MAYOR OF LONDON

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 Organisation 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 Organisation, identified PM emitted from diesel engines as a "group I carcinogen" meaning that a causal relationship has been established between exposure to 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.

[1] World Health Organisation, "Review of evidence on health aspects of air pollution – REVIHAAP Project Technical Report" (2013). 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
[4] International Agency for Research on Cancer, Monographs vol. 105 "Diesel and gasoline engine exhausts and some nitroarenes". Accessed from: http://monographs.iarc.fr/ENG/Monographs/vol105/mono105.pdf

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 objective 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 Organisation also publishes "guideline values", while 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 WHO guideline values are summarised in Table 1.

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

Pollutant	UK Objective/ EU Limit	Averaging Period	World Health Organisation guideline
Nitrogen dioxide (NO_2)	200 µg/m³ not to be exceeded more than 18 times a year	1-hour mean	200 µg/m³
	40 µg/m³	Annual mean	40 µg/m³
Particulate Matter (PM_{10})	50 µg/m³ not to be exceeded more than 35 times a year	24-hour mean	50 µg/m³
	40 µg/m³	Annual mean	20 µg/m³
Particulate Matter ($PM_{2.5}$)	25 µg/m³ And a duty to work towards reducing emissions/ concentrations of fine particulate matter ($PM_{2.5}$)	Annual mean	10 µg/m³
Ozone (O_3)	100 µg/m³, not to be exceeded more than 10 times a year	8-hour mean	100 µg/m³
Sulphur dioxide (SO_2)	266 µg/m³ not to be exceeded more than 35 times a year	15-minute mean	500 µg/m³ (10-minute mean)
	350 µg/m³ not to be exceeded more than 24 times a year	1-hour mean	-

[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 Organisation, "WHO Air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide Global update 2005" (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 (source:			
Pollutant	**UK Objective/ EU Limit**	**Averaging Period**	**World Health Organisation guideline**
	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.

The air quality policies in this strategy therefore concentrate on nitrogen dioxide and particulate matter.

Monitoring air quality

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

There have 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 organisations 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.

[8] Department for the Environment Food and Rural Affairs (Defra), "Air Pollution in the UK 2015" (2016). Accessed from: https://uk-air.defra.gov.uk/library/annualreport/
[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

Previous targets and achievements against them

It is helpful to understand the targets included in the previous Mayor's Air Quality Strategy (MAQS) to review previous policies and outline what actions now need to take place to improve London's air quality.

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 limits for PM_{10} were legally achieved but were not for NO_2.

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

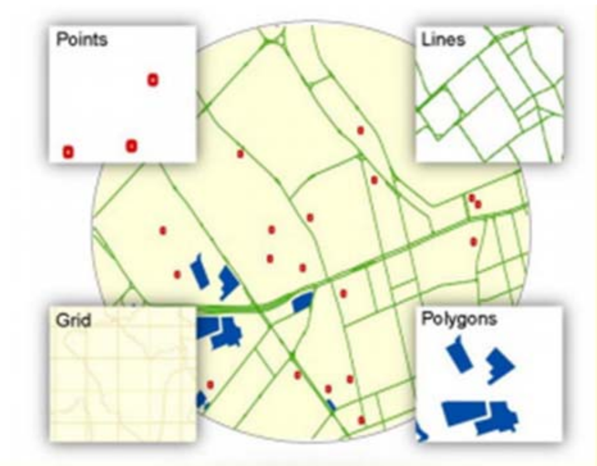
The LAEI provides an analytical evidence base, essential for strategy and policy development and planning for London. The primary functions of the inventory are strategic emissions modelling, concentrations modelling, and air quality mapping.

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 Process 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, 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 1 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)

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 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.

[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

Box 1: 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 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 will refer both to concentrations and emissions.

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.

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.

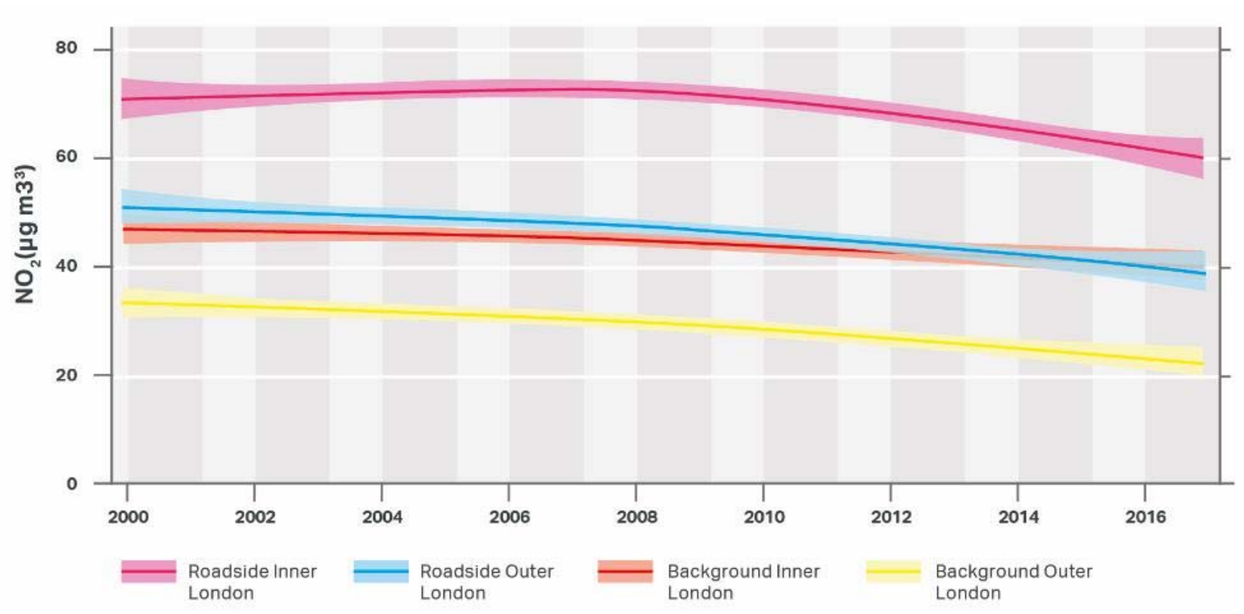
Trends in London's pollution concentrations

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.

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



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

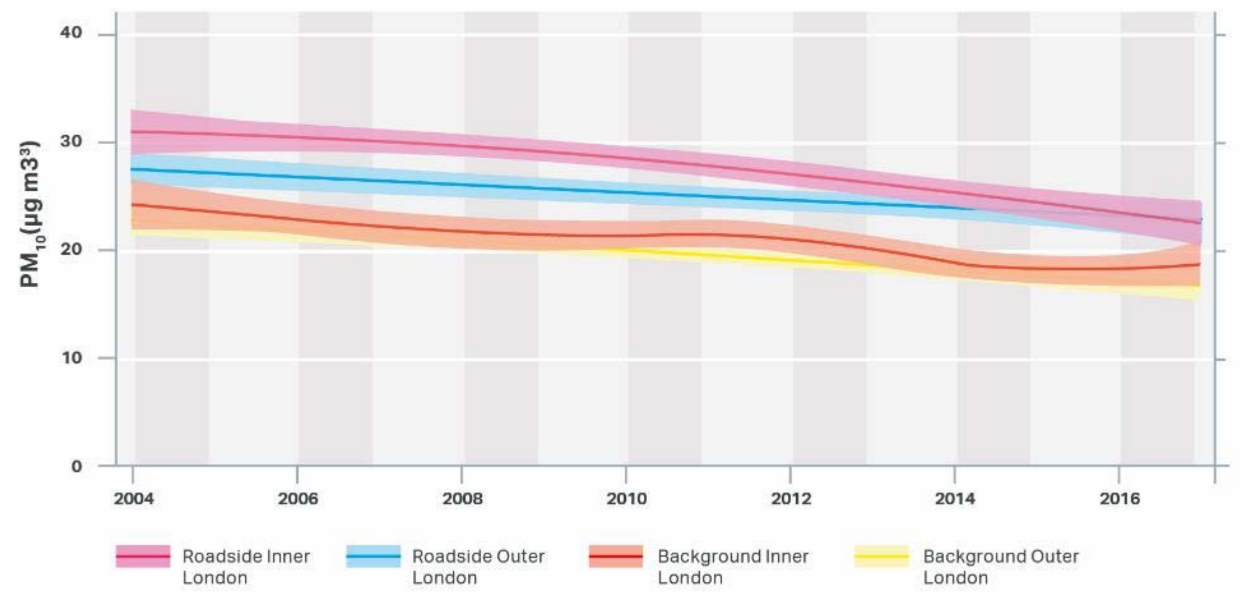
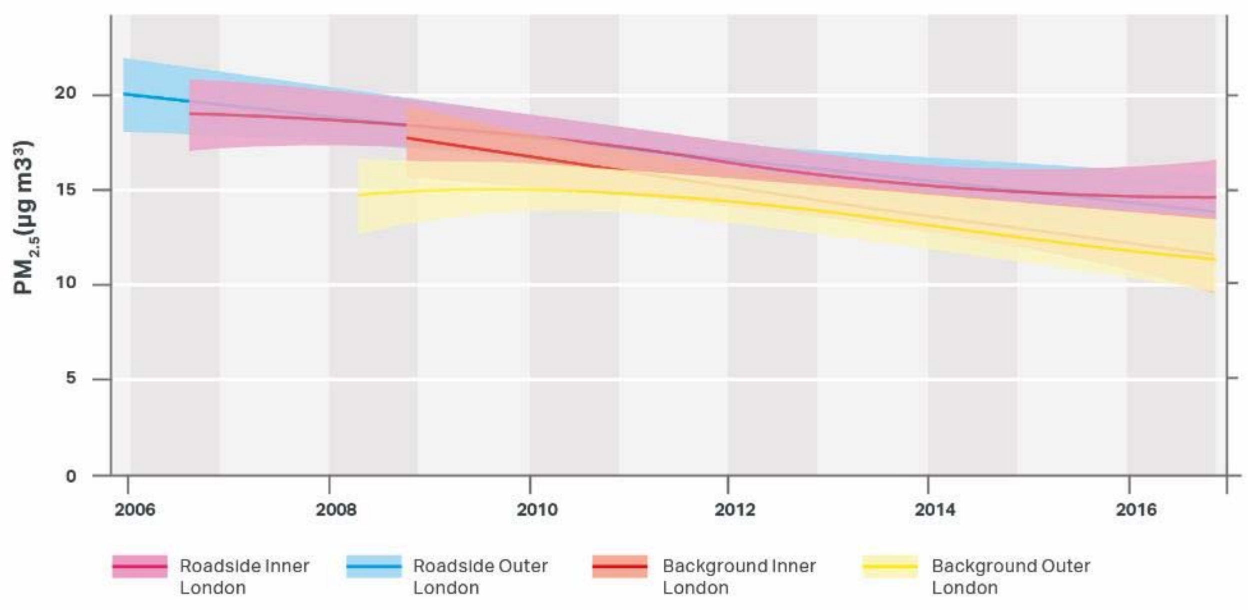


Figure 4: Trends in $PM_{2.5}$ in London – 2006[15] to 2016 (source: the London Air Quality Network and analysis by King's College London)



[15] Due to monitoring methodological changes, a time series can only be derived for $PM_{2.5}$ from 2006

These reductions are important as they show, overall, that air quality is improving in London – albeit not quickly enough. While the vast majority of roads in London met the PM_{10} EU annual mean limit value of 40 µg/m^3 in 2013, these 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.

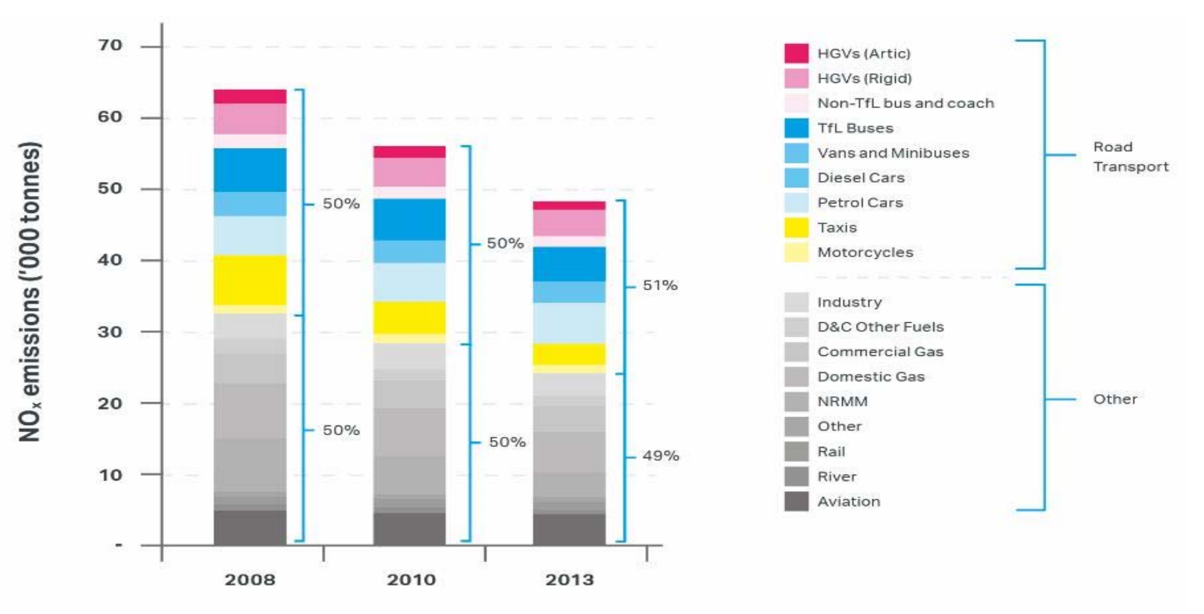
Trends in London's pollution emissions[16]

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, versus 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



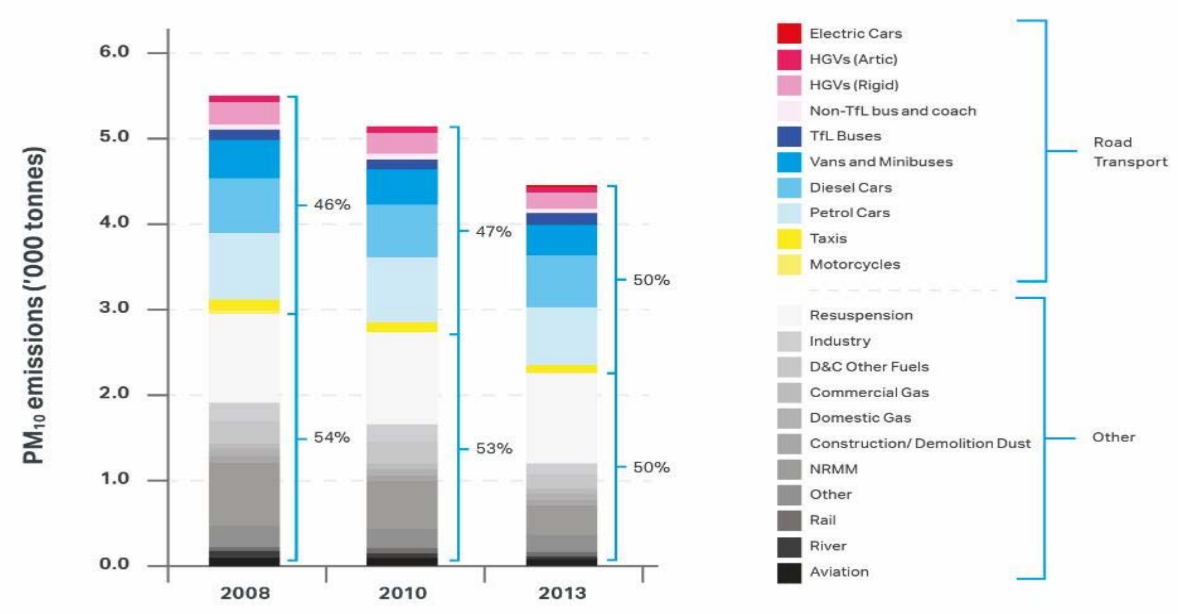
PM_{10} (all sources)

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.

16 Data for emissions quantities are taken from the LAEI 2013.

Total PM_{10} emissions fell by 20 per cent over the period 2008 to 2013, versus 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

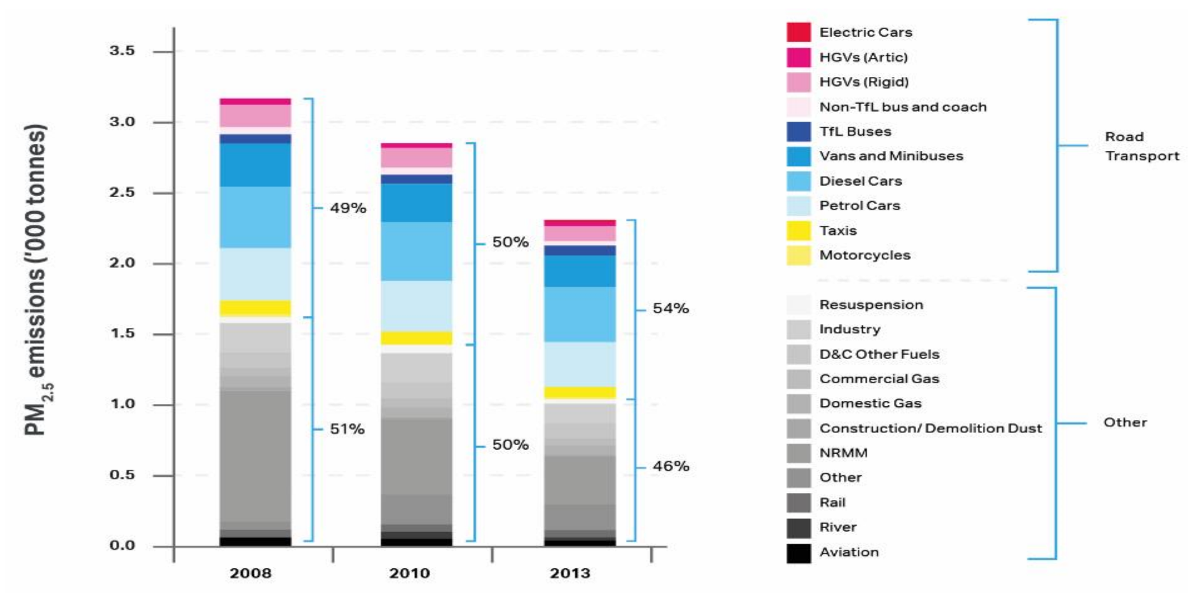


$PM_{2.5}$ (all sources)

Total $PM_{2.5}$ emissions fell by 27 per cent over the period 2008 to 2013, there was no reduction target in the previous air quality strategy (Figure 7).

The source of $PM_{2.5}$ emissions in London is similar to that 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.

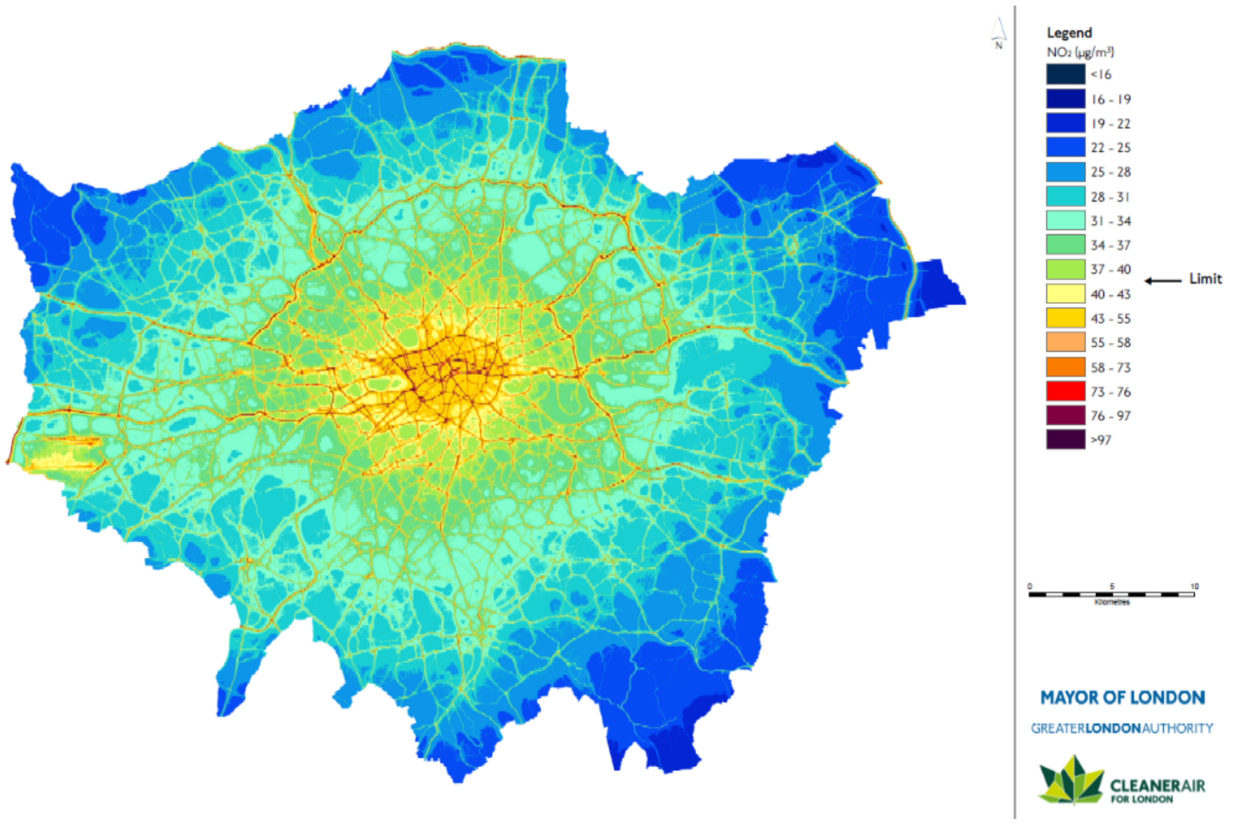
The following air quality concentration maps have been validated against real world monitoring data and indicate the geographical extent of exceedances of the limit values and can be used to determine the exposure of the local population.

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 gives us 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 (source: London Atmospheric Emissions Inventory via London Datastore)[17]

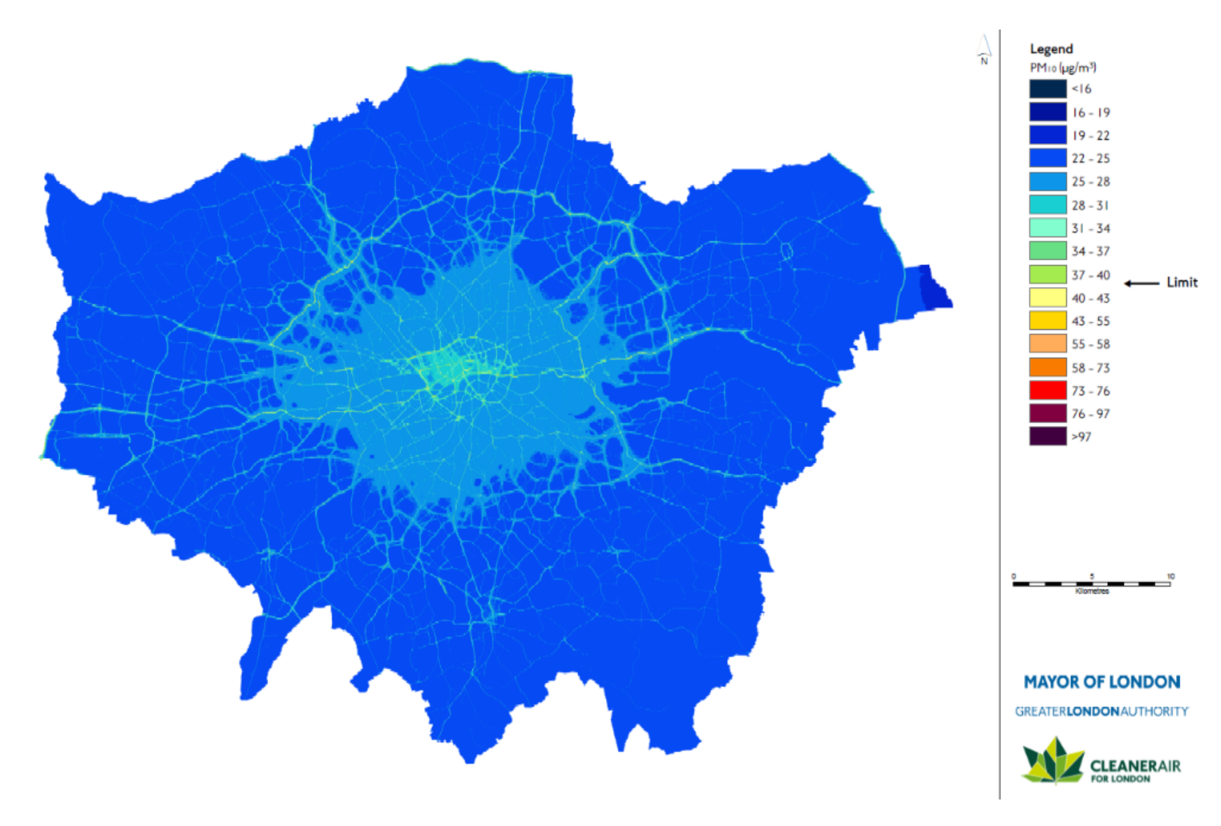


[17] GLA (2016), LLAQM bespoke borough by borough 2013 air quality modelling and data. Accessed from: https://data.london.gov.uk/dataset/llaqm-bespoke-borough-by-borough-air-quality-modelling-and-data

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 (source: London Atmospheric Emissions Inventory via London Datastore)[18]

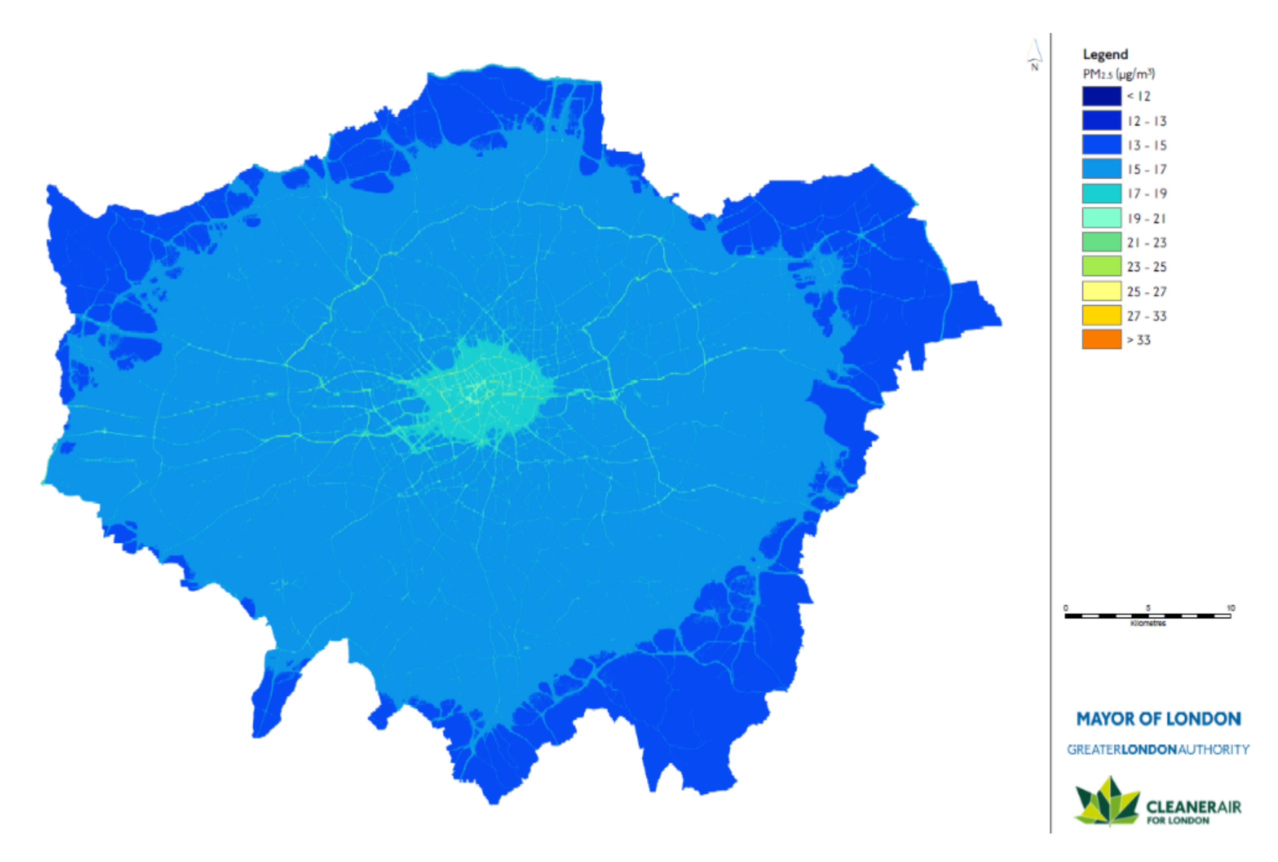


[18] *ibid*

$PM_{2.5}$ concentrations

The EU has set a target value of no more than 25 µg/m^3 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 World Health Organisation recommends a limit of 10 µg/m^3 based on the evidence from health effects (Figure 10).

Figure 10: 2013 - Annual mean $PM_{2.5}$ concentrations (source: London Atmospheric Emissions Inventory via London Datastore)[19]



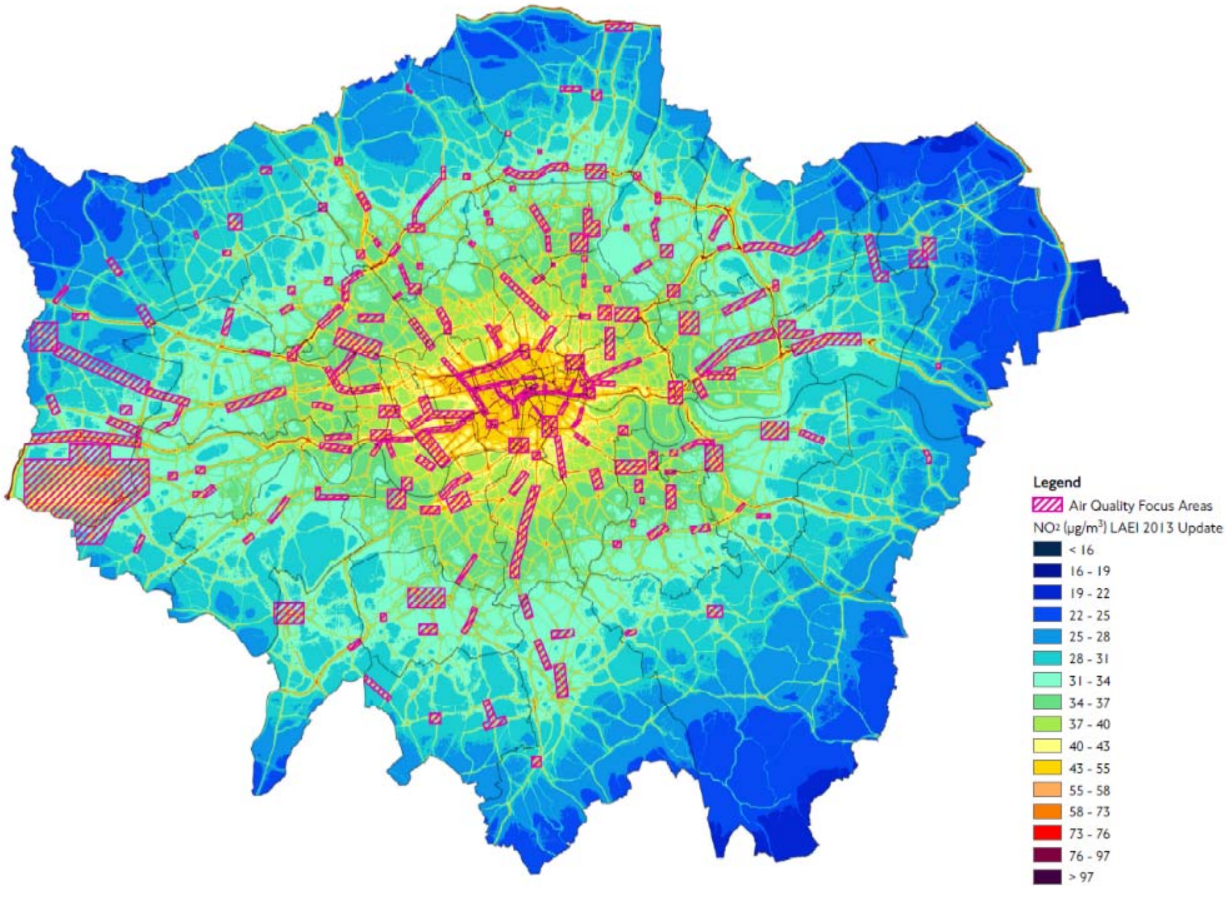
[19] *ibid*

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.

By considering the outputs of the LAEI and modelling on a smaller scale and combining them with other data sets, such as population data[20]. It 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).

Figure 11: Air Quality 'Focus Areas', based on 2013 LAEI



The Focus Areas will continue to be updated and redefined on the basis of the outputs from the latest updates to the LAEI. They are not an exhaustive definition of air quality 'hotspots', but give a good overview of the locations where action should be focused. It is likely that the location and size of the Air Quality Focus Areas will change over the lifetime of this strategy, the most up to date list will always be available on the London Datastore.

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

[20] 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

developing proposals to improve air quality these areas are prioritised where possible. One example of this is Low Emission Bus Zones.

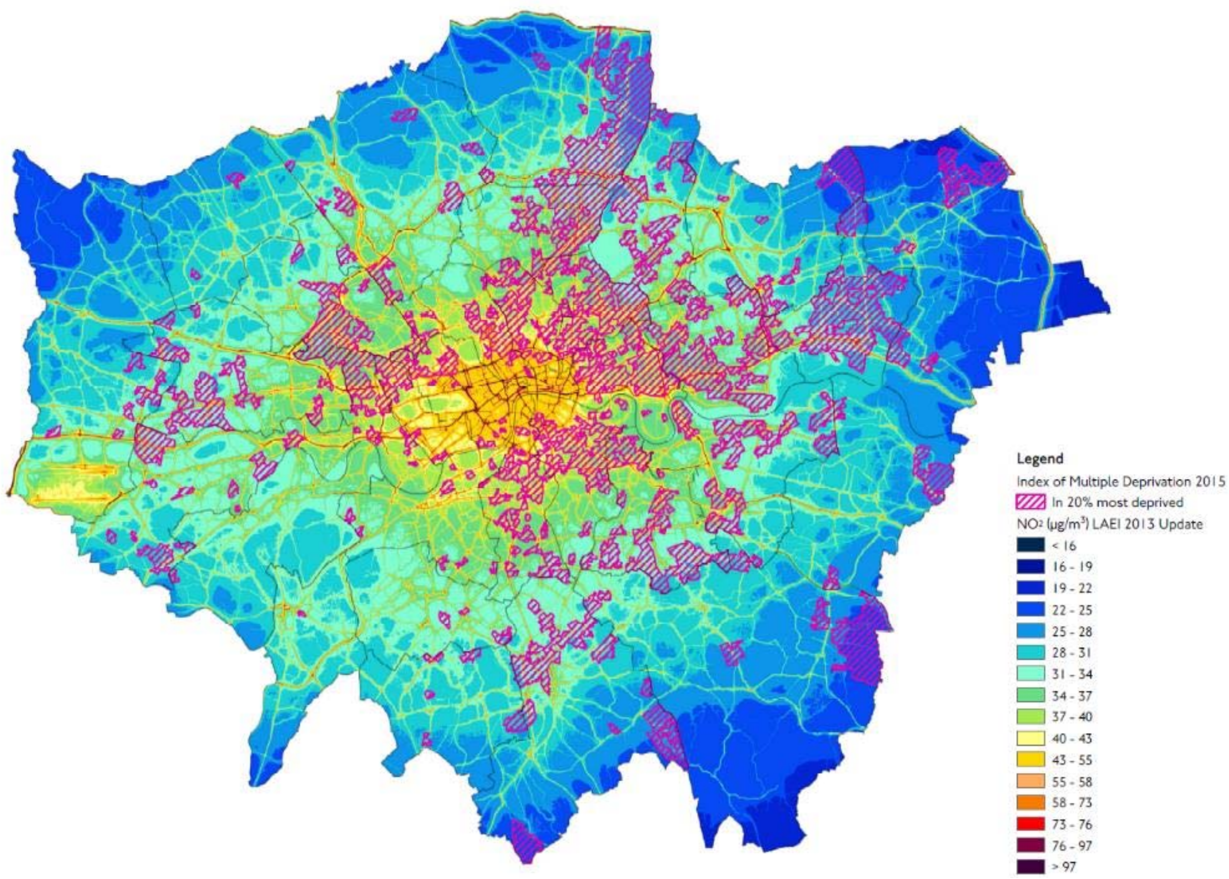
Air quality and deprivation

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[21].

Figure 12 shows the top 20 per cent of the most deprived areas (based on indices of multiple deprivation[22]) 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



[21] 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
[22] 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 often more vulnerable to the effects of air pollution, at the same time as being 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 because 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 draft London Environment Strategy. As a result, part of the benefits attributable to the strategy are actually captured in the baseline.

This section and the numbers within it may be revised in the final version of the London Environment Strategy, following the results of further modelling work. All figures and graphs should be considered interim.

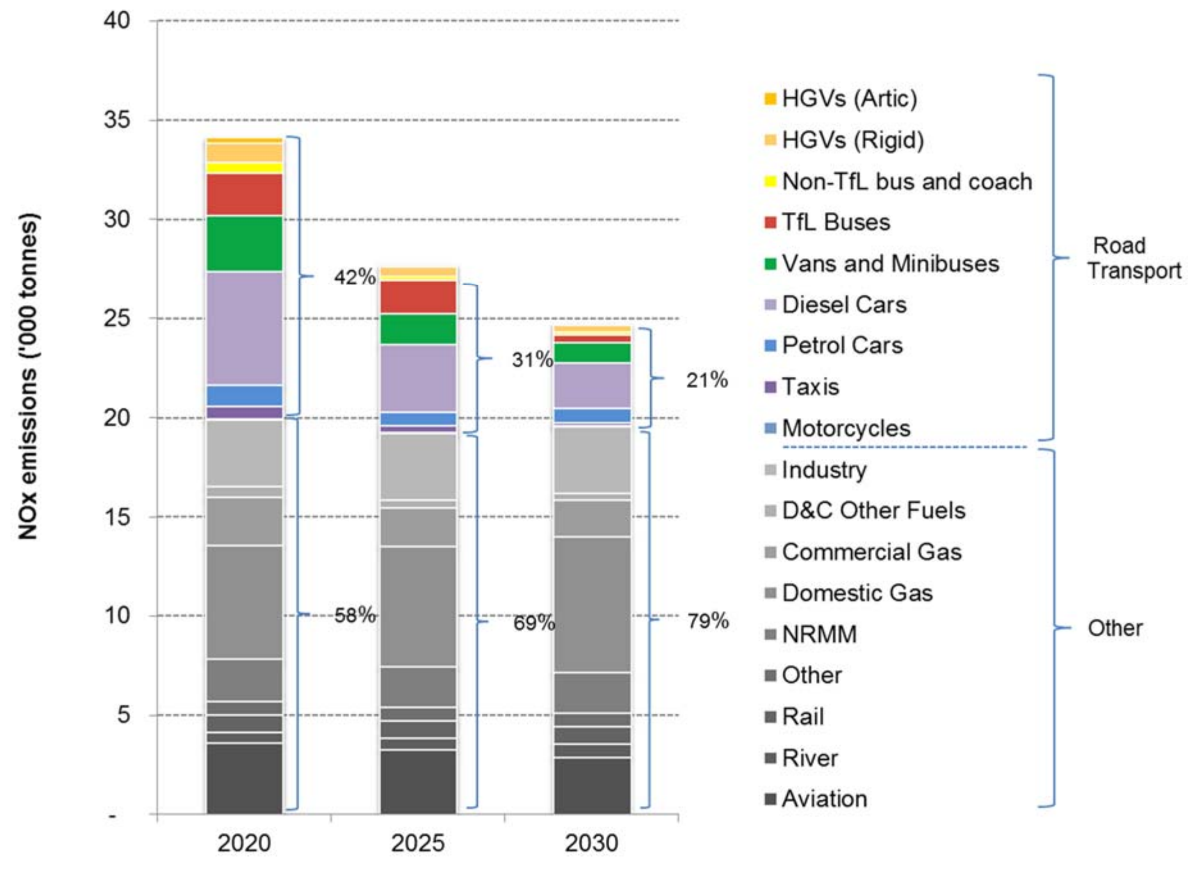
Trends in overall emissions

Total NO_x Emissions

Against 2013, NO_x emissions are expected to fall by 29 per cent to 2020, 42 per cent to 2025 and 49 per cent to 2030.

Projected reductions in NO_x emissions are most significant in the period leading up to 2025 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 transport emissions by around 20 per cent) to encourage their early uptake (Figure 13).

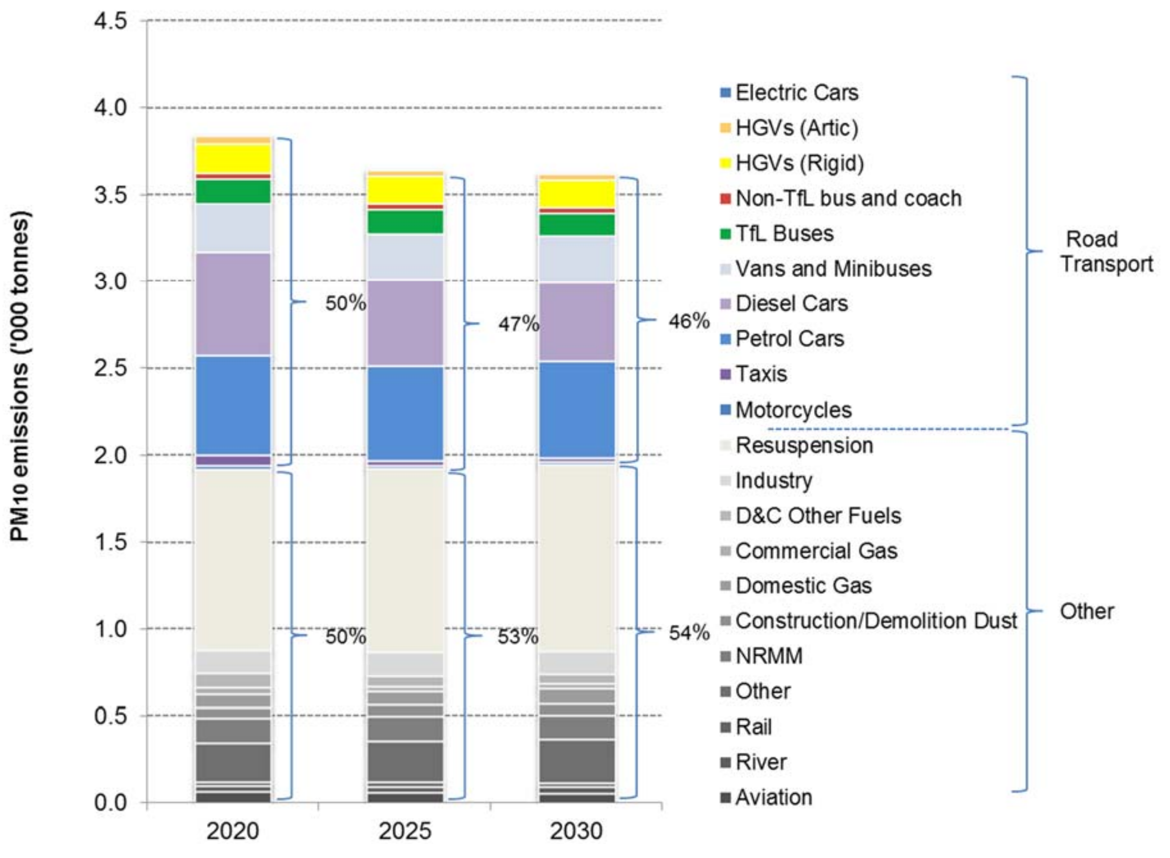
Figure 13: Emissions trend and main source categories, 2020-2030 – NO_x



Total PM_{10} Emissions

Emissions of PM_{10} are expected to fall by 13 per cent (compared to 2013) up to 2020, mainly due to reductions in road transport emissions and significant reductions in Non-Road Mobile Machinery (NRMM) emissions. Emissions are expected to fall by 18 per cent to 2025, and then level out towards 2030 (Figure 14).

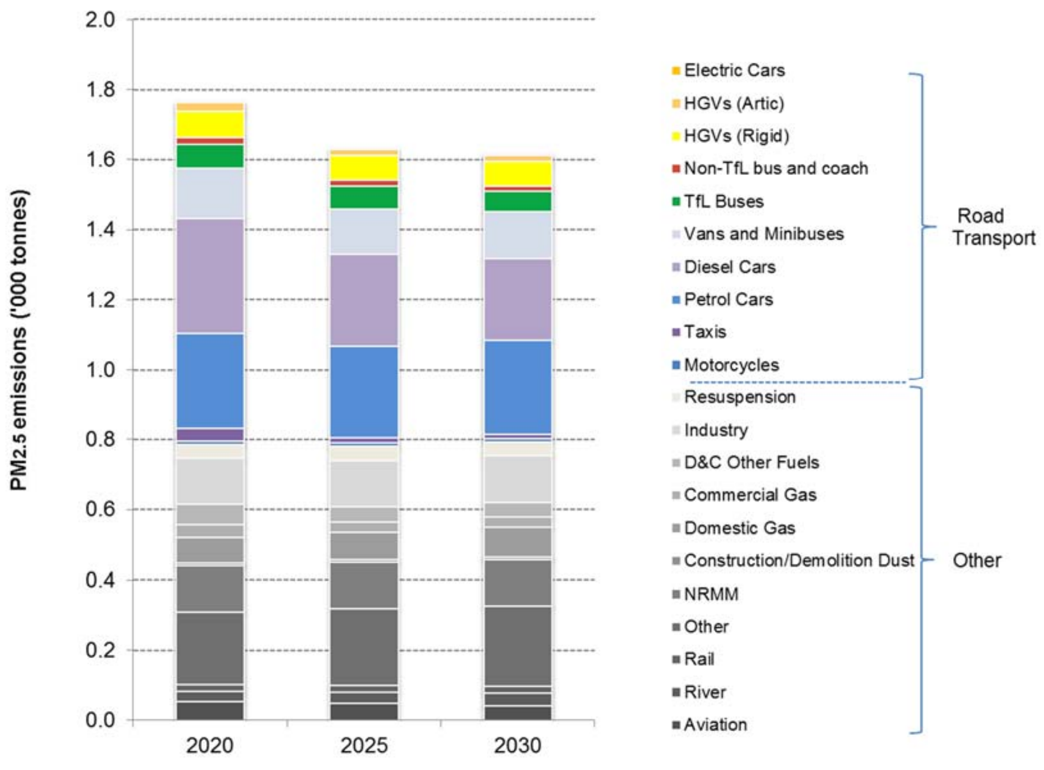
Figure 14: Emissions trend and main source categories, 2020-2030 – PM_{10}



Total $PM_{2.5}$ Emissions

Against 2013, $PM_{2.5}$ emissions are expected to fall by 23 per cent up to 2020. This figure is helped by significant reductions in non-road mobile machinery (NRMM) emissions. Small reductions are then expected to be made up to 2025 (29 per cent reduction compared to 2013) and then level out towards 2030 (Figure 15).

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



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.

