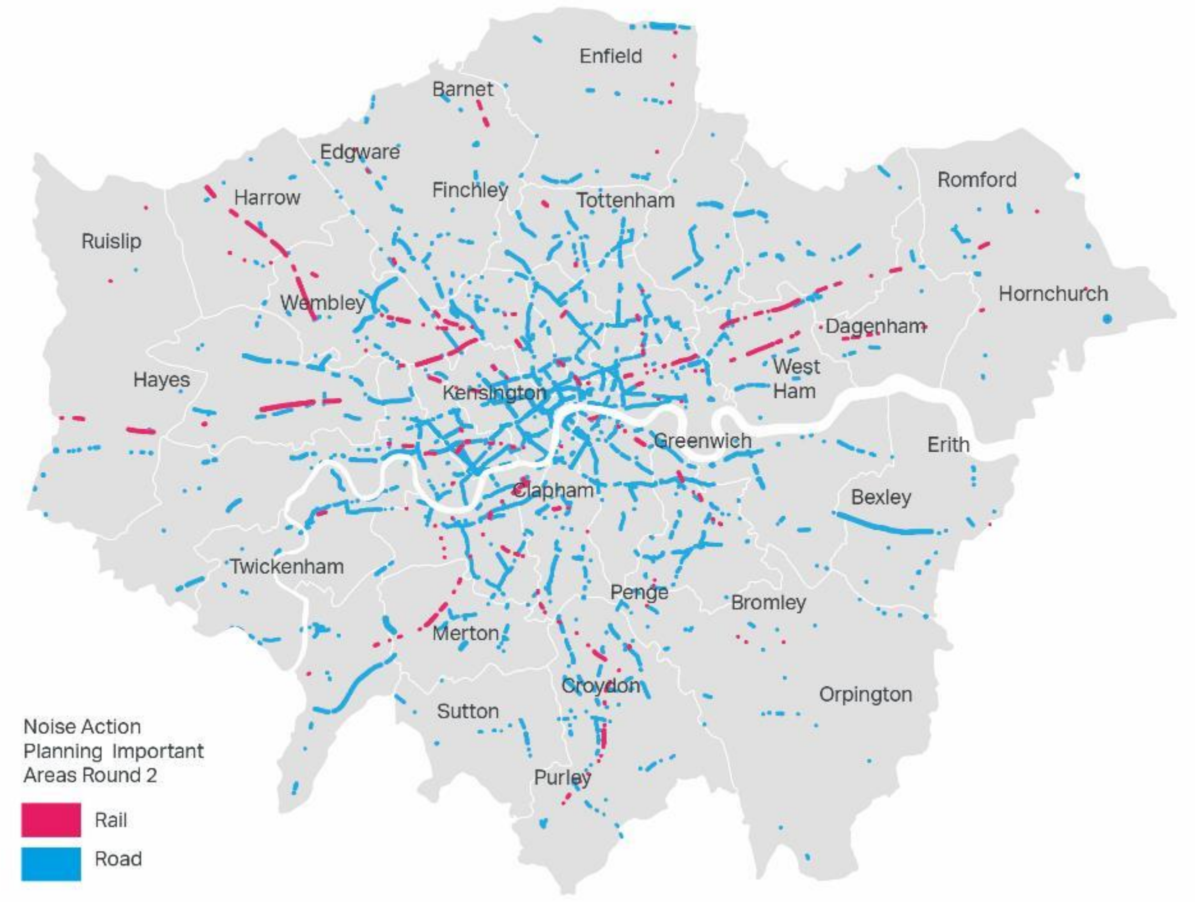


Important Areas

Noise mapping has been completed to identify Important Areas for road and rail traffic noise (Figure 98). This represents locations with the highest one per cent of noise levels. Important Areas for road traffic are mostly clustered around the city centre, rather than aligning with high noise areas highlighted in the road traffic noise map (Figure 96). When comparing Important Areas for road and rail traffic, the number of identified areas for rail traffic are much fewer.