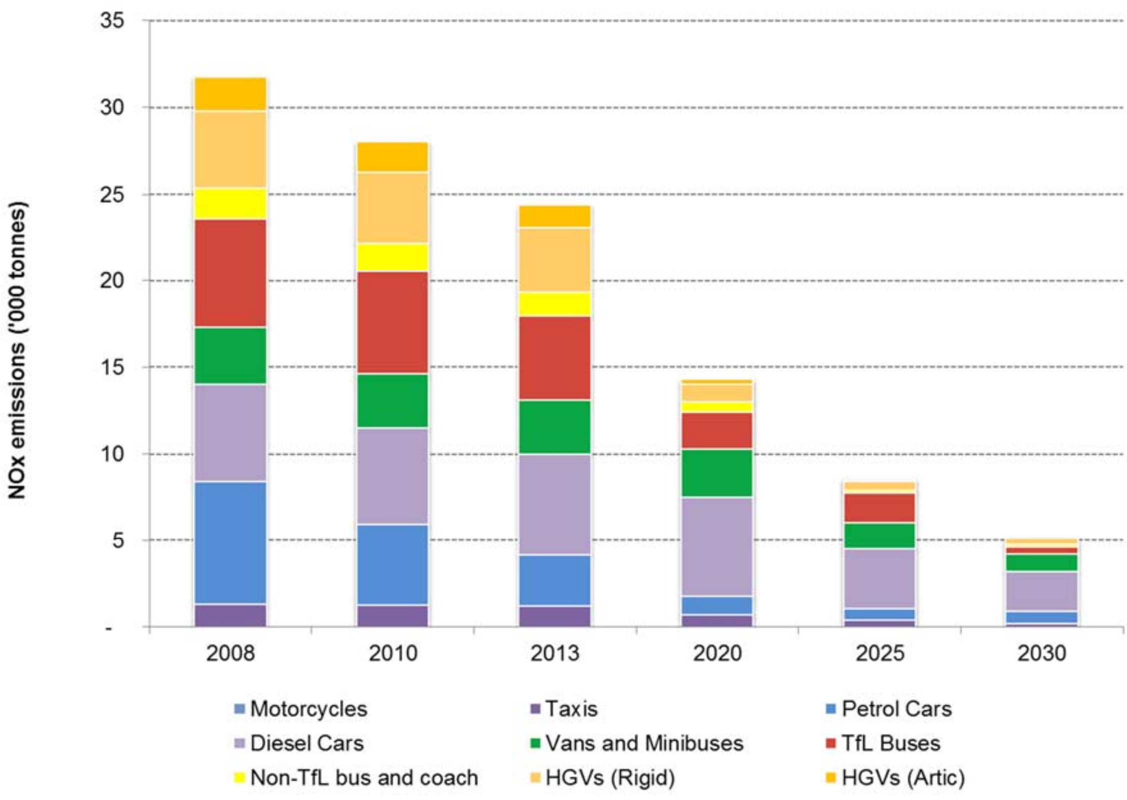
Road transport NO_x Emissions

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.

Little reduction in emissions from cars is 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 – NO_x



Breaking down emissions into vehicle types in different areas of London illustrates the impact of diesel cars across Greater London, which is overtaken by buses in central London in 2013 and by taxis in 2020 (Figure 17 and Figure 18).

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

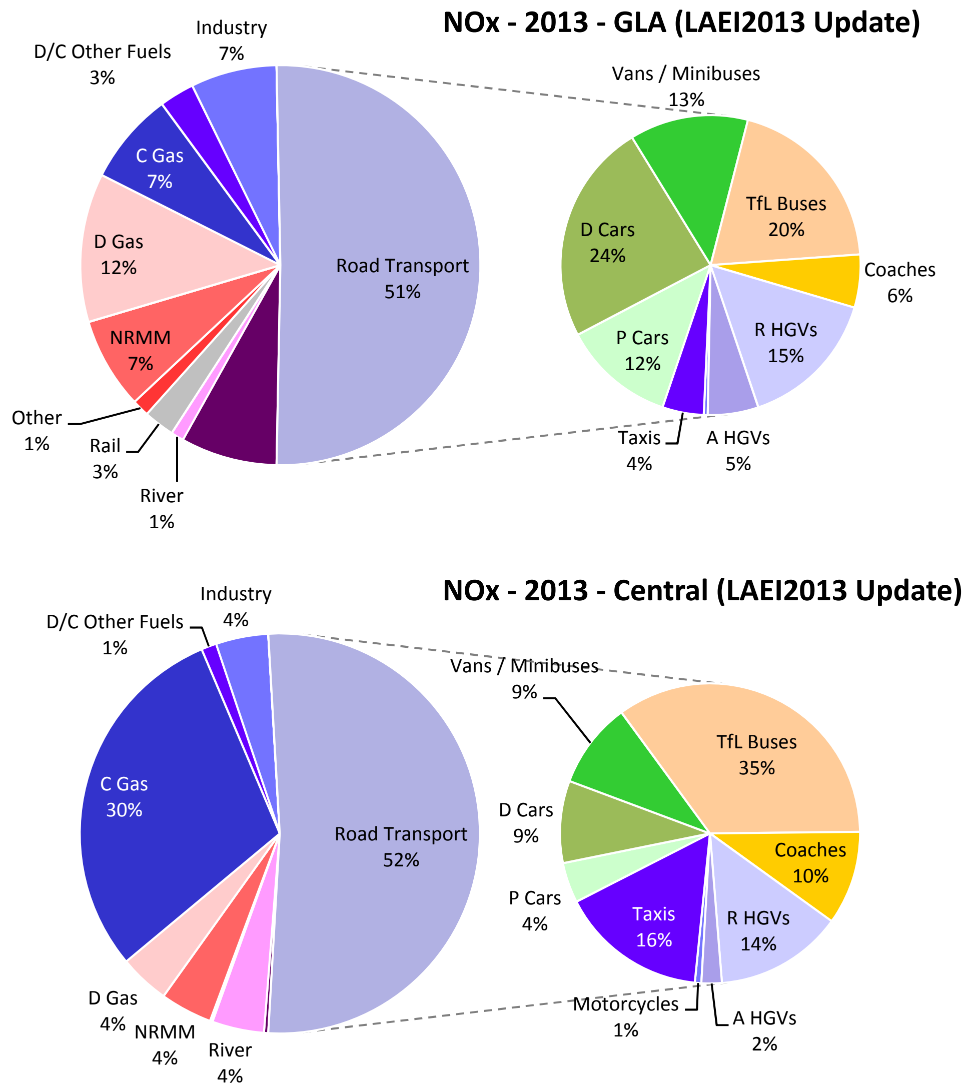
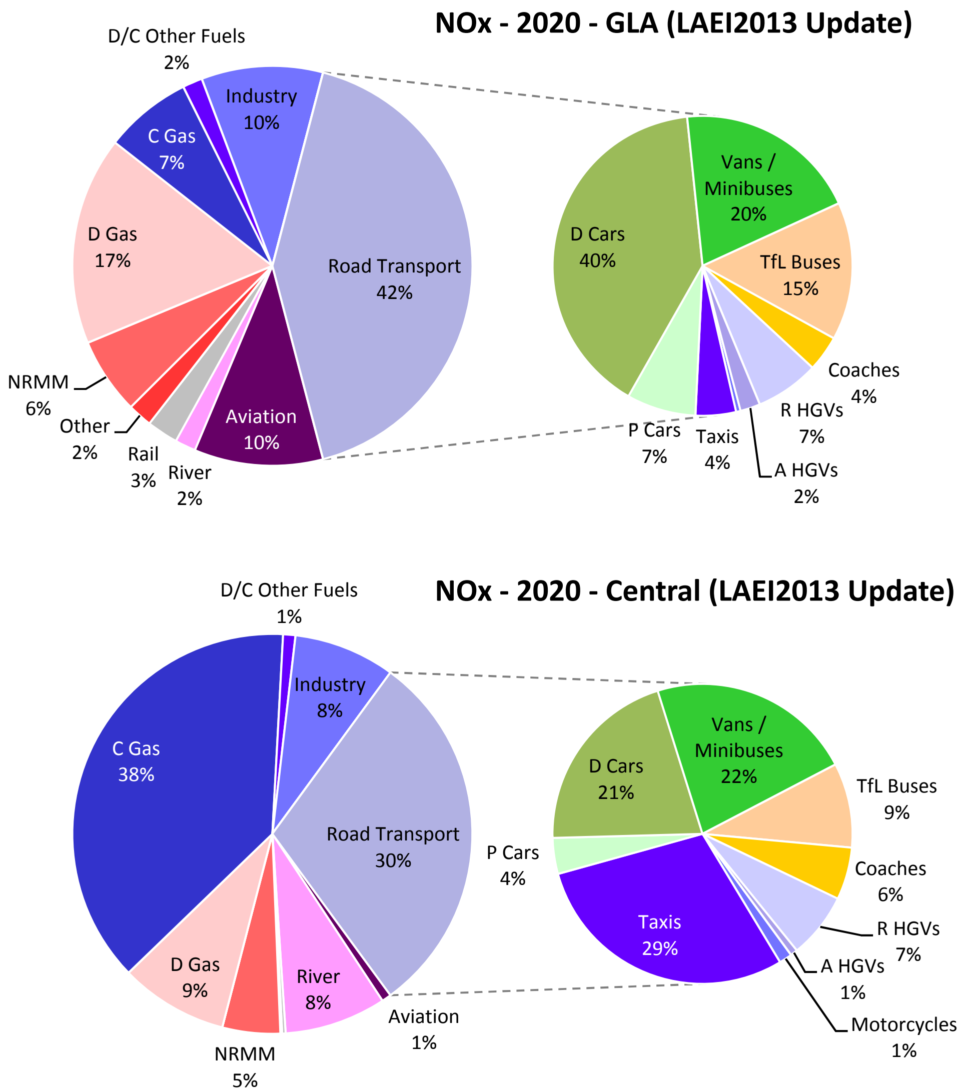


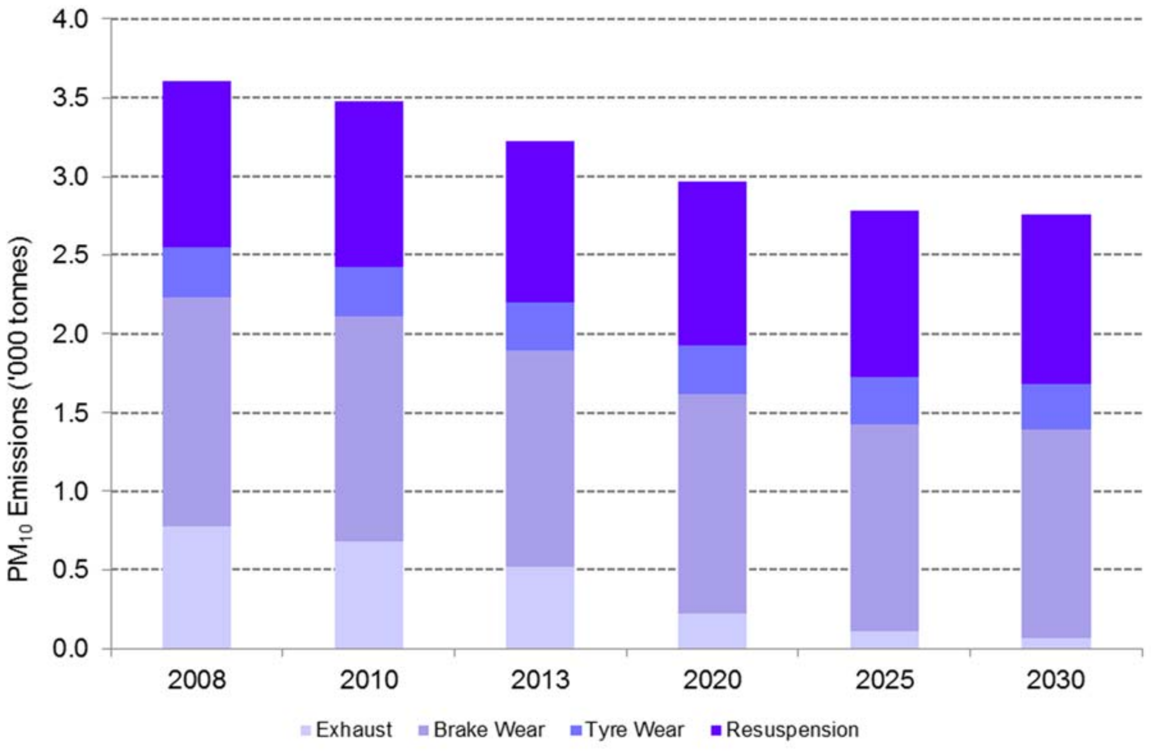
Figure 18: Comparative NO_x emissions by source for 2020 – Greater London and central London compared



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 re-suspension components of PM_{10} remain (Figure 19).

Figure 19: Trend in emissions from road transport – PM_{10}



By 2030, PM_{10} exhaust emissions should be about 10 per cent of 2008 exhaust emissions. However, from 2025, total PM_{10} emissions should level out due to these non-exhaust contributions. Currently, reductions in vehicle kilometres provide the main mechanism to reducing non-exhaust contributions over time e.g. 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

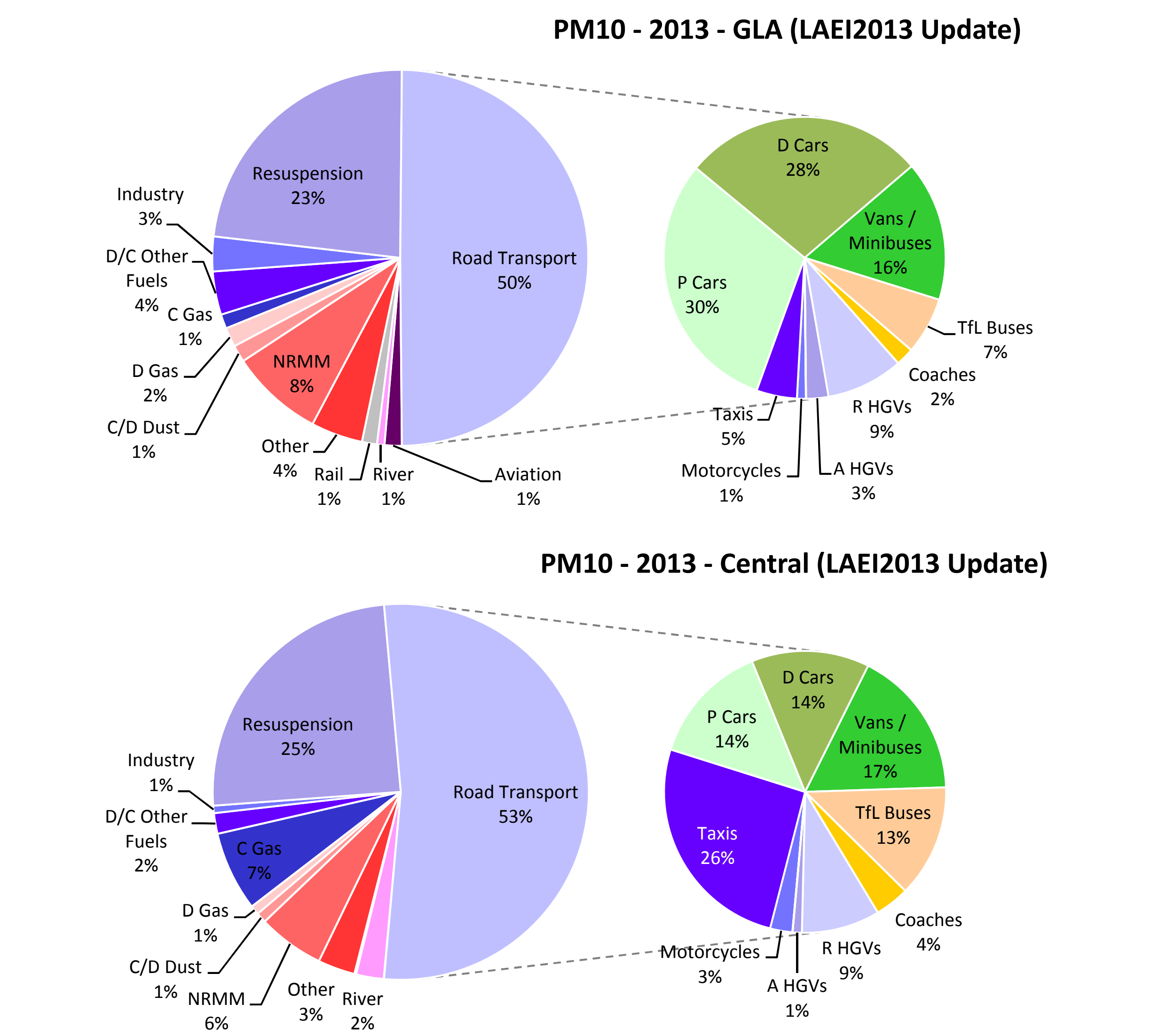
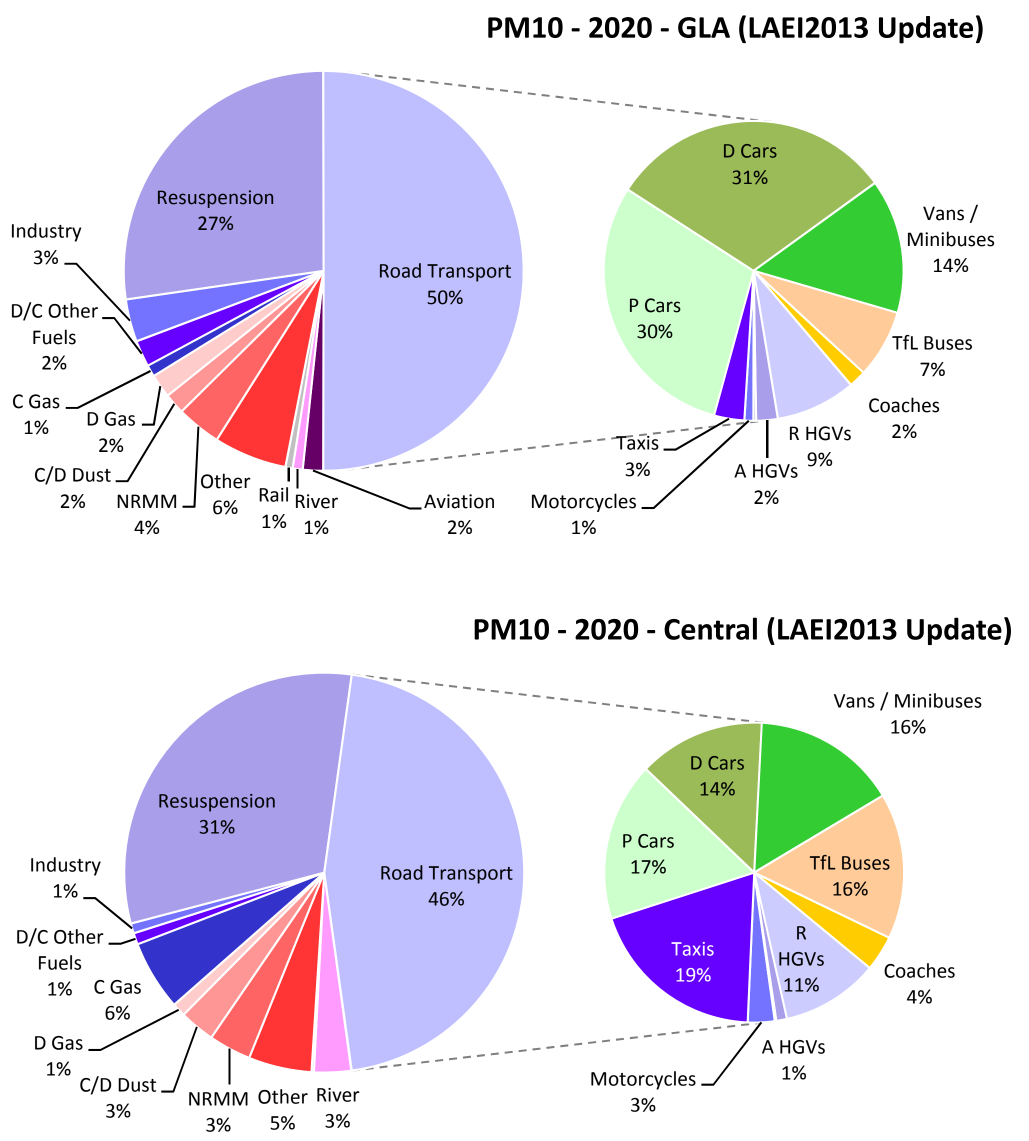


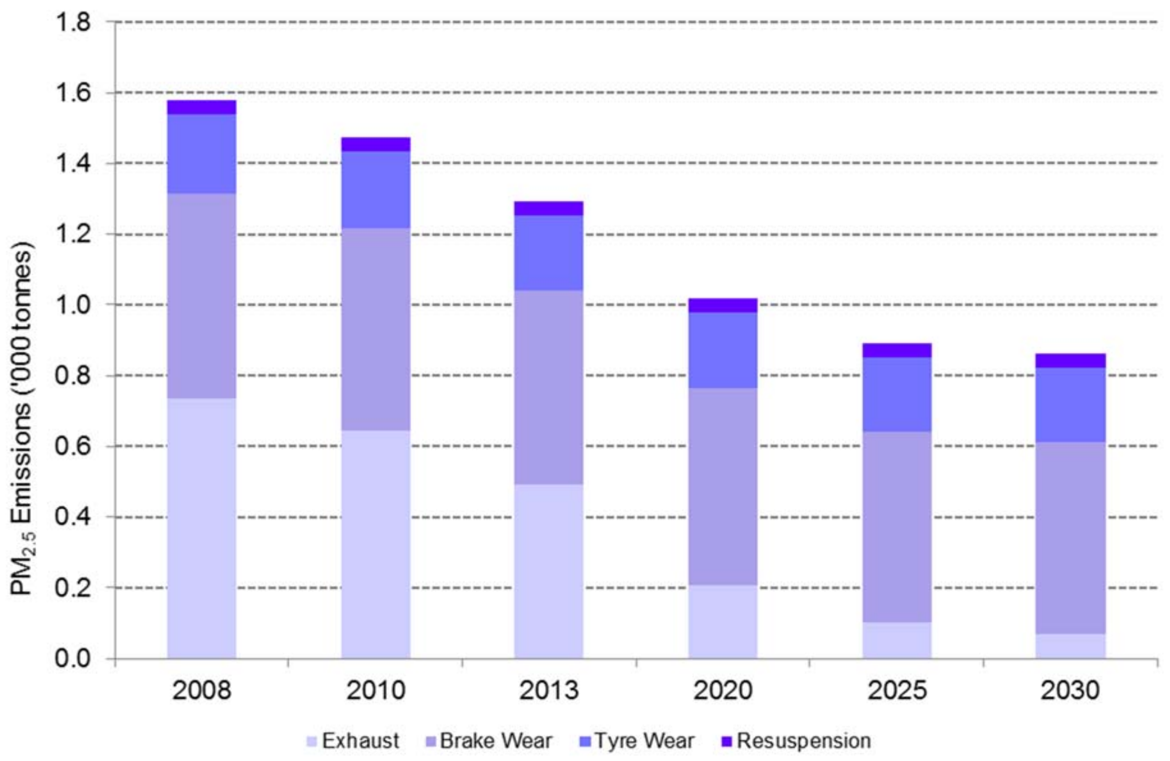
Figure 21: Comparative PM_{10} emissions by source for 2020 – Greater London and central London compared



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 2030 and 2008. 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 – $PM_{2.5}$



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

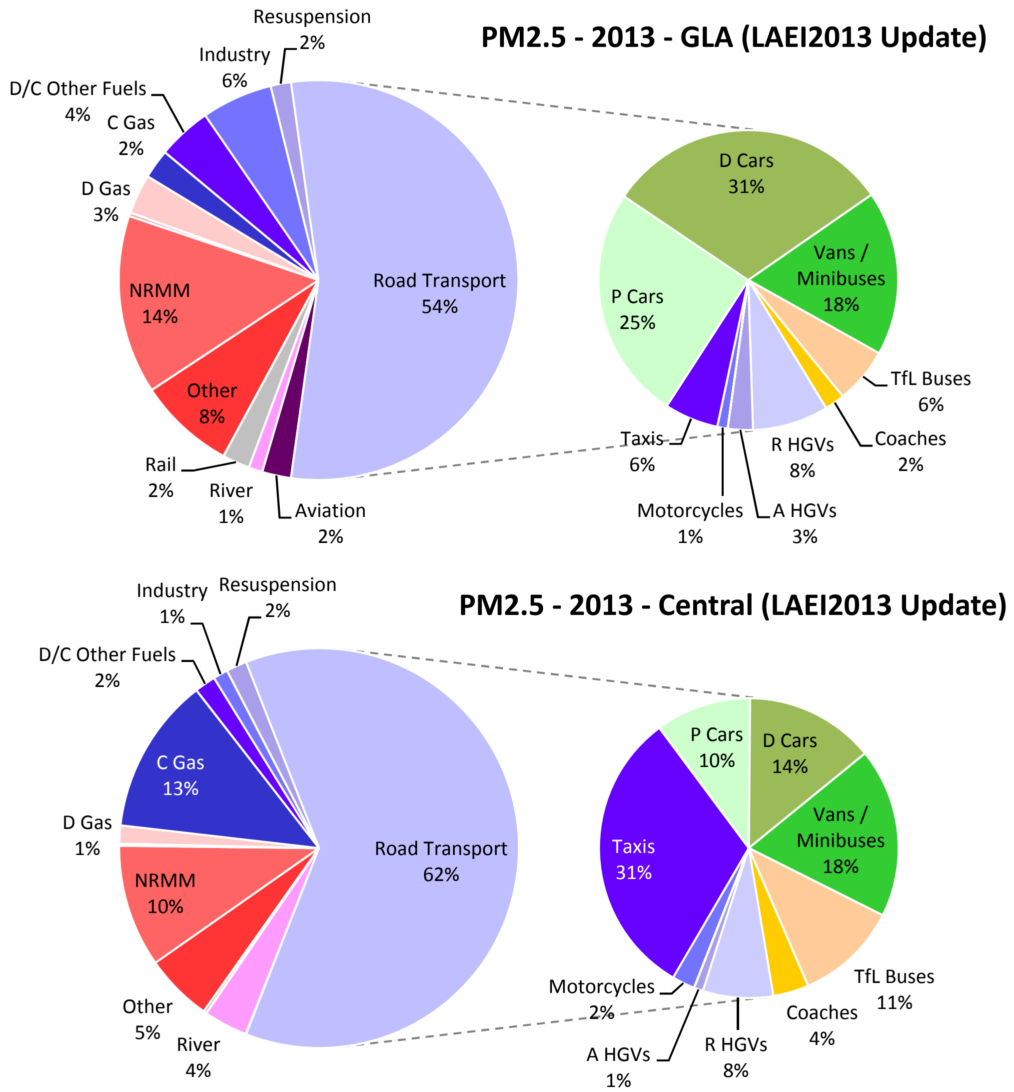
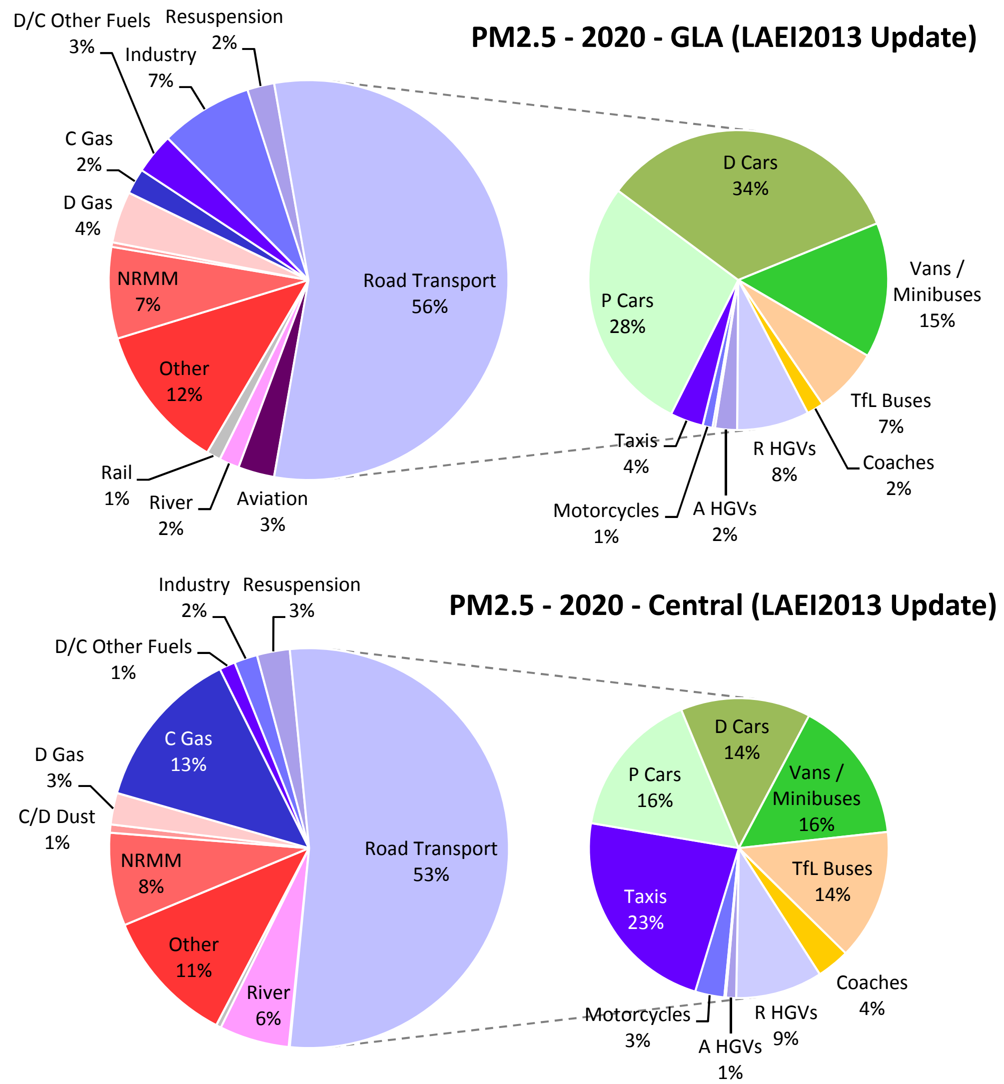


Figure 24: Comparative $PM_{2.5}$ emissions by source for 2020 – Greater London and central London compared



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 42 per cent, whilst other sources make up 58 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. The Strategy sets out additional powers required for this action to be taken by the Mayor and others.

Figure 25: Trend in emissions from non-transport – NO_x

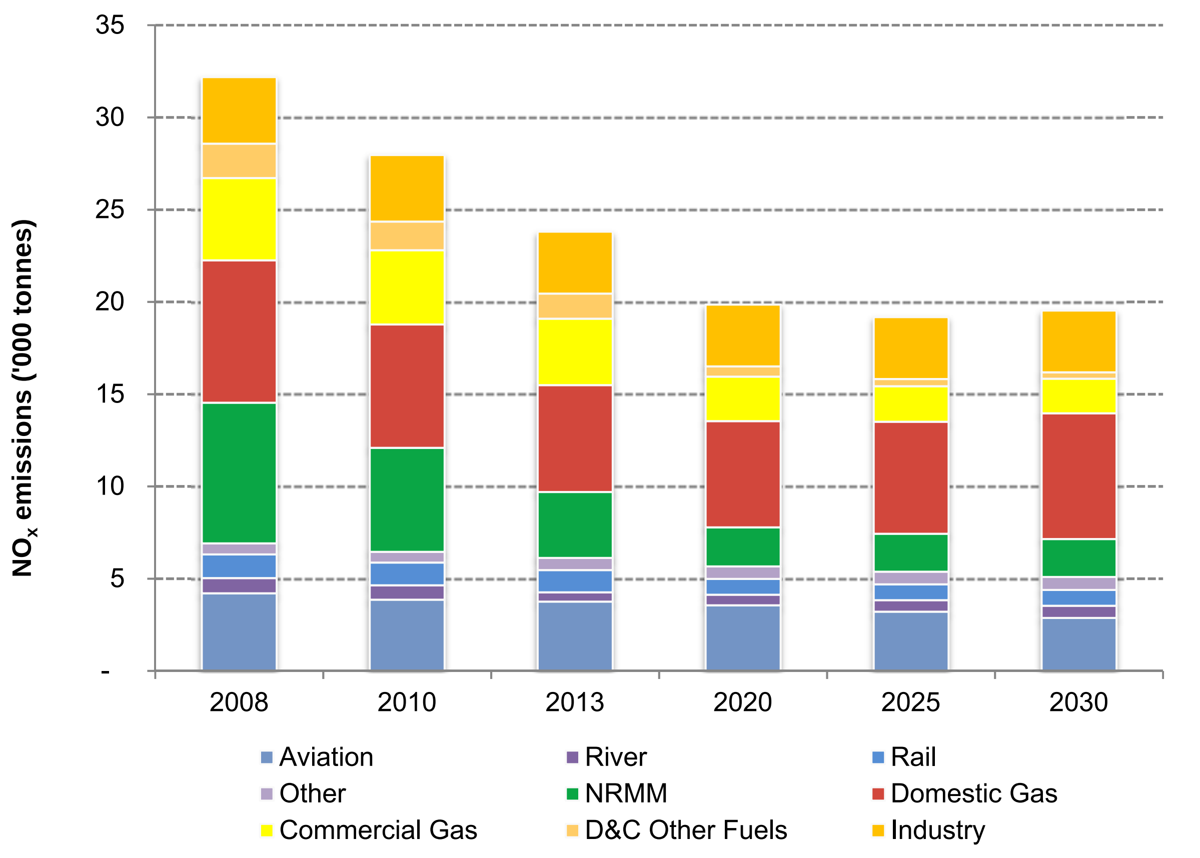


Figure 26: Trend in emissions from non-transport – PM_{10}

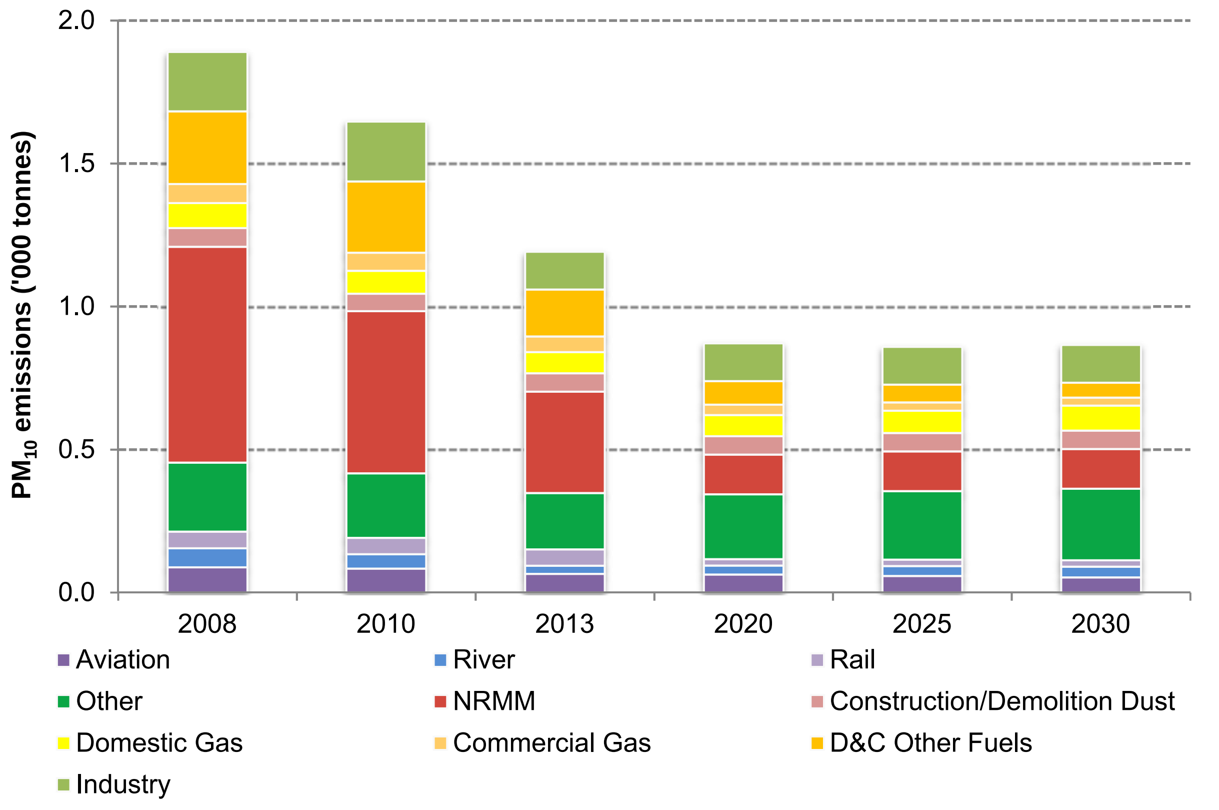
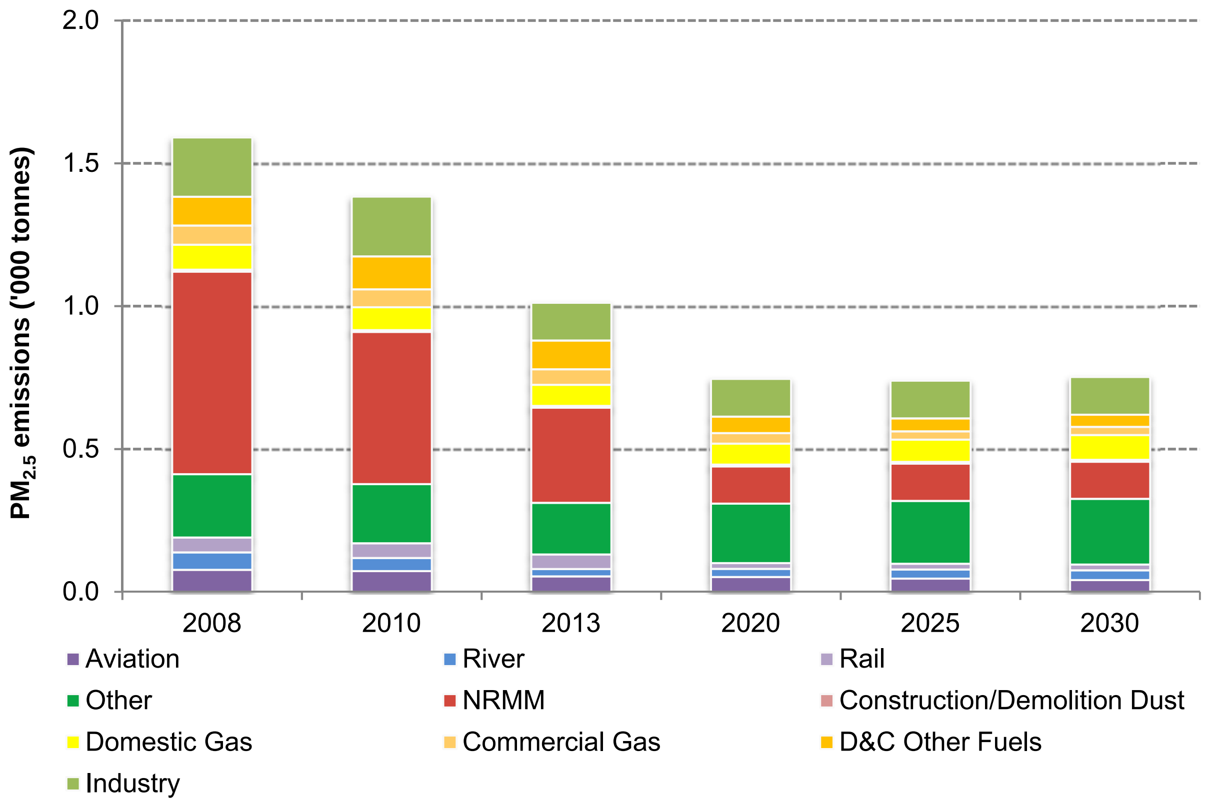


Figure 27: Trend in emissions from non-transport – $PM_{2.5}$



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 reach the expected emission reductions. In part, this was due to the underperformance of Euro engine emissions standards. Targets in this 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. Rather than a return to petrol, mode shift to sustainable forms of transport like walking and cycling wherever possible should be encouraged. Any vehicles that remain will need to transition to zero emission technology.

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 our efforts 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 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. Conversely, integrated policy design can bring benefits for both air quality and climate change, for example, by reducing black carbon emissions by switching to zero emission vehicles.

Further reductions are needed in PM_{10} and $PM_{2.5}$, particularly from transboundary pollution, tyre and brake wear and wood burning
Progress in dealing with PM emissions will stall in 2020 once exhaust emissions are significantly reduced. London is currently far from achieving WHO health-based limits for $PM_{2.5}$. One of the best ways to do this would be to reduce the number of vehicle kilometres by supporting a mode shift to walking, cycling and public transport. It will also 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

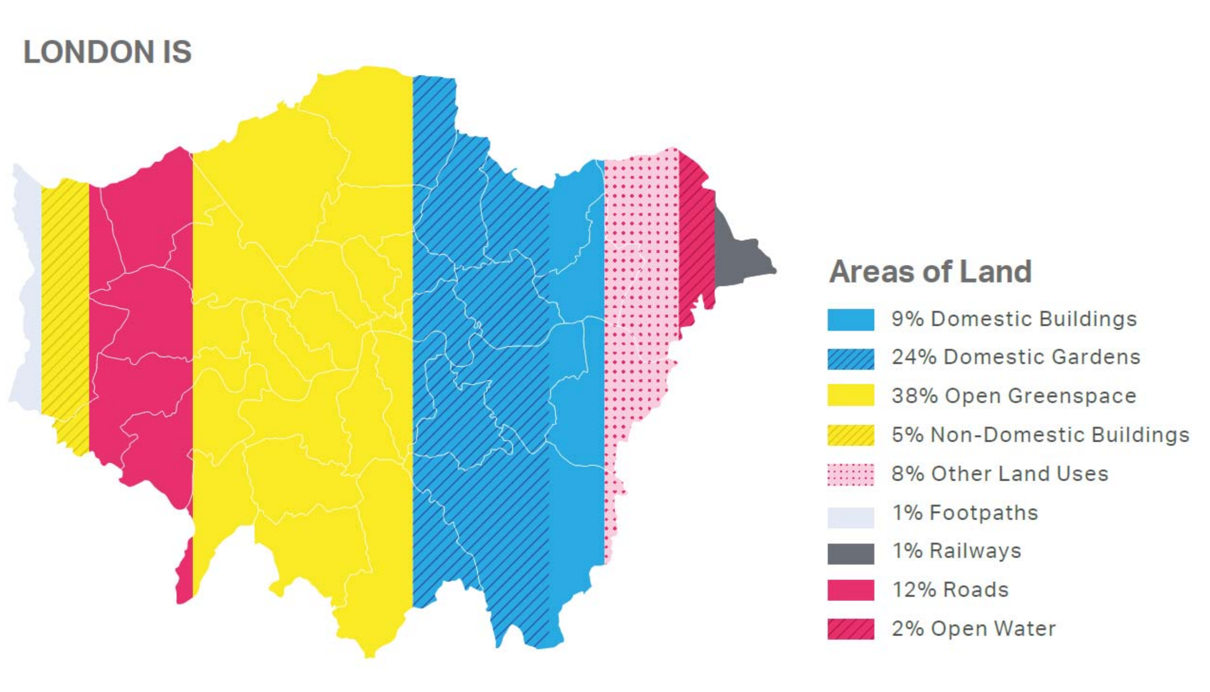
A green city

Currently, about 47 per cent of London is classified as open, green space (Figure 28). This includes parks, gardens, natural habitats, river, lakes and reservoirs, woodland and farmland. 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 London since then.

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.

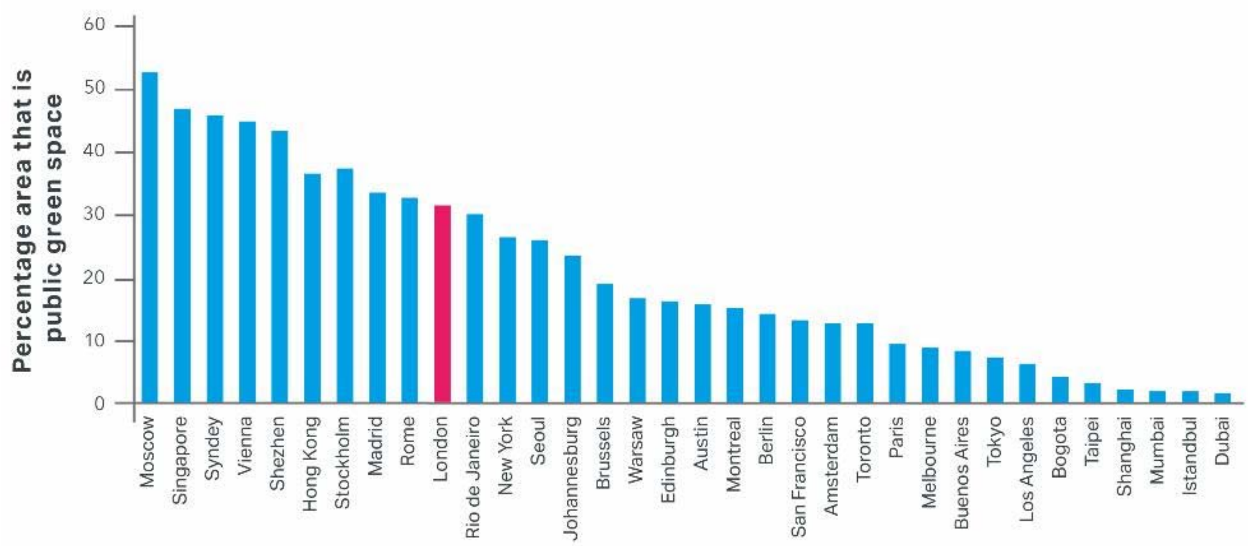
Figure 28: Relative area of land cover in London (source: a Fatuous Maps infographic for the Greater London National Park City Initiative)

N.B. the actual area of land in London which is green is 47 per cent. This is because 14 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 compares favourably with other world cities with respect to the amount of green space per head of population (Figure 29). 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 29: Percentage of green space in different world cities



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: Canopy cover in major UK cities

Public open space	Area (ha)	Percentage of Greater London (per cent)
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), and those which Londoners often value most, are the trees that line London’s streets.

The total area of canopy cover has remained relatively static since 2002. 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. The slight variation in numbers of trees or percentage of canopy cover is within any standard error caused by the assessment methodologies.

An assessment undertaken by Forest Research suggests that the majority of cities in the UK have 16-21 per cent canopy cover (Table 4). 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 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
Sheffield	16.2 (± 1.25)	i-Tree Canopy	2016
York	9.8 (± 1.33)	i-Tree Canopy	2016

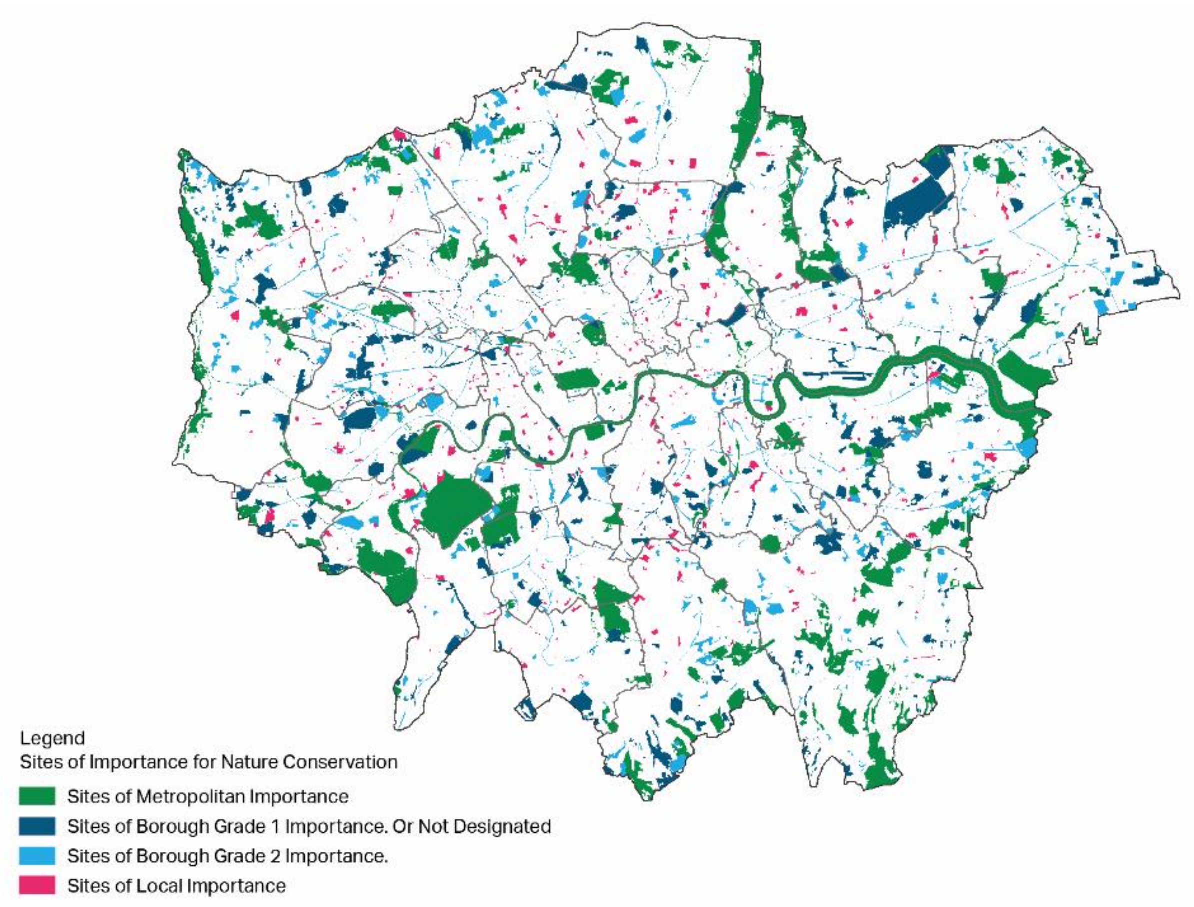
European and national nature conservation designations

London's most important sites for nature conservation have been recognised at the European and national level and consequently have been given a statutory designation. They include two Special Protection Areas (SPAs), three Special Areas of Conservation (SACs), two National Nature Reserves (NNRs) and 30 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 Policy 7.19 of the London Plan. 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 30). The total area of SINCs has increased slightly since 2002 increasing from a total of 29,855 hectares to 30,679 hectares.

Figure 30: 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.

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 land-cover figures published in the Biodiversity Strategy and current land-cover figures. 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. 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	Biodiversity Strategy (2002)	GiGL data	Per cent of London's area
Gardens	34,584ha (total area)	22,000ha (vegetated area)	22 total or 14 vegetated
SINC	29,855ha	30,679ha (2013 data)	19
Woodland	7,200ha	7,500ha (2009-10 data)	5
Chalk grassland	300ha	300ha (2009-10 data)	0.2
Reedbed	125ha	140ha (2009-10 data)	0.1
Acid grassland	1300ha	1,450ha (2009-10 data)	0.9
Heathland	80ha	55ha[23] (2009-10 data)	>0.1

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.

[23] 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.

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. The study shows that between 1999 and 2007:

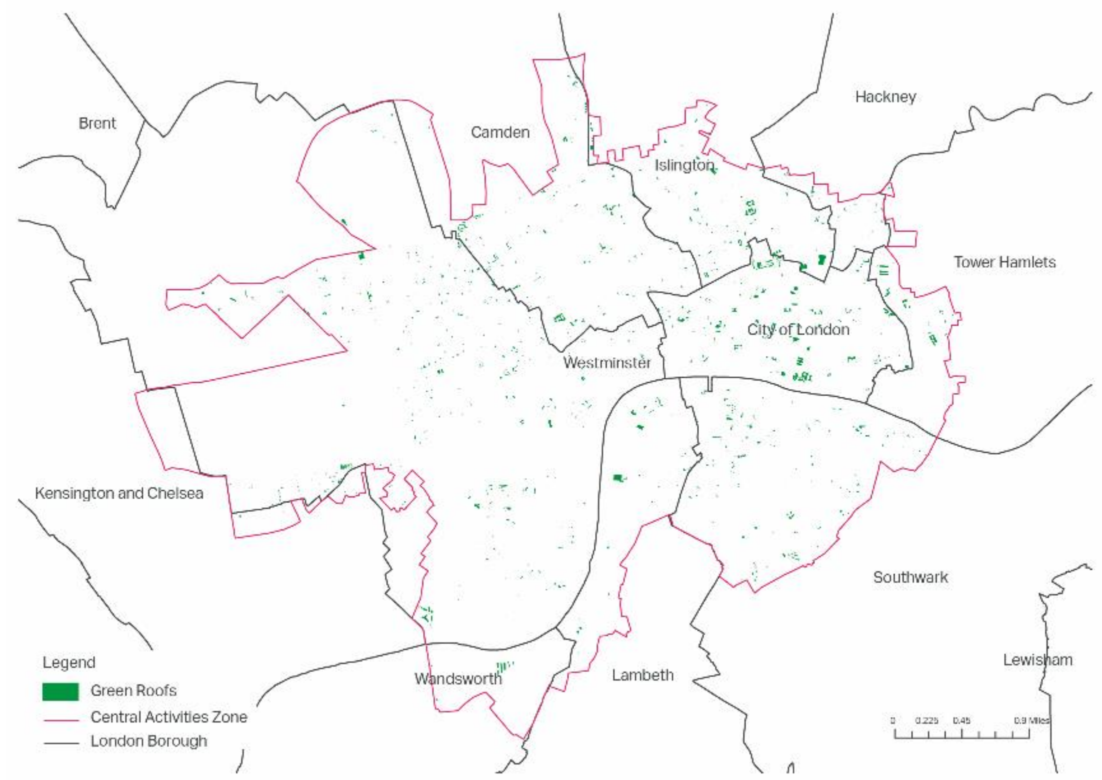
- the amount of hard surfacing in London's gardens increased by 26 per cent or 2,600 hectares
- the area of garden buildings (sheds etc.) increased by 55 per cent or 1,000 hectares
- the amount of garden lawn decreased by 16 per cent or 2,200 hectares

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 31). 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.

Figure 31: Green roofs in the Central Activities Zone

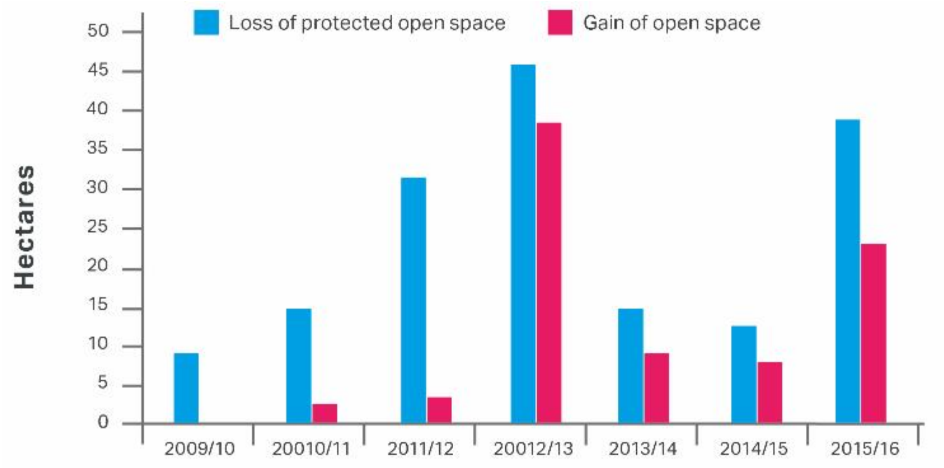


Changes in green space and biodiversity

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 32). 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.

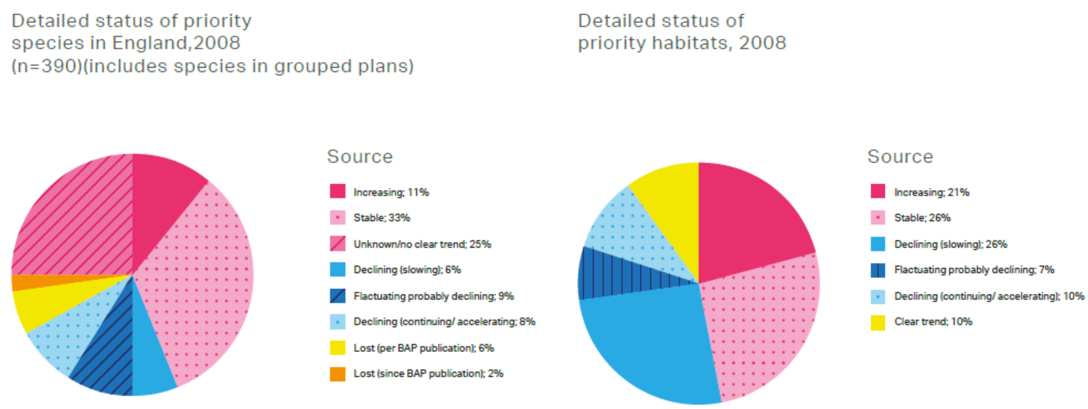
Figure 32: Losses and re-provision of protected open space



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 33).

Figure 33: 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) 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

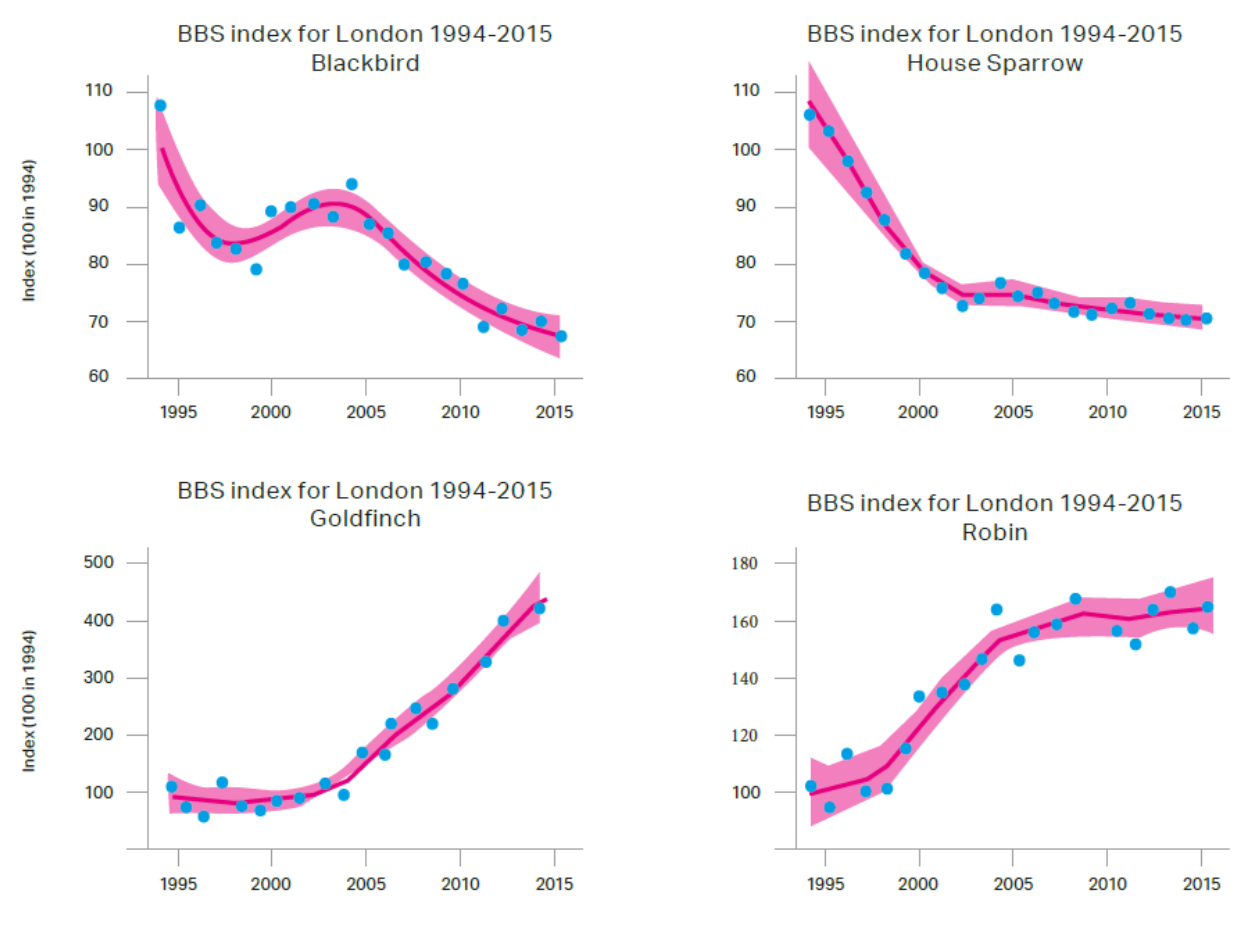
London's bird populations

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).

Five 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 34).

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. This suggests that there are no particular nature conservation or land management issues which need to be addressed specifically in London, especially as the actual causes for declines are undetermined. However, 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.

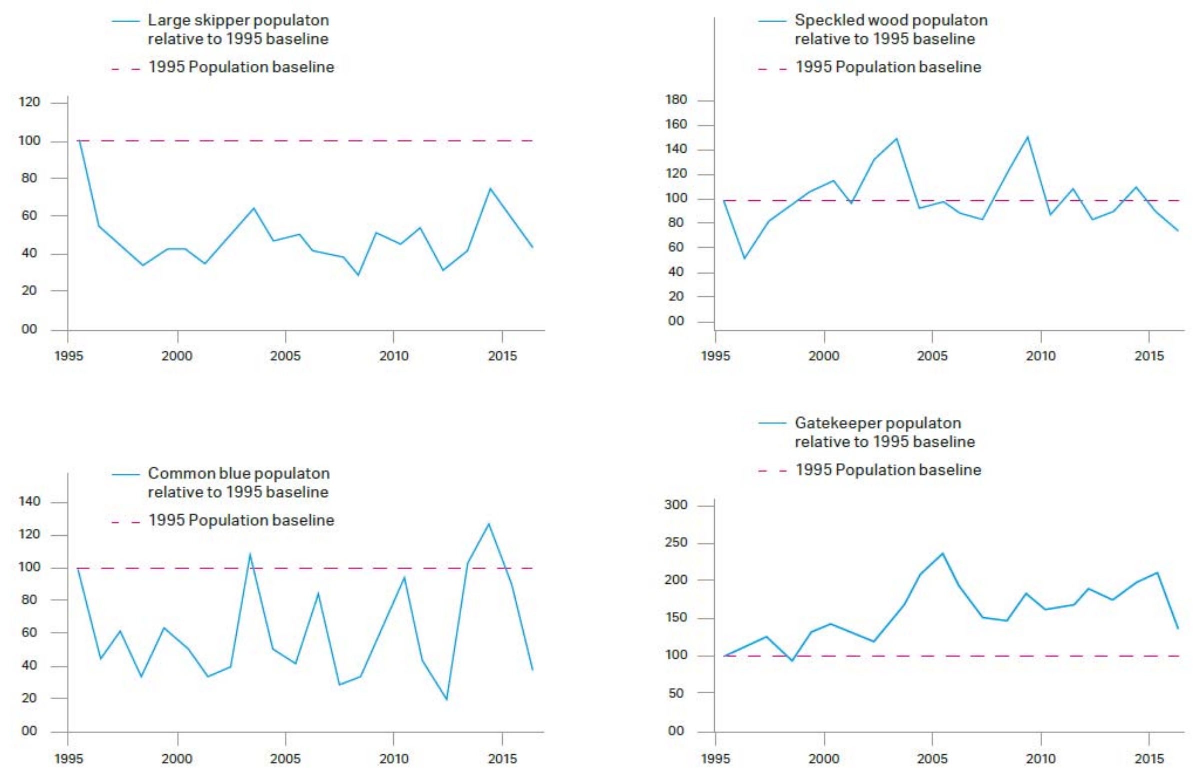
Figure 34: Blackbird, house sparrow, goldfinch and robin population trends (1994-2015)



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. 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 35).

Figure 35: Trends in British butterfly populations between 1995 and 2016



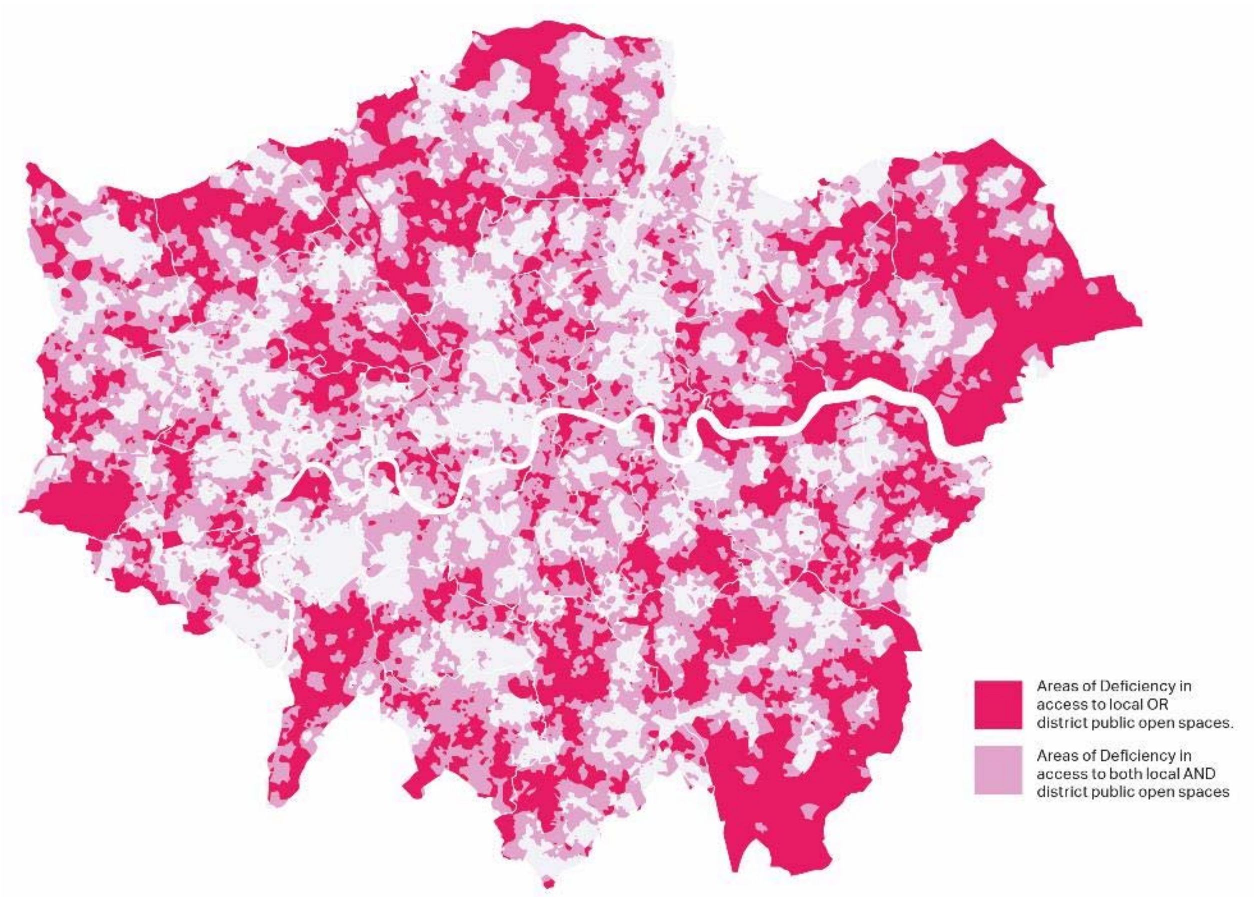
Usage and feedback from stakeholders

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:

- 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 visits to the natural environment 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 green space close to home is important

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 36). 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 36: Areas of Deficiency in Access to Public Open 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. 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.

The ecologically effective area is defined as the area of a development that is contributing to ecosystem function through, for example, stormwater drainage or habitat provision. Surfaces such as grass, gravel, vegetation, and green roofs are given a score rating based on how much they contribute to ecosystem function.

For example, a surface of concrete or asphalt would get a score of 0.0, whilst a green roof would get a score of 0.7, and a natural surface covered with vegetation would get the highest score of 1.0. This rating is then multiplied by the total area of the development that the feature covers. Adding up all of these scores gives you the ecologically effective area. This ecologically effective area is then divided by the total area of the development to give you a final green space factor score.

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

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. In the past, the importance of this resource for the health and general well-being of society was not appreciated and their potential not realised. 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
- access to urban green space is essential for good mental and physical health, childhood development, and social cohesion. More than ten per cent of the land area in England is now classified as 'urban' with about 80 per cent of the population living in urban areas, where the amount of mean accessible green space is two hectares per 1,000 people. Deprived areas systematically fare worse in terms of quantity and/or quality of green space
- urban ecosystem services could be significantly enhanced to improve climate mitigation and adaptation. Temperatures in cities are higher than in rural areas, with consequences for human well-being and the environment; increasing vegetation cover in urban areas could reduce surface water runoff and decrease peak temperatures
- 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, from different government departments and agencies to charities and private sector organisations. These 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 quantified the benefits and services provided by London's urban forest. This demonstrated that London's approximately eight million trees provide at least £133M of benefits per annum in relation to removing pollutants, carbon sequestration and reducing surface water flooding.

A natural capital account for Beam Valley Parklands, in Dagenham, East London 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.

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

Two approaches to determining where new forests should be established were tested. 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 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 published by the Heritage Lottery Fund in 2016 provides an assessment of the funding and investment in the UK's public parks and green spaces (Figure 37). 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.

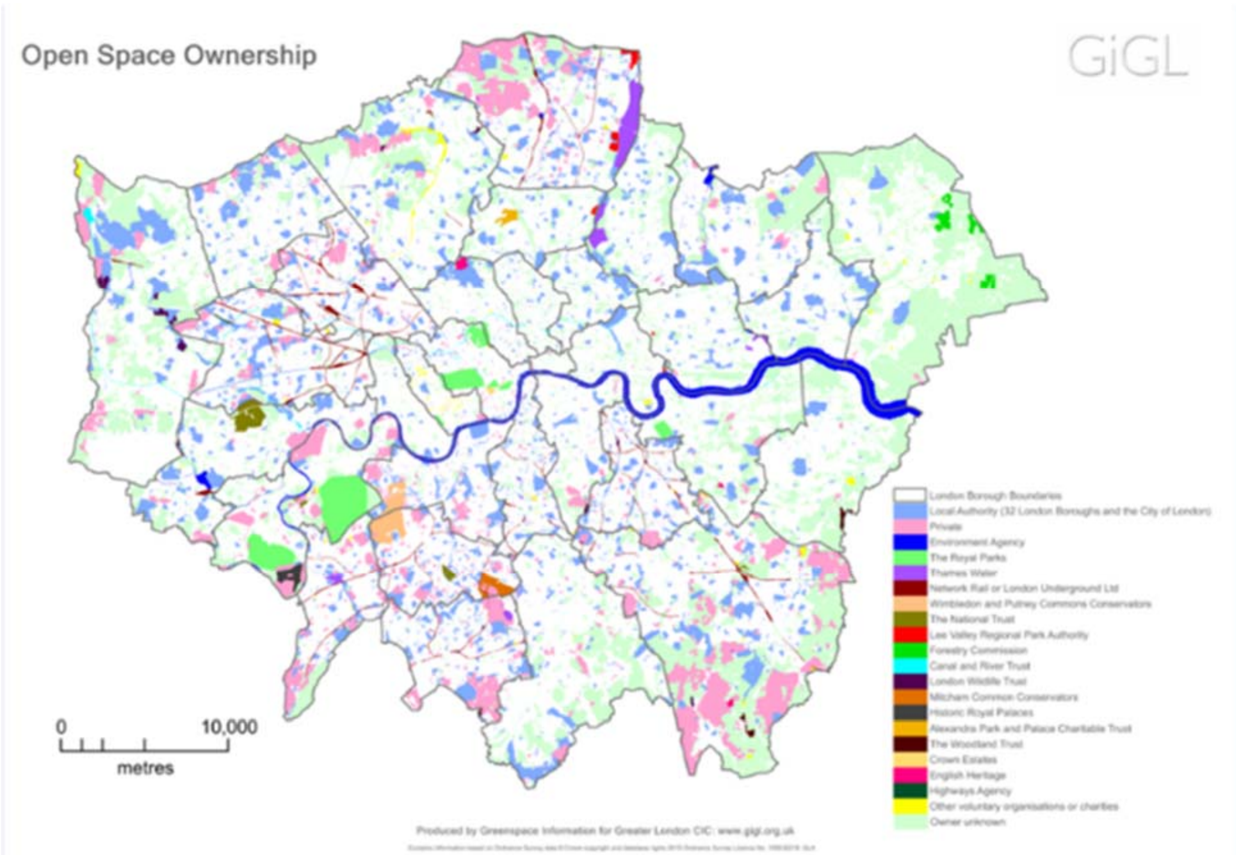
Figure 37: Anticipated levels of budgetary change in local authority parks budgets

Type of Authority	No of LAs	n	Budget increased	Budget not changed	Budget Decreased by less than 10%	Budget Decreased between 10% - 20%	Budget Decreased by more than 20%
District	201	56[2]	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[1]	33	17	0.0%	11.8%	11.8%	70.6%	5.9%
County Council	27	6[2]	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%

Notes [1] The City of London Corporation is included within the list of London Boroughs

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 being planned, designed and managed to improve the benefits it can provide (Figure 38).

Figure 38: 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[24]. 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[25] 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 198 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.

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. Through national control of 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[26], within the limits of the current UK carbon budget (31 per cent reduction in the 2013 to 2017 period). Future carbon budgets will be harder to meet and, despite recent progress, there is no clear national pathway to achieve this longer term decarbonisation. The UK government Emissions Reduction Plan (also known as the Clean Growth Plan) is expected to be published in autumn 2017. The government has a legal duty to propose policies to meet its carbon budgets and so this Plan will need to establish how it will achieve post-2020 greenhouse gas emissions targets, including the Fifth

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24 IPCC AR5 range for BaU is 2.6 to 4.8 by 2100: https://www.ipcc.ch/report/ar5/

25 Stern (2006). The Economics of Climate Change

26 BEIS (2017), Provisional UK greenhouse gas emissions national statistics 2016. Provisional statistics for 2016 are not yet available for London.

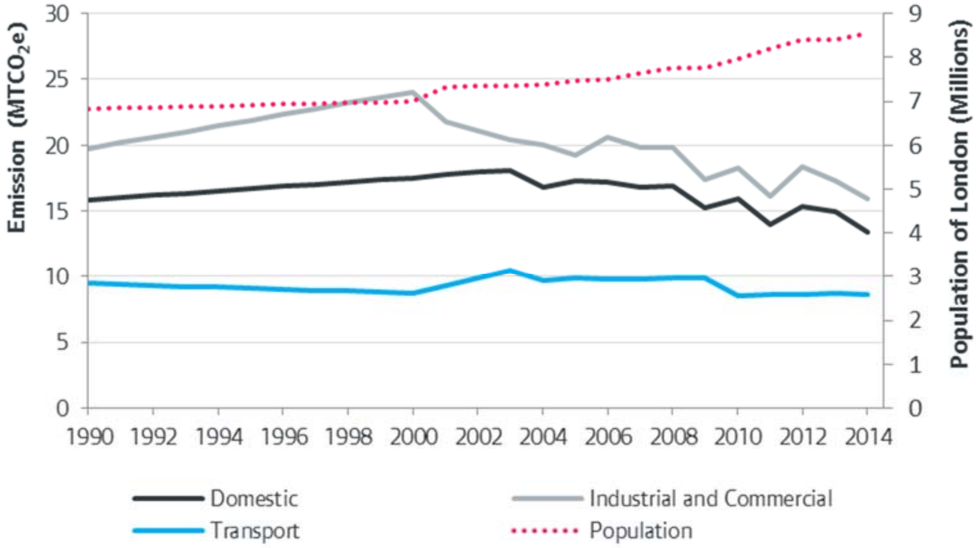
Carbon Budget. This Budget commits the government to achieving emissions 57 per cent below 1990 levels over the five year period 2028 to 2032.

London's greenhouse gas emissions

In 2014, London's greenhouse gas emissions were estimated at around 38 $MtCO_2e$ (million tonnes of carbon dioxide equivalent). This represents seven per cent of the UK's total emissions. London's emissions are reducing; having fallen by 16 per cent since 1990 (Figure 39 and Box 2).

Greenhouse gas (GHG) emissions peaked in 2000 but have been declining since then despite population growth. In 2014 our GHG emissions were around 25 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 2014 per capita emissions (4.4 tCO_2) were the lowest of any region in the UK. London's GHG data for 2015 is not yet available, but based on national trends we expect emission reductions of greater than 20 per cent compared to 1990 levels.

Figure 39: London's historic emissions (source: figures pre-2000 are extrapolated from 1990 levels and sourced from LEGGI (Box 2) and the Office for National Statistics (ONS).



Box 2: The London Energy and Greenhouse Gas Inventory

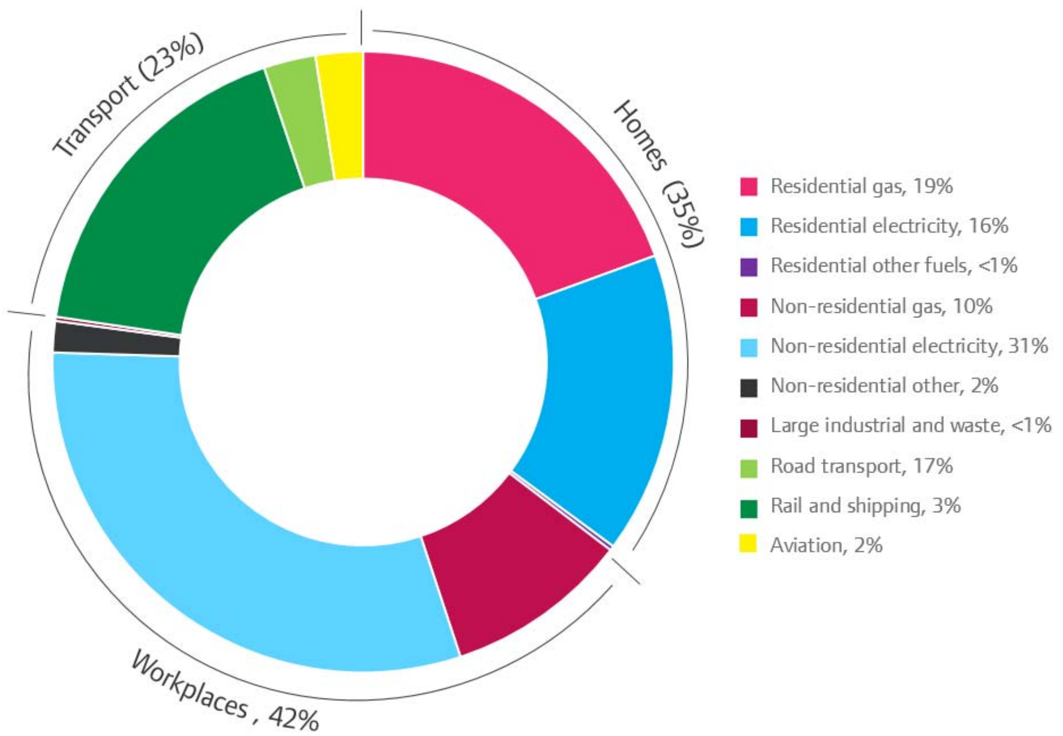
The London Energy and Greenhouse Gas Inventory (LEGGI) is a dataset of London's greenhouse gas emissions and energy consumption covering almost a quarter of a century, with the most detailed information available since 2000.

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 take-off and landing of aviation 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 2016 LEGGI assessment, reporting on 2014 emissions. Both current and historic LEGGI assessments can be accessed at London's Datastore (https://data.london.gov.uk).

London's GHG emissions are dominated by buildings and transport (Figure 40). In 2014, we estimate that 35 per cent of emissions were generated from London's homes, 42 per cent from workplaces, and 23 per cent from transport.

Figure 40: Emissions by sector (source: London Energy and Greenhouse Gas Inventory (LEGGI) 2014)



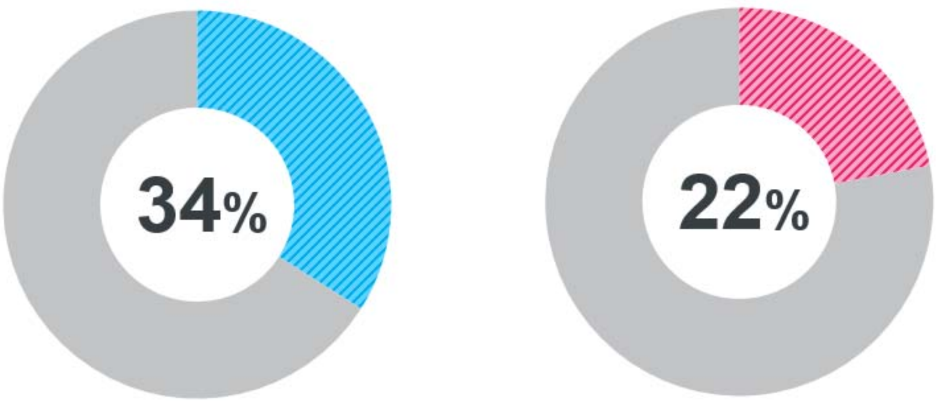
Energy use

Energy is consumed through day to day activities in the home and workplace and through transportation and industry. Consumption of energy can vary from year to year depending on factors including the weather conditions experienced, and so a long term trend is the most effective method of discerning meaningful changes in energy use.

London consumed an estimated 134,448 gigawatt hours (GWh) of energy in 2014. This represents a reduction of 16 per cent on 1990 levels of energy use, despite a population increase of 26 per cent over this time period. 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).

Gas demand in London has been reducing in recent years, attributed in part 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 a relatively warm winter in 2014, the most recent year for emissions accounting. 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 (Figure 41).

Figure 41: GHG emission trends for gas and electricity (source: London Energy and Greenhouse Gas Inventory (LEGGI) 2014)



reduction in gas emissions since 2000

reduction in electricity emissions since 2000

Electricity demand has remained steady throughout this period, 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 (see Box 2), have decreased by over one fifth since 2000 (Figure 41).

Box 3: Why carbon?

Carbon dioxide is by far the most common greenhouse gas emitted by human activity in terms of quantity released and total impact on global warming. As such carbon and CO_2 have become the common shorthand terms used when accounting harmful greenhouse gases.

For accuracy, London's carbon accounting is measured where possible in carbon dioxide equivalent or "CO_2e" emissions. This includes the conversion of other greenhouse gases such as methane from landfill and nitrous oxide and black carbon from transport emissions into their equivalent CO_2 emissions based on their relative global warming potential. Although far smaller volumes of these gasses are produced, their inclusion is important as they can be thousands of times more harmful to the environment per volume of gas.

If London only accounted for the greenhouse gas emissions within its geographic boundary it would ignore all indirect emissions associated with electricity generation outside the city, reducing the capital's total reported emissions by around 40 per cent. Clearly, this would unfairly penalise other areas of the country that generate much of the energy which London consumes. Zero carbon targets therefore include both direct and indirect emissions, as defined in scope 1 and 2 of the Greenhouse Gas Protocol.[27]

Manufactured and purchased goods also have emissions associated with generation at source, most often outside of the city. These 'scope 3' emissions are harder to trace quantitatively but are estimated to account for as much as three times the size of direct emissions. The accounting of London's scope 3 targets are embedded within the principles of a circular economy (see the Waste Chapter) and although not included in the pathway to zero carbon, we will continue to measure and reduce scope 3 emissions where possible and must avoid outsourcing our emissions.

For consistency with national and international measurement of CO_2e emissions and targets London's GHG emissions are measured against a 1990 baseline unless stated otherwise.

[27] *The Greenhouse Gas Protocol is the world's most widely used international carbon accounting tool. Details of the protocol and its standards, guidance and tools are available at: http://www.ghgprotocol.org/.*

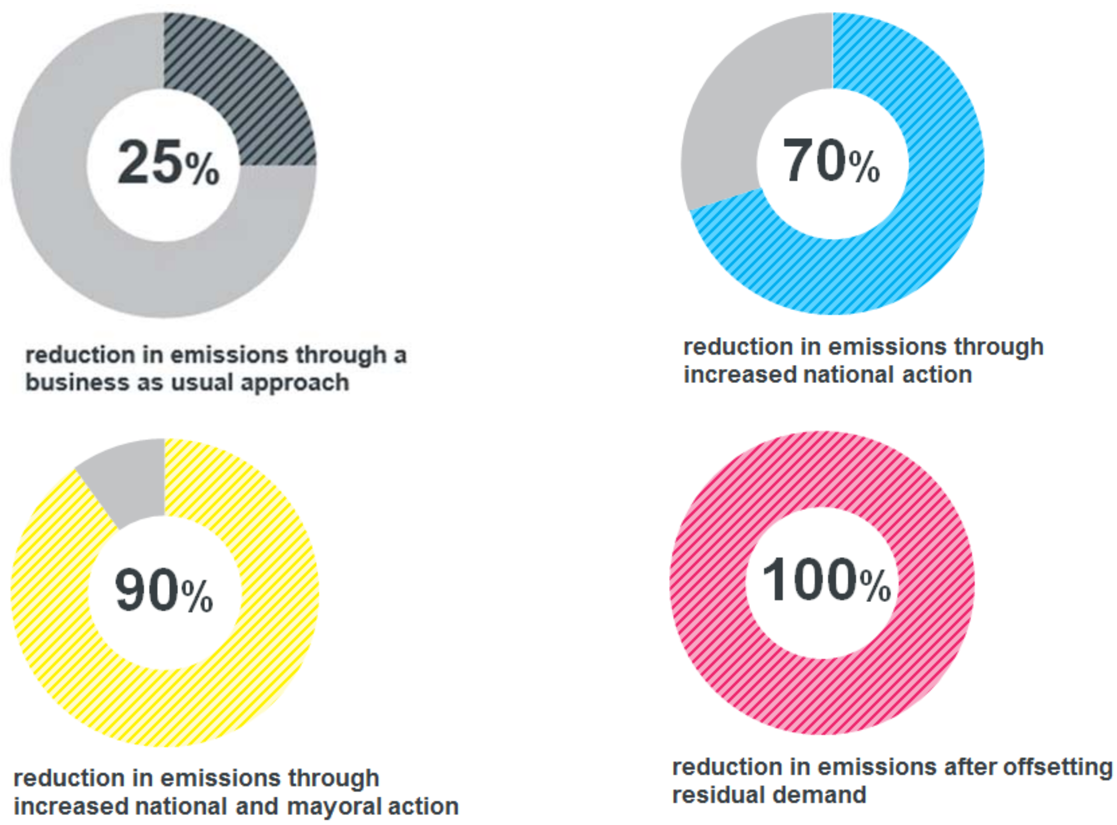
London's carbon roadmap

London's overall energy consumption is expected to remain steady at current rates in the short term, with improvements in the energy efficiency of heating systems, lighting and appliances offsetting the increase in demand due to a rising population. Over a longer horizon to 2050, an increasing population would result in an increase in demand for energy over the coming decades to meet the needs of new homes, workplaces and infrastructure – especially in areas of concentrated large scale development.

Without national policy intervention, today's existing policies driving GHG emission reduction at a UK and city level could take London to a 25 per cent reduction of 1990 levels by 2050 (Figure 42). An extra 45 per cent can be achieved through the further decarbonisation of energy systems at a UK level in line with policies and proposals to achieve UK carbon budgets. The remaining 30 per cent reduction could be met through increased action at a city level.

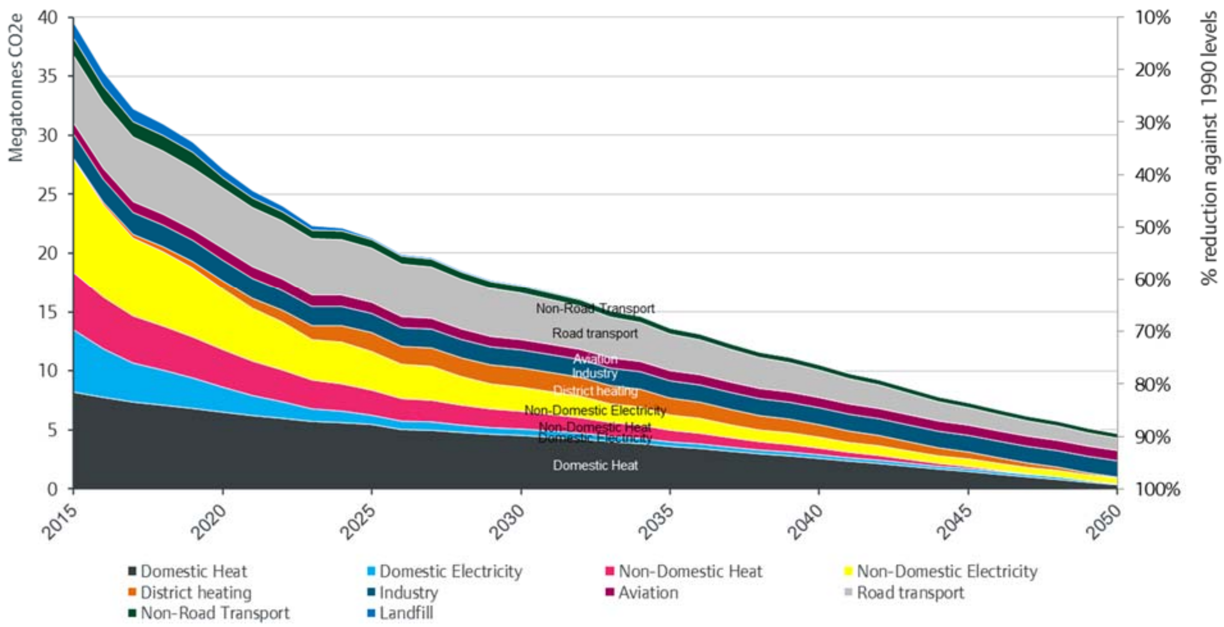
Emissions offsetting or negative emissions technologies (such as carbon capture and storage) can allow for remaining residual emissions from energy grids, historic building stock, aviation and some industry, which cannot be reduced to zero directly.

Figure 42: London's carbon roadmap



Pathways to 2050 have been developed for the ten main sectors within homes, workplaces and transport that contribute to London's emissions (Figure 43). These pathways are based on forecasts of projected future energy demand, technological change and changes in our energy supply mix.

Figure 43: Zero carbon sector trajectories (source: GLA Zero Carbon Pathways Tool (2017))



Short, medium and long-term objectives

The strategy and milestones to meet the zero carbon ambition can be broadly split into short, medium and long-term objectives. Although we want to reduce GHG emissions in the most cost effective way, we cannot rely on leaving actions to future generations or later decades when some actions may become less costly to do. This would risk unprecedented, and potentially unachievable, rates of decarbonisation in the 2030s and 2040s.

Short term (next five years)

In the next five years, a large proportion of the emission reductions required to help put London on track to zero carbon can be met via additional energy efficiency (in new developments and existing buildings), continued decarbonisation of the national electricity grid, low carbon decentralised energy and using low carbon forms of transport. This will avoid long term lock-in to polluting fossil fuels for power or heating needs. Mayoral programmes will be developed for implementation at scale, exploring opportunities for aggregation of demand and finance and promoting the hierarchy of lean, clean and green buildings:

1. Be lean: use less energy and manage demand in construction and operation
2. Be clean: exploit local energy resources such as secondary heat and supply energy efficiently and cleanly
3. Be green: generate, store and use renewable energy on-site

Medium term (2020-2030)

To reflect a rapidly decarbonising electricity grid and help address London's air quality problems, all energy programmes will need to increasingly look to move away from combustion of fossil fuels in buildings and vehicles.

The 2020s should see London fully embrace a transition towards the increased use of heat pumps and secondary heat in preference to gas boilers, both at an individual building level and through district heating in areas with the most concentrated heat demand. Changes in heating systems should occur alongside deeper building retrofits, increasingly including whole house retrofits to reduce demand for heating.

The impact of population growth, increased renewable generation, and the electrification of transport and heat will increase the need for flexibility in London's electricity grid in the 2020s. The role of smart technology systems becomes increasingly important in this period, providing targeted demand reduction, local generation and energy storage. These balancing mechanisms, collectively known as demand side response (DSR) will allow consumers to use energy at times of lowest carbon and lowest cost, reducing the peak demand on the national grid (peak demand is most associated with high carbon generation as typically older fossil fuel-fired power stations are used at short notice to meet this demand).

By 2030 at the latest the UK government must also set out plans for the long-term role of gas to facilitate the full decarbonisation of London's heating systems by 2050. A clear government vision of what the carbon content of gas and electricity needs to be in 2050 would then provide a minimum 20 year period to transition to a new zero carbon heat supply.

Long term (2030-2050)

By 2050 most of London's building stock will have been retrofitted with measures to deliver high levels of energy efficiency. Remaining demand will be met through a mix of low carbon electricity and / or low to zero carbon gas. Londoners will be protected against future volatility in energy markets through an integrated smart system, utilising local generation and smart storage to consume only affordable renewably generated energy. Transport will have taken an increasing lead in this revolution, with the majority of public transport zero carbon by 2040.

Zero emission vehicles (such as electric or hydrogen-fuelled), district heating and local storage of heat and electricity will play an increasing role in energy balancing; storing renewable energy generated at times of low demand (such as at night) to offset periods of higher carbon - and more expensive - generation.

UK Grid decarbonisation

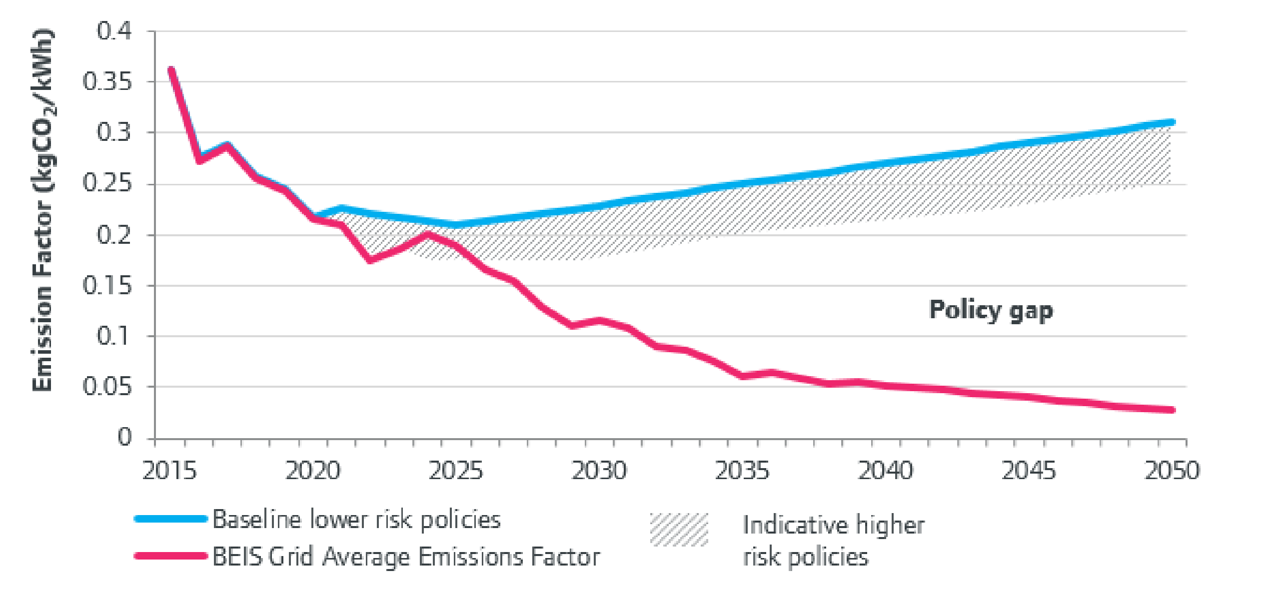
The vast majority of London's primary energy demand (approximately 94 per cent) is currently sourced from outside of the city. London has limited space; it can never be fully self-sufficient in energy production, even by reducing energy demand and generating more renewable energy within the city boundaries. That's why London's zero carbon pathways are intrinsically linked to the decarbonisation of the UK's electricity and gas grids.