[144] Defra (2016), Rail Noise – Lden – England Round 2. Accessed from: https://data.gov.uk/dataset/rail-noise-lden-england-round-21

Figure 98: Noise map of Important Areas for road and rail traffic noise across London[145]



Aviation noise

In 2014, London welcomed 28.8 million overnight visitors. As the fourth most visited international destination in the world, the city's international connectivity will continue to be important in its growth. Expansion of airports and/or increases in flight movements will need to carefully consider environmental impacts, including noise, and the effect it will have on Londoners. The Survey of Noise Attitudes (SoNA 2013) examines attitudes in England towards noise, including consideration of aircraft noise to address the emerging evidence that annoyance from aircraft noise has been increasing.

[145] Defra (2016), Noise Action Planning Important Areas Round 2 England. Accessed from: https://data.gov.uk/dataset/noise-action-planning-important-areas-round-2-england1

According to the SoNA (2013), approximately one third (31.3 per cent) of respondents (n = 2,383) do not hear noise from aircraft/airports/airfields. Those that do hear noise from aircraft/airports/airfields are predominantly not affected by it (41.5 per cent), or only slightly affected by it (16.6 per cent). This is reflected in phone interviews with London residents (March 2016, n=1004)[146] where only 16 per cent of respondents felt that aircraft noise was a problem. The number of people exposed to aviation noise is much smaller than the number exposed to road traffic, and is much more geographically concentrated. However, aviation noise is thought to have more detrimental effects on health.

Under the Environmental Noise Directive, major airports with over 50,000 flight movements annually are required to carry out noise mapping. London is served by six main airports:

- Heathrow Airport
- Gatwick Airport
- London City Airport
- London Stansted Airport
- London Luton Airport
- London Southend Airport

Each of these airports is required to produce noise maps and action plans that show the number of people and dwellings affected by noise within different noise contours. Airports also produce data on the number of noise complaints received. The details of this are outlined in Table 21.

Table 21: Summary of key airport statistics 2011[147]

London Airport	Heathrow	London City	Stansted	Gatwick	Luton	Southend
Flight Movements[148] (2016)	474,963	85,169	180,430	280,666	128,519	23,449

[146] Greater London Authority (2016), March 2016 – congestion, night-tube, noise, volunteering and growth. Accessed from: https://data.london.gov.uk/dataset/gla-poll-results

[147] Sourced from independent airport noise action plans unless otherwise specified

[148] Civil Aviation Authority (2016), Aircraft Movements. Accessed from: https://www.caa.co.uk/uploadedFiles/CAA/Content/Standard_Content/Data_and_analysis/Datasets/Airport_stats/Airport_data_2016_annual/Table_03_1_Aircraft_Movements.pdf

Table 21: Summary of key airport statistics 2011[147]						
London Airport	**Heathrow**	**London City**	**Stansted**	**Gatwick**	**Luton**	**Southend**
Noise Complaints (2015)	108,255[149]	86[150]	747[151]	15,189[152]	960[153]	352[154]
People affected by ≥ 55 L_{DEN} (dBA)	766,100	26,100	7,400	11,300	14,300	2,200
Dwellings affected by ≥ 55 L_{DEN} (dBA)	329,900	12,250	2,950	4,500	6,450	1,000
Area (km^2) affected by ≥ 55 L_{DEN} (dBA)	221.9	7.8	57.5	85.6	33.2	1.7

Noise from helicopter flights can also be a particular source of annoyance for Londoners. London Heliport records both flight movements and number of complaints. These are reported through the London Heliport Consultative Group (Table 22).