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. Total UK renewable electricity generation has increased to record levels of around 25 per cent in 2015, up from 19 per cent in 2014 while coal generation has reduced from 30 per cent of generation in 2014 to 22 per cent in 2015. There is a clear national pathway to further decarbonisation of the electricity grid and the UK government has projected a fall from 455g CO_2 per kWh today, to 27g CO_2 per kWh in 2050[28].

This projection (Figure 44) is updated annually and used by the GLA to underpin the wider energy modelling work. A second scenario considering only low risk policy implementation has also been referenced in the GLA's modelling, to show the impact that could be expected with no national policy interventions. This scenario is derived in part from Committee on Climate Change analysis[29] and has been combined with baseline growth projections in London to generate the business as usual trajectory shown in the Environment Strategy and accompanying models.

There is a significant gap between these scenarios beyond 2020. The UK government's forthcoming Emissions Reduction Plan should set out a clear pathway to achieving these projected reductions in the longer term and a proposed strategy for closing the policy gap.

Figure 44: Decarbonisation of the UK's National Electricity Grid (source: reproduced from HM Treasury Green Book Supplementary Guidance: valuation of energy use and greenhouse gas emissions for appraisal (March 2017) and Committee on Climate Change analysis based on BEIS (2017) updated emissions projections and adjusted for 2016 levels)



There is, however, no equivalent pathway towards the decarbonisation of the national gas grid, making gas, and by association heat, one of the major challenges in realising a zero carbon future. 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.

Improving energy efficiency

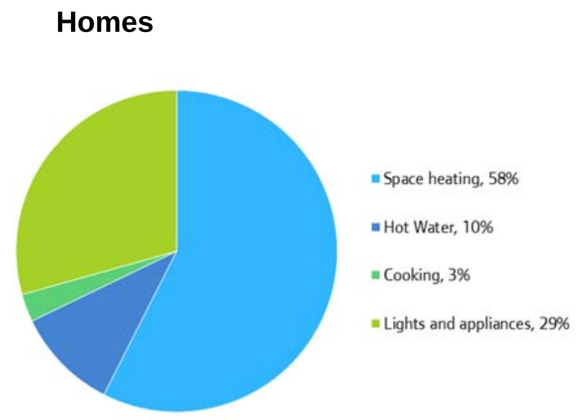
London is home to buildings of all ages, and their energy efficiency varies considerably (Figure 45). More energy is used to heat and power our buildings in London than for anything else. Buildings are responsible for around four fifths of London's total GHG emissions and 70 per cent of final

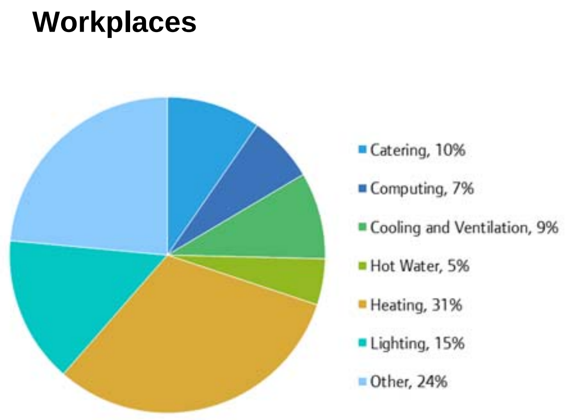
[28] https://www.gov.uk/government/publications/updated-energy-and-emissions-projections-2016
[29] Committee on Climate Change (2017). Report to Parliament – Meeting Carbon Budgets: Closing the policy gap

energy use. This year, it is estimated that over £7bn will be spent on heating and powering buildings across London.

By 2050 some 1.3 million new homes and over ten million square metres of new schools, hospitals and workplaces are needed. This will lock in emission patterns for 60-120 years (the average building and infrastructure lifespan). As a result, by 2050 the emissions footprint of London's buildings will need to be close to zero. Some will even need to be climate positive, that is, they will need to generate more clean energy than they consume.

Figure 45: Typical energy use breakdown (source: BEIS (2016), Digest of UK Energy Statistics (DUKES))





Through the Mayor's flagship energy efficiency programmes, savings of 670,000 tonnes of CO_2 were achieved in 2015, a threefold increase over 2011 levels. 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 previous Mayor's 2011 Climate Change Mitigation and Energy Strategy.

Although modest at a London level, the development of the Mayor's programmes can serve to catalyse the wider market, simulating indirect savings that are harder to quantify. GLA programmes can help to drive reductions across the city, and also facilitate the delivery of projects by aggregating measures to leverage the large level of finance required to develop city-wide programmes at scale.

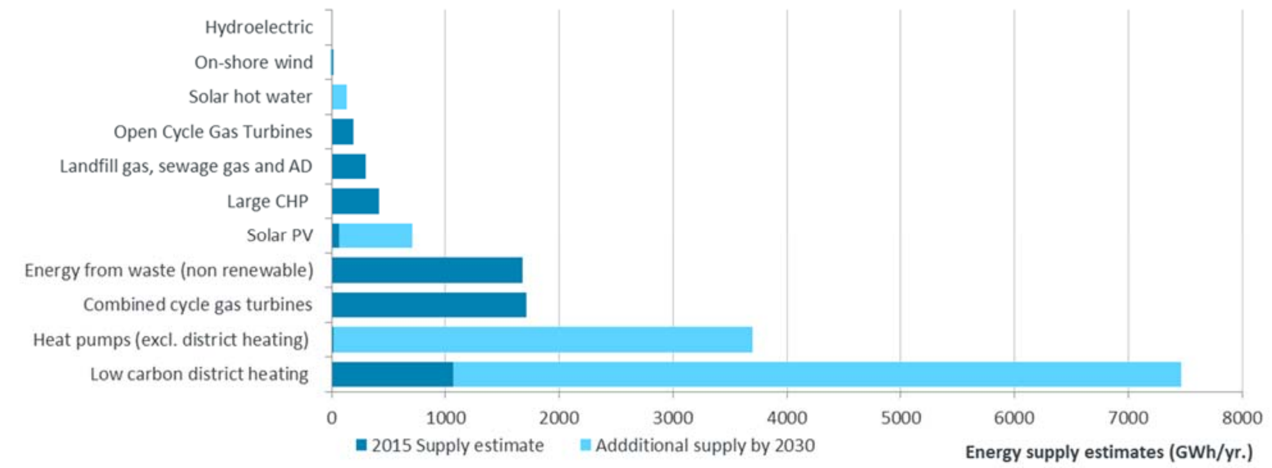
Increasing decentralised and renewable energy

Although we will become more efficient with our energy use, demand for energy in some sectors and in some parts of London is forecast to grow out to 2050. Demand for electricity, especially in areas of concentrated development, is likely to increase, as low carbon supply supports the electrification of heating and vehicles.

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). Decentralised energy is expected to increase, meeting up to 15 per cent of demand by 2030 through district heating and renewable sources alone.

Figure 46 shows the current mix of decentralised energy across London, alongside these projected increases out to 2030.

Figure 46: Existing and projected decentralised energy supply in London (source: Contains data from HM Government Digest of UK Energy Statistics (DUKES) 2015 and GLA modelling.)



Solar Energy

In 2015 there were over 21,000 solar photovoltaic (PV) installations in London, generating an estimated 70 gigawatt hours (GWh) of electricity, 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.

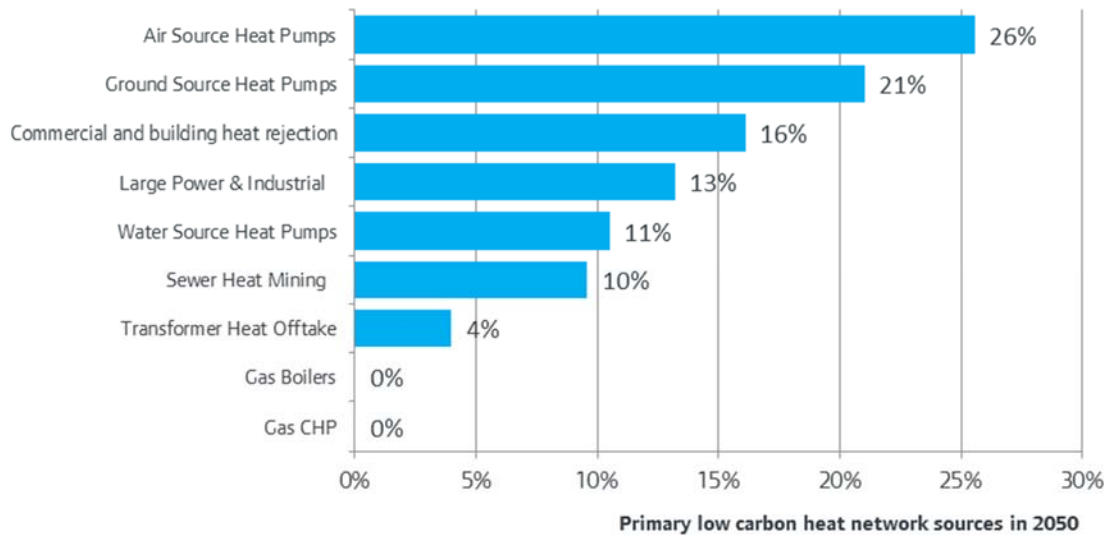
Heat Networks

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 appropriate solution to 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 percent of London's total energy demand. A map showing the location of existing networks and future opportunities is available through the London Heat Map[30].

As the UK electricity grid decarbonises, London's district heating schemes are increasingly looking to transition towards the use of waste secondary heat as a fuel source. The Mayor's Secondary Heat Study[31] sets out the potential for district heating to be supplied by zero carbon sources, giving a detailed background to the concept of secondary heat and the opportunities available to London. Indicative potential for district heating supply by 2050 is shown in Figure 47.

Figure 47: Indicative district heating supply in 2050 (source: GLA modelling (2017))



Heat Pumps

A heat pump is a device that extracts low grade heat from the environment, such as from the air, ground, water or waste heat sources. This typically low grade heat energy is then converted into usable higher grade heat, for space heating and hot water. Heat pumps require some electricity to run, but significant proportions of the energy supplied can be considered as renewable, in addition to the renewable content of the electricity supplying the heat pump.

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

[31] GLA (2013), Secondary Heat Study – London's Zero Carbon Energy Resource. Accessed from: https://www.london.gov.uk/WHAT-WE-DO/environment/environment-publications/secondary-heat-study-londons-zero-carbon-energy

Heat pumps are well established in Europe but currently make only a small contribution to the UK energy market due to the prevalence of gas boilers in our older building stock for space heating and hot water provision. As the carbon content of London's electricity grid continues to fall and the energy efficiency of buildings continues to increase (including through retrofit measures), this trend is likely to change. Gradually, heat pumps will offer a more attractive low carbon solution in lower density areas of the city where heat networks are less viable (Figure 47).

Although a high penetration of heat pumps has the potential to increase the demand on London's electricity grid at peak times, innovations in energy storage and hybrid fuel heat pumps are expected to play a large role in alleviating this risk as deployment of this technology increases.

Other renewable energy sources

As a proportionally small amount of London's total energy supply, other renewable energy sources, such as wind, tidal, landfill gas and anaerobic digestion, are less crucial to London's total emissions pathway, but can have a significant local impact.

These energy sources are also difficult to predict in forecasting models, as their development is subject to market conditions, local planning constraints and political will at a national level. This can be seen in particular with onshore wind, which played a significant role in previous 2050 outlooks but has now been scaled back in light of reduced support from national government including significant subsidy reductions.

Notwithstanding viability constraints, the maximum potential capacity of all renewable sources is estimated in the Mayor's Decentralised Energy Capacity Study[32]. This study provides detailed opportunity maps for ten additional renewable energy sources, many of which have been incorporated as part of the GLA's zero carbon pathways tool and web map.

Reducing greenhouse gas emissions from waste, industry and transport

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.

Industry and power generation

The industrial sector (including light and heavy industry) represents five per cent of London's emissions today but could be one of the larger emitting sectors in 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 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. Reduction of industry due to other factors would likely relocate, not reduce, the total emissions within London. As such, no reduction in the levels of industry is assumed in the 2050 modelling beyond known plant closures.

[32] GLA (2011), Decentralised Energy Capacity Study. Accessed from: https://www.london.gov.uk/WHAT-WE-DO/environment/environment-publications/decentralised-energy-capacity-study-0

A review of opportunities for industrial emission reduction has been carried out by Ricardo AEA targeting significant energy consuming processes for the largest of London's industrial sites in both the short and long term. This work is ongoing, focusing on the top five energy consuming sites that collectively represent 90 per cent of all industrial energy consumption in London.

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 draft Transport Strategy[33]. Aviation is perhaps the most difficult transport sector to decarbonise, due to a lack of alternative fuels and currently contributes around two and a half per cent of London's total GHG emissions.

A smart energy future

In the context of energy, a smart city is one that optimises its supply and use of energy. Energy consumption and emissions can be minimised, the use of renewables maximised and the supply to consumers done so at the least cost. Advanced process control can predict demand and control energy systems to meet specific objectives, such as to avoid energy peaks. Smart metering can empower consumers to engage more with their energy use and enable the market to develop solutions to help them reduce their energy bills and use less primary energy.

In a more connected city every supermarket freezer, every washing machine and every electric car could intelligently programme their time of operation, optimising demand when renewable generation is available. This will become increasingly important as more intermittent energy such as solar and wind is deployed in the UK.

Where renewable generation cannot be used instantaneously, storage will play an important role, capturing this energy for times when it is needed, rather than using more carbon-intensive fuels and technologies.

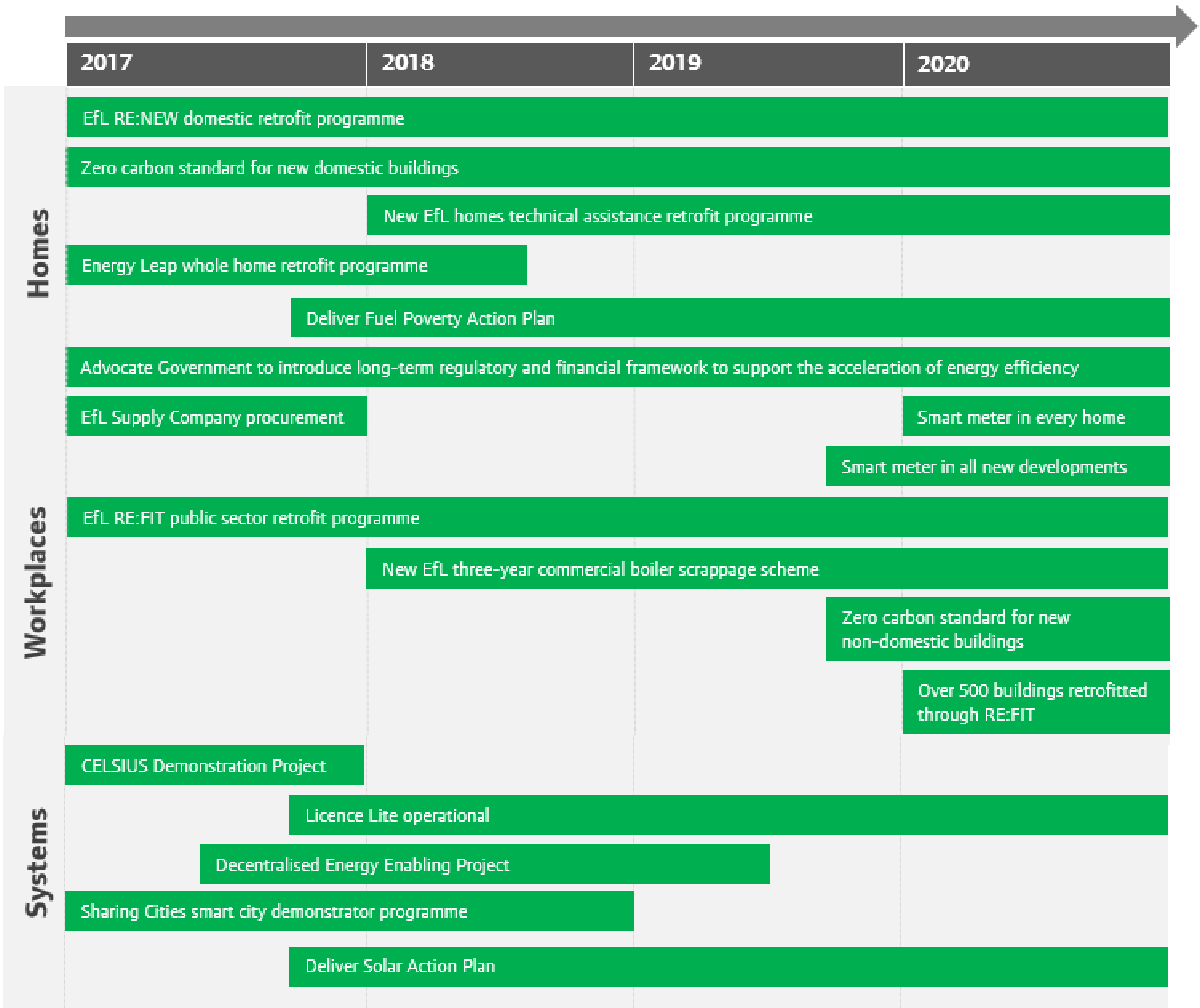
Residual emissions

By virtue of its urban density and historic building stock, London has some of the highest concentrations of energy demand in the country. After maximising energy efficiency retrofits and renewable energy supply there will come a tipping point where emissions cannot be reduced further without unfairly penalising Londoners - when compared to renewable energy investment outside of the capital.

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.

[33] https://www.london.gov.uk/what-we-do/transport/our-vision-transport/draft-mayors-transport-strategy-2017

Figure 48: Timeline of activities

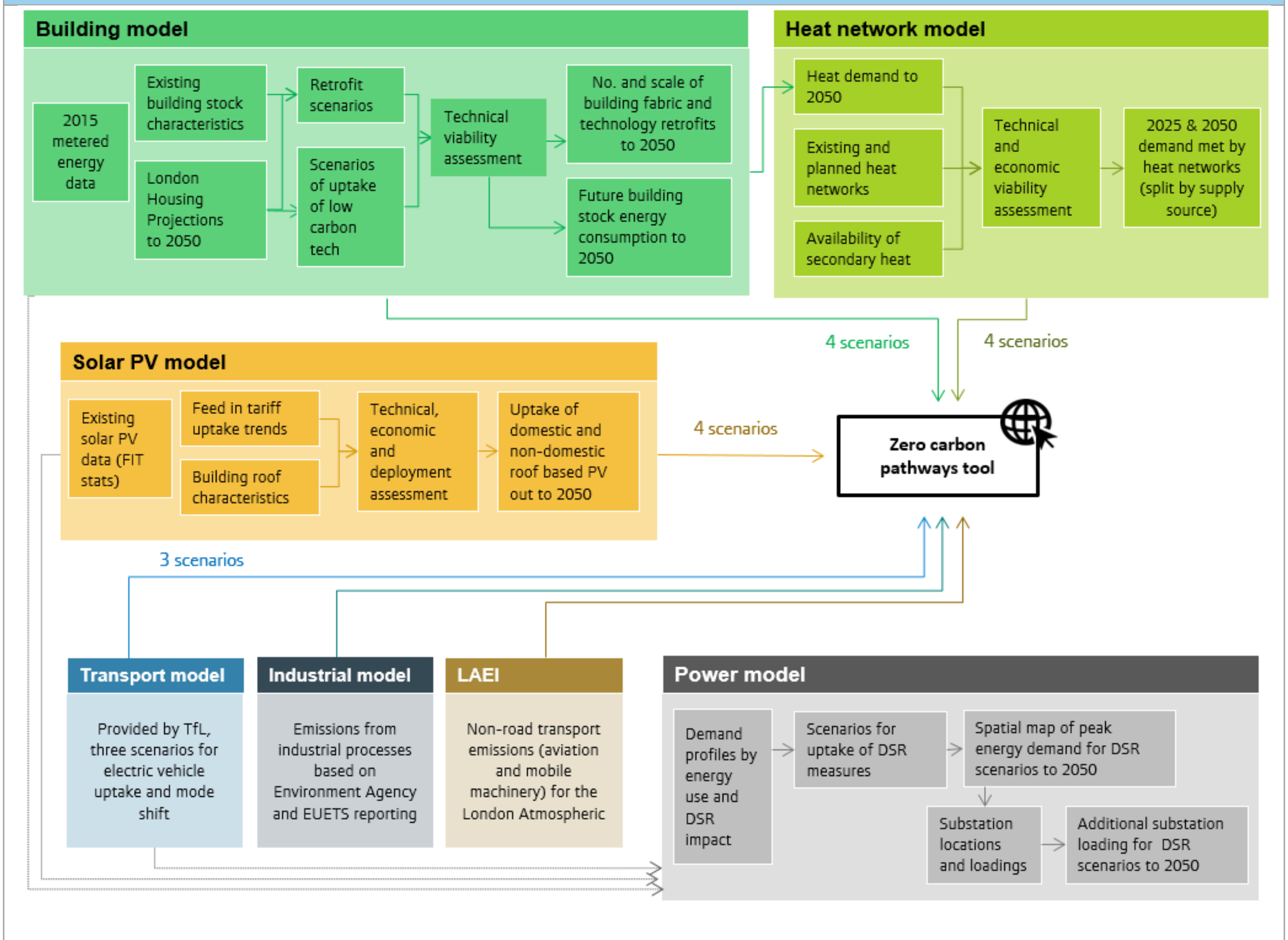


Building a zero carbon climate model

To effectively plan and implement the actions required to reduce London's net GHG emissions to zero, the GLA continues to undertake research to develop the evidence base that informs the policy direction and programme development set out in the Mayor's strategies.

Part of the analysis includes the work undertaken to develop London's Zero Carbon Pathways Tool. This combines datasets developed by the GLA over the past five years under one modelling framework (Figure 49) and considers the different routes to a zero carbon city considering future energy demand scenarios and supply options for London's energy system. The model is used to test the impact of actions to cut GHG emissions, and provides a detailed spatial analysis of London's carbon emissions and energy use between now and 2050.

Figure 49: GLA zero carbon modelling architecture



In addition to in-house models, the underlying datasets include scenarios and projections developed through the following research programmes (Table 6).

Table 6: Research programmes contributing scenario and projection data

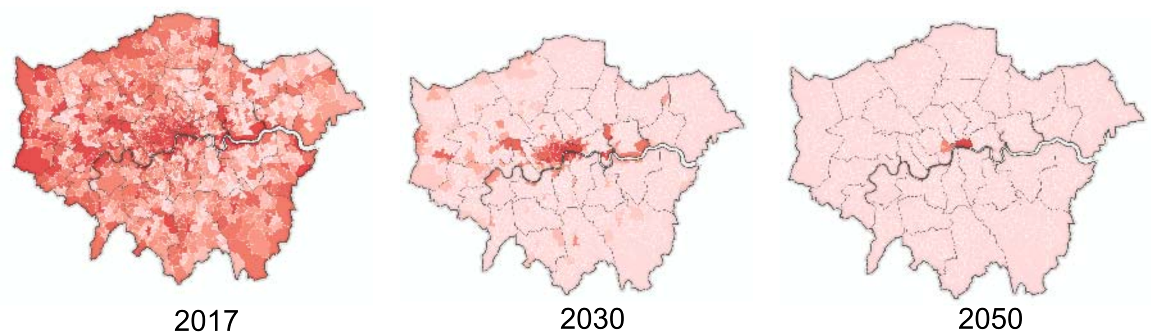
Research	Link	Details
Decentralised Energy Capacity Study (published 2011)	https://www.london.gov.uk/WHAT-WE-DO/environment/environment-publications/decentralised-energy-capacity-study-0	The London Decentralised Energy Capacity Study presents the findings of a regional assessment of the potential for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

Interactive maps and datasets
In support of London's zero carbon pathways, the GLA have developed an interactive map to explore different scenarios for energy demand and supply out to 2050. Users can vary the uptake of measures such as energy efficiency, low carbon transport and electricity grid decarbonisation.

As well as a tool for stakeholders across the city, the maps (illustrated in Figure 50) provide a focus point for aligning energy and carbon strategies across London's 32 boroughs.

The interactive tool and associated datasets are available at www.maps.london.gov.uk/zerocarbon.

Figure 50: Map of London's projected carbon emissions (source: GLA (2017) Zero Carbon Pathways Tool)



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 (household waste), public buildings, and businesses (non-household waste). Local authorities only deal with about half of this waste (3.7 million tonnes); the rest is dealt with by the private sector. Figure 51 shows how London's local authority collected waste (LACW) is managed.

Figure 51: LACW management methods 2015/16: Total 3.7 million tonnes (source: Defra (2017), LACW statistics 2015/16. Accessed from: https://www.gov.uk/government/statistical-data-sets/env18-local-authority-collected-waste-annual-results-tables)

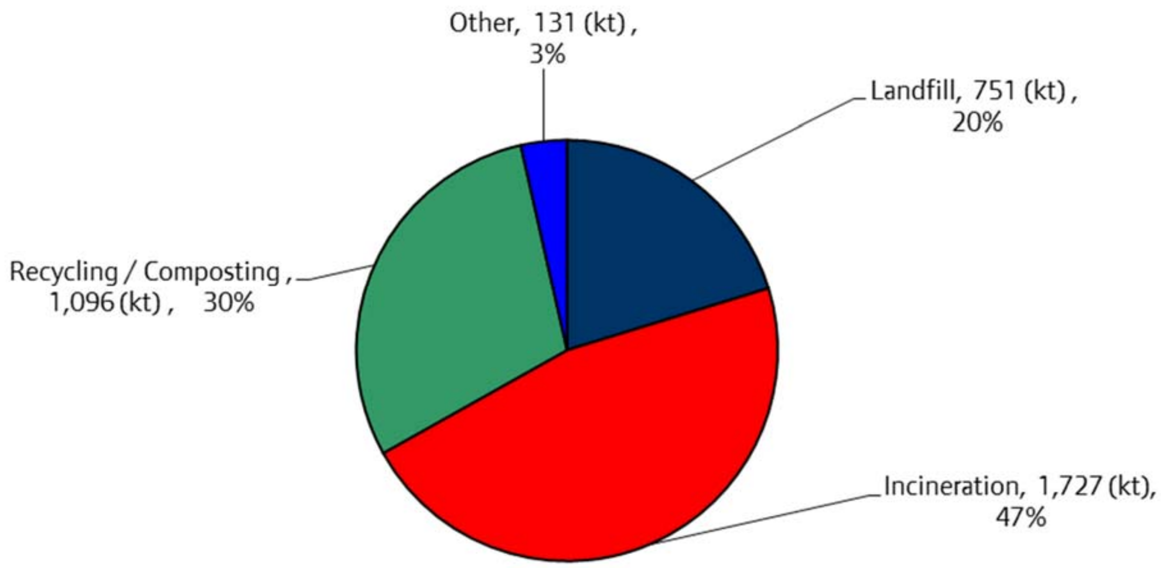
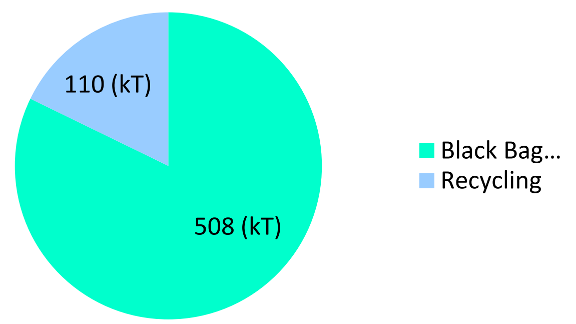


Figure 52 shows the amount of non-household waste collected by local authorities, the majority of which is black bag waste going to incineration or landfill.

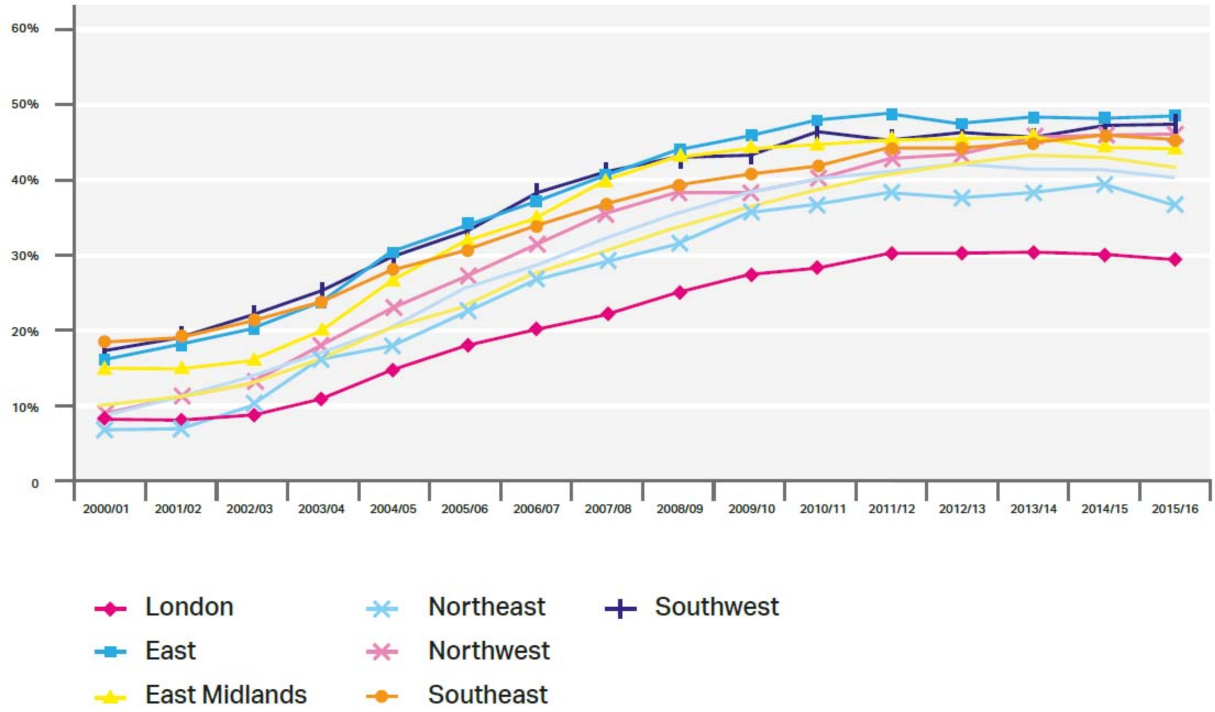
Figure 52: Management method for Local authority collected non-household waste (source: Defra (2017), LACW statistics 2015/16. Accessed from: https://www.gov.uk/government/statistical-data-sets/env18-local-authority-collected-waste-annual-results-tables)



Between 2003 and 2010, London significantly improved how it managed its waste. London's LACW recycling rates went from eight to 30 per cent, and landfill rates went down from 65 per cent to 20 per cent. This improvement was largely due to the EU Landfill Directive. This has restricted 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.

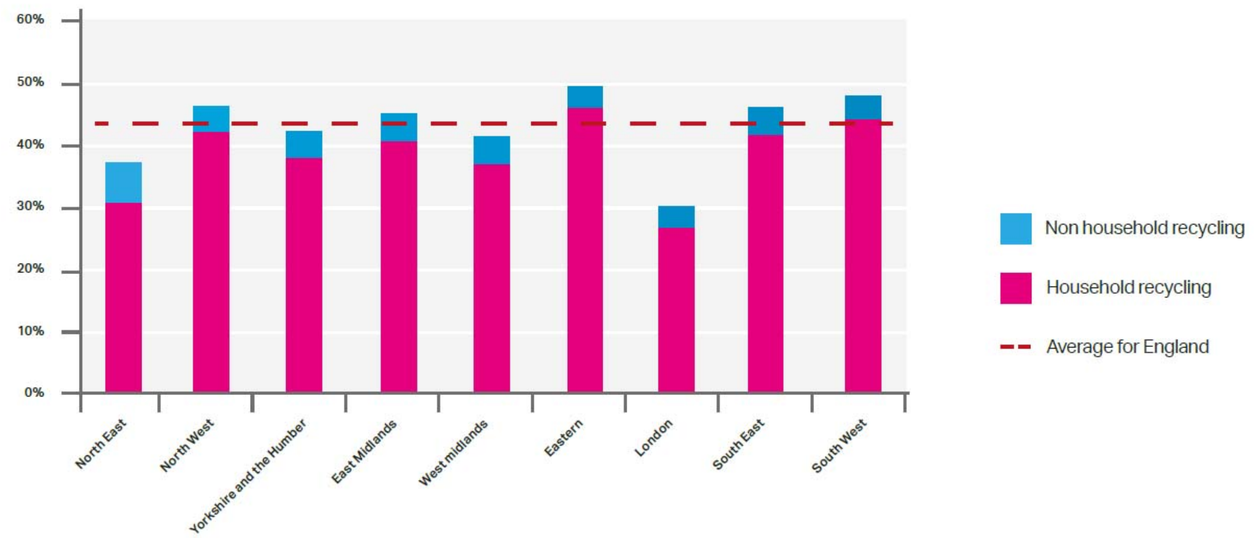
Figure 53 shows London's LACW recycling performance against other UK regions since 2001. Despite improvements in recycling performance, London continues to be the lowest performing region. Since 2011, regional recycling rates have stalled, with London's performance levelling off at 30 per cent.

Figure 53: Regional LACW Recycling performance 2001 – 2016 (source: Defra (2017), LACW statistics 2015/16. Accessed from: https://www.gov.uk/government/statistical-data-sets/env18-local-authority-collected-waste-annual-results-tables)



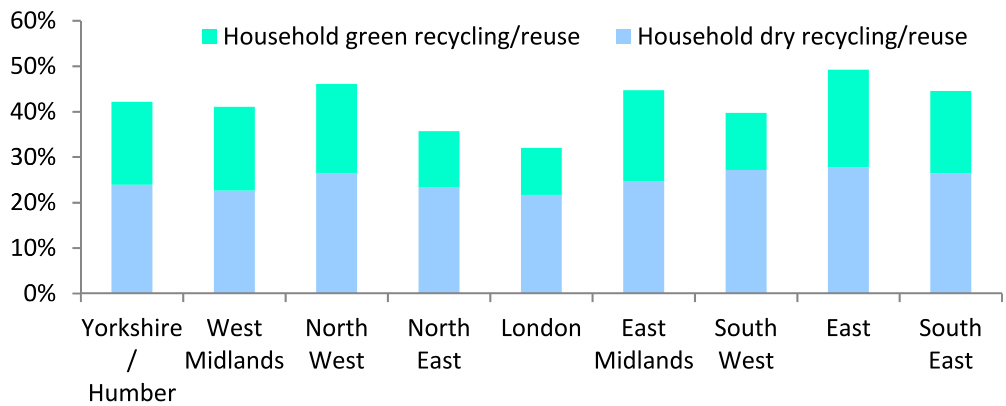
London has always performed poorly compared to other UK regions, and is sitting well below the national average recycling rate of 43 per cent in 2016 (Figure 54).

Figure 54: Regional LACW recycling rates 2015/16 (source: Defra (2017), LACW statistics 2015/16. Accessed from: https://www.gov.uk/government/statistical-data-sets/env18-local-authority-collected-waste-annual-results-tables)



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 green garden waste for composting (Figure 55), which makes it more difficult to perform against the UK recycling weight-based targets.

Figure 55: Regional household dry recycling and composting rates 2015/16 (source: Defra (2017), Local authority collected waste generation from April 2000 to March 2016 (England and regions) and local authority data April 2015 to March 2016)



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 lead to a period of public sector austerity that saw local authority budgets decline significantly. Local authorities had to consider how they could meet their statutory requirements with decreased budget. This led to a reduction in some non-statutory functions, such as local recycling and real nappy promotional campaigns.

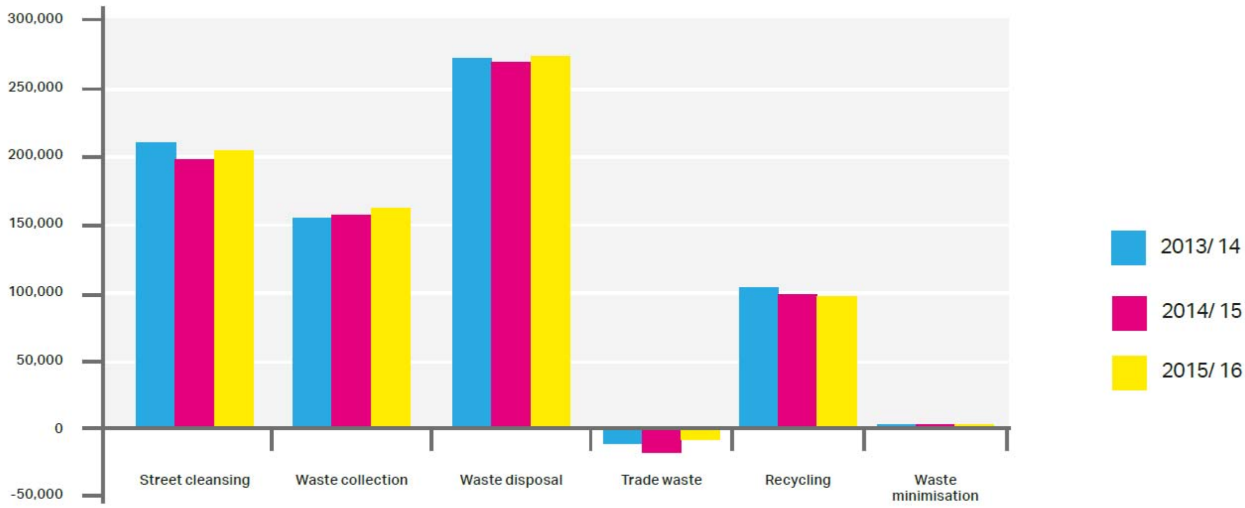
Finally, during this time London's LACW sent to incineration doubled from 900,000 tonnes (24 per cent) in 2011, to 1.8 million tonnes (47 per cent) in 2016. London now has the second highest incineration rate across the UK (behind the North East at 50 per cent).

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 with 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 56 shows London's local authority waste management costs over the past three years. Waste disposal (incineration and landfill) is the greatest area of spend (£270m), followed by street cleansing and waste collection.

Figure 56: LACW net expenditure on waste services 2015/16 (source: DCLG (2016), Local authority revenue expenditure and financing England. Accessed from: https://www.gov.uk/government/collections/local-authority-revenue-expenditure-and-financing#2016-to-2017)



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 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 is also then applied to waste disposed to landfill – currently £86 per tonne and rising to £89 per tonne from April 2018. The cost differential between recycling and incineration or landfill is wide, ranging from £24 per tonne for the former to £100 - £102 per tonne for the latter[34]. 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 provides. For example, local authorities providing trade (commercial) waste collection services can generate a net income, which reached a high of £15m in 2015/16. With the amount of commercial waste produced in London, there is scope for more income to support local budgets during times when waste authorities are hard pressed to find efficiencies. Increasingly, more London waste authorities have revenue share agreements in place, as the value of recycling has become better understood.

[34] WRAP Gatefees report 2016.

Reducing LACW waste arisings by just one per cent and achieving a 50 per cent LACW recycling rate could help shave £78m off London's LACW waste disposal costs per year[35].

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 57 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 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 kerbside properties and flats.

Figure 57: Local Authority waste collection services (source: Resource London Partnership (2016). N.B. Based on best available information; some services may have changed)

[35] Assumes 1 per cent or 37,000 tonnes of London's LACW 2015/16 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.

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 58).

Figure 58: Household recycling performance by borough 2015/16 (source: Defra (2017), LACW statistics 2015/16. Accessed from: https://www.gov.uk/government/statistical-data-sets/env18-local-authority-collected-waste-annual-results-tables)

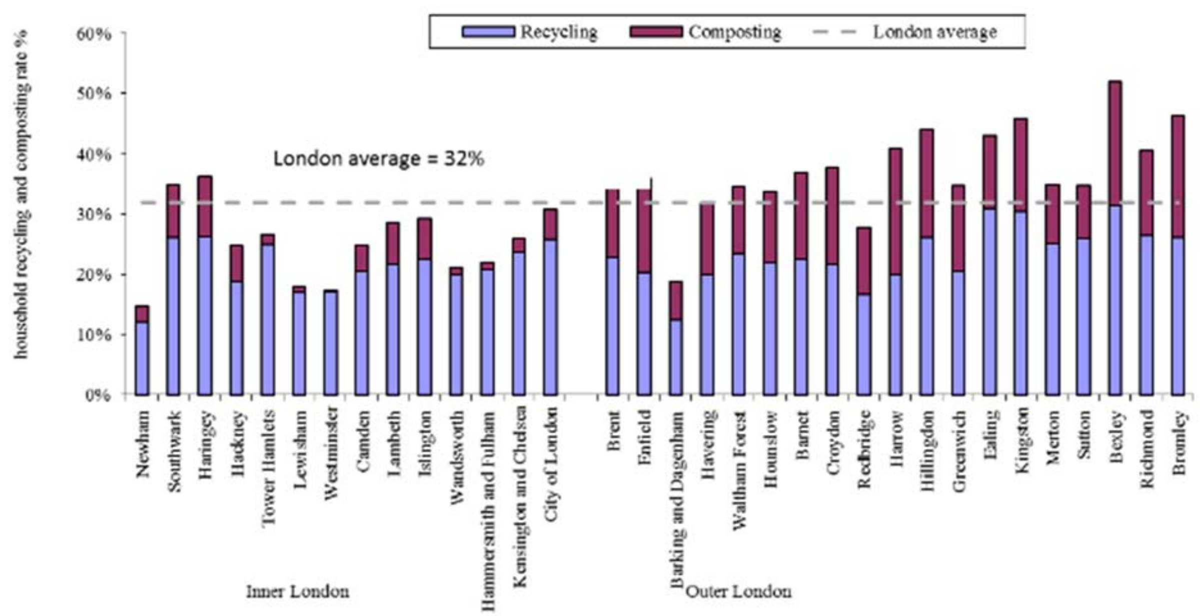
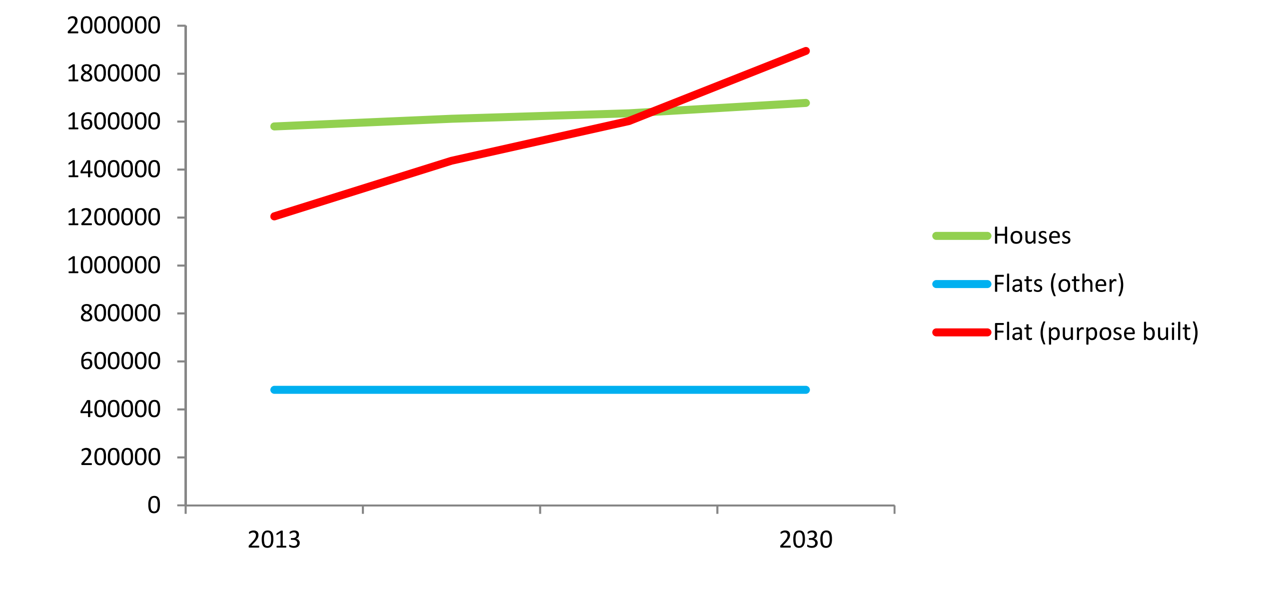


Figure 58 shows that, on average, the recycling rate is higher for outer boroughs, mostly as a result of higher composting rates. However, there is no similar relationship between inner and outer London boroughs for dry recycling performance (paper, glass, plastics and metals).

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 59).

Figure 59: Projected housing stock in London. Source: Resource London 2017



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 and other producers of non-household waste can choose whether they use waste and recycling collection services provide 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.

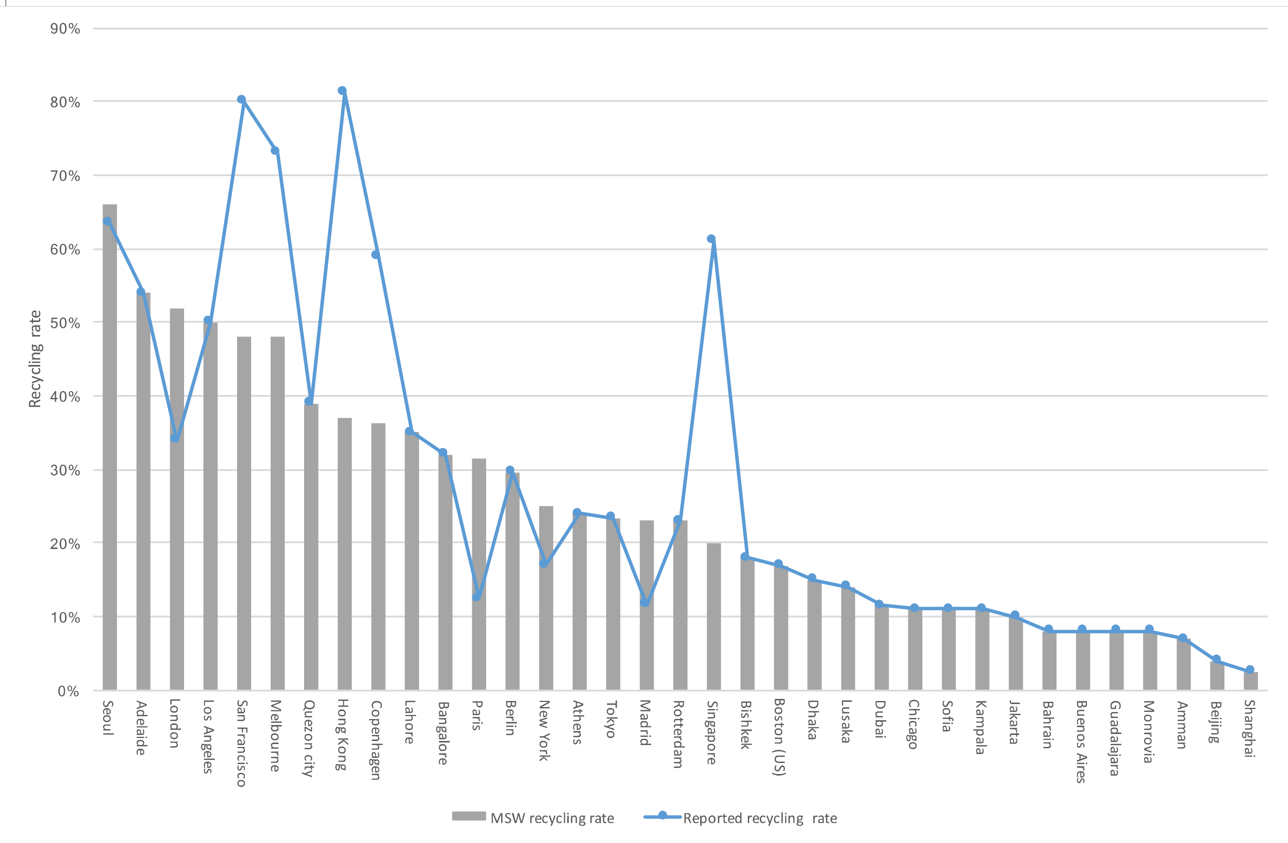
In April 2017, the government published the Litter Strategy for England, identifying a number of actions to be taken nationally that could have a significant impact on litter and fly tipping in London.

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, schools, and other public buildings 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.

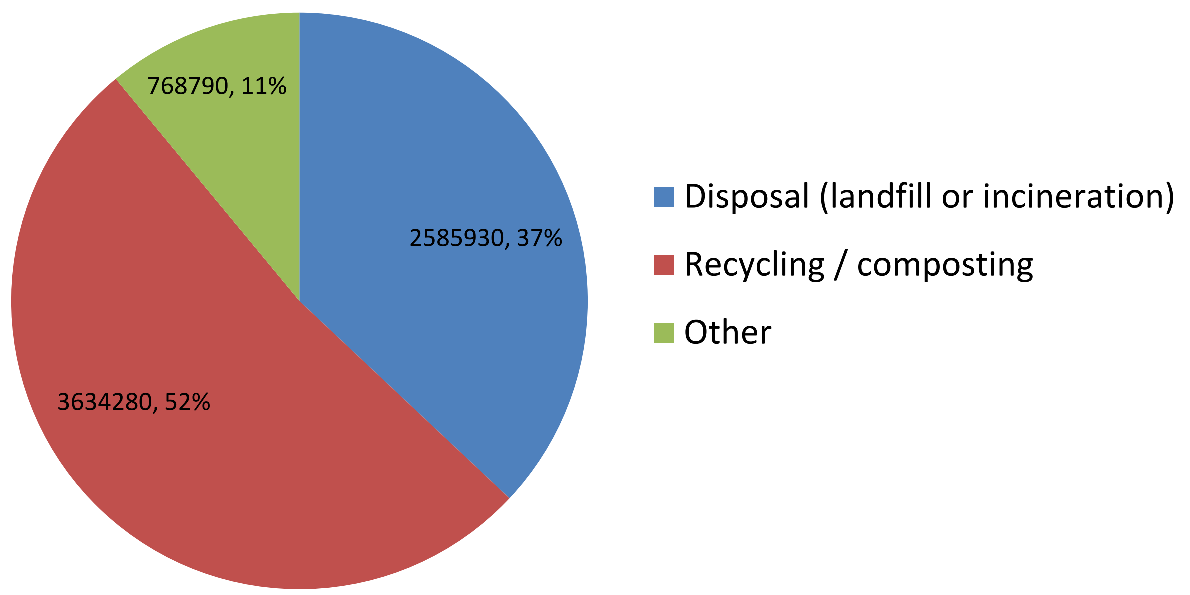
Under the revised definition of municipal waste now used by Defra, the scope of waste in London to be managed increases significantly. This is an opportunity and a challenge. However, whilst London's LACW performance is poor in the UK, it does better when compared to other global cities where waste is reported as 'municipal waste' that includes non-household municipal waste (mainly commercial waste). Rather than the current rate of 30 per cent, London achieves a 52 per cent municipal waste recycling rate, sitting 3rd behind Seoul (67 per cent) and Adelaide (54 per cent). On reporting rates (the blue line in Figure 60) 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 60: London's municipal waste performance comparison with other cities (source: http://www.lwarb.gov.uk/wp-content/uploads/2016/09/LWARB-International-recycling-rate-comparison.pdf)



Applying the broader EU definition of municipal waste brings an additional 3.3 million tonnes of non-household waste (mainly commercial waste collected by private companies) into scope for London, giving a total of seven million tonnes. Figure 61 shows London's total municipal waste management performance, combining waste from household and non-household sources (expressed both in tonnes and as a percentage of the total). The overall recycling performance is greatly improved as a result of higher estimated recycling rates of non-household waste (around 65-70 per cent recycling rates - not shown in chart).

Figure 61: London Municipal Solid Waste (MSW) arisings and management methods 2016 (in tonnes and as a percentage of the total). Total seven million tonnes 2016. (N.B. given the limitations of available data on municipal non-household 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)



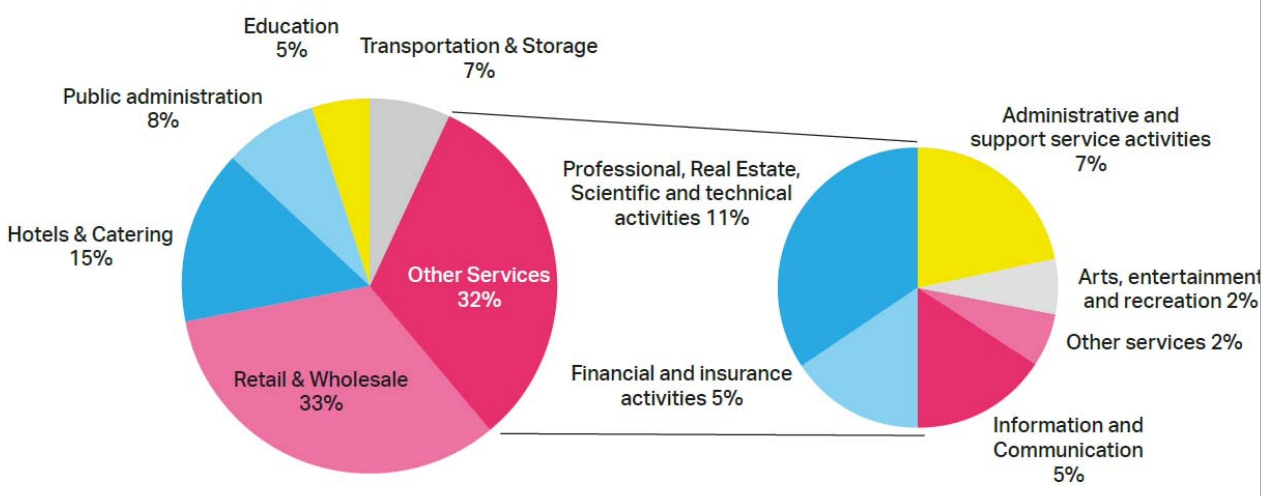
The opposite, however, is the case for local authority-run commercial waste services. Figure 54 shows that the recycling performance for commercial waste collected by local authorities is poor, contributing 7-18 per cent to LACW recycling performance nationally, and around ten per cent in London. It is estimated that local authorities control around a 13 per cent share of London's commercial 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". This suggests there is sizeable opportunity for improvement and income generation at the same time. 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[36].

Local authorities face several challenges to boosting their commercial 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.

Figure 62 shows how London's municipal non-household waste is managed (as percentage of total) and where it's from by sector. The bulk of London's non-household waste comes from retail and wholesale activities (1.1 million tonnes, or 33 per cent) and other services (1 million tonnes, or 32 per cent) including administration, financial services, art and culture collectively making up 65 per cent of total non-household waste.

Figure 62: London municipal non-household waste arisings by sector 2016: total 3.3 million tonnes. Source: GLA waste modelling. (N.B. the municipal non-household 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)



[36] Taken from http://www.eelga.gov.uk/documents/support%20services/environment/local%20authority%20trade%20waste%20-%20top%20tips.pdf. Last accessed 12 June 2017.

The Mayor does not have any powers over commercially collected waste and no national or regional mandatory non-household waste reduction or recycling targets have been set by government. As such, private companies, charities, and public organisations including schools and government buildings are not required to report their waste management data to Defra, so it is not captured in a formal way at the local or national level. Non-household waste performance is collected through surveys, the most recent being in 2009[37], and by extracting data from the government's waste interrogator tool although this does not provide clarity on where the waste is generated from. It is clear that there is an economic value in the materials being disposed of by businesses and public organisations and there is a need for better data to gain an improved understanding of the levels and type of commercial waste recycled from private services.

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 up around an 85 per cent market share.

Waste infrastructure

London manages around half the waste it produces. Most exported waste goes to landfills, 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 waste each year, costing around £100 million[38]. 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 waste 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[39].

The GLA has developed a GIS map of London's waste facilities (https://maps.london.gov.uk/webmaps/waste/). 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 identity and access local waste facilities and suitable sites for new facilities.

[37] Defra revised national commercial and industrial waste estimates in 2016 and updated these figures in February 2017. The GLA is working with Defra to validate these figures in developing the final adopted version of the Mayor's London Environment Strategy.
[38] GLA (2017), London Plan waste forecasts and apportionments, Task 3 – Strategic waste data
[39] 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.

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 recently published a report[40] 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 perfectly edible.

In the UK the Courtauld Commitment 2025 is a voluntary agreement bringing together around 130 organisations across the food sector to cut food and drink waste and associated greenhouse gas emissions by 20 per cent per head by 2025. In 2013 Defra released its waste prevention strategy *Prevention is better than cure*, which was followed by a suite of documents aimed at supporting citizens, local authorities and businesses to cut waste as a first priority, in line with the waste hierarchy.

Single use packaging

Single use packaging materials, including coffee cups and plastic bottle waste, is another key waste stream that continues to grow and place increasing pressure on local waste management services. Plastic packaging blights 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.

The government has spoken recently of the need to put in place measures to divert plastics from incineration, including a potential 10-20p bottle charge on single use plastic bottles not recycled in the home. This view was shared in a London Assembly Environment Committee report[41] published in April, which recommended, amongst other things, trialling a plastic bottle deposit return scheme and providing better access to tap water across London.

A recent YouGov poll 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 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 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 million tonnes of 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. Growing public pressure has led to large coffee chains, including Starbucks and Costa, offering reusable cups and setting up separate coffee cup recycling bins around their shop locations.

Re-use

Limited reported data exists on material re-use, as in most cases these materials never enter the waste stream (rightly so) and therefore are not reported. However, it is known that significant re-

[40] 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/
[41] https://www.london.gov.uk/about-us/london-assembly/london-assembly-publications/bottled-water

use activity happens through people using platforms like Ebay, Gumtree and Freecycle to shift their unwanted items of value. Re-use and repair provides significant employment opportunities, 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[42].

Capturing value from waste
To date, the main focus of London's waste authorities has been to manage municipal waste as efficiently as possible and at minimal cost to the taxpayer. Traditionally, this has been by adopting low-cost collection methods and outsourcing treatment and disposal (usually sending it to incineration or landfill).

One consequence of this approach is that sometimes waste authorities have not actively pursued the opportunity to generate income from their waste management activities. Part of the problem lies in the fact that waste authorities have tended to enter into long-term inflexible contracts, where the emphasis has been on a stable pricing structure. These contracts have rarely been linked to the revenue generated by private contractors from selling on materials and generating energy from waste, partly due to legislation and partly due to a preference to outsource risk.

This is no longer the most cost effective approach, as London's waste bill will continue to grow under business as usual. More waste authorities are seeing the value of jointly procuring services to achieve economy of scale benefits, and entering into revenue share agreements. The data in Figure 56 (LACW waste costs), Box 4 and Box 5 suggest there are significant savings to be made and the means to provide waste authorities with an income stream.

Box 4: Improved food waste collection. Credit: London borough of Ealing waste services
Recycling rates in Ealing have risen by five percentage points in the last year (April 2016-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 2016-17 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 food waste is broken down to produce biogas for electricity and biofertiliser. In total, the service change will deliver an annual saving of £1.7m from operational efficiency, reduced need for street cleaning, and savings in waste disposal.

[42] GLA waste modelling

Box 5: Commercial waste recycling. Credit: London borough of Westminster services
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 fetch 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 7.

Table 7: Average prices paid for common recyclable materials 2016 (source: 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)

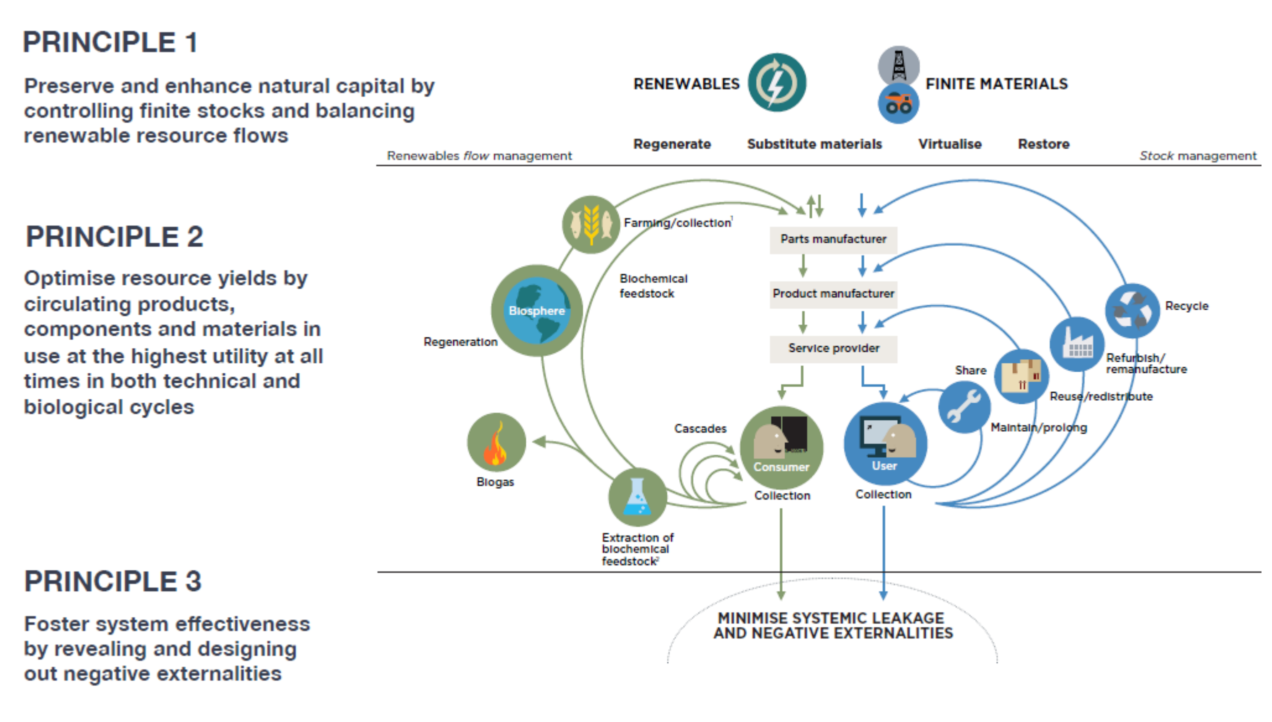
Material	Price per tonne 2016	CO_2e emissions saved per tonne recycled
Mixed paper	£69	0.34 tonnes
Mixed glass	£10	0.20 tonnes
Mixed plastic bottles	£87	1.17 tonnes
Aluminium cans	£687	8.70 tonnes
Steel cans	£48	1.83 tonnes
Textile: banks	£212	6.00 tonnes

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. Government in responding to the EU Circular Economy Policy Package has indicated it is 'less keen' on weight based recycling targets and that the 65 per cent target firstly proposed in the EU CE policy package was 'too high to be achievable' if the weight based approach is not amended to reflect carbon. 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 consumption. It is restorative and regenerative by design, aiming to keep materials, products and components in technical and biological loops, keeping them at their highest value in use for as long as possible (Figure 63). 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[43] 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 base 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.

Figure 63: The circular economy (source: Ellen MacArthur Foundation – adapted from the cradle-to-cradle (C2C) design protocol by Braungart and McDonough)



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[44]. Table 8 estimates employment in reuse, repair, recycling, and rental/leasing generates around 46,700 jobs.

[43] London Waste and Recycling Board (2017), Circular Economy effects on waste production in London.
[44] GLA (2015), Towards a circular economy; GLA (2015), Employment and the circular economy – job creation through resource efficiency in London.

Table 8: 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
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. Growing London's reuse, repair and recycling infrastructure can create community assets that deliver wider social benefits. These include apprenticeships and skills development, and helping to alleviate poverty through the redistribution of refurbished items to those in need in a resource efficient and cost effective way.

In June 2017 LWARB in partnership with the Mayor and other stakeholders published a circular economy route map to accelerate London's transition to a circular economy. The route map identifies five focus areas – the built environment (including construction), food, textiles, electricals and plastics – for driving action to achieve significant resource efficiency improvements that could contribute £2.8 billion towards the £7 billion opportunity identified.

Improving London's Recycling Rate

Household waste recycling

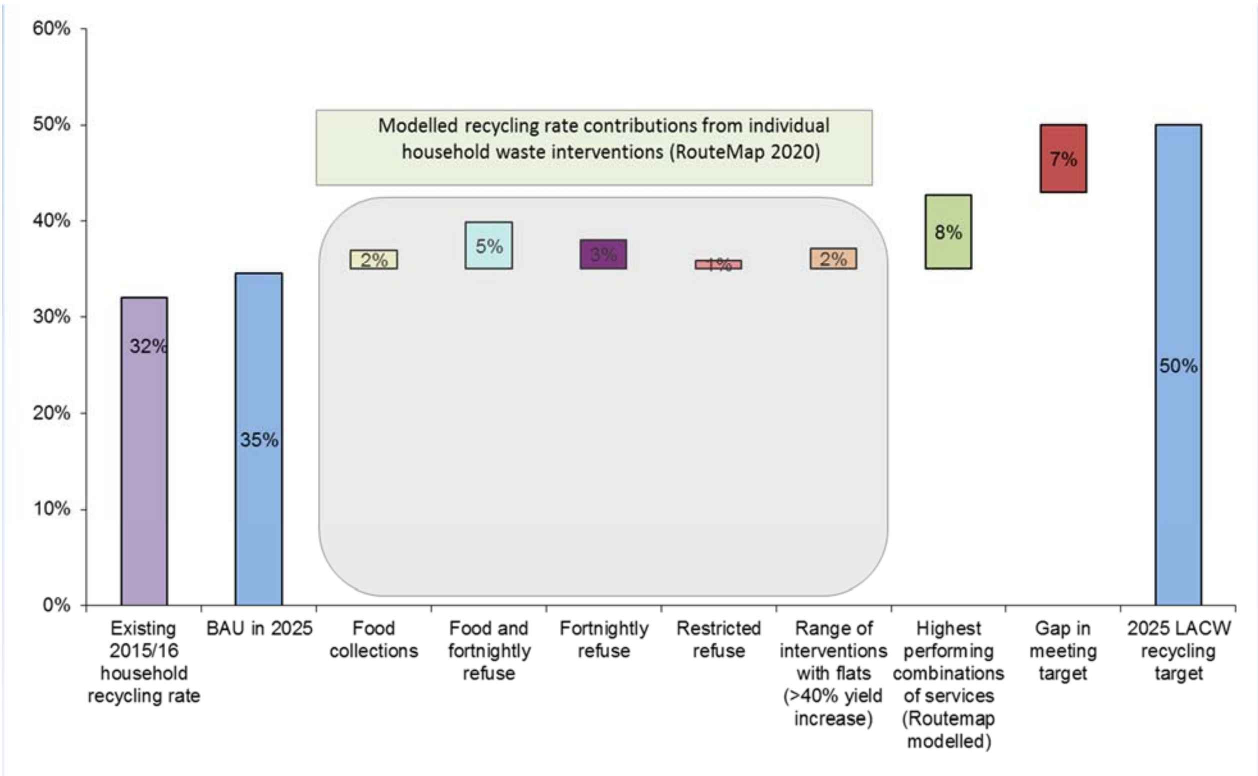
LWARB/Resource London commissioned WRAP to model scenarios for how London's household recycling rate can be improved meeting the national 50 per cent recycling target by 2020.

The study found that London would only be able to achieve a 42-43 per cent household waste recycling rate by 2022 from the current 32 per cent rate. Achieving this would require significant investment and improvements to services offered on a consistent basis across London.

Figure 64 shows the current household recycling rate of 32 per cent and 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.

Figure 64: How London can meet a 50 per cent LACW recycling target by 2025. Source WRAP and GLA modelling 2017



The modelling then looked at a combination of individual services that would achieve the highest household recycling rate of 43 per cent by 2022. This leaves a seven per cent shortfall in reaching the national 50 per cent household recycling target. Figure 64 shows a trajectory for how London could meet a 50 per cent LACW recycling target based on the modelling work.

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 9.

Table 9: 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 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 10 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 per cent increase in recycling from flats. Significant savings in both combination scenarios are forecast made from reduced bulking and treatment costs (mainly landfill or incineration) and increased revenue from the sale of the additional recyclables collected.

Table 10: 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**

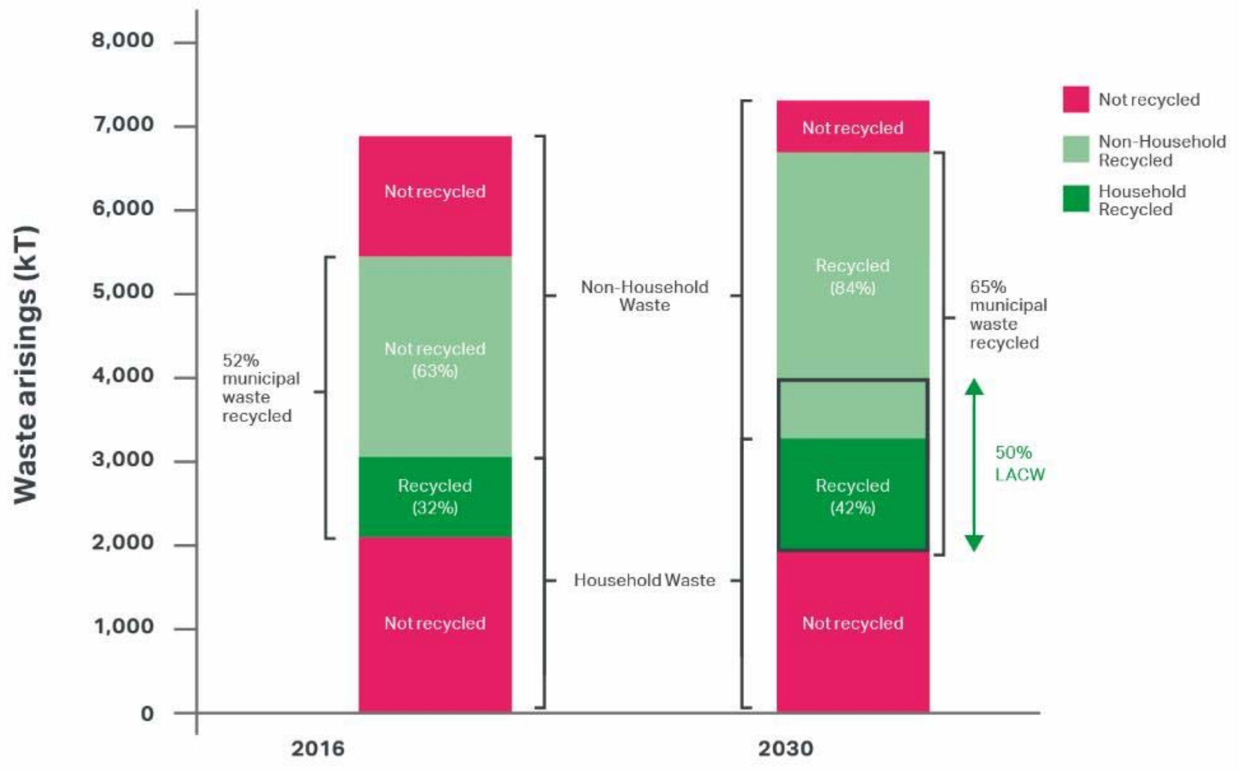
In summary, the highest performing combination scenario (1b, 5a, 6c) achieving a 42-43 per cent household recycling rate would bring a cumulative cost of £129m in addition to business as usual costs. The second considered scenario (1a, 2, 5a) achieving a 40 per cent household recycling rate would present 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.

Achieving a 65 per cent municipal waste recycling rate by 2030

To achieve the Mayor's 65 per cent municipal waste recycling rate, improvements in both household and non-household waste are needed.

Figure 65 shows how London can move from 52 per cent municipal waste recycling rate today to 65 per cent by 2030. This rate will be achieved by increasing recycling from non household waste sources from around 63 per cent today to 84 per cent by 2030. Implementing the best set of household waste recycling services identified in WRAP modelling would contribute an eight per cent increase from a Business as Usual approach (35 per cent).

Figure 65: How London can achieve a 65 per cent municipal recycling rate by 2030 (source: GLA (2017), GLA Waste Model; Resource London (2016), RouteMap 2020). NB non-household waste data is estimate only informed by the Defra Commercial and Industrial waste survey 2009. Data should be treated with caution and not reported as official data.



Reducing greenhouse gas emissions

Sending waste to landfill generates greenhouse gas emissions – particularly 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.

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 was recently discussed and supported in a Policy Exchange report *Going Round in Circles*. 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.

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 good 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 flexibility, particularly for London waste authorities that struggle to meet current weight based recycling targets to instead focus on materials and techniques offering the greatest economic and environmental benefits.

London's 2015/16 EPS performance resulted in an overall annual saving of -171 ktCO_2e. This is despite London's weight based LACW recycling rate levelling off since 2011 at 30 per cent. These improvements are largely a result of more waste being diverted from landfill to incineration with some improvements in recycling. Taking an EPS approach has demonstrated the value of a carbon based metric in understanding the true environmental impact of waste in climate change terms.

In addition to the EPS, a minimum CO_2e emissions level was set to help decarbonise London's energy sector by ensuring clean and efficient 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 generating electricity only, 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 and highly carbon polluting because they don't capture and use 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.

There are plans for all of London's incinerators to operate in combined heat and power mode that could potentially meet the CIF with the optimal design specification, although the full effect of this is not expected to be realised until 2025.

Developing a new EPS
In developing this strategy, the EPS has been reviewed and rebased 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 proposed EPS compared to those used to develop the current EPS are:

- London achieving a lower LACW recycling rate in 2015/16 (31 per cent) than previously forecasted (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

The revised proposed EPS targets compared to the EPS targets in the previous municipal waste strategy are set out in Table 11.

Table 11: EPS targets	
Proposed EPS targets – tonnes of CO_2e per tonnes of waste managed	**Previous EPS targets - tonnes of CO_2e per tonnes of waste managed**
-0.069 by 2020	-0.186 by 2020
-0.084 by 2025	
-0.167 by 2030	-0.243 by 2030

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 modelled achieving a LACW recycling target 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 66 shows London's current and projected performance against the proposed 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 stars show the current EPS targets for comparison.

Figure 66: London's current and projected performance against the EPS in tonnes of CO_2e produced per tonne of waste managed

More information on developing the new proposed EPS can be found in Appendix 2C

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. The period since 2000 accounts for two-thirds of hot-day records and close to half of wet-day records since 1910[45].

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.[46]

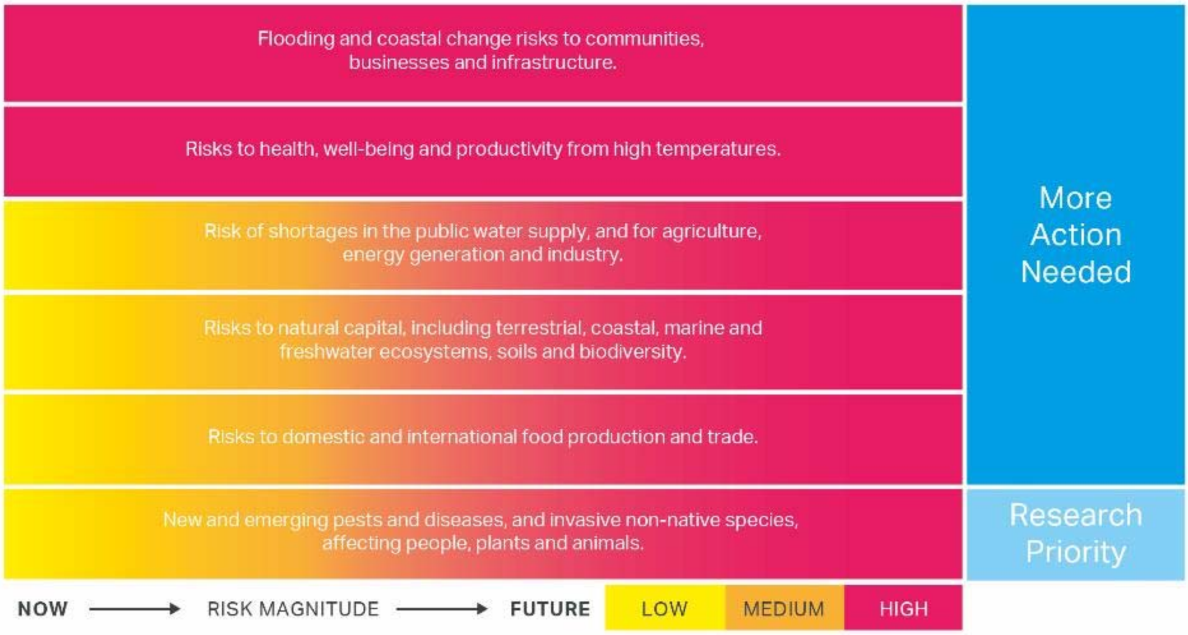
Box 6: Climate adaptation and resilience[47]
Adaptation is the process (or outcome of a process) that leads to a reduction in harm or risk of harm, or realisation of benefits associated with climate variability and climate change. Resilience is the ability of a system to recover from the effect of an 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, and current UK climate projections tell us that London will experience three major climate risks: flooding, drought, and heat. 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.

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 67).

[45] 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/.
[46] 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.
[47] 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.

Figure 67: Top six areas of inter-related climate change risks for the United Kingdom. Source: Adaptation Sub-Committee (source: Committee on Climate Change (2017), UK Climate Change Risk Assessment Evidence Report 2017: Introduction)



While these broadly align with London's priority risks, London recognises that the risks from climate change are locally specific and need to be understood in the context of the city's own characteristics, needs, and priorities. We are further ahead in our understanding and management of some of these risks than others, but 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 Adaptation Sub-Committee 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 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 currently there is no systematic collection of data to illustrate how well the city is adapting to the impacts of severe weather and longer-term climate change.

London currently uses six key questions to assess the city's ability to become more resilient to climate impacts. These questions are:

- does the risk have an agreed owner/s?
- do we understand the risk now and in the future?
- do we have an emergency response for a severe event today?

- do we have a forward looking plan for managing the risk?
- are the actions in the plan being delivered?
- is the activity sufficient to maintain an acceptable level of risk?

Applying these questions to the key climate change risks for London provides a picture of London's ability to adapt and progress made in assessing the risks since 2011 (Table 12).

Table 12: 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.	

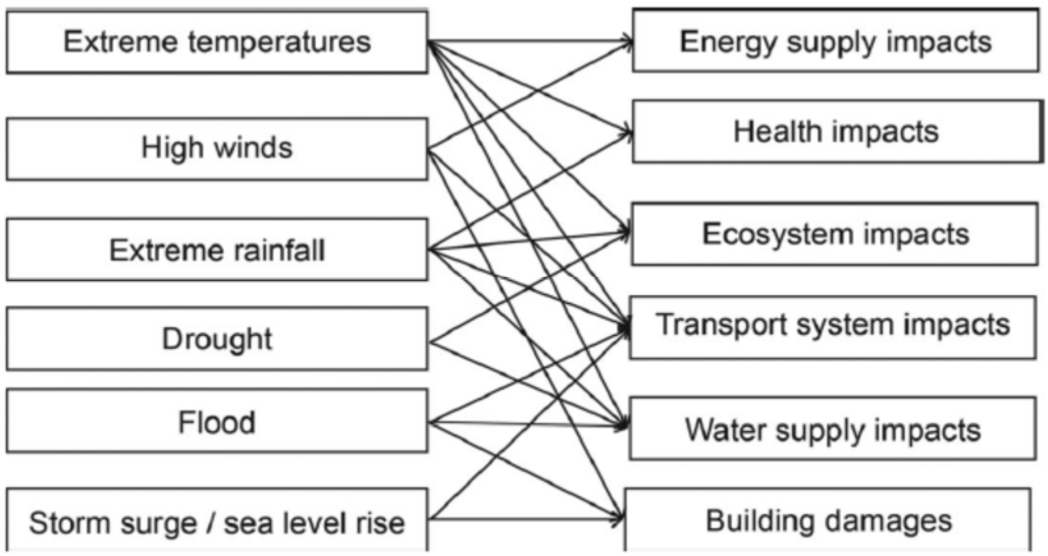
Interconnected risks and responses

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.

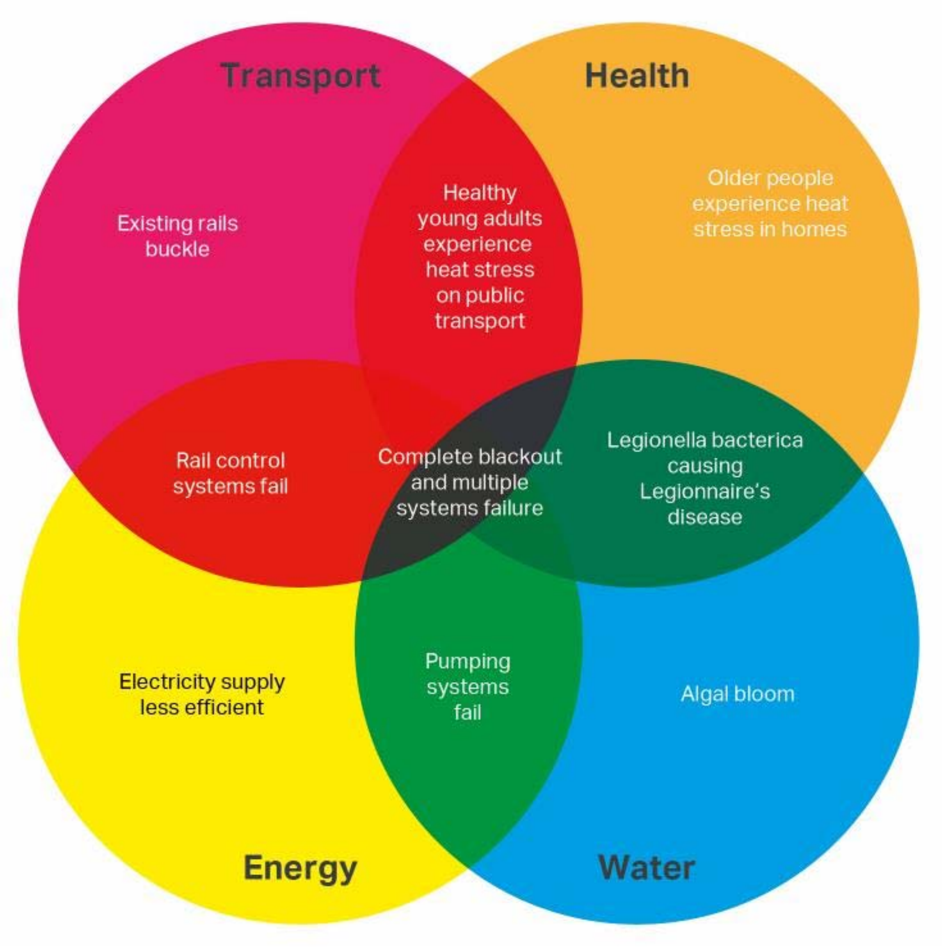
Cities are complex and interdependent systems, and climate resilience will depend on anticipating the possible knock-on effects caused by climate-related impacts, in combination with other pressures and challenges, including population growth, development, and other non-climate-related risks (Figure 68).

Figure 68: Climate extremes and potential impacts on urban systems (source: Solecki *et al*, 2015 Annals of the New York Academy of Sciences 1336 (2015) 89-106)



The Anytown methodology developed by London Resilience Group (which coordinates emergency preparedness and resilience across a partnership of 170 organisations) illustrates the "ripple effect" of infrastructure disruption. It helps London's decision-makers identify potential vulnerabilities and cascading consequences where interconnected parts of the system come together, and to prioritise those which require attention (Figure 69).

Figure 69: Venn diagram of heat risk-related interdependencies between four urban systems.



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.

A survey of 750 experts conducted by the World Economic Forum found a catastrophe due to climate change to be the biggest potential threat to the global economy in 2016, ahead of weapons of mass destruction, water crises, mass involuntary migration and a severe energy price shock. It also recognised the strong connections between climate change and other risks, such as involuntary migration.

The Chief Risk Officer for Zurich insurance, has stated that: "*Climate change is exacerbating more risks than ever before in terms of water crises, food shortages, constrained economic growth, weaker societal cohesion and increased security risks.*"

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.

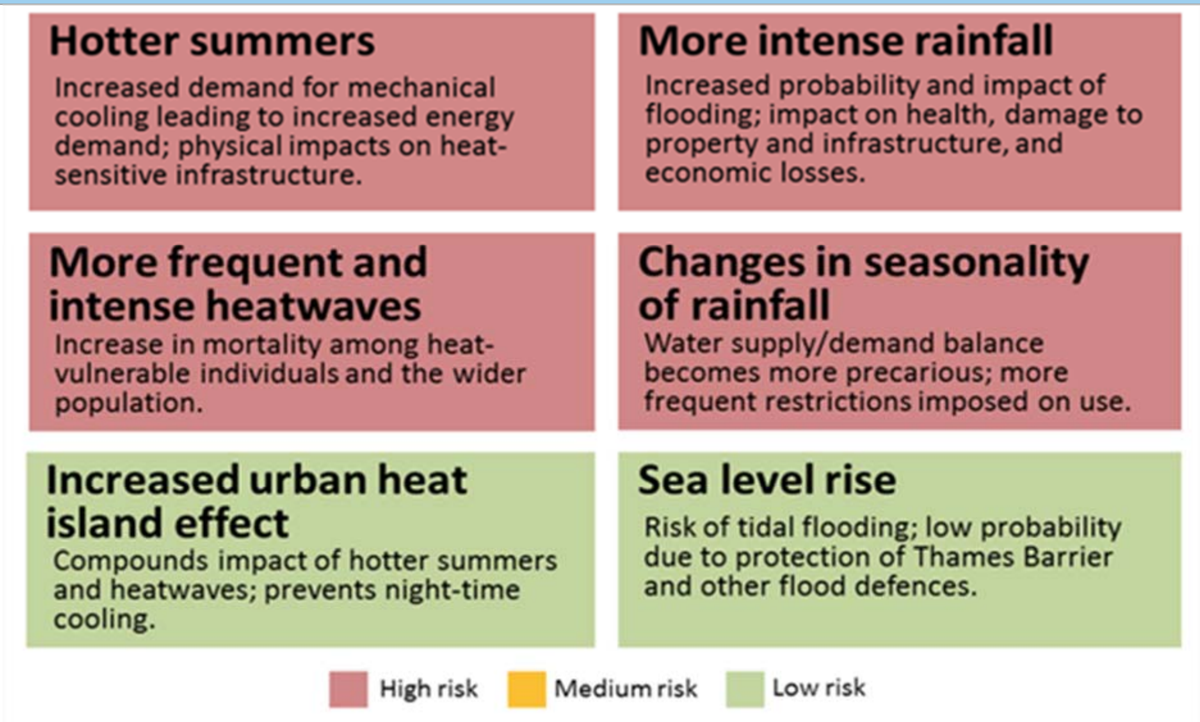
The Economist Intelligence Unit (EIU) has reported that:

- 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 70).

Figure 70: London businesses will see an increase in physical climate change impacts

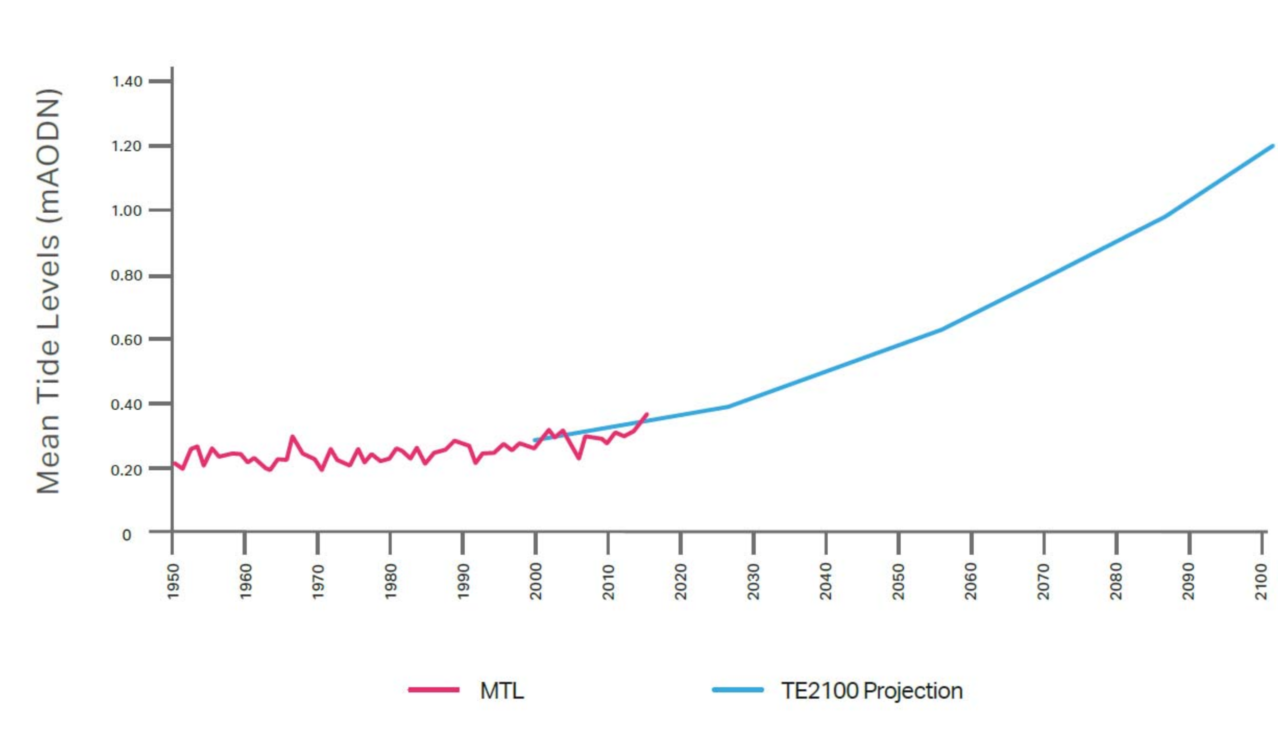


Flood risk

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. London is vulnerable to flooding from five sources: tidal, river, surface, sewer, and groundwater. Wetter winters and more frequent and severe downpours, along with rising sea levels and higher tidal surges (Figure 71), 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.

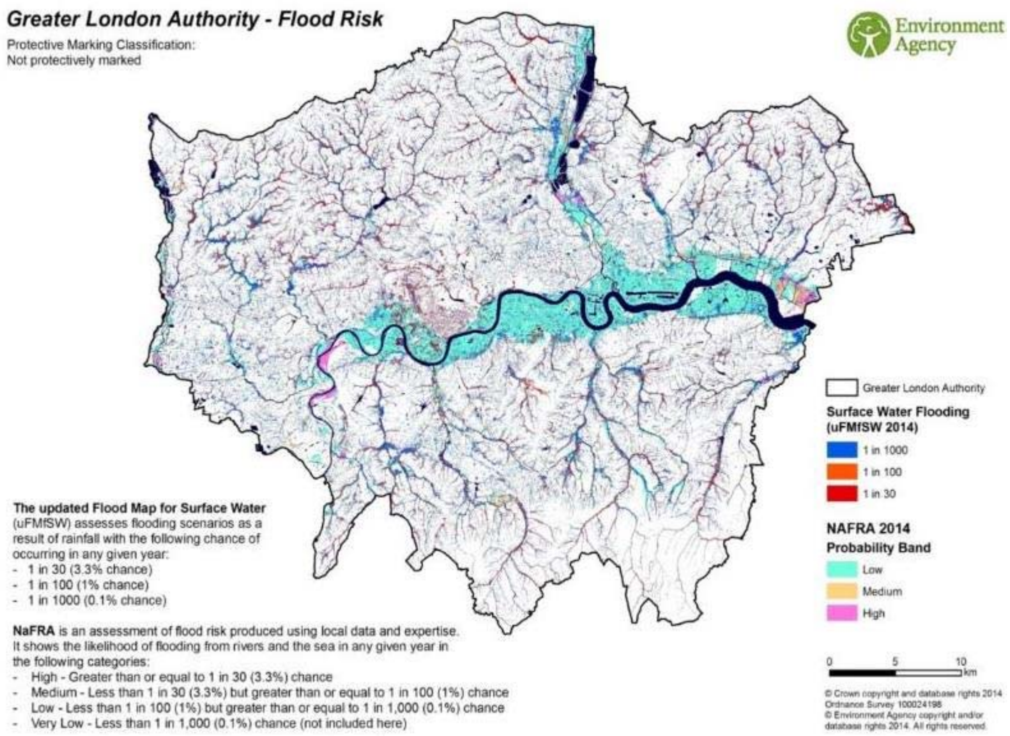
Figure 71: Mean tide levels at Southend with climate change projections to 2100



A large proportion of the city is currently potentially at risk from flooding (Figure 72). 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)[48]. Building on a flood plain puts these properties at higher risk, and the displaced water can exacerbate problems elsewhere.

Figure 72: Flood map for London showing tidal, fluvial and surface water flood risk



[48] 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.

Tidal and fluvial flood risk

The flood defences that we have in place are crucial to the functioning of the city (Figure 73 and Figure 74). 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.