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[149] Heathrow Airport Limited (2015), Noise complaints – 2015 report. Accessed from: http://www.heathrow.com/file_source/HeathrowNoise/Static/Noise_complaints_report_2015.pdf

[150] London City Airport (2016), 2015 Section 106 Annual Performance Report. Accessed from: https://www.londoncityairport.com/content/pdf/LCY%20Annual%20Performance%20Report%202015%20AW%20inc%20Appendices%20LowRes.pdf

[151] London Stansted Airport (2015), Our Noise Performance. Accessed from: http://www.stanstedairport.com/community/local-environmental-impacts/noise/our-noise-performance/

[152] Gatwick Airport (2015), Flight Performance Team Annual Report. Accessed from: http://www.gatwickairport.com/globalassets/publicationfiles/business_and_community/all_public_publications/2015/2015-annual-report-final.pdf

[153] London Luton Airport (2015), Annual Monitoring Report. Accessed from: http://www.london-luton.co.uk/CMSPages/GetFile.aspx?guid=2cd18311-bb7f-41f2-a3fa-7b09ace5fea9

[154] Southend-on-Sea Borough Council (2016), London Southend Airport Monitoring Report. Accessed from: http://democracy.southend.gov.uk/documents/b7297/London%20Southend%20Airport%20Monitoring%20Report%2020th-Sep-2016%2018.30%20London%20Southend%20Airport%20Monitoring%20W.pdf?T=9

Table 22: Battersea Heliport key statistics 2016[155]		
	Flight Movements	**Noise Complaints**
Quarter 1	1,983	1
Quarter 2	3,276	1
Quarter 3	3,493	7
Quarter 4	2,641	1

Industrial noise
Noise from industrial sources is managed in three ways, through:

- development control in land use planning
- the Environmental Permitting Regulation process
- the use of Statutory Nuisance Legislation

As stated in Defra's *Noise Action Plan for Agglomerations*, these are thought to provide the necessary mechanisms for the management of industrial noise issues. Table 20 shows the number of people affected by industrial noise. Compared to transport sources, industrial noise impacts significantly fewer people. This is reflected in the Survey of Noise Attitudes (2013), which shows that 90.3 per cent of respondents do not hear industrial noise.

Usage and feedback from stakeholders

In addition to noise mapping, Defra, and its predecessor body, have run a number of large scale attitudinal surveys for noise across the whole of the UK (National Noise Attitude Survey 1990, 2000, and 2012; Survey of Noise Attitudes 2013). These are designed to provide a good estimate of current attitudes to various elements of environmental, neighbour and neighbourhood noise, and to show substantive change in attitudes between survey periods.

The latest National Noise Attitude Survey (2012) found that although many had a generally positive attitude to their local noise environment, 48 per cent of respondents felt that their home life is spoilt to some extent by noise. The most frequently heard sources of noise for English people in their homes are:

- road traffic noise (84 per cent)

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[155] Sourced from independent agenda papers. Accessed from: http://www.wandsworth.gov.uk/downloads/download/354/battersea_heliport_and_helicopter_noise

- noise from neighbours and/or other people nearby (84 per cent)
- aircraft, airports and airfield noise (75 per cent)
- noise from building, construction, demolition, renovation and road works (50 per cent)

The Survey of Noise Attitudes (SoNA) was developed in 2013 and is based on the questionnaire used for the last National Noise Attitude Survey. As the latest survey of noise attitudes in England, a summary of the results are outlined in Table 23.

Table 23: How much respondents are bothered by different noise sources[156]

Noise Source (N=2,383)	Per cent bothered, annoyed or disturbed				
	Not at all	Slightly	Moderatel y	Very or extremely	Don't hear
Neighbours and/or other people nearby	29.7	27.8	14.2	10.7	17.6
Road Traffic	29.9	26.9	15.0	6.7	21.0
Aircraft/Airports/Airfields	41.5	16.6	7.3	3.3	31.3
Building, construction, demolition, renovation or road works	15.5	14.3	5.6	4.0	60.6
Trains or railway stations	17.0	4.8	0.9	0.7	76.5
Sports events	22.1	5.6	1.2	0.7	70.5
Other entertainment or leisure	16.3	7.4	1.9	1.4	73.0
Community buildings	24.2	6.3	1.9	0.8	66.7
Forestry, farming or agriculture	14.0	2.5	0.5	0.1	83.0
Industrial sites	4.2	3.9	0.9	0.6	90.3
Other commercial premises	5.0	2.9	0.9	0.6	90.6
Sea, river or canal traffic	3.9	0.4	0.2	0.0	95.2

In March 2016, the Greater London Authority completed a series of telephone interviews with more than 1,000 London residents. Respondents were asked how much of a problem certain noise sources were in their day-to-day lives. Generally, Londoners did not seem to feel affected by noise, with the majority stating that each noise source was not a problem.