Figure 73: River Thames Tidal Defence System

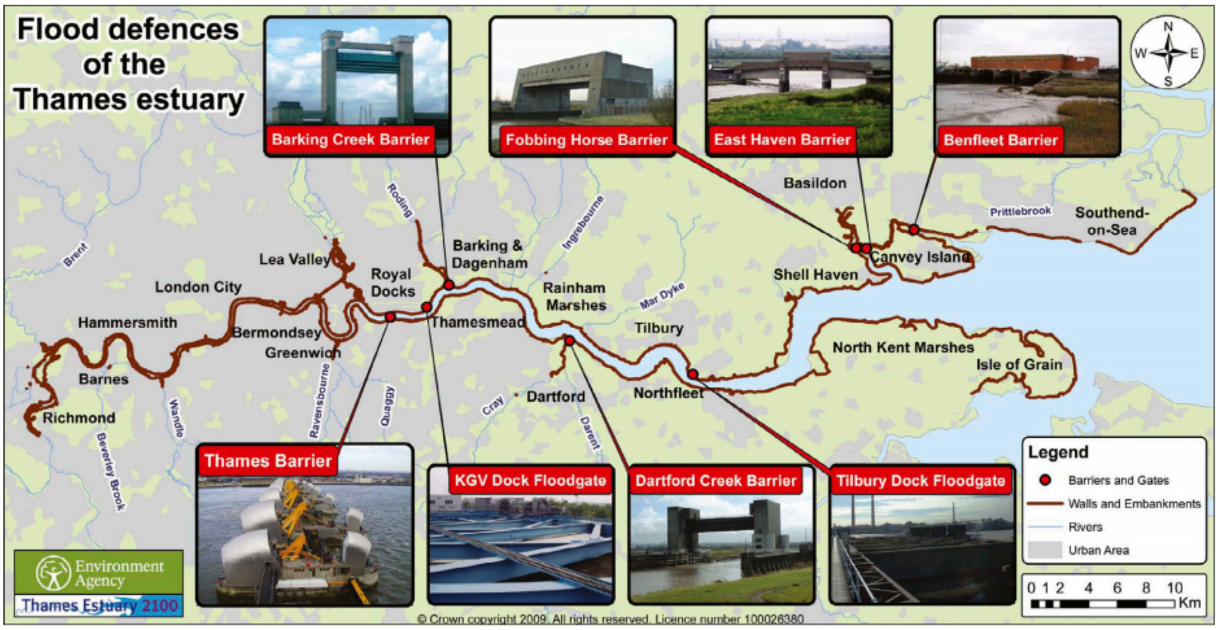
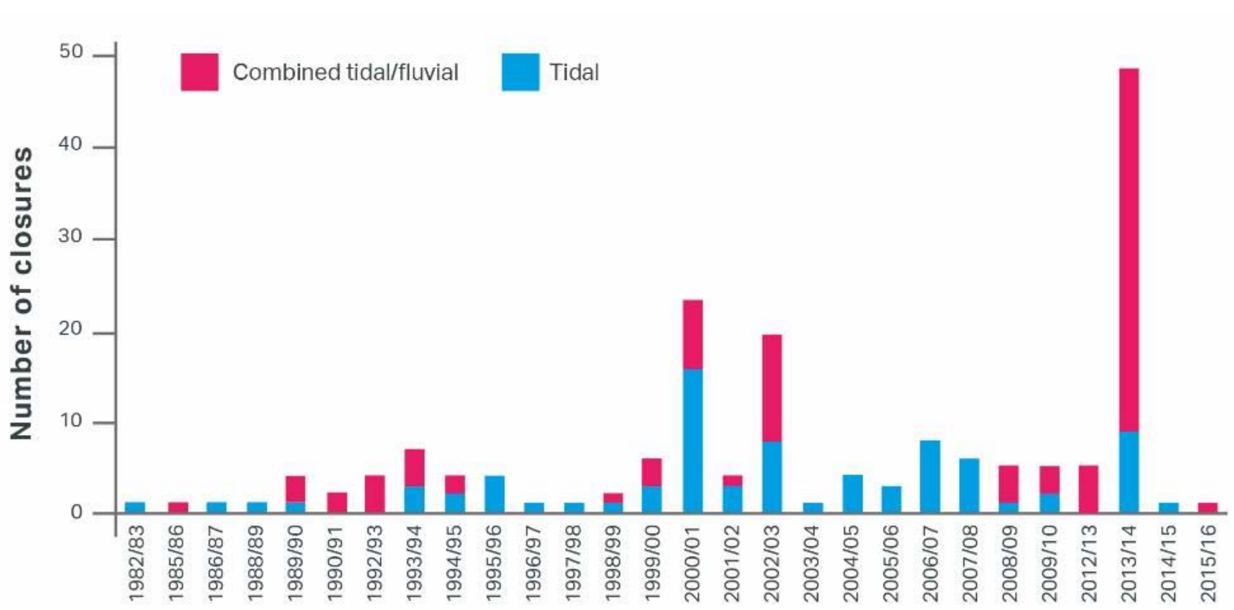


Figure 74: Number of Thames Barrier closures by season



Surface water flood risk
There are 68,000 properties in London at high risk of surface water flooding including residential and commercial properties (Figure 75). Of the various forms of flooding that can affect London, the most difficult to predict and plan for is surface water flooding.

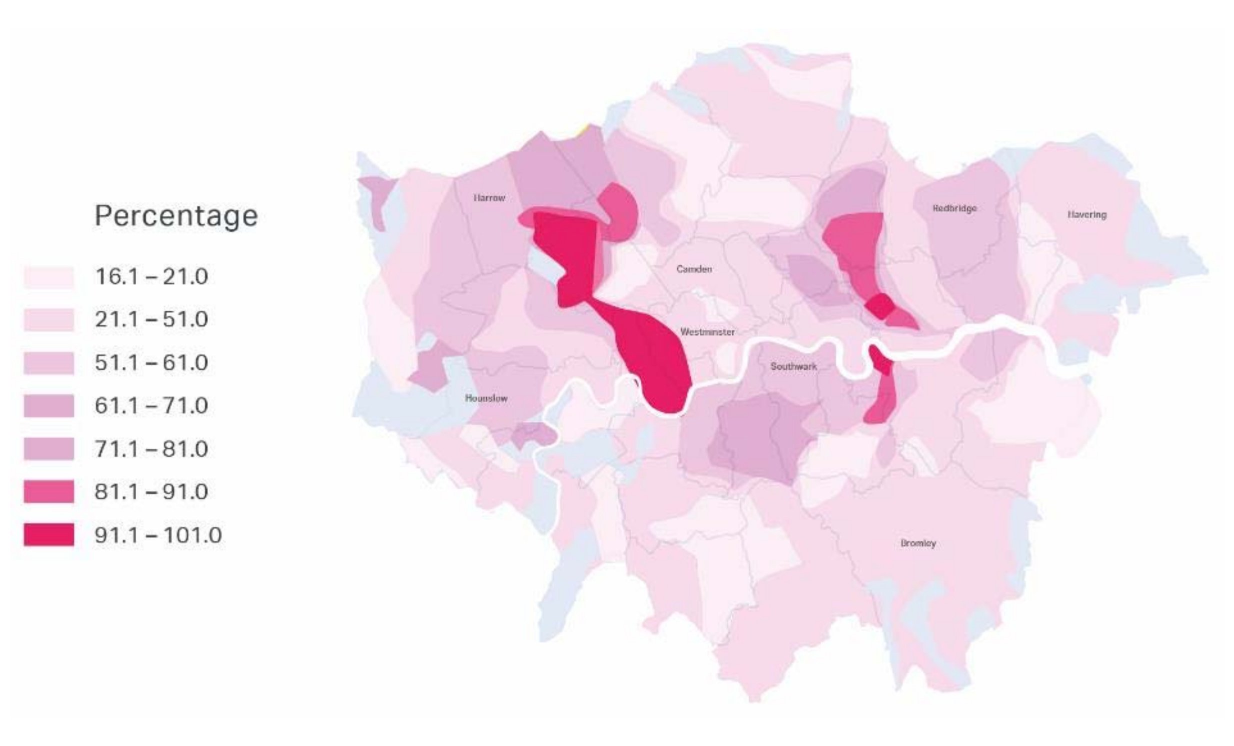
There is an effective flood warning service for tidal, fluvial and groundwater flooding where there is take-up of this service. However, predicting when and where a heavy downpour will cause (often localised but potentially serious) surface water flooding is far more difficult. There is, therefore, no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

Figure 75: Number of properties at risk of surface water flooding in London

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

There is varying available capacity in London's drainage and sewerage network (Figure 76). In some areas, there is very limited capacity available. The map in Figure 76 reflects the predicted capacity (red reflects over 90 to 100% of the flow capacity is predicted) on the network in 2050. However, it does not include the projected growth in London, such as in the Old Oak Common and Park Royal Opportunity Area, which is located in an area that already has low capacity.

Figure 76: Capacity of the drainage network – Thames Water

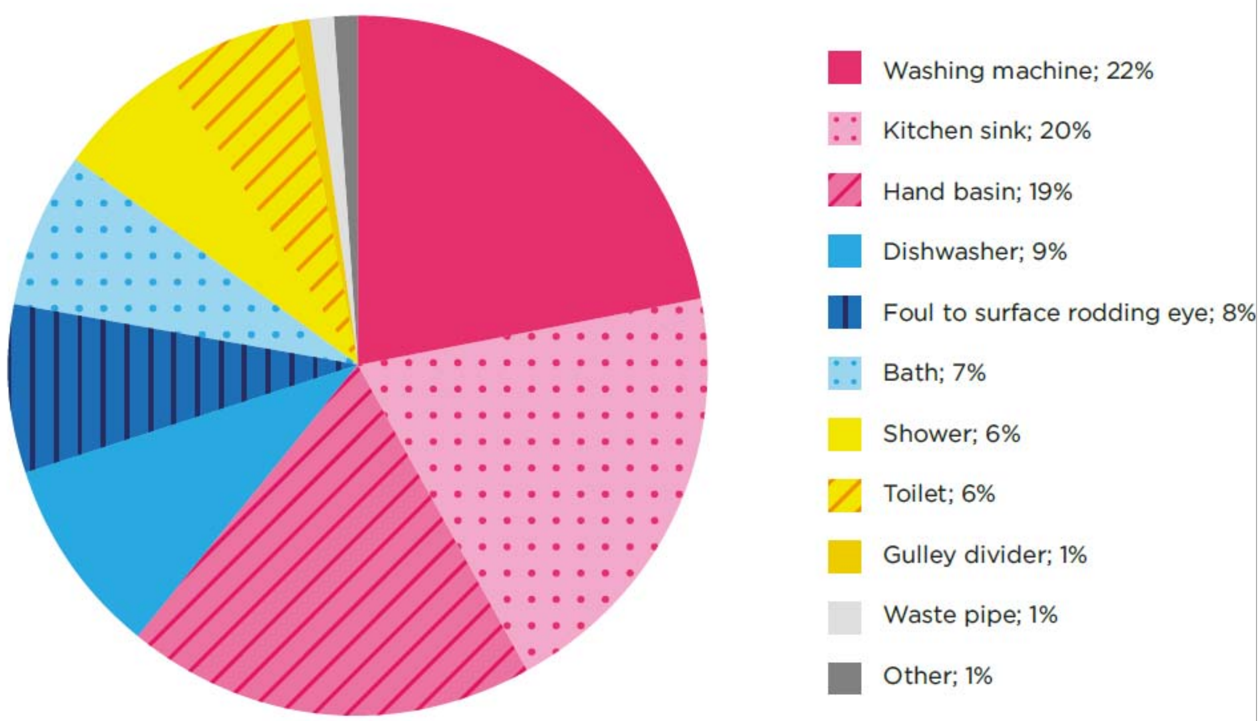


Water quality

The Environment Agency monitors river water quality as part of the EU Water Framework Directive (see Appendix 4 for more information on this Directive),

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

Figure 77: Misconnections



Drought

Potential water shortages present a threat to people and industries, especially when combined with other pressures, including increasing development and population.

Figure 78 shows that the average household water consumption in London is 155 litres per person per day and the average leakage rate in London is 17.6 per cent. This shows the dual pressure on water use in London.

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

Figure 78: Household consumption and leakage rates in London[49]

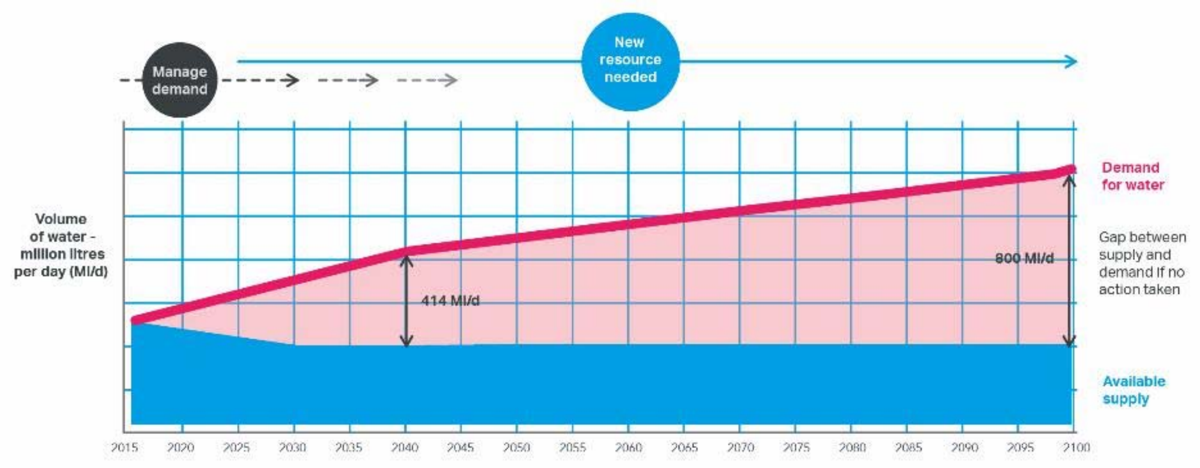
Water Company	No of households supplied	No of businesses supplied	Average daily household consumption l/p/d		Average leakage amount & rate l/d & %	
			2000	2015(or a recent available date)	2000	2015(or a recent available date)
Thames Water	2 684 440	176 980	n/a	160.6[1] 130.9[2] 152.5[3]	n/a	642 Ml/d 22.1%[4]
Affinity Water	444,338	20,880	173.6	155.8	45.3 21%	45.15 19%
Essex & Suffolk Water	178,995	7,966	160.1	150.05	38.37 Ml/d 18%	29.09 Ml/d 15%
Sutton & East Surrey Water[5]	122,140	5,219	162.73	164.80	9.7 Ml 14.68%	10.2 Ml/d 14.13%

49 1 For un-metered households in London supply area – note that this also includes households outside London, notably in the Lee valley area north to Hertford
2 For metered households area – note that this also includes households outside London
3 Average for London supply area
4 Figure relates to all of Thames Water supply area

Figure 79 shows that Thames Water forecast a water resource deficit of over 100 Ml per day by 2020, rising to a deficit of over 400 Ml per day by 2040. This is equivalent to the water needed by around two million people. In response, water companies that serve London are working together to further improve demand management (further reduce leakage, increase water efficiency and increase role out of water metering) and develop new water resource options and water supply infrastructure. Currently Thames Water, which supplies 70 per cent of London's water customers, is looking at a range of variations of four principle new water resource options. These are:

- a new reservoir –which would be located outside London
- a raw (untreated) water transfer pipeline from the west of England
- effluent re-use (treating effluent to a potable standard)
- additional desalination plants

Figure 79: Water deficit projections, Thames Water[50]



50 Draft baseline forecast resource deficit in London water resource zone (April 2017) – Thames Water

Heat risk

Context

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. Figure 80 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

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[51]

Figure 80: Average monthly temperatures (ºC) in London over the century, under a medium emissions scenario, compared to baseline period [UCP09]

[51] 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

Urban heat island effect

London also generates its own microclimate, known as the urban heat island, which can result in the centre of London being up to 10°C warmer than the rural areas around the city. Figure 81 shows night-time temperature across the city, with clear ‘hot spots’ in more densely developed inner London compared with outer London.

Figure 81: Mean midnight temperature (˚C), May-September 2011

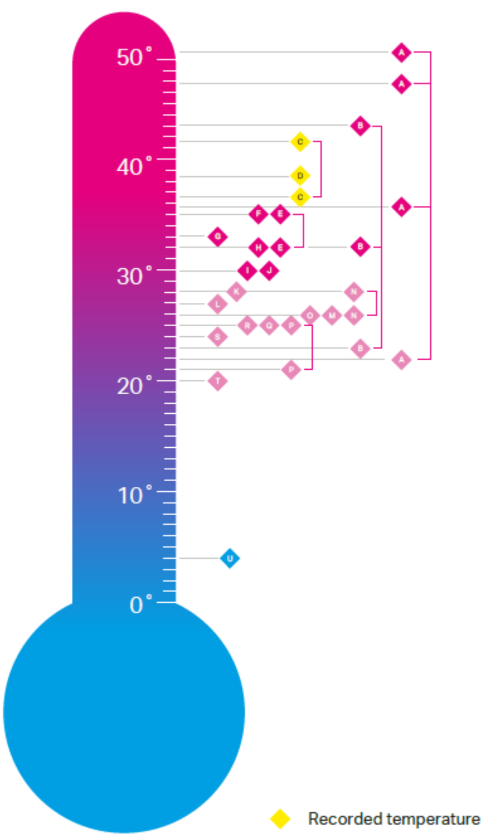
Heat thresholds in London

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 82 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[51]

Figure 82: Heat thresholds in London (source: London Climate Change Partnership)



	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.

AMBIENT NOISE

Noise as an environmental health risk

The World Health Organisation (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 7: 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.[52]

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.[52]

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.

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.

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

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[53] are lost every year from traffic related noise in the western part of Europe,[54] 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. 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).

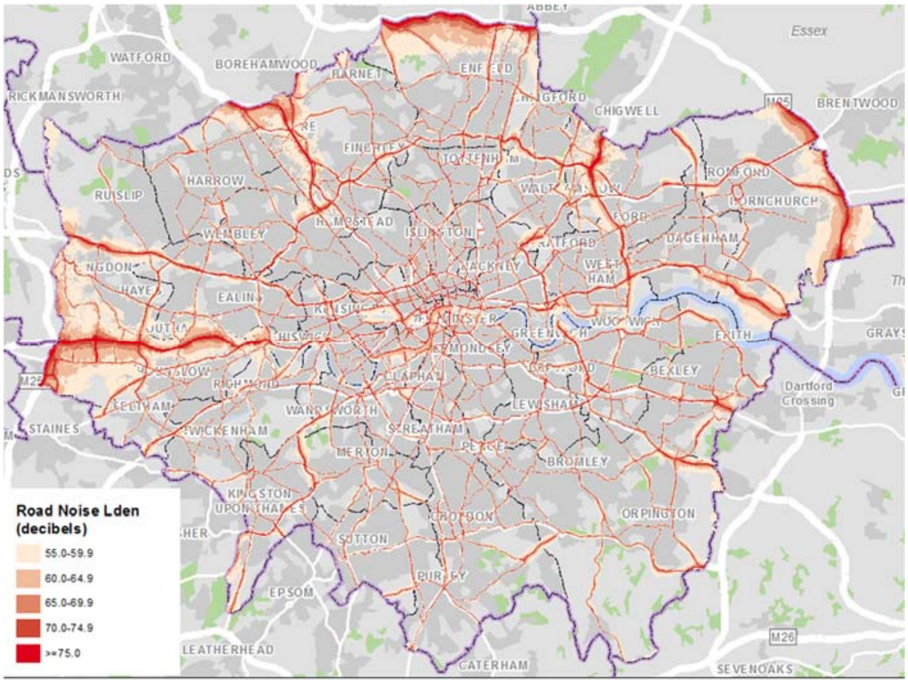
Table 13: Number of people affected by road traffic, rail and industrial noise in the Greater London Urban Area, 2011 (Based on an annual average 24 hour period for 2011)[55]

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

[53] 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.
[54] World Health Organisation (2011), Burden of disease from environmental noise, accessed via: http://www.euro.who.int/__data/assets/pdf_file/0008/136466/e94888.pdf?ua=1
[55] Defra (2014), Noise exposure data – England. Accessed from: https://data.gov.uk/dataset/noise-exposure-data-england

Noise maps show the geographic dispersal of estimated levels of road traffic noise along major transport routes (Figure 83). 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.

Figure 83: Noise map of estimated L_{DEN} road traffic noise levels across London[56]



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),[57] 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 13 above shows that much fewer people are exposed to rail noise above 55dB, than their counterparts under road noise.

[56] Defra (2016), Road Noise – Lden – England Round 2. Accessed from: https://data.gov.uk/dataset/road-noise-lden-england-round-21
[57] Greater London Authority (2016), Accessed from: https://data.london.gov.uk/dataset/gla-poll-results

Noise maps show the geographic dispersal of estimated levels of rail traffic noise along major transport routes (Figure 84). Major Railways are defined as sections of rail route that 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.

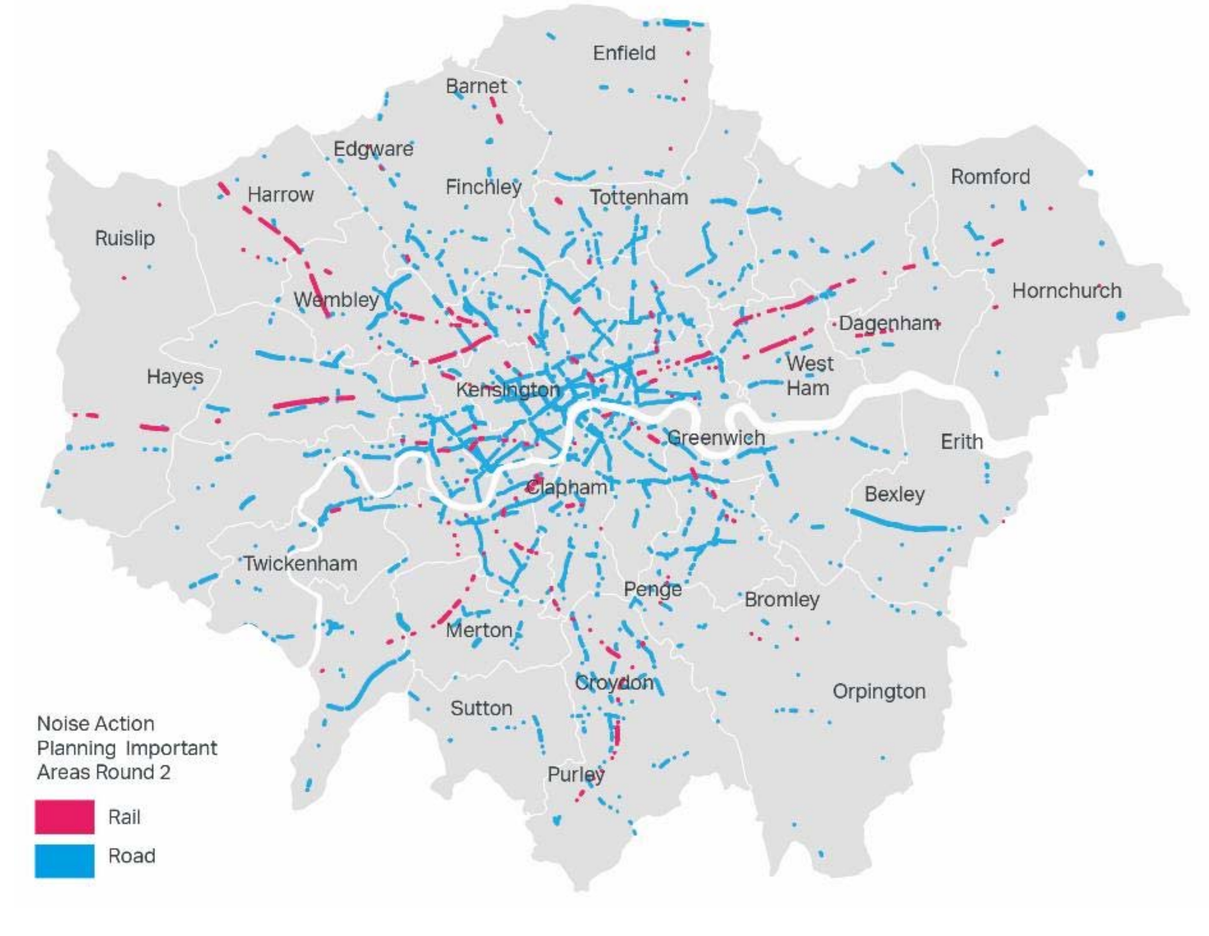
Figure 84: Noise maps of estimated L_{DEN} rail traffic noise levels across London[58]

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

Important Areas

Noise mapping has been completed to identify Important Areas for road and rail traffic noise (Figure 85). 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 83). When comparing Important Areas for road and rail traffic, the number of identified areas for rail traffic are much fewer.

Figure 85: Noise map of Important Areas for road and rail traffic noise across London[59]



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.

[59] 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)[60] 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 14.

Table 14: Summary of key airport statistics 2011[61]

London Airport	Heathrow	London City	Stansted	Gatwick	Luton	Southend
Flight Movements[62] (2016)	474,963	85,169	180,430	280,666	128,519	23,449
Noise Complaints (2015)	108,255[63]	86[64]	747[65]	15,189[66]	960[67]	352[68]
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

[60] Greater London Authority (2016), GLA poll results. Accessed from: https://data.london.gov.uk/dataset/gla-poll-results
[61] Sourced from independent airport noise action plans unless otherwise specified
[62] 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
[63] Heathrow Airport Limited (2015), Noise complaints – 2015 report. Accessed from: http://www.heathrow.com/file_source/HeathrowNoise/Static/Noise_complaints_report_2015.pdf
[64] 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
[65] London Stansted Airport (2015), Our Noise Performance. Accessed from: http://www.stanstedairport.com/community/local-environmental-impacts/noise/our-noise-performance/
[66] 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
[67] London Luton Airport (2015), Annual Monitoring Report. Accessed from: http://www.london-luton.co.uk/CMSPages/GetFile.aspx?guid=2cd18311-bb7f-41f2-a3fa-7b09ace5fea9
[68] 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

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 15: Battersea Heliport key statistics 2016[69]

	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 13 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 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)
- 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 16.

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

Table 16: How much respondents are bothered by different noise sources[70]					
Noise Source (N=2,383)	per cent bothered, annoyed or disturbed				
	Not at all	Slightly	Moderately	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. 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 17.

Table 17: 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?[71]			
N=1004	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.

[70] Defra (2013), Survey of Noise Attitudes. Accessed from: http://randd.defra.gov.uk/Document.aspx?Document=13319_NANR322SoNA2013ReportFinalNov2015.pdf
[71] Greater London Authority (2016), accessed from: https://data.london.gov.uk/dataset/gla-poll-results

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 draft 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.

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APPENDIX 2A: LONDON BIODIVERSITY ACTION PLAN – REVIEW OF PRIORITY SPECIES

2. London BAP Priority Species

The new list of London BAP Priority Species is as follows;

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*	●	● (grey)		●	
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*	● (grey)		●		

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**	**Amber**	
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*	●	○	●		
Reptiles, Amphibians, Mammals & Fish						
Adder	*Vipera berus*	●	○			●
Common lizard	*Lacerta vivipara*	●				●
Common toad	*Bufo bufo*	●				
Grass snake	*Natrix natrix*	●	○			●
Slow-worm	*Anguis fragilis*	●	○			●
Great crested newt	*Triturus cristatus*	●				
Brown hare	*Lepus europaeus*	●				
Brown long-eared bat	*Plecotus auritus*	●	○			●
Common dormouse	*Muscardinus avellanarius*	●				
Common pipistrelle (bat)	*Pipistrellus pipistrellus*	○				●
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*	●	○			●
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*	●	○			
Sea/Brown trout	*Salmo trutta*	●				
Twaite shad (fish)	*Allosa phallax*	●				
***Species removed from the London BAP Priority list*;**						
Buttoned snout (moth)	*Hypena rostralis*	○			○	
Four-spotted (moth)	*Tyta luctuosa*	●		●		e.
Pale shining brown (moth)	*Polia bombycina*	●				e.
Toadflax brocade (moth)	*Calophasia lunula*	○		○		
Grey heron	*Ardea cinerea*					○

○ = reviewed status e. = extinct

MAYOR OF LONDON

APPENDIX 2B: LONDON BIODIVERSITY ACTION PLAN – PRIORITY HABITATS

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.

MAYOR OF LONDON

APPENDIX 2C: LONDON RECYCLING ROUTEMAP 2020

Resource London

London Recycling Routemap 2020:

Analysis of options to increase recycling performance in London

June 2017

Resource London

Executive Summary

Resource London was established in 2015 as a jointly funded partnership between LWARB and WRAP to maximise the resources of both organisations for the benefit of London. The aim of the programme (at the time of the analysis and reflecting the published Mayor's Municipal Waste Management strategy 2011) was that by 2020 London will have more consistent and more efficient waste and recycling services that:

- achieve the Mayor of London's target that London recycles 50% of local authority collected waste by 2020; and
- are able to make a significant contribution towards England achieving 50 % household waste recycling by 2020.

The aim of this study was to provide analysis which could help steer Resource London's support to London Local Authorities to help contribute towards the Mayoral and national 50% targets. The study updates an earlier 50% analysis undertaken by WRAP in 2016 with the same objective: to provide clear indications of the target materials for collection and their volumes; the most cost effective collection systems; and the timeframe for action required to meet the targets.

The project was undertaken by Resource London as a collaboration of LWARB and WRAP staff gathering the necessary data and assumption, determining appropriate scenarios and undertaking a detailed analysis. Whilst the Mayoral 50% target for London is based on a definition of Local Authority collected municipal waste the analysis in this project was undertaken using Defra's 'waste from household' definition.

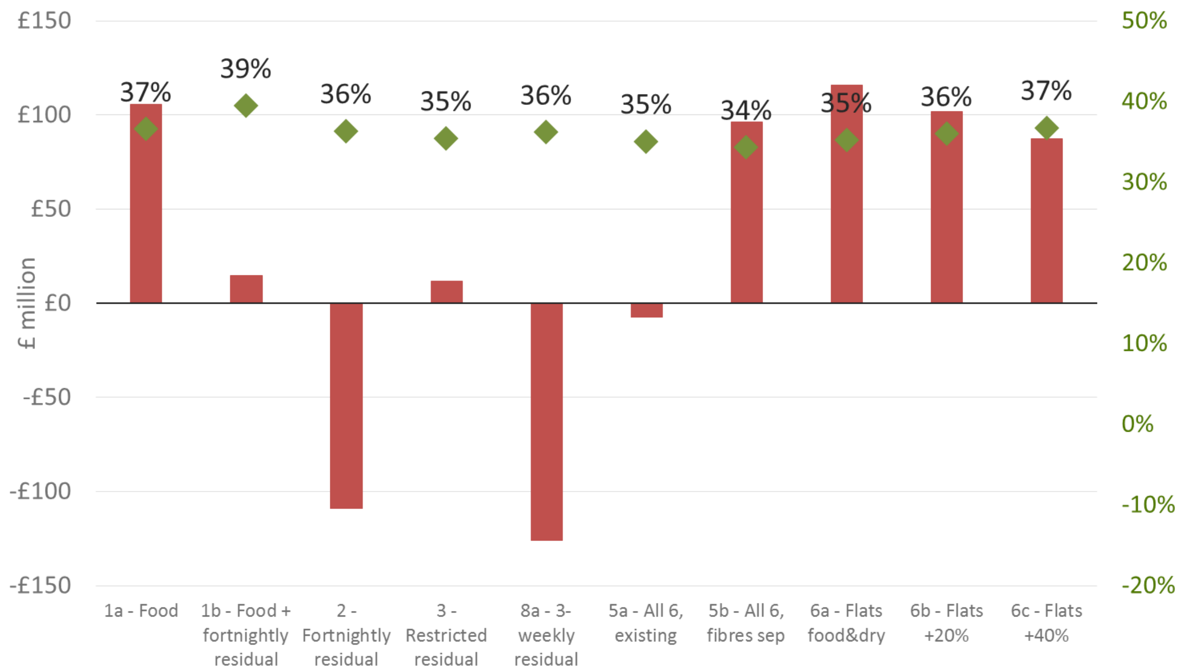
As the project was an internal strategic study London Local Authorities were not directly involved in the project. Baseline data on scheme profiles and waste volumes generated were gathered indirectly from a range of validated sources. The option modelling uses default standardised values appropriate to the LA (geography/deprivation etc.) and were adjusted, where appropriate, to account for London values compared to national average defaults.

The analysis looked at a range of new recycling scenarios selected by Resource London which were designed to be rolled out in all 33 London boroughs and considering the changes over time. A new strategic model was created to run the scenarios (London Recycling Routemap) and review of the impact of the new scenarios on the London recycling rate. The model functionality and all project assumptions within were peer reviewed. The London Recycling Routemap approach included for any major constraints that would block the scenario from being implemented and also considered the rate of implementation that an Authority could achieve in delivering the scenario. The cumulative performance uplift, and the roll out and operational costs are considered over time as the scheme is implemented. Results are presented as cumulative annual net costs (collection and treatment) over the period 2018/19 – 2025/26.

In May 2016 a new Mayor of London was appointed. The Mayor wants London to achieve an overall 65 per cent municipal waste recycling rate (by weight) by 2030. Whilst this modelling work was initiated under the Mayor's Municipal Waste Management Strategy 2011, a separate costs analysis was carried out up to the target year 2030 for the GLA to support development of the Mayor's London Environment Strategy (see appendix 1).

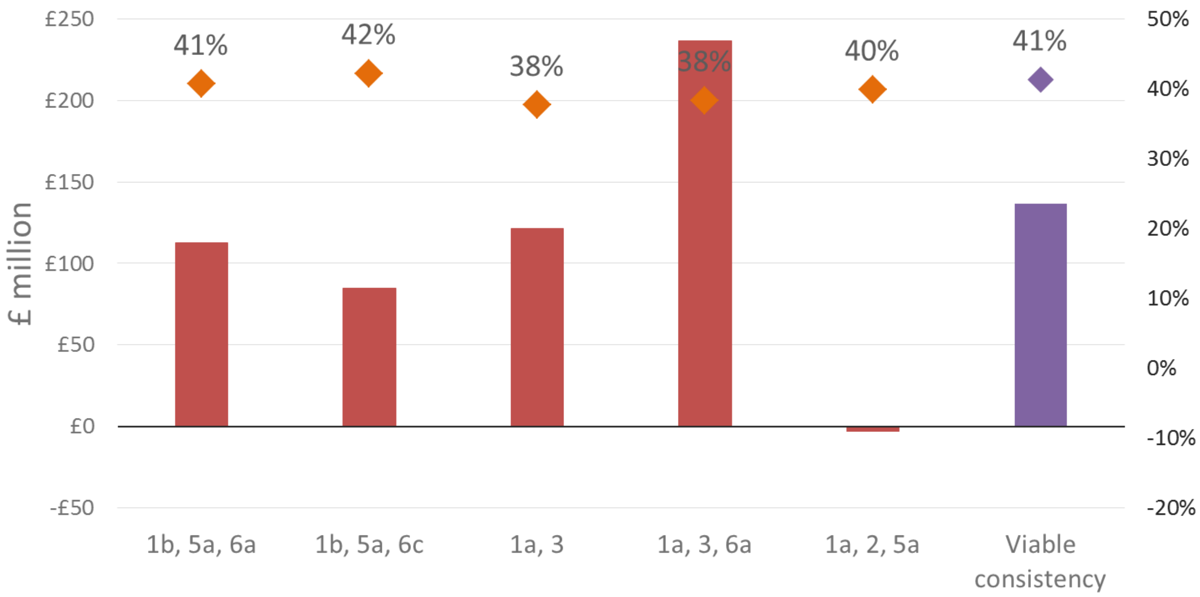
Findings

Based on the scenarios selected and application to London Authorities it does not appear possible for London to collectively to meet 50% recycling by 2020, 2025 or 2030 based on the waste from household's definition. The highest individual performing scenario reaches 39% and comes from a large scale roll out of weekly food waste collections in conjunction with alternate weekly residual collections.



In order to understand where the ceiling of recycling performance might be Resource London selected a number of key scenarios to be combined. Further analysis was required to ensure no duplication of effect from combining scenarios. The maximum recycling rate of 42% is reached in 2021/22 based on a roll out of combined scenarios (1b, 5a, 6c – weekly food, fortnightly refuse, all dry materials and intensive flats support).

The recycling rates would be delivered on the basis of all London Authorities rolling out the key scenario profiles and achieving the performance values assigned in the analysis. A recycling rate of 41% is achievable from this combined scenario in 2020 but will depend on support activities in 2017/18 to enable the changes to start to happen in 2018/19. Generally, from the scenario start date (2018/19) the key scenarios take 3 years to be implemented and mature and reach their optimum recycling rate.



Factors affecting performance

The high proportions of low performing flatted properties, limited quantities of garden waste and higher levels of population transience and deprivation compared to the national average are all key factors impacting on London's recycling rate. In terms of funding the new collection scenarios there appear to be large variations in which avoided disposal savings are shared by the Disposal Authorities. Cost sharing arrangement may be impacting on the affordability for collection authorities to develop new recycling services. The Local elections in 2018 and large number of outsourced waste management contracts with varying end dates means that the adoption of new scenarios appears to happen gradually and beyond the timeframe of the 2020 target.

A range of high performing scenarios were reviewed for inclusion in the analysis and best available evidence sourced in order to run them. Additional scenarios may provide some further contribution to increasing performance such as reducing contamination of dry recyclables and maximising the capture of available garden waste. However, the latter option contrasts with an increasing trend to move to chargeable garden waste collections in London.

Next steps

Given the scale of change and limited mobilisation period for London Authorities it is suggested that there is a narrow range of intensive and focussed Local Authority support required in 2017/18 and 2018/19 in order to drive the necessary changes. The results identified a number of support measures which have been incorporated into the Resource London programme delivery plan for 2017/18.

Contents

1 Rationale

Resource London was established in 2015 as a jointly funded partnership between LWARB and WRAP to maximise the resources of both organisations for the benefit of London. The aim of the programme (at the time of the analysis and reflecting the published Mayor's Municipal Waste Management strategy 2011) was that by 2020 London will have more consistent and more efficient waste and recycling services that:

- achieve the Mayor of London's target that London recycles 50 percent of local authority collected waste by 2020; and
- are able to make a significant contribution towards England achieving 50 percent household waste recycling by 2020.

A range of support will be deployed by the programme and it is intended that support will be provided on a targeted basis i.e. focused where the performance returns on investment are highest and tailored to individual authority circumstances.

The national recycling rate for England in 2015 was 45% with large ranges in recycling performance across Authorities. Typically, urban regions tended to have lower recycling performance due to a range of factors such as high transience of residents, large proportions of flatted properties with less storage space for recyclables, higher concentrations of deprivation, and constraints in waste composition profiles such as lower quantities of garden waste.

The intention of the study summarised in this note was to develop the earlier analysis by considering the rate at which London Authorities could roll out impactful scenarios. The pace at which Authorities could implement the influential scenarios would provide insights into when the maximum recycling performance would be achieved, when the scenarios would need to be both initiated and implemented and the type of support or measures that might be required to facilitate the necessary change.

The rationale to undertake this new analysis was therefore to help with mapping out potential routes to meet the 50% target, to develop the earlier analysis on from what impactful scenarios might look like and provide insights to how and when they can be implemented to have the desired impact.

The report refers to the maximum recycling performance that can be achieved by the local authorities adopting new recycling scenarios. This phrase specifically describes the contribution that can be made to recycling based on the scenarios that were selected in this study and includes the period at which they are mature following full implementation.

It is important to note that the intention is that the outputs of the study are to be used internally by Resource London to help plan potential new support activities. As such limited consultation has happened with London Authorities, aside from instances where baseline data needed to be confirmed. The nature of the analysis also allows for further updates as Resource London staff engage with London Authorities and consider further scenarios.

2 Project objectives

The brief for the project was agreed with Resource London officers as follows:

To undertake an analysis which allows decision makers to understand the impact that different waste and recycling collection scenarios would have on the recycling rate for London, when the impact would occur and the associated costs. More specifically the objectives were:

1. Understanding individual waste authority performance and the local conditions that underpin that performance;
2. Updating the modelling assumptions with further London specific data;
3. Updating the earlier 2020 scenarios taking account of scenarios modelled as part of the Mayor's Municipal Waste Management strategy (Chapter 3);
4. Identifying which areas offer the greatest opportunities to improve recycling performance;
5. Undertaking projections over time which includes for local factors enabling or inhibiting the preferred scenarios to determine how and when key scenarios should be implemented;
6. Identifying a list of possible interventions which could encourage the necessary changes;
7. Establishing what realistic and achievable performance targets might be up to 2020; and
8. Discussing the potential to achieve the Mayor's and the national recycling targets.

3 Approach to Analysis

The approach to the project was to:

1. Agree project scope
2. Agree scenarios
3. Agree constraints
4. Gather London specific assumptions relative to the selected scenarios
5. Develop London Recycling Routemap model
6. Peer review of approach and assumptions
7. Build scenarios into London Recycling Routemap model
8. Generate initial results for discussion
9. Produce Routemap draft summary report

A scoping document was developed and subsequently agreed which detailed the content and boundaries of the analysis. Key elements of the scope were that:

- The analysis should be sufficiently robust to take into account the London Authority's scheme profiles, recent waste arisings and recycling performance,
- The approach should focus on household waste rather than all local authority collected waste (municipal)
- Scenarios rolling out to 2020 and 2025, in case performance could not be raised in time to meet the 50% target in 2020
- Future-proofing the approach was important to ensure that the analysis could be updated and used to include potential other scenarios in future

Development of the model

For the London study a new model was created from WRAP's national Routemap model but refined in approach and assumptions specifically for London. This update project included using more up to date collection scheme profile information, regional gate fees and accounting for cost- sharing operating in the Joint Waste Disposal Authority areas. The London Recycling Routemap model was also re-configured to enable more specific collection scenarios to be run including collections from flatted properties. The collection scenarios and constraints specific to London were discussed and selected at the workshop with Resource London officers and key stakeholders.

Data included in the analysis:

The London Recycling Routemap analysis was undertaken with data on household waste collected from kerbside, bring and HHWRC. The Mayor's 50% recycling target includes by definition all Local Authority collected waste including street sweepings and commercial waste. The reason for the focus on household waste in this modelling is that the broader scope would require new and very specific data sets (e.g. costs and yields for different municipal and commercial waste collections plus current and forecast market share) which were known not to be currently available from the London Authorities. However, commentary on the impact of the household recycling diversion on the LAWC target is provided.

The arisings and benchmark data used for both the baseline analysis and to run scenarios was derived from WDF 2014/15. Waste statistics for 2015/16 only became available to WRAP in December 2016 and required further cleansing for use and were not in sync with the project timescales for inclusion.

Given the thousands of data points and many assumptions used in the analysis it is not possible to list all assumption values publicly. Further detail can be available on request. Data for each scenario was collected from the best available sources known to Resource London officers.

Local Authority collection costs are not formally reported and given the differing approaches to accounting collecting and validating data from all 33 London Boroughs was considered unrealistic given the project timescale available. It was agreed that indicative costs from WRAP's Kerbside Costing Tool could be used in the analysis where particular costs are attributed to collection scheme types relative to the local geography and deprivation for specific Authority 'types'. The Kerbside Analysis Tool (KAT) models supply the cost values for the range of scheme types covered in the new scenarios. The costs are provided for 6 rurality groups which reflect local geography and deprivation with the majority of London Authorities being classified as either rurality 1 or 2 groupings, reflecting the urban characteristics of the region.

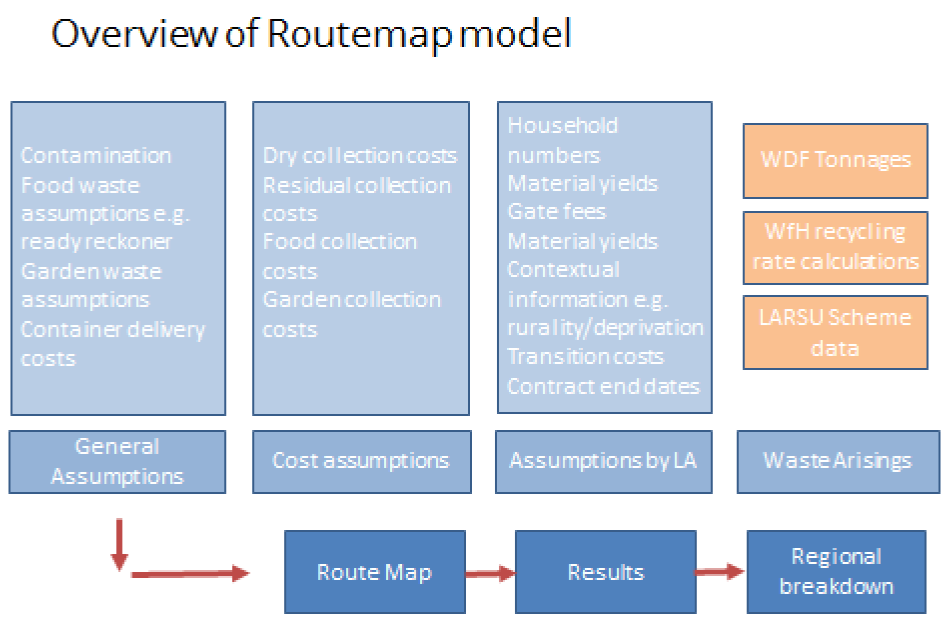
Resource London has access to collection cost data for the majority of London Local Authorities due to direct support projects over the last few years. Although incomplete and variable due to the mix of in-house and outsourced contracts there appeared consistencies in overheads and salaries sufficient to develop a set of standardised collection costs. The costs differed in composition to the national rate primarily due to staff salaries and so were adjusted to reflect the regional average for loaders and drivers.

Due to limited data sets and a large variety of high density property types flats collection costs are more limited and have been derived from one-off studies and recent Local Authority values submitted as part of the application process for WRAP's urban pilot programme.

The London Recycling Routemap model focuses on tonnages from household sources to the points at which material is counted as recycling for the recycling rate calculation. It does not consider export of material or actual end destinations of dry recyclables.

WRAP organised both an internal and external peer review of the model to provide quality assurance that the analysis followed good practice and the risk of error in calculations was minimised. The internal review was undertaken by WRAP staff with key collection assumptions checked by collections team members. A consultancy experienced in analytical techniques including statistics, modelling, simulation and testing of spread sheet tools were employed to peer review the structure of the model.

A range of outputs were generated from the analysis including capital and operating costs, treatment and disposal costs, costs associated with transition between collections systems. Net costs are shown cumulatively in the charts for the period between the theoretical start date for the scenario (2018) and the roll out completion in2025. The recycling tonnage collected by each scenario and contribution to the target are reported for London as a whole. Although the scenario results can be shown for each London borough this is only demonstrated for a few key scenarios in this report.



4 Scenario development

A workshop was held at Resource London offices in summer 2016 with the aim of proposing a key range of options to take forward for analysis. The objective of the session was to achieve consensus on a list of key scenarios which could then be further refined for inclusion in the Routemap model.

The general criteria and guide for selecting scenarios were:

- To limit the number of scenarios to around 10 to ensure that the analysis was manageable and remained focussed.
- That the scenario must be considered to be high impact in its contribution to 50% recycling, based on knowledge in the group from experience in the UK
- That the scenario could be adopted by the majority of London Authorities
- That the scenario should cover a range of property types
- That the scenario could be implemented in the next 3 years in order to have time to influence the recycling target
- That good supporting information for the scenario can be obtained to inform the performance and cost assumptions necessary to undertake the analysis

The original WRAP London Recycling Routemap (2016) scenarios were reviewed to check whether they were still relevant and to consider any omissions. From the discussion and follow up dialogue it was agreed that some of the scenarios could be removed (scenarios 4 A-C, and 5 C) and that given specific Local Authority interest a scenario that considers 3 weekly residual waste would be applied to some of the boroughs. From the workshop the agreed scenarios to run were:

SCENARIO	DESCRIPTION
BAU	*"Business as usual" -No change to any service. Increasing household numbers are accounted for over the time period of the analysis.*
1A	*All low-rise properties moving to separate weekly food waste collections.*
1B	*All low-rise properties moving to separate weekly food waste collections and fortnightly residual waste collections.*
2	*All low-rise properties move to fortnightly residual waste collections.*
3	*All low-rise properties restrict residual containment capacity but maintain current frequency of collections.*
8A	*All low-rise properties move to fortnightly residual waste collections with 11 Authorities extending to three weekly residual waste collections.*
4A	*All low-rise properties receive, as a minimum, the collection of five main dry recyclable materials (glass, cans, paper, card and plastic bottles).*
4B	*All low-rise properties receive a separate collection of fibres (paper and card) and, as a minimum, the three main dry recyclable materials (glass, cans,and plastic bottles).*
4C	*All low-rise properties receive a separate collection of glass and, as a minimum, the four main dry recyclable materials (cans, paper, card and plastic bottles).*
5A	*All low-rise properties receive, as a minimum, the collection of six main dry recyclable materials (glass, cans, paper, card, plastic bottles and household plastic packaging).*
5B	*All low-rise properties receive a separate collection of fibres and, as a minimum, the four main dry recyclable materials (glass, cans, plastic bottles and household plastic packaging).*
5C	*All low-rise properties receive a separate collection of glass and, as a minimum, the five main dry recyclable materials (cans, paper, card, plastic bottles and household plastic packaging).*
6A	*All high-rise properties receive, as a minimum, the collection of five main dry recyclable materials (glass, cans, paper, card and plastic bottles) plus a separate weekly food waste collection.*

6B	*All high-rise properties receive, as a minimum, the collection of five main dry recyclable materials (glass, cans, paper, card and plastic bottles) plus a separate weekly food waste collection and performance on both services is assumed to increase by 20%.*
6C	*All high-rise properties receive, as a minimum, the collection of five main dry recyclable materials (glass, cans, paper, card and plastic bottles) plus a separate weekly food waste collection and performance on both services is assumed to increase by 40%.*

The workshop also considered the factors that could constrain when a London Authority might adopt a scenario and the rate at which it could be implemented. The timing of the adoption of the scenario was considered important in whether performance could be increased in sufficient time to meet the 50% target and the annual cost of doing so.