[156] Defra (2013), Survey of Noise Attitudes. Accessed from: http://randd.defra.gov.uk/Document.aspx?Document=13319_NANR322SoNA2013ReportFinalNov2015.pdf

However, there is a significant minority of Londoners that are experiencing noise as a problem. Summary results for this survey question are presented in Table 24.

Table 24: As a percentage, how much of a problem, if at all, do you consider each of the following to be in your day-to-day life?[157]

N=1,004	Is a problem	Is not a problem	Don't know
Road traffic noise	27	73	*
Rail/underground noise	8	91	1
Airplane noise	16	83	*
Deliveries/noise from businesses	12	87	1
Anti-social behaviour/nuisance noise	29	70	*
Crowds	26	73	1

While the perception of noise may not be highlighted as a key issue by Londoners, the adverse impacts it has on health and social cost ensure that it needs to be considered seriously as the city grows.

Evidence gap

The data presented here provides some valuable insights which help to target noise intervention. However, it also shows that there is a gap in city wide research and data collection. Typically, complaints data is collected by the boroughs, while surveys and key research are completed at the England or UK level. This shows that there is capacity for improvement and an opportunity to further build the evidence base on noise for London.

There is currently limited data for London that provides an adequate baseline against which progress can be measured. The Mayor's Transport Strategy has expressed the intention to work with Transport for London (TfL) and the boroughs to monitor noise close to major road corridors. This will establish baseline data against which the impact of road noise objectives can be measured.

[157] Greater London Authority (2016) March 2016 – congestion, night-tube, noise, volunteering and growth. Accessed from: https://data.london.gov.uk/dataset/gla-poll-results

Appendix 2A: London Priority Species

(based on London Biodiversity Action Plan review - 2007)

LONDON BAP PRIORITY SPECIES

		UK BAP Priority	UK SCC	UK Red Data List	UK Scarce	London SAP current
Vascular plants						
Annual knawel	*Scleranthus annuus*	●		●		
Autumn squill	*Scilla autumnalis*				●	
Basil thyme	*Clinopodium acinos*	●		●		
Black poplar	*Populus nigra betulifolia*					●
Borrer's saltmarsh-grass	*Puccinellia fasciculata*	●		●		
Chalk eyebright	*Euphrasia pseudokerneri*	●		●	● (grey)	
Chamomile	*Chamaemelum nobile*	●	● (grey)	●		
Copse-bindweed	*Fallopia dumetorum*	●		●	● (grey)	
Creeping marshwort	*Apium repens*	●		●		
Cut-grass	*Leersia oryzoides*	●		●		
Divided sedge	*Carex divisa*	●		●		
Dodder	*Cuscuta epithymum*			●		
Dwarf milkwort	*Polygala amarella*			● (grey)		
Early gentian	*Gentianella anglica*	●			●	
Fine-leaved sandwort	*Minuartia hybrida*	●		●		
Fly orchid	*Ophrys insectifera*	●		●		
Greater yellow-rattle	*Rhinanthus angustifolius*		●	●		
Green-flowered helleborine	*Epipactis phyllanthes*				●	
Juniper	*Juniperus communis*	●				
Lesser calamint	*Clinopodium calamintha*			●	● (grey)	
Man orchid	*Aceras anthropophorum*	●		●	● (grey)	
Marsh sow-thistle	*Sonchus palustris*				●	
Mistletoe	*Viscum album*					●
Mudwort	*Limosella aquatica*				●	
Narrow-fruited cornsalad	*Valerianella dentata*		●	●		
Narrow-leaved bitter-cress	*Cardamine impatiens*			●		
Narrow-leaved water-dropwort	*Oenanthe silaifolia*			●	● (grey)	
Pennyroyal	*Mentha pulegium*	●		●		
River water-dropwort	*Oenanthe fluviatilis*		●			
Round-leaved wintergreen	*Pyrola rotundifolium*			●	● (grey)	
Slender bedstraw	*Galium pumilum*	●		●	● (grey)	
Tower mustard	*Arabis glabra*	●		●		●
Wall bedstraw	*Galium parisiense*			●	● (grey)	
White helleborine	*Cephalanthera damasonium*	●		●		
Yellow bird's-nest	*Monotropa hypopitys*	●		●	● (grey)	

Lower plants						
Veilwort (a liverwort)	*Pallavicinia lyellii*	●		●		
Fungi						
Bear cockleshell	*Lentinellus ursinus*		●	●		
Crimson bolete	*Rubinoboletus rubinus*			●		
Golden-gilled bolete	*Phylloporus rhodoxanthus*	●		●		
Hedgehog fungus	*Hericium erinaceum*	●		●		
Nail fungus	*Poronia punctata*	●		●		
Oak polypore	*Piptoporus quercinus*	●		●		
Olive earthtongue	*Microglossum olivaceum*	●		●		
Pink waxcap	*Hygrocybe calyptriformis*	● (grey)		●		
Tiered tooth	*Hericium cirrhatum*			●		
tooth fungi (grouped)	*Hydnellum, Phellodon* spp.	●		●		
Zoned rosette	*Podoscypha multizonata*			●		
Invertebrates						
Brown hairstreak (butterfly)	*Thecla betulae*	●			●	
Chalkhill blue (butterfly)	*Lysandra coridon*		●			
Dark green fritillary (butterfly)	*Argynnis aglaja*		●			
Dingy skipper (butterfly)	*Erynnis tages*	●				
Grayling (butterfly)	*Hipparchia semele*	●				
Grizzled skipper (butterfly)	*Pyrgus malvae*	●				
Heath fritillary (butterfly)	*Melicta athalia*	●		●		
Small blue (butterfly)	*Cupido minimus*	●	● (grey)			
Small heath (butterfly)	*Coenonympha pamphilus*	●				
Wall (butterfly)	*Lasiommata megera*	●				
White admiral (butterfly)	*Ladoga camilla*	●				
White-letter hairstreak (butterfly)	*Strymonidia w-album*	●			●	
August thorn (moth)	*Ennomos quercinaria*	●				
Autumnal rustic (moth)	*Eugnorisma glareosa*	●				
Balsam carpet (moth)	*Xanthorhoe biriviata*			●		
Beaded chestnut (moth)	*Agrochola lychnidis*	●				
Blood-vein (moth)	*Timandra comae*	●				
Brindled beauty (moth)	*Lycia hirtaria*	●				
Broom moth	*Melanchra pisi*	●				
Broom-tip (moth)	*Chesius rufata*	●				
Brown-spot pinion (moth)	*Agrochola litura*	●				
Buff ermine (moth)	*Spilosoma luteum*	●				
Centre-barred sallow (moth)	*Atethmia centrago*	●				
Cinnabar (moth)	*Tyria jacobaeae*	●				
Crescent (moth)	*Celaena leucostigma*	●				
Dark spinach (moth)	*Pelurga comitata*	●				
Dark-barred twin-spot carpet (moth)	*Xanthorhoe ferrugata*	●				
Deep-brown dart (moth)	*Aporophyla lutulenta*	●				
Dot moth	*Melanchra persicariae*	●				
Double dart (moth)	*Graphiphora augur*	●				
Double line (moth)	*Mythimna turca*				●	
Dusky brocade (moth)	*Apamea remissa*	●				
Dusky thorn (moth)	*Ennomos fuscantaria*	●				