The constraints discussed at the workshop were:

- Collection contract end dates
- Treatment contracts
- Local Elections
- Waste partnership strategy commitments
- Procurement of collection infrastructure (vehicles, containers, etc.)
- Rate of mobilisation or roll out, e.g. delivery of new containers and communications materials.

Following discussion, it was decided to include both collection contracts and the rate of mobilisation in the analysis in order to understand the impact of these on the take up of scenarios. Local Elections across London in 2018 meant that officers felt it would be unlikely to pursue major scheme changes before this point and that mobilisation of new scenarios should start in 2019. The other constraints were left out at this stage on the basis that they were factors that could either be overcome or managed so as not to considerably delay the adoption of the scenario.

For Authorities currently in a collection contract the known contract end dates were built into the analysis to ensure that the scenario could not start until the existing contract had ceased. A range of assumptions were used to determine the transition costs depending on the type of service change.

5 Results

The scenarios were modelled using the London Recycling Routemap model (version 2.4i) and their impacts on the Waste from Households recycling rate are detailed in figure 1. The scenarios that contribute most significantly to increasing the recycling rate by 2025/26 are 1b (+4.9 percentage points), 1a (+2.0 percentage points), 2 (+1.8 percentage points), 8a (+2 percentage points) and 6a-c (+0.7-2.2 percentage points)

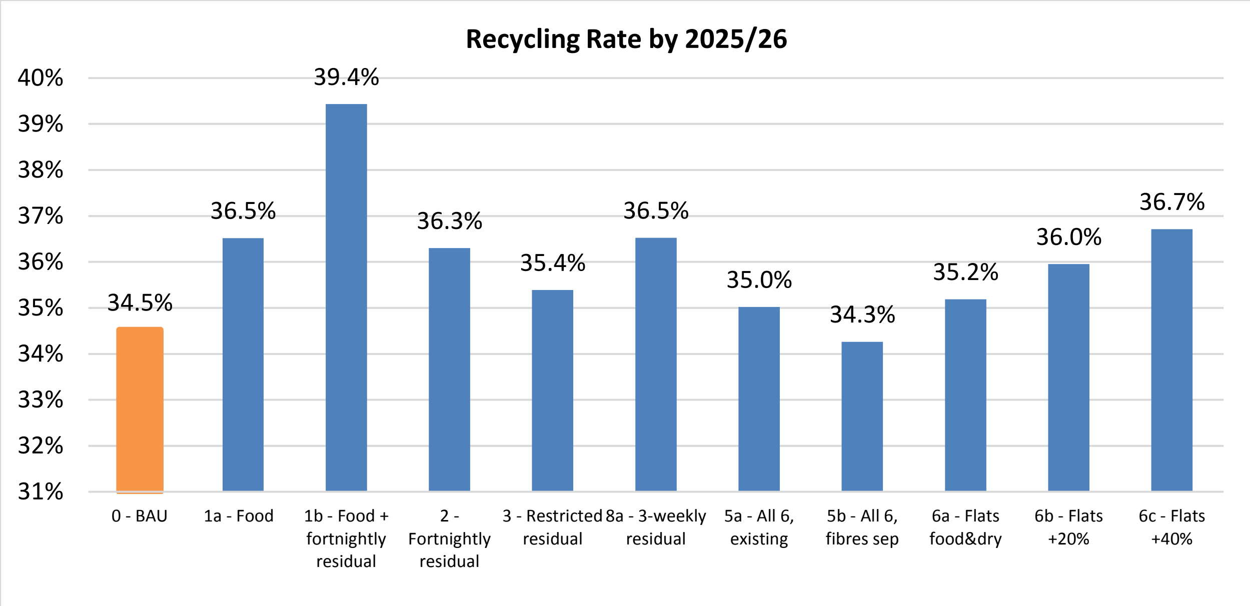


Figure 1: The modelled waste from households recycling rate achieved by 2025/26 for each scenario against a scenario of business as usual.

Several of the scenarios were shown to have a negative cumulative net service cost (Figure 2) of up to -4% (scenario 8a). The greatest cost savings can be seen against scenarios 8a (-£133 million by 2025/26), 2 (-£108 million by 2025/26), 3 (-£15 million by 2025/26) and 5a (-£9 million by 2025/26).

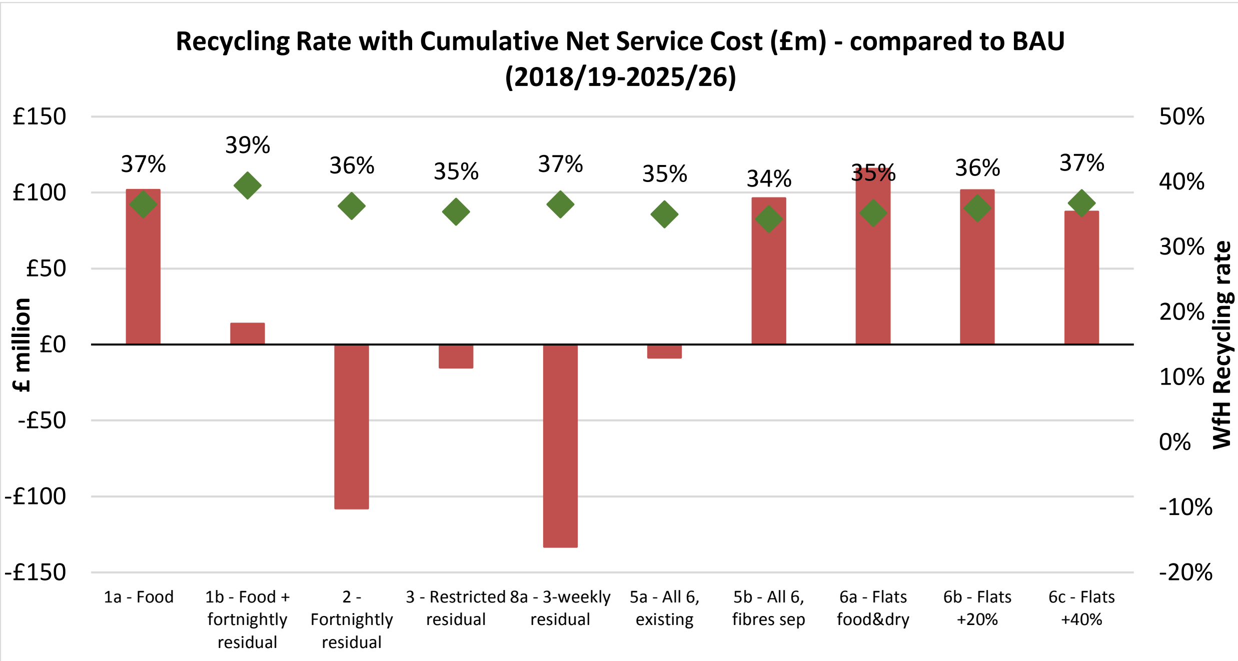


Figure 2: Waste from Households recycling rate overlaid with the cumulative net service cost to 2025/26 for each scenario.

These cumulative costs are then broken into their component costs in figure 3. Scenario 8a stands out as having the greatest net service cost saving. When broken down we can see that a large proportion of this is due to the operational cost savings of changing from a weekly to a 3-weekly residual waste collection, combined with the saving from reduced tonnage to residual waste disposal. This is the same for scenario 2 where there would be similar cost savings from changing to fortnightly residual collections.

Scenario 3 (restriction on residual capacity) has a smaller cost saving as operational costs have not changed and there is an additional cost for issuing smaller residual waste bins to all households. However, the cost saving from reducing the residual waste tonnage for disposal outweighs this.

Figure 3 also highlights the substantial costs for many of the scenarios relating to the capital costs of containers (shown in green) when rolling out a new service.

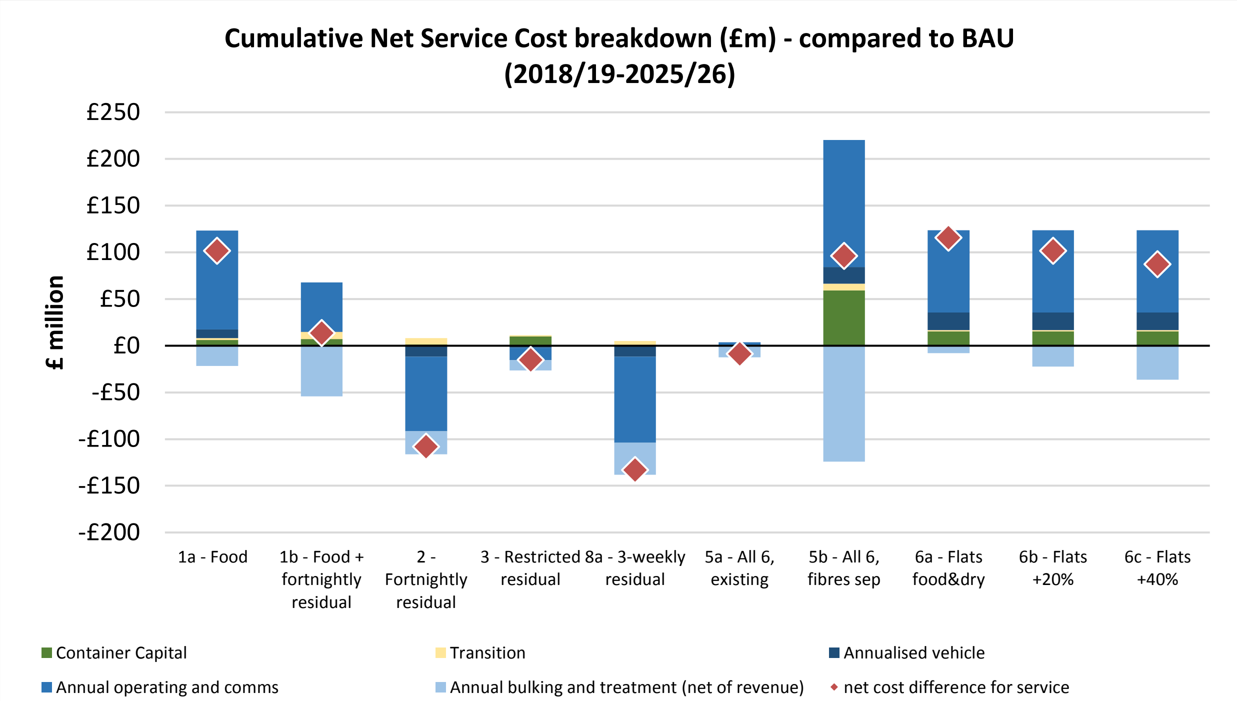


Figure 3: Cumulative net service cost breakdown to 2025/26 compared to a business as usual scenario.

Scenario 1b – Separate weekly food and fortnightly residual waste collections to all low-rise households

Scenario 1b was shown to have the greatest impact on increasing the waste from households recycling rate with an anticipated increase of 4.9 percentage points by 2025/26 (figure 1). Looking at the results for this scenario in more detail, figure 4 shows that the cumulative net service cost makes this change most favourable for waste collection authorities under West London Waste Authority, attributed to the big reductions in residual collection costs and avoided disposal.

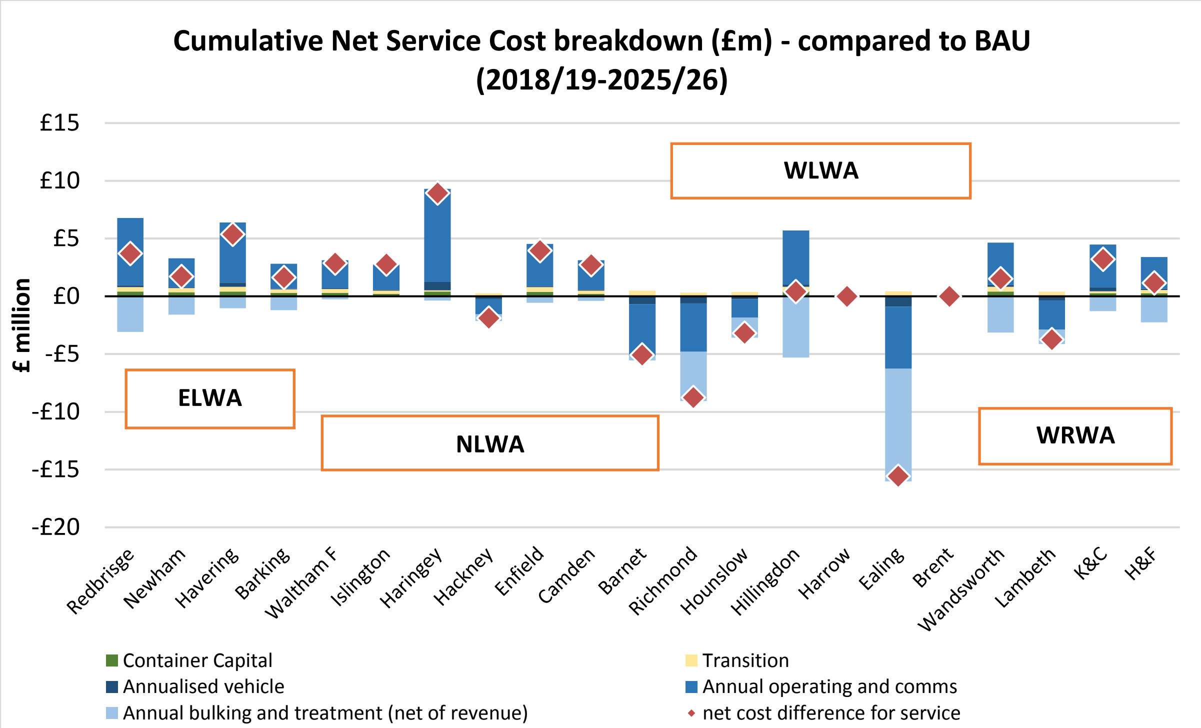


Figure 4: Cumulative net service cost breakdown for scenario 1b,2018/19 to 2025/26, compared to a business as usual scenario for each of the waste collection authorities in the four statutory waste disposal authority areas.

Amongst the unitary authorities in London, the greatest net service cost savings for scenario 1b would be seen in Sutton and Merton (figure 5) with estimated reductions of annualised operational and treatment costs of £0.8 million and £3.5 million respectively, across the period of 2018/19 to 2025/26, compared to the business as usual scenario.

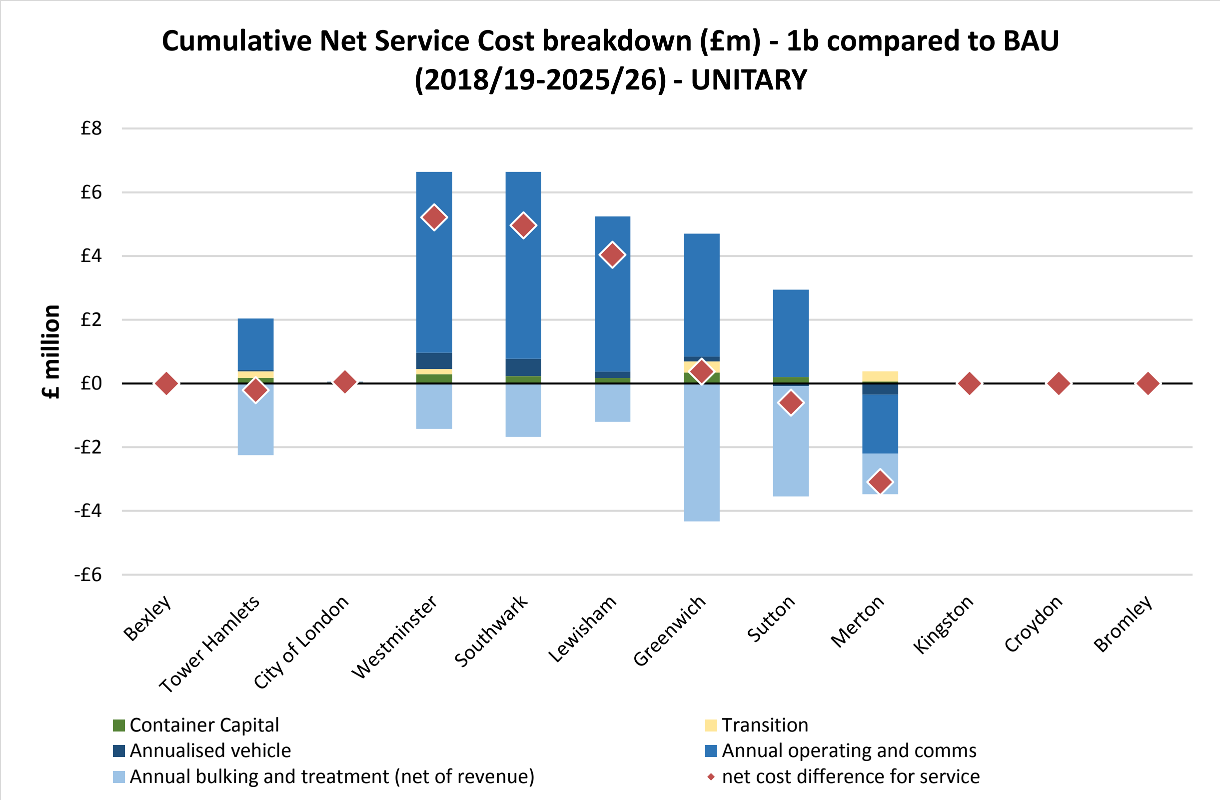


Figure 5: Cumulative net service cost breakdown for scenario 1b, to 2025/26, compared to a business as usual scenario for each of the London unitary authorities.

The majority of London authorities are estimated to increase their recycling rate under this scenario (Figure 6). The greatest increases are forecast to include +12.3 percentage points for Ealing, +10.6 percentage points for Hammersmith and Fulham and +9.6 percentage points for Redbridge by 2025/26.

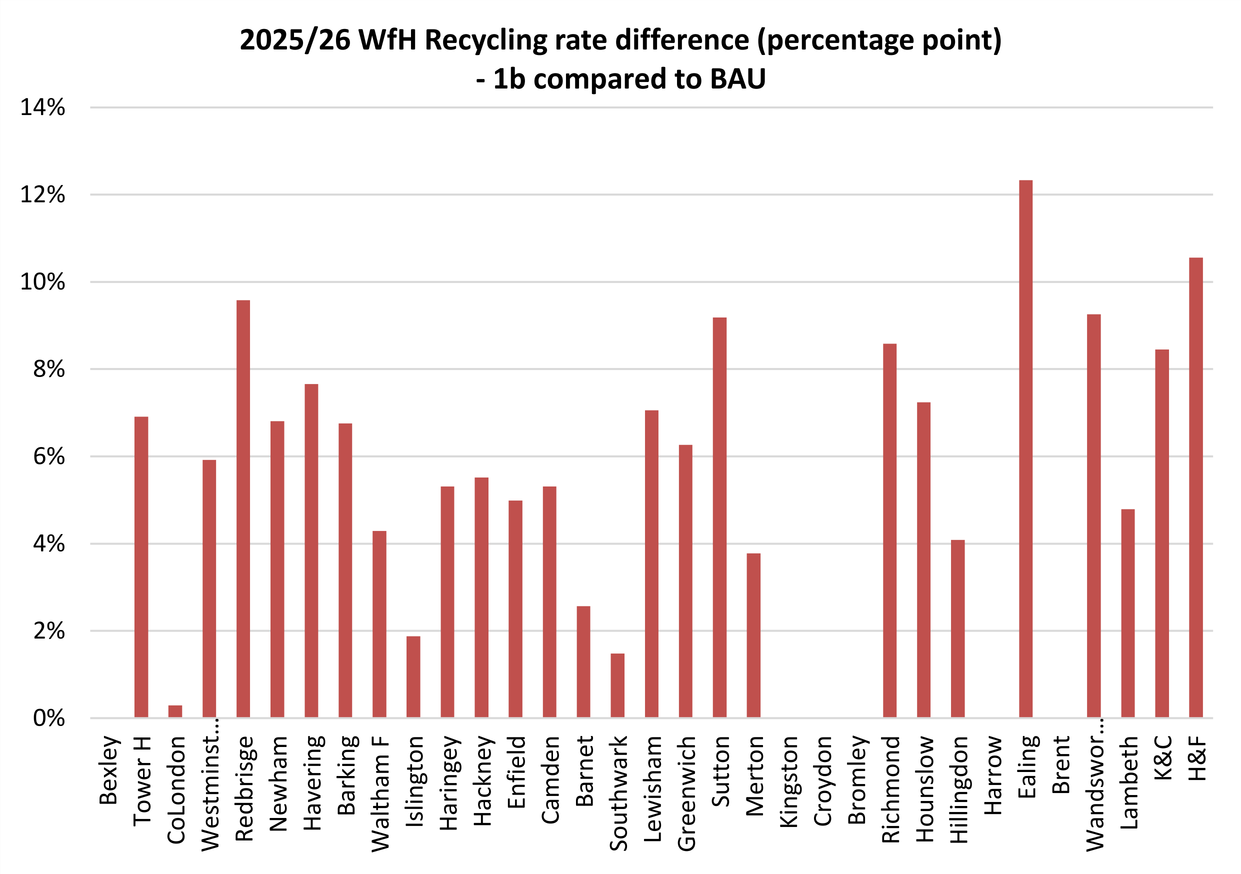


Figure 6: Difference in recycling rate for scenario 1b compared to business as usual in 2025/26 for each of the London boroughs.

Figure 7: Overall scenario costs; cumulative net service cost breakdown (£m) compared to BAU (2018/19 to 2025/26)

	1a - Food	1b - Food + fortnightly residual	2 - Fortnightly residual	3 - Restricted residual	8a - 3-weekly residual	5a - All 6, existing	5b - All 6, fibres sep	6a - Flats food&dry	6b - Flats +20%	6c - Flats +40%
Container Capital	£6	£7	£1	£10	£0	£0	£59	£15	£15	£15
Transition	£2	£8	£7	£1	£5	£0	£7	£1	£1	£1
Annualised vehicle	£9	£0	-£12	-£2	-£12	£0	£18	£19	£19	£19
Annual operating and comms	£106	£53	-£80	-£13	-£92	£3	£136	£88	£88	£88
Annual bulking and treatment (net of revenue)	-£22	-£54	-£25	-£11	-£34	-£12	-£124	-£8	-£22	-£36
net cost difference for service	£102	£14	-£108	-£15	-£133	-£9	£96	£116	£102	£87

6 Mapping out potential routes forward

Based on the outcomes for the 10 scenarios, combinations of key and impactful scenarios were modelled in order to demonstrate the maximum potential uplift in performance. These combined scenarios are described below:

- **1b, 5a and 6a** - *All households receiving separate weekly food waste collections. All low-rise properties receiving a collection of the 6 main dry recyclable materials (glass, cans, paper, card, plastic bottles and household plastic packaging), as a minimum, and fortnightly residual waste collections. All high-rise properties receiving a collection of the 5 main dry recyclable materials (glass, cans, paper, card and plastic bottles), as a minimum.*

- **1b, 5a and 6c** - *All households receiving separate weekly food waste collections. All low-rise properties receiving a collection of the 6 main dry recyclable materials (glass, cans, paper, card, plastic bottles and household plastic packaging), as a minimum, and fortnightly residual waste collections. All high-rise properties receiving a collection of the 5 main dry recyclable materials (glass, cans, paper, card and plastic bottles), as a minimum, with the performance of high-rise properties increased by 40% for both dry and food recycling.*

- **1a and 3** – *All low-rise properties receiving separate weekly food waste collections and restricted container capacity for residual waste whilst maintaining the current collection frequency.*

- **1a, 3 and 6a** - *All low-rise properties receiving separate weekly food waste collections and restricted container capacity for residual waste whilst maintaining the current collection frequency. All high-rise properties receiving a collection of the 5 main dry recyclable materials (glass, cans, paper, card and plastic bottles), as a minimum, plus separate weekly food waste collections.*

- **1a, 2 and 5a** - *All low-rise properties receiving separate weekly food waste collections and fortnightly residual collections. No change to exiting high rise properties.*

- **Viable consistency –** *All low-rise properties adopt the national Consistency Vision scenario or closest viable option to it depending on individual starting points. This includes low-rise properties receiving separate weekly food waste collections and dry recyclables collections either using a kerbside sort service profile and moving to weekly collection cycles or fortnightly 2 stream scenarios depending on individual starting points. A restricted container capacity for residual waste whilst maintaining the current collection frequency. All high-rise properties receiving a collection of the 5 main dry recyclable materials (glass, cans, paper, card and plastic bottles), as a minimum, plus separate weekly food waste collections.*

In terms of overall results all of the combined scenarios are predicted to generate a considerable increase in the waste from households recycling rate (figure 8). The best performing combined scenario is with the combination of 1b, 5a and 6c expected to achieve 42% at a cost of around £84 million over the period of 2018-2025. The Viable Consistency scenario also reaches 42% but at a higher net cost of around £140 million. This is followed by 41% for the combined scenarios 1b, 5a and 6a, 38% for 1a, 3 and 6a, and 38% for 1a and 3 by 2025/26.

The least combined option is for scenario 1a,2 5a at 38% but this does not include extensions of recycling services to high rise flats.

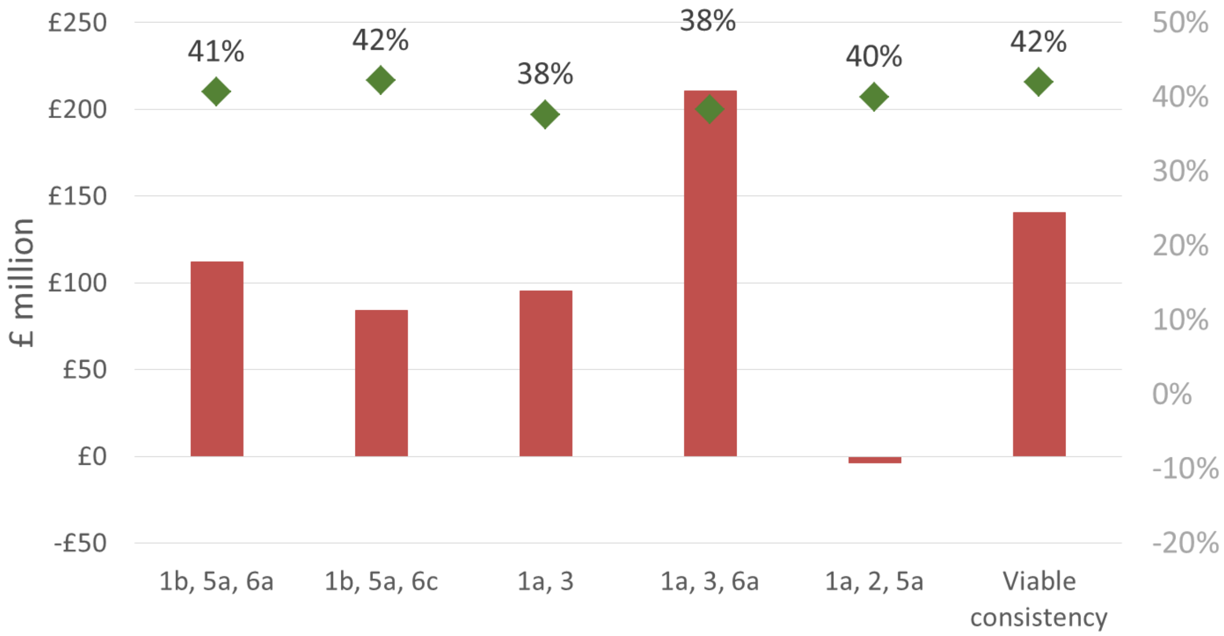


Figure 8: The modelled waste from households recycling rate achieved by 2025/26 for each combined scenario against business as usual with cumulative net costs (2018-2025) for each combined scenario.

In the breakdown shown below (figure 9) we can see that the higher recycling rates enable savings from reduced bulking and treatment costs and increased revenue from the sale of the additional recyclables collected. However, these are not enough to negate the additional costs associated with operational delivery, transition costs, communications, and container capital required to improve the collection services and consequently increase the waste from households recycling rate.

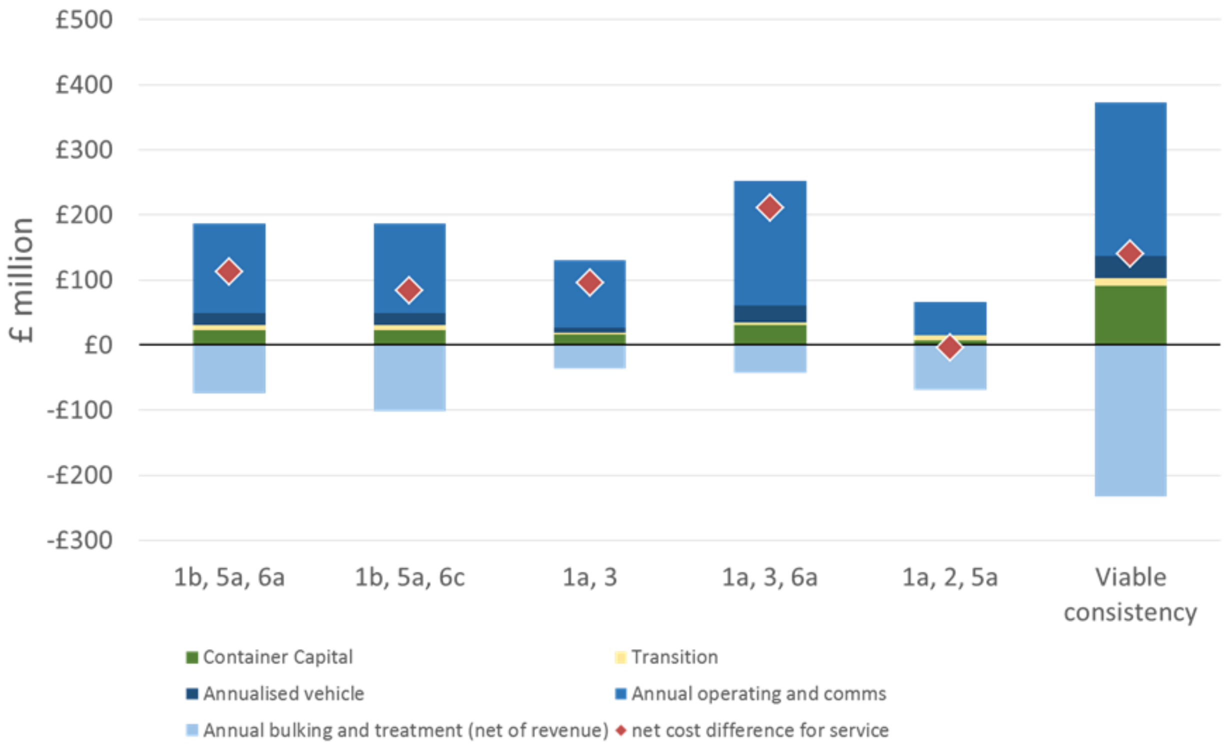


Figure 9: Breakdown of the cumulative net service costs to 2025/26 for each scenario combination compared to the business as usual scenario.

	1b, 5a, 6a	1b, 5a, 6c	1a, 3	1a, 3, 6a	1a, 2, 5a	Viable consistency
Container Capital	£23	£23	£16	£30	£7	£90
Transition	£8	£8	£3	£4	£7	£12
Annualised vehicle	£18	£18	£9	£27	£0	£34
Annual operating and comms	£137	£137	£104	£191	£51	£236
Annual bulking and treatment (net of revenue)	-£74	-£102	-£36	-£42	-£69	-£233
net cost difference for service	£112	£84	£95	£210	-£4	£140

Figure 10: Overall combined scenario costs; cumulative net service cost breakdown (£m) compared to BAU (2018/19 to 2025/26)

Contracts and the impact on recycling performance

The majority of the 33 London boroughs (24) have private sector waste management companies operating their waste and recycling collection services. Although the London Recycling Routemap scenarios start 2017/18 the underlying assumptions do not allow changes to local authorities with a waste management contract until the contract has expired. To help drive scenarios to be initiated would require Resource London support measures in the target authorities the year prior to the change to influence the key target Authorities in adopting the preferred scenarios.

A number of Authorities' collection contracts are due to end in the next 18 months such as Tower Hamlets, Camden, Hounslow and Westminster. If the new contracts do not include service configurations that reflect the optimum combined scenario, e.g. 1b +5a + 6c, then the recycling performance may not be maximised until the end of the contract period (e.g. 2025-2027 depending on the option for contract variations). The procurement of particular containers and vehicles in the forthcoming contracts may also limit the ability of the Authority, either technically or economically, to adopt the preferred combined scenarios.

A key issue in adopting those scenarios that could contribute most to the 50% target is that 11 London boroughs have waste collection contracts ending in 2020 and beyond. If these Authorities are unable to amend their contracts and adopt the preferred scenarios prior to 2020 then the maximum recycling performance predicted from the Routemap modelling may not be achieved until 2022, meaning that the 50% target would not be achieved in 2020. Understanding the detail of the existing contracts and the ability to vary these to add new services will be important to understanding when the maximum predicted recycling performance level in London can be reached.

7 Conclusions from the analysis

In terms of performance against recycling targets the conclusions from the updated analysis for London are that:

- Based on scenarios selected and application to LAs it does not appear possible for London collectively to meet 50% recycling by 2020, 2025 or 2030 based on Defra's Waste from Households definition.
- The maximum recycling rate of 42% is reached in 2021/22 based on roll out of combined scenarios (1b, 5a, 6c – weekly food, fortnightly refuse, all dry materials and intensive flats support).
- A recycling rate of 41% is achievable in 2020 (from combined scenario 1b, 5a, 6c) but will depend on support activities in 2017/18 to enable the changes to happen in 2018/19.
- From the scenario start date (2018/19) the key scenarios take 3 years to reach the optimum recycling rate based on roll out assumptions made for individual LAs.
- The tailored "Viable Consistency" scenario is high performing although slightly lower in recycling rate than the optimum combined scenario . This is due to the slightly lower performing two stream options compared to the reported performance of existing schemes operating in London.

In terms of drawing conclusions from the analysis to help determine activities in programmes to support Local Authorities:

- The key themes that will impact on recycling rate are the restriction on residual waste capacity by reducing frequency, expansion of separate food waste collections and intensive support to overhaul flats recycling
- Due to high operational (staff) costs scenarios with reductions in residual waste frequency where and crew costs are saved offer the biggest financial savings (e.g. fortnightly or 3 weekly)
- Other themes, such as adding in missing dry materials, offer little impact on recycling rate due to the good range of materials already collected and that missing materials are lightweight e.g. plastics
- Levy/menu pricing and cases of limited sharing of avoided refuse disposal cost by disposal authorities has significant impact on the business case and provides low incentive for boroughs (collection authorities) to collect more
- Performance and overall cost profiles depend on LAs adopting the scenario profiles detailed in the analysis before they commit to new systems. Otherwise LAs may be locked into service profiles that prevent them from achieving maximum performance in line with the scenarios in this study
- The business case for adopting scenarios differs for each LA according to their starting point and disposal arrangements. However, targeted funding to relieve transition will improve the business case for certain key LAs adopting the influential scenarios.

8 Discussion of measures to enable change to happen

The plateauing recycling performance in London, financial constraints on Local Authorities and the large gap to the 50%/2020 recycling target means that new localised support measures will be required to enable the changes needed to achieve higher recycling performance.

Resource London support measures that could help initiate change will likely require a combination of **direct technical support and financial support** in the transition to the preferred collection scheme profiles outlined in this analysis. Working within the existing legislative framework it will be important to ensure that particular technical support is delivered in time to initiate the change ahead of 2020 and that they are targeted to the key Authorities. However, it is recognised that changing the collection service profile is the responsibility of the individual Local Authorities and there may be several local reasons for not moving towards the optimum service profile.

Specific support measures which are also relevant to the findings in the analysis results are:

Procurement support to assist Local Authorities to adopt a preferred and consistent collection profile: the London Recycling Routemap analysis has highlighted that there are limited collection profiles that can deliver significant uplifts in performance to contribute to both individual Local Authority and London's overall recycling performance. Given the large proportion of outsourced collection contracts it appears extremely important that the procurement of any new services is in line with the high performing collection scenarios outlined in the analysis. Scheme profiles procured in the next 18 months which do not follow the optimum service profile is likely to mean that the opportunity to change profiles may not re-appear until around 2025, given the investment in vehicles and their lifespan. Similarly, there may be opportunities within existing contracts to vary terms and amend service profiles or collection frequencies. The narrow range of collection profiles that are likely to improve recycling performance and financial pressures on Local Authorities offer the opportunity for Resource London to help with **the implementation of more consistent service profiles** across London.

Support optimising the profile of weekly food waste collection services to both increase household satisfaction and increase capture: Whilst a large proportion of London Authorities offer food waste collection services to their households, performance appears low and provides limited contribution to London's recycling performance. Recent WRAP research has reported on the service configurations necessary to achieve high satisfaction rates from households using food recycling services and to capture high proportions of food waste for recycling. The optimum service profile includes weekly food collection, fortnightly residual waste collection, a free on-going liner supply, and clear and focussed communications which discourage food into the residual waste stream. These findings confirm the service profiles disseminated following earlier trials.

There are wide variations in food service profiles across London including differing food and residual waste frequencies, combining with and without garden waste, as well as differing commitments to liner supply. Given the important contribution of food waste to regional recycling performance it will be important to provide technical support to demonstrate the business case to adopt the full suite of changes necessary to raise performance. In order to maximise participation, it is important that measures are joined up with restrictions in residual waste.

Modelling support to Joint Waste Authorities to help review options to incentivise their constituent Collection Authorities to recycle more: The analysis of the London Recycling Routemap scenarios shows a large range of cost profiles for the same scenario with patterns for Authorities in particular Joint Disposal Authority tending to collectively increase or decrease in net costs. In many cases this appears to be due to limited avoided disposal savings which are not covering the additional service costs borne by the Collection Authority. There may be opportunities to review recycling credit or future levy payment mechanisms in the two-tier areas to identify more influential arrangements which incentivise Collection Authorities to invest in key scenarios. WRAP is currently looking at financial arrangements in two-tier authorities and will share the results in the summer.

Business case support for the restriction of residual waste: There is now well established evidence that Local Authorities who reduce the available weekly capacity of residual waste are associated with higher levels of recycling performance. Similarly, there are strong correlations between weekly food waste capture and households with a fortnightly residual frequency. A key activity area for 2017/18 could be around scoping out targeted technical support to Local Authorities that appear to provide a large weekly residual waste capacity currently. Given the scale of the performance gap to 50% and budgetary pressures on Local Authorities there may be opportunities to help to demonstrate the potential business case for options which enhance recycling capacity at a reduced cost.

High intensity flats recycling: Due to the difficulties in disaggregating data for flatted property collections there is limited cost and performance data, and therefore limited evidence, for high recycling performance from flats. From the best available data sourced to date recycling performance from flats appears considerably lower than kerbside yields, primarily due to lower levels of participation by households. It's likely that raising performance significantly to achieve the levels outlined in this study (40% improvement on current performance) will require high intensity engagement with estates to overhaul collection services in order to maximise recycling capacity and likely restrictions in residual capacity. The performance data may be used to update the assumptions in the London Recycling Routemap modelling and help understand the contribution higher intensity recycling services might make to London's performance.

Investigate alternative scenarios: The scenarios taken forwards for analysis in the London Recycling Routemap project could be extended beyond the current list. Further scoping of options such as the impact of activities to reduce contamination in dry recyclables collections may offer additional performance. and opportunities to maximise trade waste recycling. It is understood that around 10% of commercial waste collected by boroughs is recycled at present.

9 Recommendations on next steps

The aim of this study was to support Resource London in providing evidence for supporting London Authorities in key areas which would contribute towards both the Mayoral and national 50% targets by 2020. The approach provides clear indications of the target materials, collection systems and the timeframe for action.

As it stands London is unlikely to meet the 50% recycling target by 2020 and the maximum performance level predicted by the Routemap modelling (42%) may not be reached until 2022 assuming the optimum profile is adopted in new collection contracts. Given the additional costs for dry recycling and food collections it seems unlikely that recycling performance will raise much beyond the current rate in the short term without intervention or large scale adoption of restrictions of residual waste.

Given the required scale of change and limited mobilisation period for London Authorities it is recommended that intensive and focussed Local Authority support is offered by Resource London in financial years 2016/17 and 2017/18. It is important to understand the options for varying existing Local Authority contracts in order to confirm the potential for improving recycling performance at the earliest opportunity.

Based on the analysis the key activity areas are:

- Restrict residual waste collections by reducing frequency and/or container capacity
- Maximise the roll-out of food waste collections to all suitable properties and ensure all collections are performing optimally. In order to maximise participation, it is important that measures are joined up with restrictions in residual waste.
- Develop programmes of work on high intensity activity on flats recycling.

10. Differences between 2016 and 2017 Routemap analyses

It is important to consider that results from the original analysis and the update are not directly comparable due to:

- Updated WDF tonnages for 2015/16 Financial Year
- Updated scheme data – accounts for changes between years
- Revised yields (due to minor differences in WDF)
- Increased operational costs (from access to LA cost data)
- London specific waste arisings projections have been used
- The recycling rate for 2015/16 is 0.63% lower than last year (2014/15) (provided by Defra)
- The number of households has reduced due to use of RL scheme data. This means that when we are scaling up our assumed yields the total increase is lower than the original
- The more tailored approach in selecting LAs to adopt certain scenarios rather than applying all scenarios to all LAs means that the yield contribution and therefore recycling rate is lower

Resource London

Appendix 1 . Output table to show individual borough recycling rate

Shows the modelled potential performance of each waste authority. This was then averaged for London which calculated a maximum London wide recycling rate of 42-43 per cent.

Table 1: Modelled household waste recycling performance by waste authority			
Waste authority	**Business as usual**	**Combined scenarios**	
		1b, 5a, 6c	**1a, 2, 5a**
Barking and Dagenham LB	24	36	35
Barnet LB	39	44	42
Bexley LB	56	56	56
Brent LB	37	38	38
Bromley LB	50	51	51
Camden LB	27	35	33
City of London	36	51	36
Croydon LB	44	45	45
Ealing LB	40	54	53
Enfield LB	39	47	44
Greenwich LB	35	43	41
Hackney LB	28	36	33
Hammersmith and Fulham	21	34	31
Haringey LB	38	45	44
Harrow LB	47	49	49
Havering LB	33	46	45
Hillingdon LB	44	50	48
Hounslow LB	34	43	42
Islington LB	35	41	36
Kensington and Chelsea	25	37	34
Kingston upon Thames	47	49	47
Lambeth LB	28	37	33
Lewisham LB	19	29	26
Merton LB	39	44	43
Newham LB	17	30	28
Redbridge LB	28	43	41
Richmond upon Thames LB	43	53	51
Southwark LB	36	41	38
Sutton LB	39	50	48
Tower Hamlets LB	27	38	34
Waltham Forest LB	37	44	41
Wandsworth LB	20	33	30
Westminster City Council	24	35	30
Total	**35**	**42**	**40**

London Route map project

London Waste & Recycling Board

Appendix 2.

Update 2016 – additional cost analysis for 2018 -2031

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Overview

"An analysis to allow decision makers to understand the impact which different waste and recycling collection scenarios would have on the household recycling rate for London, when the impact would occur and the associated costs."