Dusky-lemon sallow (moth)	*Xanthia gilvago*	●				
Ear moth	*Amphipoea oculea*	●				
Feathered gothic (moth)	*Tholera decimalis*	●				
Figure-of-eight (moth)	*Diloba caerleocephala*	●				
Flounced chestnut (moth)	*Agrochola helvola*	●				
Forester (moth)	*Adscita statices*	●			●	
Galium carpet (moth)	*Epirrhoe galiata*	●				
Garden dart (moth)	*Euxoa nigricans*	●				
Garden tiger (moth)	*Arctia caja*	●				
Ghost moth	*Hepialus humuli*	●				
Goat moth	*Cossus cossus*	●	○		●	
Grass rivulet (moth)	*Perizoma albulata*	●				
Green-brindled crescent (moth)	*Allophyes oxyacanthae*	●				
Grey dagger (moth)	*Acronicta psi*	●				
Heath rustic (moth)	*Xestia agathina*	●				
Hedge rustic (moth)	*Tholera cespitis*	●				
Knot grass (moth)	*Acronicta rumicis*	●				
Lackey (moth)	*Malacosoma neustria*	●				
Large nutmeg (moth)	*Apamea anceps*	●				
Latticed heath (moth)	*Chiasmia clathrata*	●				
Minor shoulder-knot (moth)	*Brachylomia viminalis*	●				
Mottled rustic (moth)	*Caradrina morpheus*	●				
Mouse moth	*Amphipyra tragopoginis*	●				
Mullein wave (moth)	*Scopula marginepunctata*	●				
Oak hook-tip (moth)	*Drepana binaria*	●				
Oak lutestring (moth)	*Cymatophorima diluta*	●				
Powdered quaker (moth)	*Orthosia gracilis*	●				
Pretty chalk carpet (moth)	*Melanthia procellata*	●				
Rosy minor (moth)	*Mesoligia literosa*	●				
Rosy rustic (moth)	*Hydraecia micacea*	●				
Rustic (moth)	*Hoplodrina blanda*	●				
Sallow (moth)	*Xanthia icteritia*	●				
September thorn (moth)	*Ennomos erosaria*	●				
Shaded broad-bar (moth)	*Scotopteryx chenopodiata*	●				
Shoulder-striped wainscot	*Mythimna comma*	●				
Small emerald (moth)	*Hemistola chrysoprasaria*	●				
Small phoenix (moth)	*Ecliptopera silaceata*	●				
Small square-spot (moth)	*Diarsia rubi*	●				
Spinach (moth)	*Eulithis mellinata*	●				
Sprawler (moth)	*Asteroscopus sphinx*	●				
Star-wort (moth)	*Cucullia asteris*		●		●	
Streak (moth)	*Chesias legatella*	●				
V-moth	*Macaria wauaria*	●				
White ermine (moth)	*Spilosoma lubricipeda*	●				
Horehound long-horn (micromoth)	*Nemophora fasciella*	●			●	
Scarce emerald damselfly	*Lestes dryas*		●	●		
a cardinal click beetle	*Ampedus cardinalis*		●	●		
a false click beetle	*Eucnemis capucina*	○		●		

a wood-boring weevil	*Dryophthorus corticalis*	(●)		●		
a click beetle	*Elater ferrugineus*	(●)		●		
a ground beetle	*Calosoma inquisitor*	●			●	
Poplar leaf-rolling weevil	*Byctiscus populi*	●		●		
Violet oil-beetle	*Meloe violaceus*	●			●	
Streaked bombardier beetle	*Brachinus sclopeta*	●		●		
Saltmarsh shortspur (beetle)	*Anisodactylus poeciloides*	●		●		
Stag beetle	*Lucanus cervus*	●			●	●
Brown-banded carder bee	*Bombus humilis*	●				●
Long-horned mining bee	*Eucera longicornis*	●			●	
Sea-aster Colletes (bee)	*Colletes halophilus*	●			●	
Shrill carder bee	*Bombus sylvarum*	●			●	
Five-banded tailed digger wasp	*Cerceris quinquefasciata*	●		●		
Black-backed meadow ant	*Formica pratensis*	●		●		
Southern wood-ant	*Formica rufa*	●				
Southern yellow splinter (a cranefly)	*Lipsothrix nervosa*	●				
Hornet robber-fly	*Asilus crabroniformis*	●			●	
Phoenix (a picture-winged) fly	*Dorycera graminum*	●		●		
Duffey's bell-head spider	*Baryphyma duffeyi*	●		●		
Serrated tongue-spider	*Centromerus serratus*	●			●	
a spider	*Ero aphana*		●	●		
Depressed river mussel	*Pseudanodonta complanata*	●			●	
Desmoulin's whorl-snail	*Vertigo moulinsiana*	●			●	
German hairy snail	*Perforatella rubiginosa*			●		
Little whirlpool ram's-horn snail	*Anisus vorticulus*	●		●		
Swollen spire snail	*Pseudamnicola confusa*	●	(●)	●		
Thames/two-lipped door snail	*Laciniaria biplicata*			●		
Birds				Red	Am ber	
Bittern	*Botaurus stellata*	●		●		
Black redstart	*Phoenicurus ochrurus*		●		●	(●)
Bullfinch	*Pyrrhula pyrrhula*	●		●		
Corn bunting	*Miliaria calandra*	●		●		
Cuckoo	*Cuculus canorus*	●			●	
Dunnock	*Prunella modularis*	●			●	
Grasshopper warbler	*Locustella naevia*	●	(●)	●		
Grey partridge	*Perdix perdix*	●		●		
Hawfinch	*Coccothraustes coccothraustes*	●			●	
Herring gull	*Larus argentatus*	●			●	
House sparrow	*Passer domesticus*	●		●		●
Lapwing	*Vanellus vanellus*	●			●	
Lesser redpoll	*Carduelis flammea*	●			●	
Lesser spotted woodpecker	*Dendrocopos minor*	●		●		
Linnet	*Carduelis cannabina*	●		●		
Marsh tit	*Parus palustris*	●	(●)	●		
Marsh warbler	*Acrocephalus palustris*	●		●		
Peregrine	*Falco peregrinus*		●		●	(●)
Reed bunting	*Emberiza schoeniclus*	●		●		
Sand martin	*Riparia riparia*		●		●	●

Skylark	*Alauda arvensis*	●		●		
Song thrush	*Turdus philomelos*	●		●		
Spotted flycatcher	*Muscicapa striata*	●		●		
Starling	*Sturnus vulgaris*	●		●		
Tree pipit	*Anthus trivialis*	●		●		
Tree sparrow	*Passer montanus*	●		●		
Turtle dove	*Streptopelia turtur*	●		●		
Wood warbler	*Phylloscopus sibilatrix*	●			●	
Yellow wagtail	*Motacilla flava*	●			●	
Yellowhammer	*Emberiza citrinella*	●	● (grey)	●		
Reptiles, Amphibians, Mammals & Fish						
Adder	*Vipera berus*	●	● (grey)			●
Common lizard	*Lacerta vivipara*	●				●
Common toad	*Bufo bufo*	●				
Grass snake	*Natrix natrix*	●	● (grey)			●
Slow-worm	*Anguis fragilis*	●	● (grey)			●
Great crested newt	*Triturus cristatus*	●				
Brown hare	*Lepus europaeus*	●				
Brown long-eared bat	*Plecotus auritus*	●	● (grey)			●
Common dormouse	*Muscardinus avellanarius*	●				
Common pipistrelle (bat)	*Pipistrellus pipistrellus*	● (grey)				●
Daubenton's bat	*Myotis daubentoni*		●			●
Harvest mouse	*Micromys minutus*	●				
Hedgehog	*Erinaceus europaeus*	●				
Leisler's bat	*Nyctalus leisleri*		●		●	●
Nathusius' pipistrelle (bat)	*Pipistrellus nathusii*		●	●		●
Natterer's bat	*Myotis nattereri*		●			●
Noctule (bat)	*Nyctalus noctula*	●	● (grey)			●
Otter	*Lutra lutra*	●				
Serotine (bat)	*Eptesicus serotinus*		●		●	●
Soprano pipistrelle (bat)	*Pipistrellus pygmaeus*	●				●
Water vole	*Arvicola terrestris*	●				●
Whiskered & Brandt's bats	*Myotis mystacinus, M.brandtii*		●			●
Atlantic salmon	*Salmo salar*	●				
European eel	*Anguilla anguilla*	●				
River lamprey (fish)	*Lampetra fluviatilis*	●				
Sea lamprey (fish)	*Petromyzon marinus*	●				
Smelt (fish)	*Osmerus eperlanus*	●	● (grey)			
Sea/Brown trout	*Salmo trutta*	●				
Twaite shad (fish)	*Allosa phallax*	●				

● (grey) = reviewed status

Appendix 2B: London Priority Habitats

The habitats listed below are those which are of most importance in a London context by virtue of their rarity, vulnerability or overall conservation value because of their extent or benefits they provide. Woodlands, for example, are particularly important in an urban context.

Chalk grassland
Chalk grassland develops on shallow lime-rich soils that are nutrient-poor and free draining. They support a wide array of wildflowers, butterflies, grasshoppers and other invertebrates, many of which are restricted to chalk soils. Examples - Farthing Down; Hutchinson's Bank

Acid grassland
Acid grasslands are found on free-draining sands and gravels that are low in nutrients. They usually contain a limited range of fine-leaved grasses and wildflowers that support a distinctive group of insects and other invertebrates. Examples - Richmond Park; Wanstead Flats.

Heathland
Heathland is found on free-draining acid soils that are low in nutrients. It consists characteristically of a mix of tussocky grasses and dwarf shrubs such as heather, broom and gorse. Areas of bare ground may also be present, as well as boggy areas and small pools where the ground is locally wetter. Examples - Wimbledon Common; Hounslow Heath.

Woodland
Woodlands are areas dominated by trees where there is near complete canopy cover over much of the site. Ancient woodland – areas that have been continually wooded for over 400 years - are a particular priority as they support the most rare and vulnerable species and are irreplaceable. Examples - Oxleas Wood; Sydenham Hill Woods.

Orchards
Orchards are areas of land which have been planted with fruit trees, usually apples, but sometimes with other fruiting trees such as plum, and occasionally with nut-bearing trees such as hazel. Old orchards with mature trees are particularly valuable from a nature conservation perspective as they often support rare invertebrate species. Examples – Claybury Park; Bethlem Royal Hospital.

Meadows
Meadows are areas of grassland that are infrequently mown or lightly grazed that contain a wide variety of native wildflowers within the sward. Meadows provide important habitat and foraging and for a wide range of butterflies, bees and grasshoppers, and for small mammals such as field voles. Examples - Frays Farm Meadows; Totteridge Fields.

Rivers & streams (including Tidal Thames)
Rivers and streams are areas of free-flowing water within a channel. In urban areas many of the channels have been straightened, embanked or piped. Though same areas of natural channel still exist and are being re-established through river restoration initiatives. Examples - River Wandle; River Crane.

Standing water
Standing water comprises London's lakes, reservoirs and ponds. Examples - Walthamstow Reservoirs; Hampstead Heath Ponds.

Reedbeds
Reedbeds are areas of shallow water dominated by a tall wetland grass – common reed. Reedbeds occur at the margins of all kinds of waterbodies and slow moving rivers, and in other areas where the ground lies wet for most of the year. Examples – Ingrebourne Marshes; London Wetland Centre.

Coastal and floodplain grazing marsh
Areas of grassland dissected by freshwater or saline ditches. This habitat also includes the small areas of saltmarsh found in London. Examples – Rainham Marshes; Crayford Marshes.

Open Mosaic habitats
Open Mosaic habitats exist where plants and animals have colonised bare ground resulting from quarrying; historic land-fill; or abandonment of previously developed land. They often contain rare or unusual assemblages of species and micro-habitats because of the variable and often extreme conditions in which they occur. Examples – Barking Riverside; Braeburn Park Nature Reserve.

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