- Quantify impact of increased recycling
- Timeline for change
- Help identify opportunities & enablers for change
- Plan support activities

Overview

1. Updates the earlier 50% analysis ~~in~~ from February 2016.
2. Resource London collaboration - analysis undertaken by WRAP
3. Analysis undertaken using Defra's 'waste from household' definition
4. Baseline data gathered indirectly from LAs
5. Modelling uses default standardised values appropriate to the LA (geography/deprivation etc) and scenario
6. Scenario performance data uses good practice yields rather than a theoretical maximum
7. Similar scenarios to original study (+addition of 3 weekly residual waste)
8. Scenarios are selectively applied to LAs considered to be able to adopt them
9. Scenarios are run from 18/19 financial year – allowing for Local Elections
10. Scenarios are modelled to be adopted when LAs can change relative to their collection contract end date (for LAs with contracted out services)
11. Accounts for phased implementation of scheme changes following adoption of scenario
12. Results are presented as cumulative annual net costs (collection and treatment) over the period 2018/19 – 2025/26

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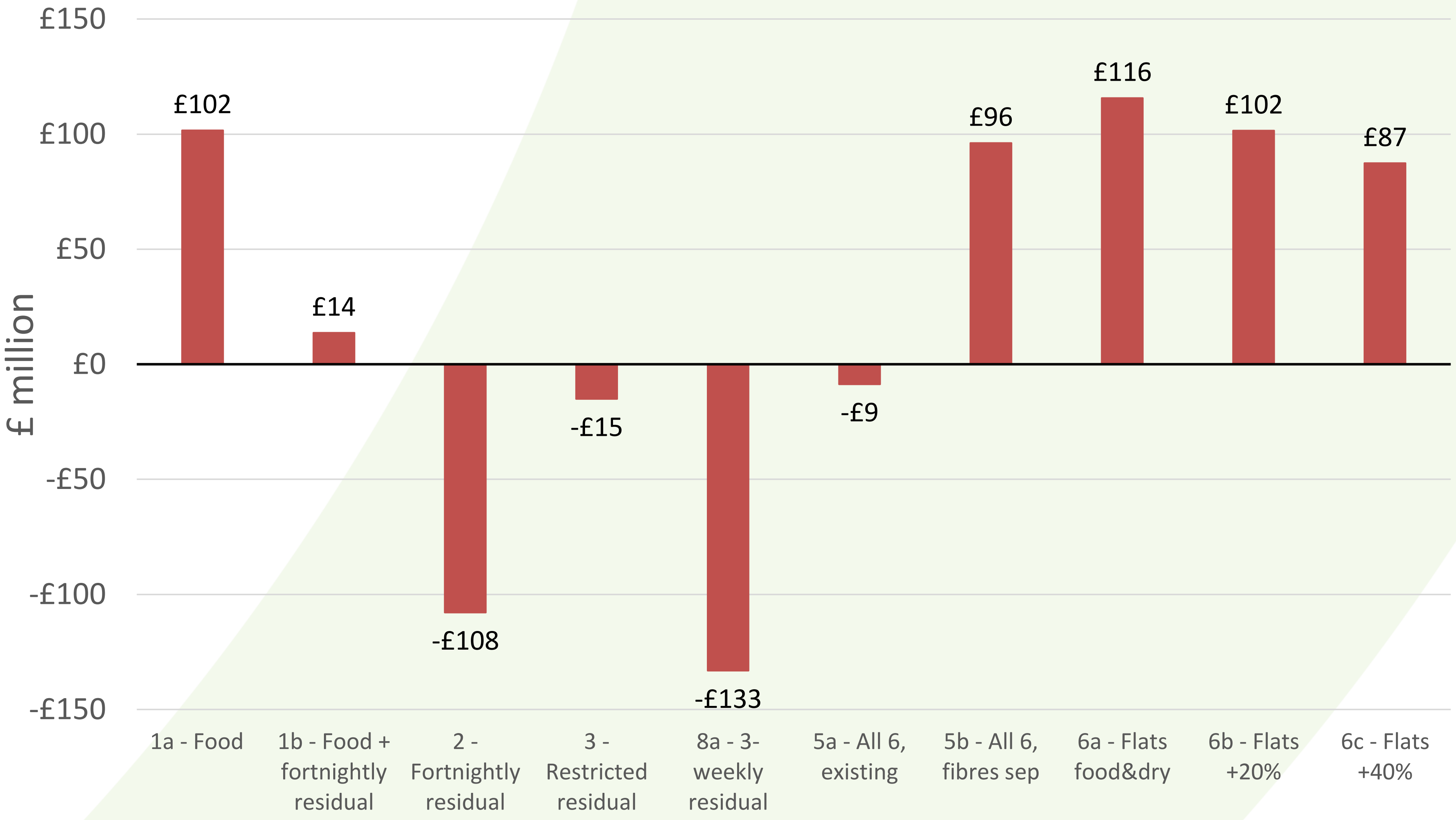
Cumulative net service cost (£m) compared to BAU (2018/19-2025/26)



RESOURCE LONDON
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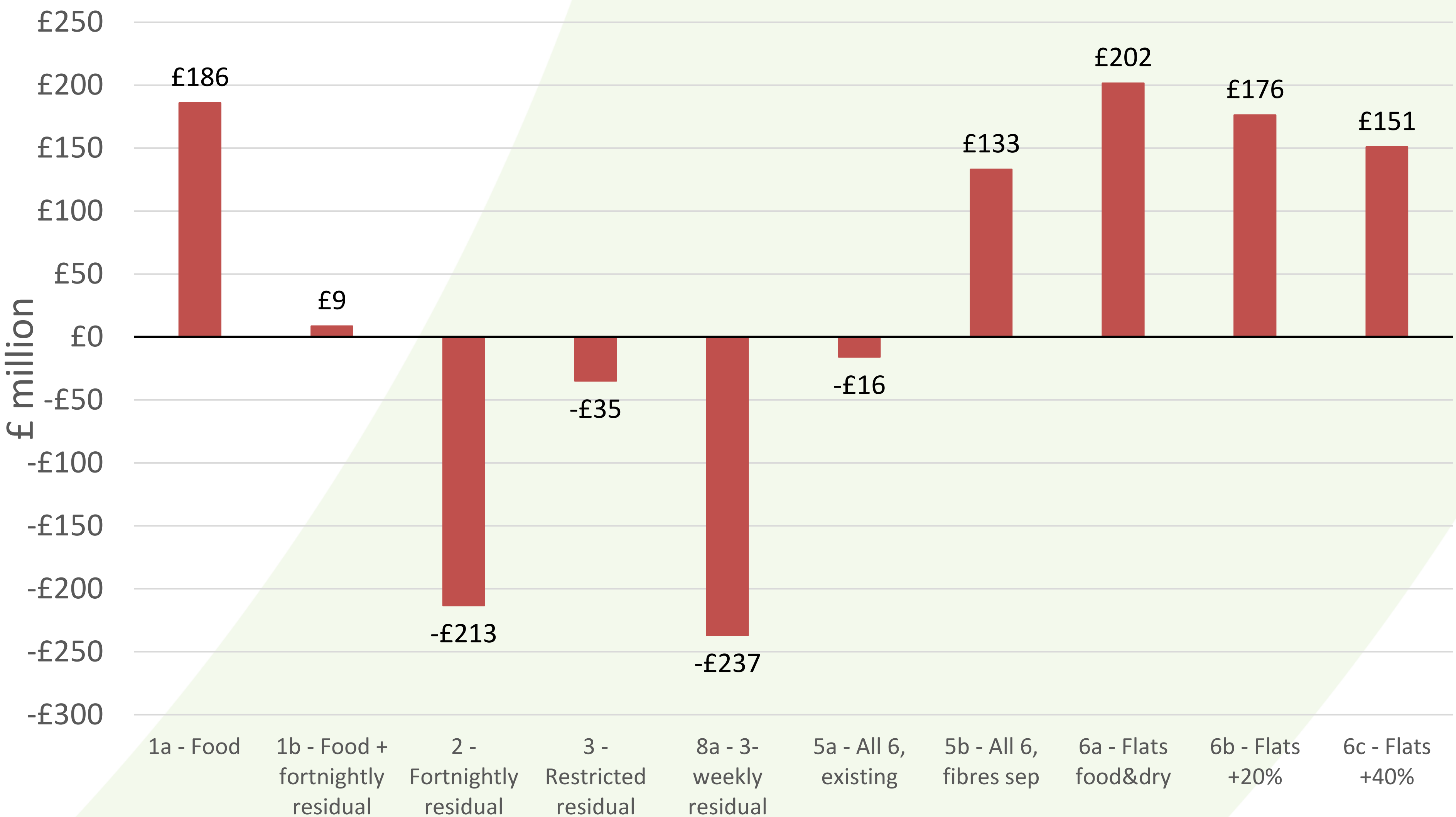
Cumulative net service cost (£m) compared to BAU (2018/19-2030/31)



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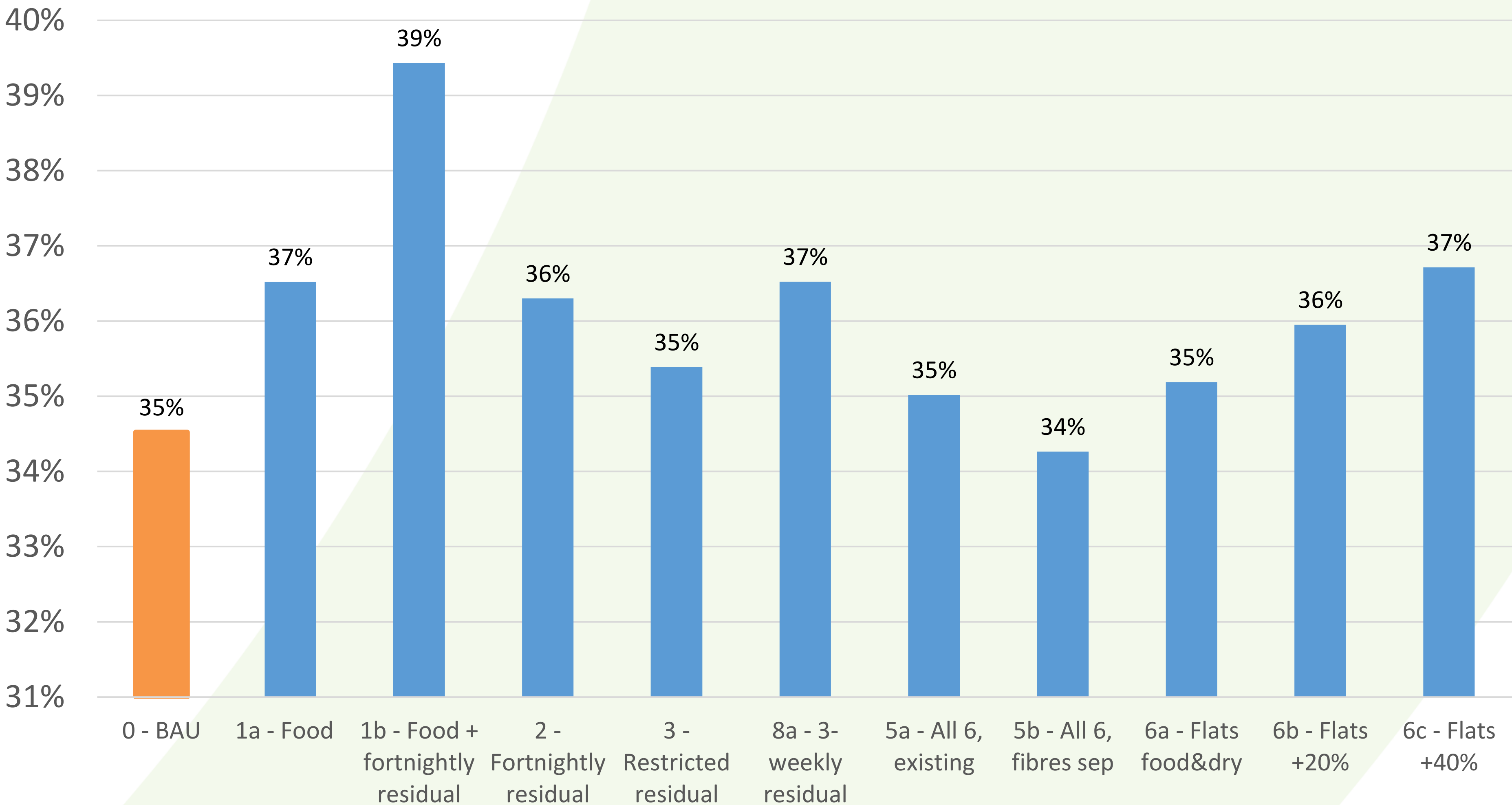
Waste from Households Recycling Rate by 2025/26



Scenario	1a	1b	2	3	8a	5a	5b	6a	6b	6c
WfH rate diff from BAU	2.00%	4.91%	1.78%	0.87%	1.61%	0.50%	-0.26%	0.67%	1.43%	2.19%

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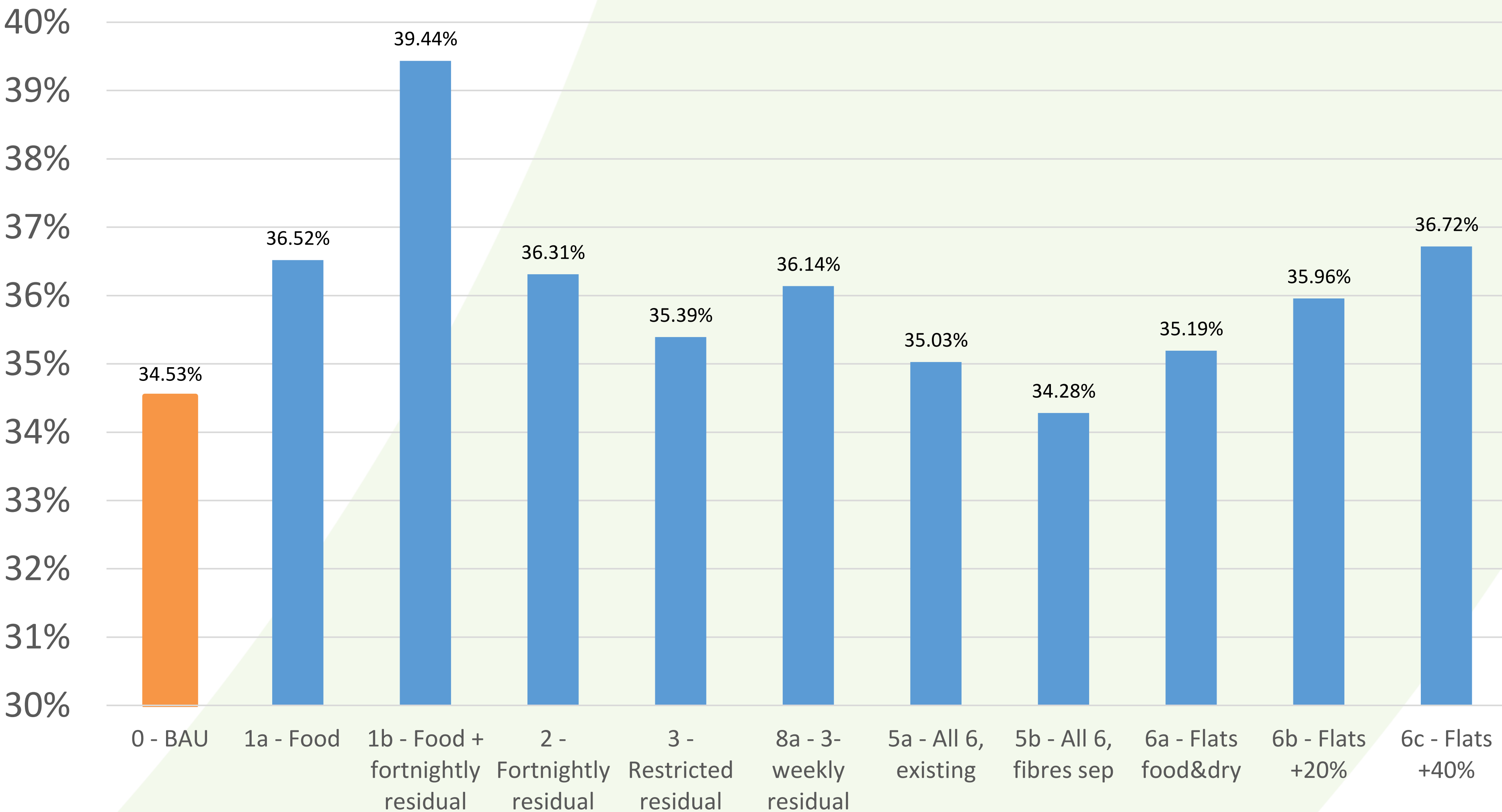
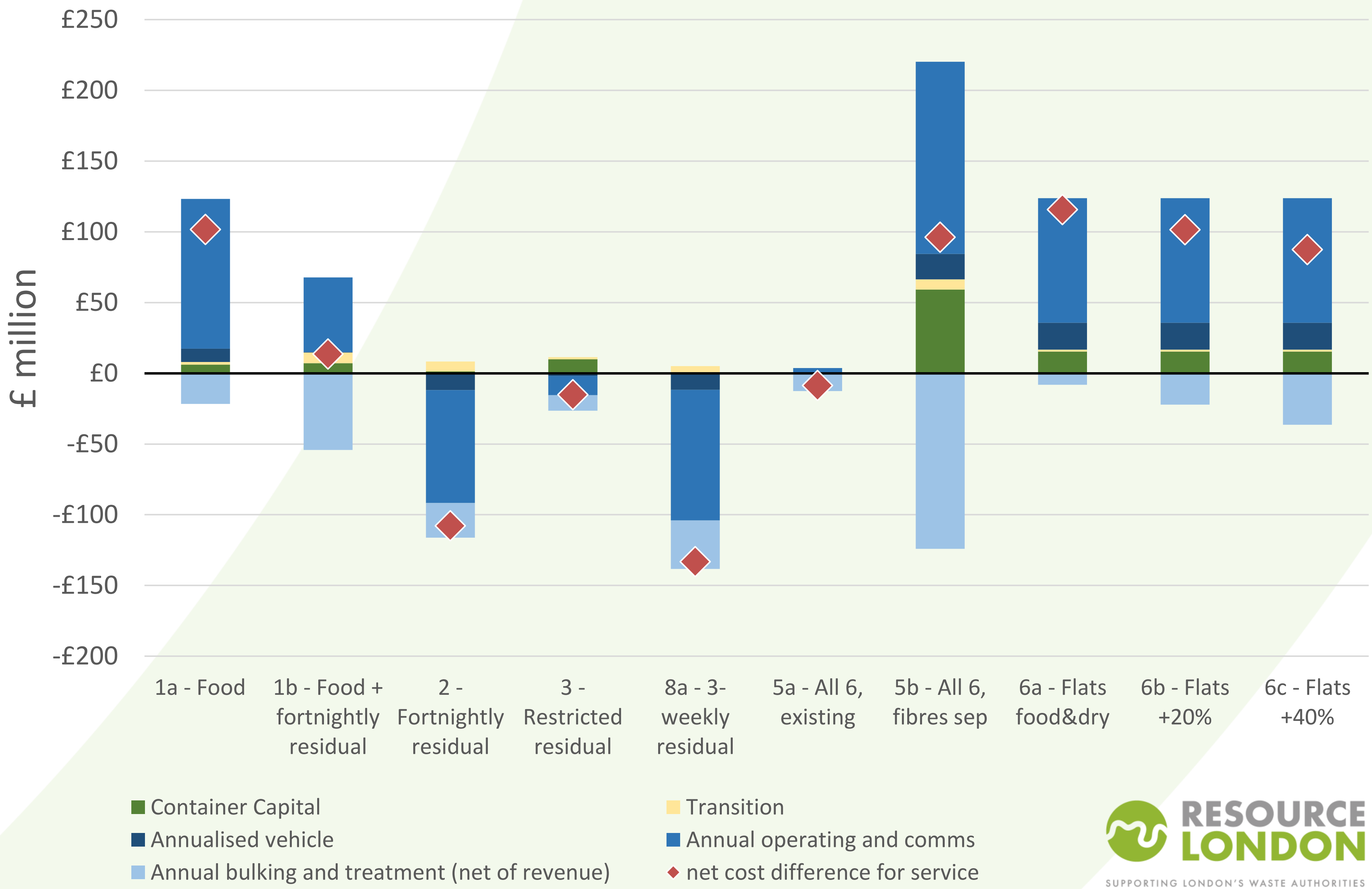
Waste from Households Recycling Rate by 2030/31



Scenario	1a	1b	2	3	8a	5a	5b	6a	6b	6c
WfH rate diff from BAU	1.99%	4.91%	1.78%	0.86%	1.61%	0.50%	-0.25%	0.67%	1.43%	2.19%

RESOURCE LONDON
SUPPORTING LONDON'S WASTE AUTHORITIES

Cumulative net service cost breakdown (£m) compared to BAU (2018/19 to 2025/26)



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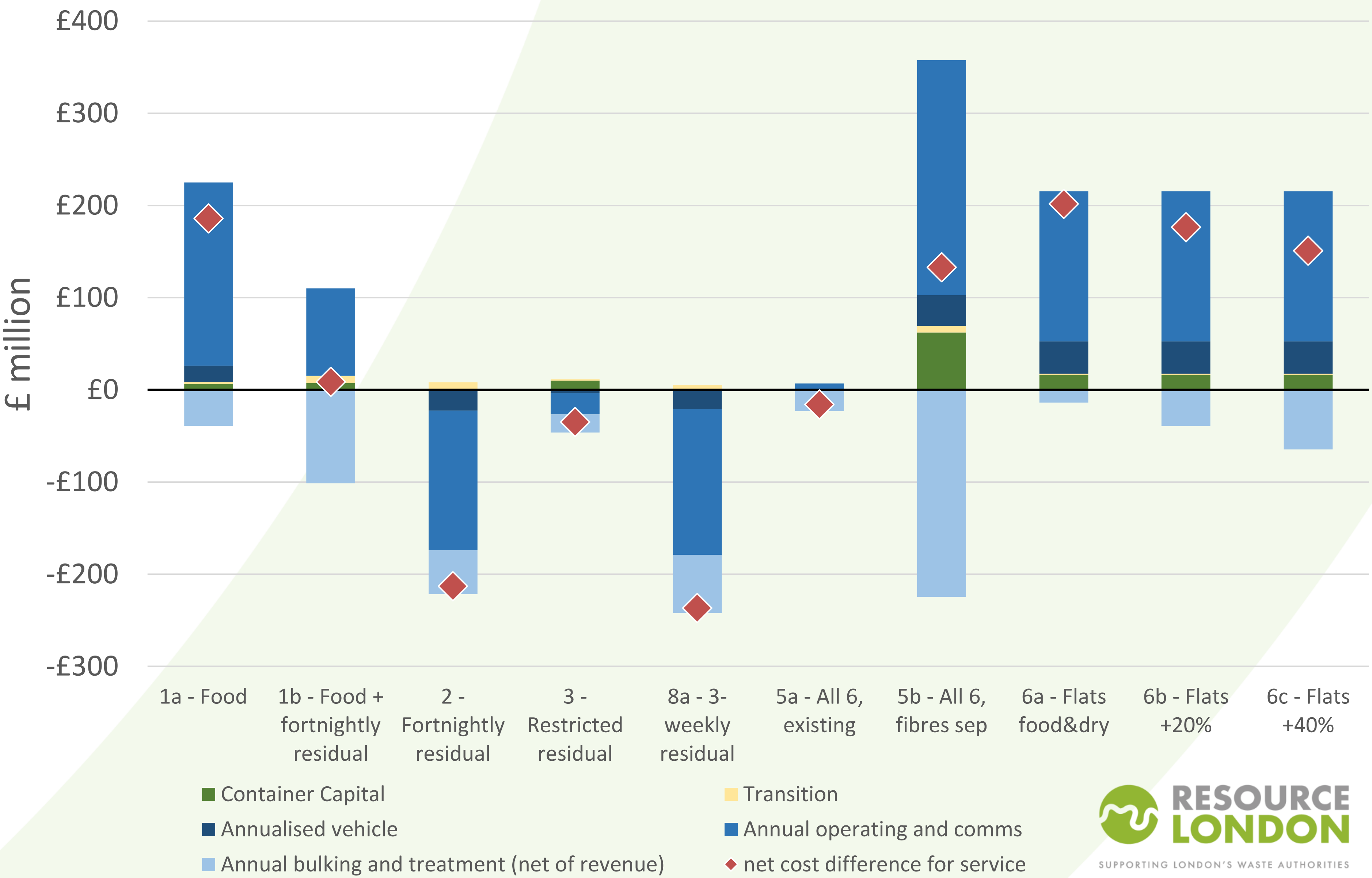
Cumulative net service cost breakdown (£m) compared to BAU (2018/19 to 2025/26)

	1a - Food	1b - Food + fortnightly residual	2 - Fortnightly residual	3 - Restricted residual	8a - 3-weekly residual	5a - All 6, existing	5b - All 6, fibres sep	6a - Flats food&dry	6b - Flats +20%	6c - Flats +40%
Container Capital	£6	£7	£1	£10	£0	£0	£59	£15	£15	£15
Transition	£2	£8	£7	£1	£5	£0	£7	£1	£1	£1
Annualised vehicle	£9	£0	-£12	-£2	-£12	£0	£18	£19	£19	£19
Annual operating and comms	£106	£53	-£80	-£13	-£92	£3	£136	£88	£88	£88
Annual bulking and treatment (net of revenue)	-£22	-£54	-£25	-£11	-£34	-£12	-£124	-£8	-£22	-£36
net cost difference for service	£102	£14	-£108	-£15	-£133	-£9	£96	£116	£102	£87

RESOURCE LONDON
SUPPORTING LONDON'S WASTE AUTHORITIES

Cumulative net service cost breakdown (£m) compared to BAU (2018/19 to 2030/31)



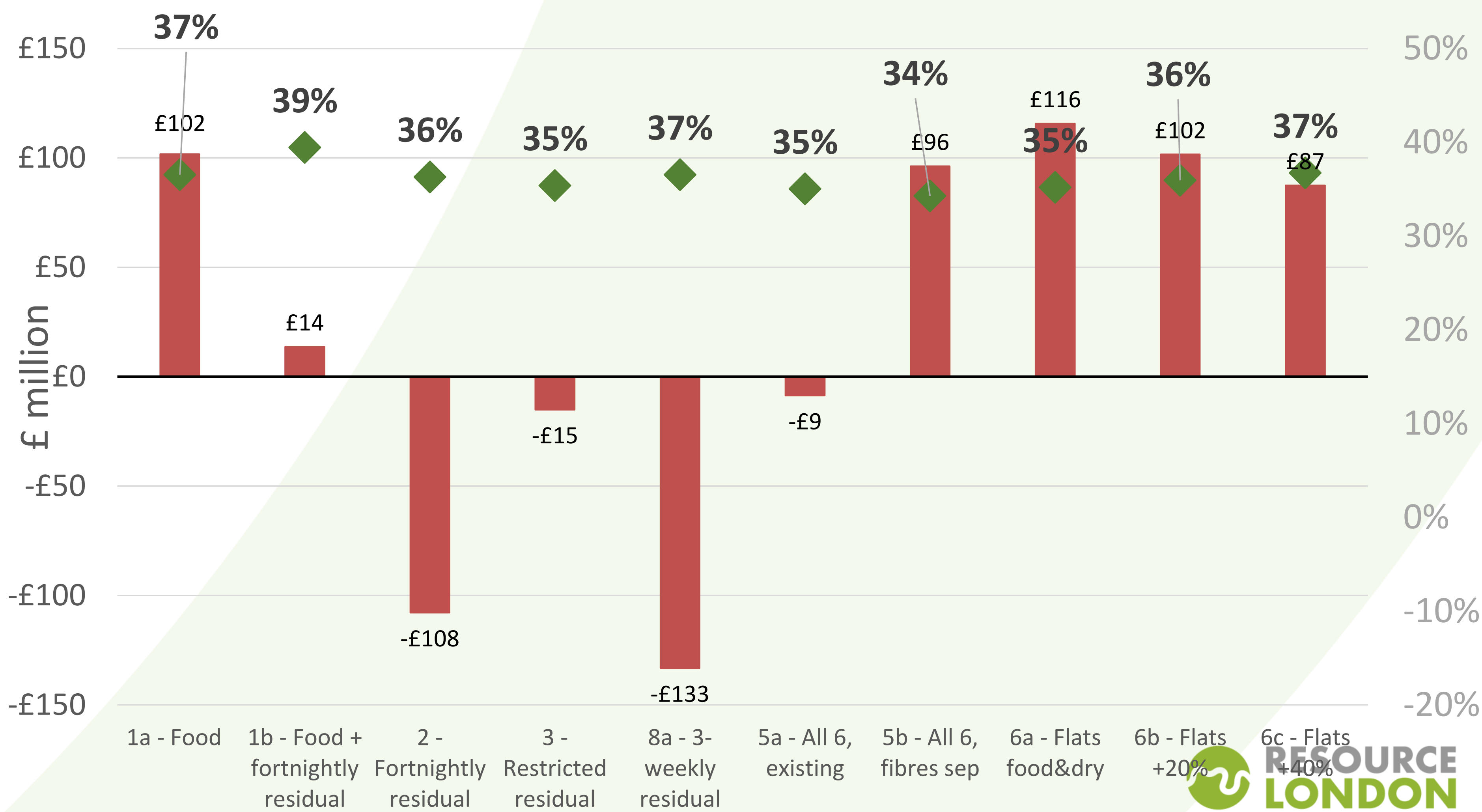
RESOURCE LONDON
SUPPORTING LONDON'S WASTE AUTHORITIES

Cumulative net service cost breakdown (£m) compared to BAU (2018/19 to 2025/26)

	1a - Food	1b - Food + fortnightly residual	2 - Fortnightly residual	3 - Restricted residual	8a - 3-weekly residual	5a - All 6, existing	5b - All 6, fibres sep	6a - Flats food&dry	6b - Flats +20%	6c - Flats +40%
Container Capital	£6	£7	£1	£10	£0	£0	£62	£16	£16	£16
Transition	£2	£8	£7	£1	£5	£0	£7	£1	£1	£1
Annualised vehicle	£18	£0	-£22	-£3	-£21	£0	£34	£35	£35	£35
Annual operating and comms	£199	£95	-£151	-£23	-£158	£6	£255	£163	£163	£163
Annual bulking and treatment (net of revenue)	-£39	-£101	-£48	-£20	-£63	-£23	-£225	-£14	-£39	-£65
net cost difference for service	£186	£9	-£213	-£35	-£237	-£16	£133	£202	£176	£151

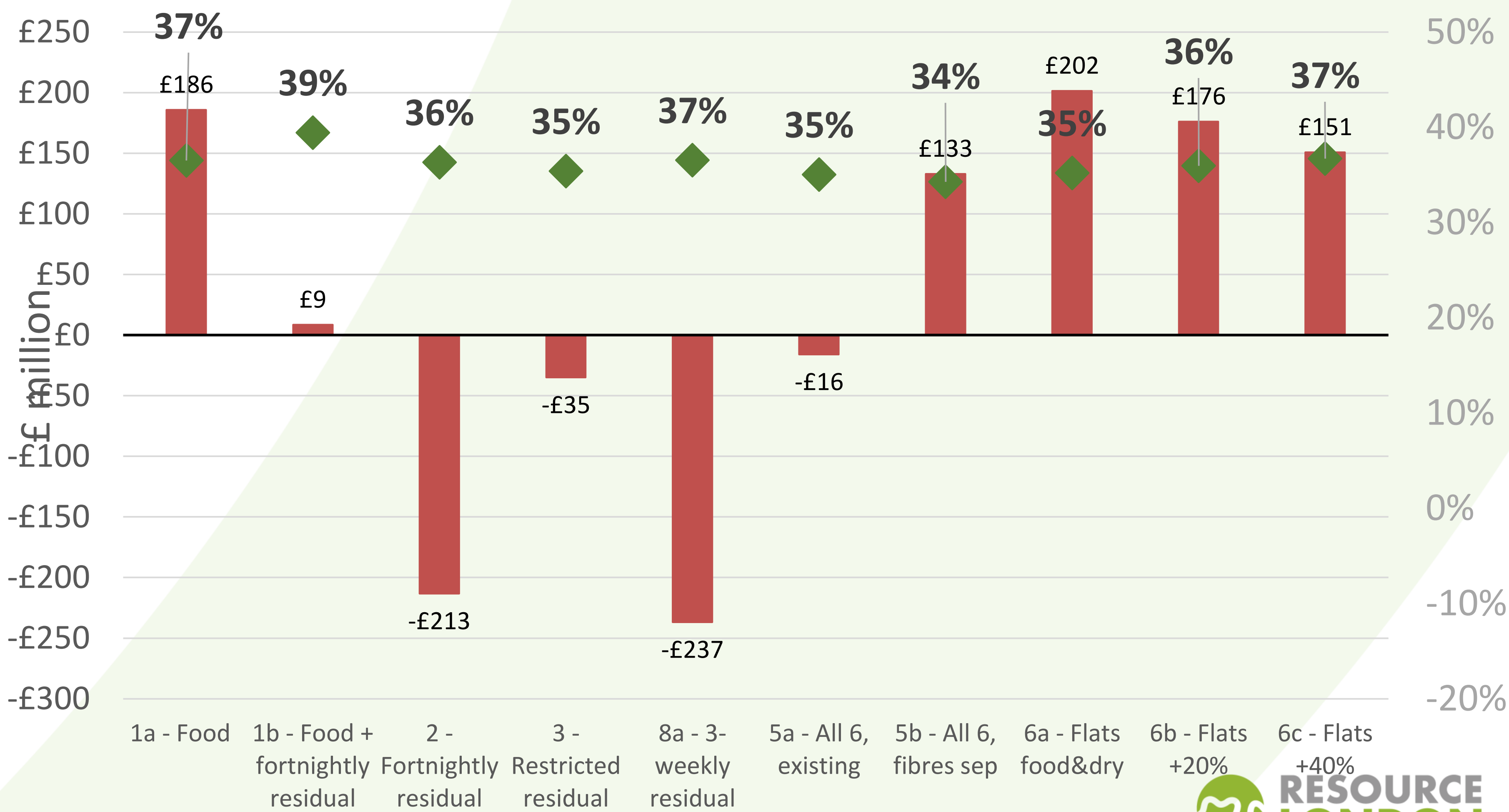
RESOURCE LONDON
SUPPORTING LONDON'S WASTE AUTHORITIES

Recycling Rate with Cumulative Net Service Cost (£m) compared to BAU (2018/19-2025/26)



RESOURCE LONDON
SUPPORTING LONDON'S WASTE AUTHORITIES

Recycling Rate with Cumulative Net Service Cost (£m) compared to BAU (2018/19-2030/31)



RESOURCE LONDON

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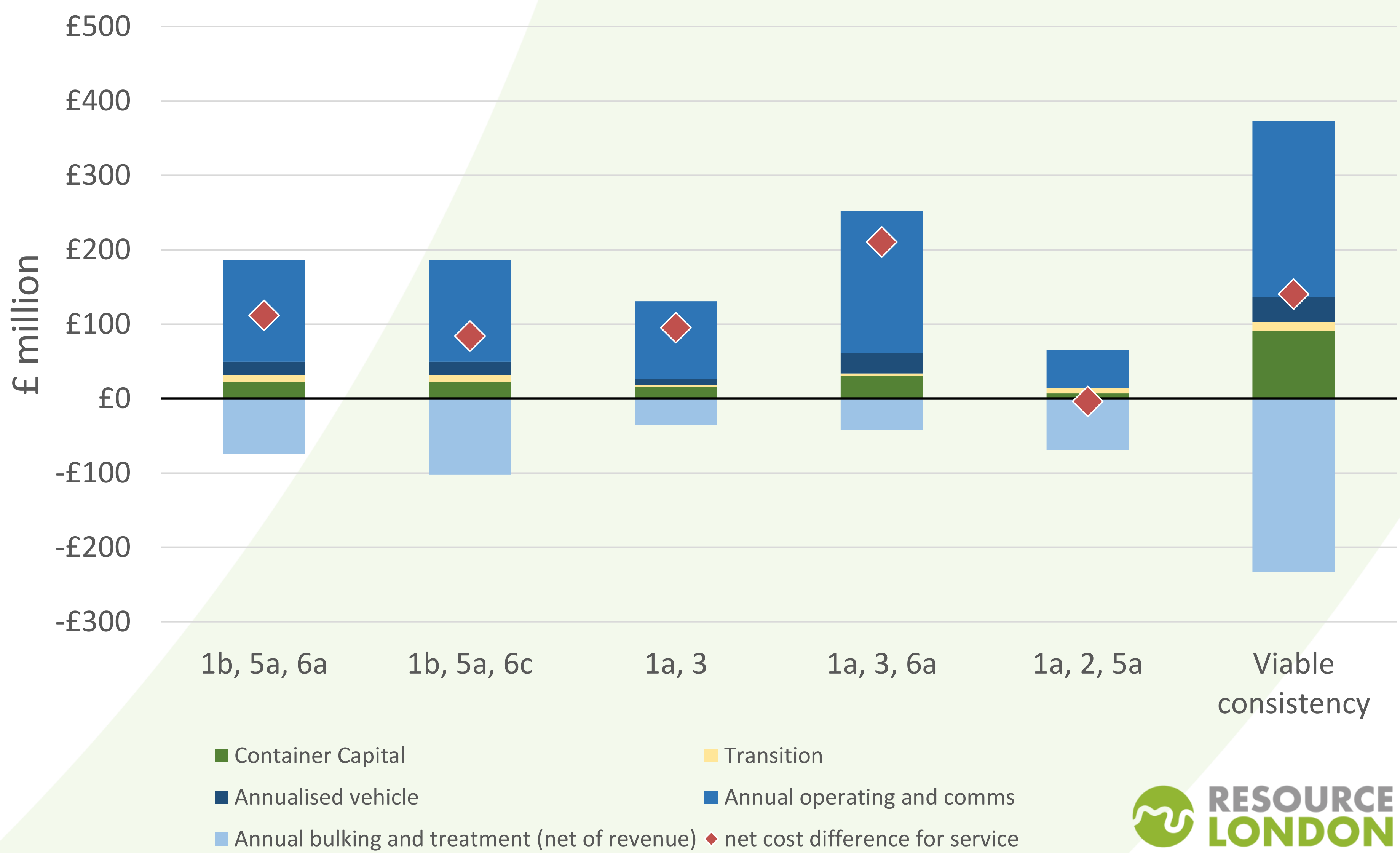
Combined scenarios: Cumulative Net Service Cost breakdown (£m) compared to BAU (2018/19-2025/26)



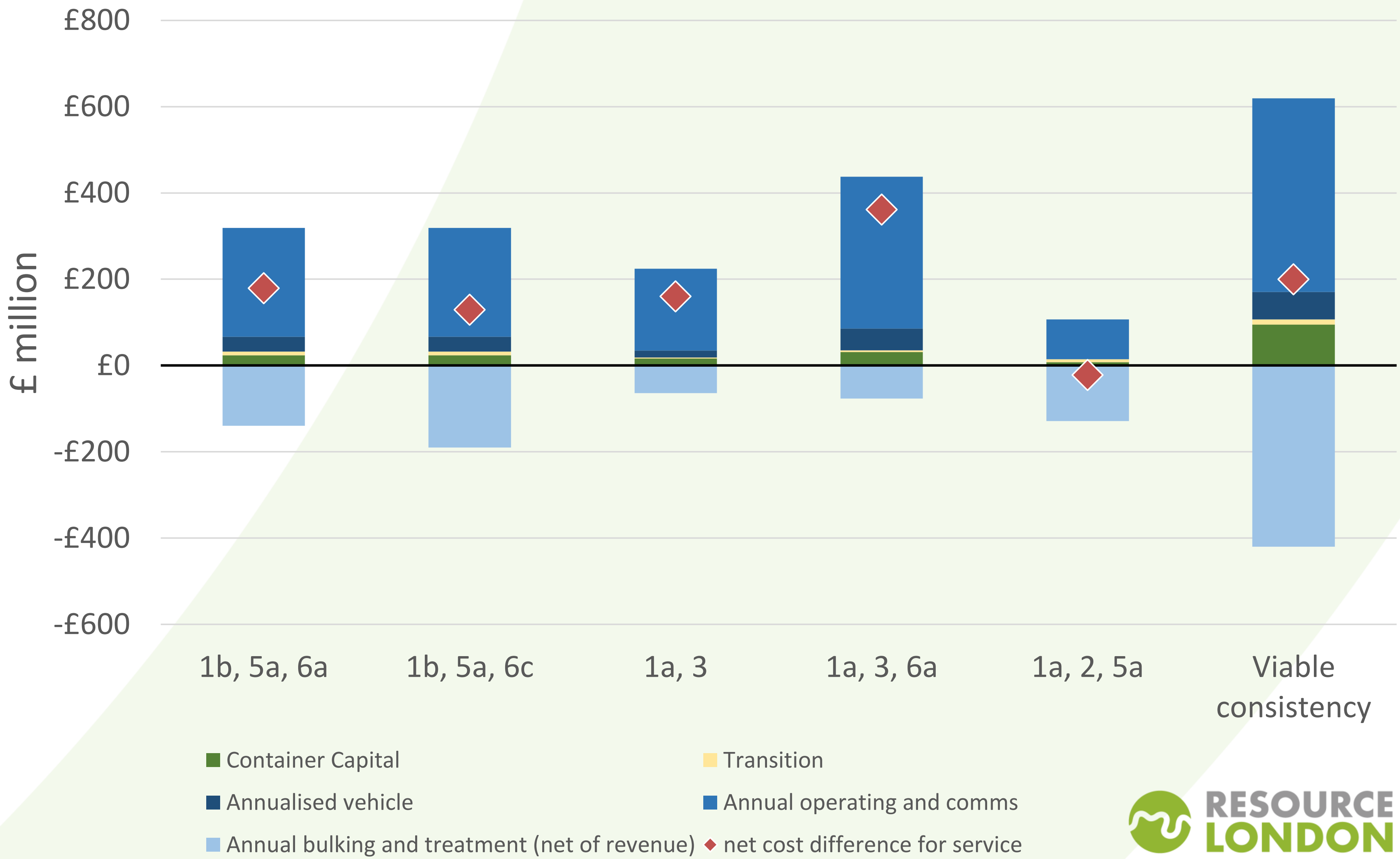
RESOURCE LONDON
SUPPORTING LONDON'S WASTE AUTHORITIES

Cumulative net service cost breakdown (£m) compared to BAU (2018/19 to 2025/26)

	1b, 5a, 6a	1b, 5a, 6c	1a, 3	1a, 3, 6a	1a, 2, 5a	Viable consistency
Container Capital	£23	£23	£16	£30	£7	£90
Transition	£8	£8	£3	£4	£7	£12
Annualised vehicle	£18	£18	£9	£27	£0	£34
Annual operating and comms	£137	£137	£104	£191	£51	£236
Annual bulking and treatment (net of revenue)	-£74	-£102	-£36	-£42	-£69	-£233
net cost difference for service	£112	£84	£95	£210	-£4	£140

RESOURCE LONDON
SUPPORTING LONDON'S WASTE AUTHORITIES

Combined scenarios: Cumulative Net Service Cost breakdown (£m) compared to BAU (2018/19-2030/31)



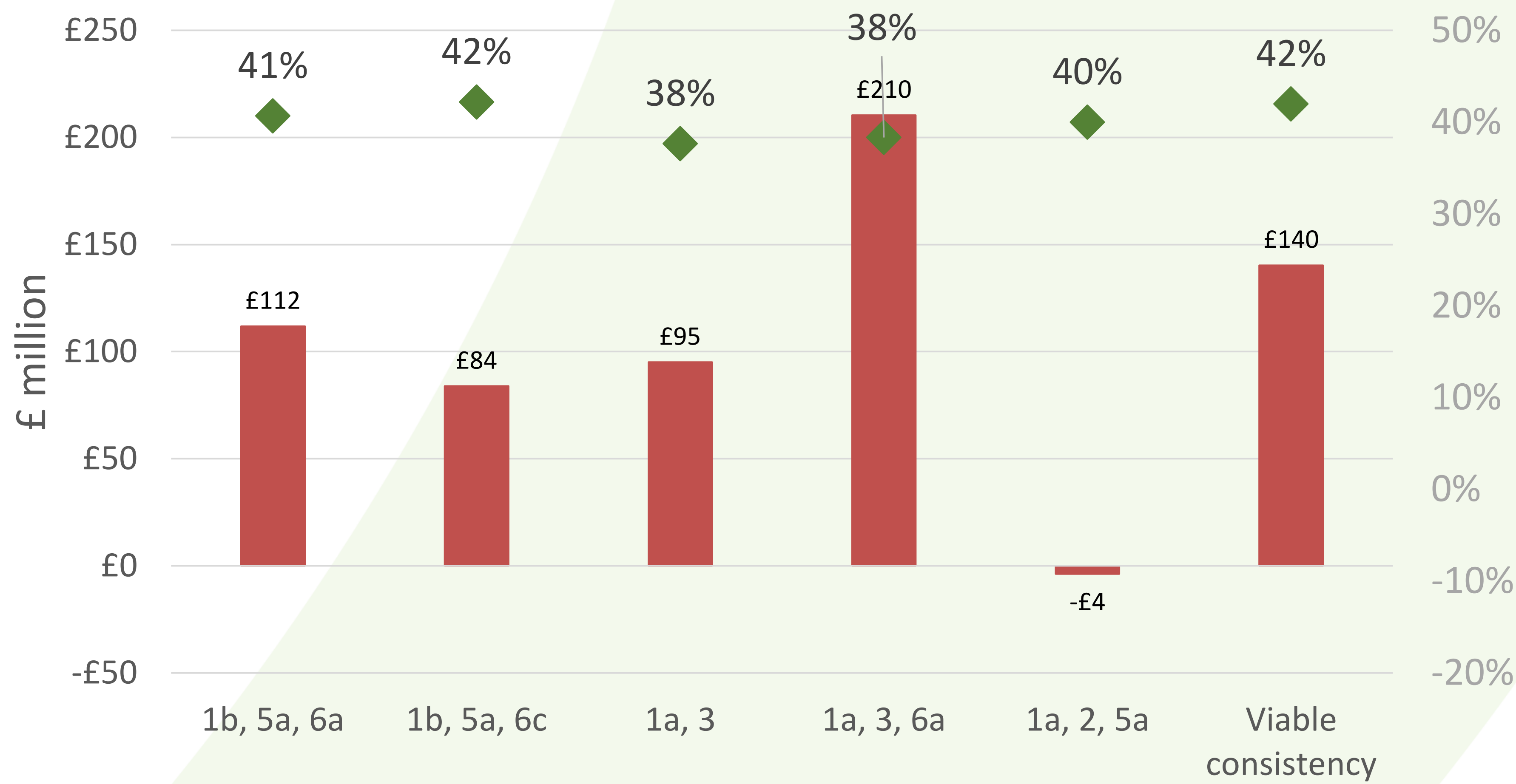
RESOURCE LONDON
SUPPORTING LONDON'S WASTE AUTHORITIES

Cumulative net service cost breakdown (£m) compared to BAU (2018/19 to 2030/31)

	1b, 5a, 6a	1b, 5a, 6c	1a, 3	1a, 3, 6a	1a, 2, 5a	Viable consistency
Container Capital	£24	£24	£16	£31	£7	£95
Transition	£8	£8	£3	£4	£7	£12
Annualised vehicle	£34	£34	£16	£51	£0	£63
Annual operating and comms	£252	£252	£190	£352	£92	£449
Annual bulking and treatment (net of revenue)	-£140	-£190	-£64	-£76	-£129	-£420
net cost difference for service	£179	£129	£160	£361	-£22	£200

RESOURCE LONDON
SUPPORTING LONDON'S WASTE AUTHORITIES

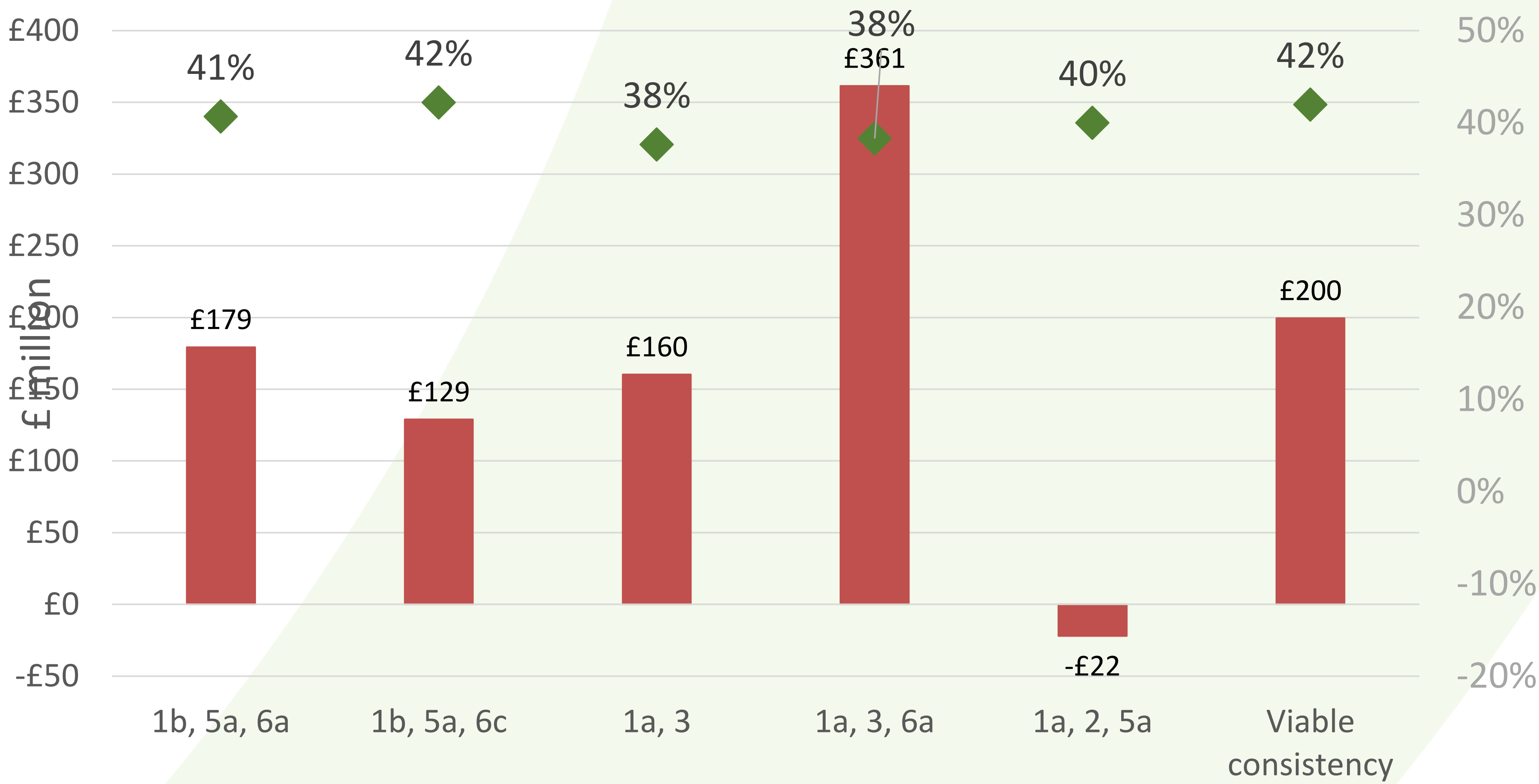
Combined Scenarios: Recycling Rate with Cumulative Net Service Cost (£m) compared to BAU (2018/19-2025/26)



Scenario	1b, 5a, 6a	1b, 5a, 6c	1a, 3	1a, 3, 6a	1a, 2, 5a	Viable consistency
WfH rate diff from BAU	6.14%	7.67%	3.13%	3.79%	5.34%	6.77%

RESOURCE LONDON
SUPPORTING LONDON'S WASTE AUTHORITIES

Combined Scenarios: Recycling Rate with Cumulative Net Service Cost (£m) compared to BAU (2018/19-2030/31)



Scenario	1b, 5a, 6a	1b, 5a, 6c	1a, 3	1a, 3, 6a	1a, 2, 5a	Viable consistency
WfH rate diff from BAU	6.14%	7.67%	3.11%	3.78%	5.34%	6.77%

RESOURCE LONDON
SUPPORTING LONDON'S WASTE AUTHORITIES

Conclusions from update – performance against recycling target

1. Based on scenarios selected and application to LAs it does not appear possible for London collectively to meet 50% recycling by 2020, 2025 or 2030 based on Defra’s Waste from Households definition.

2. The maximum recycling rate of 42% is reached in 2021/22 based on roll out of combined scenarios (1b, 5a, 6c – weekly food, fortnightly refuse, all dry materials and intensive flats support).

3. 41% achievable in 2020 (from combined scenario 1b, 5a, 6c) but will depend on support activities in 2017/18 to enable the changes to happen in 2018/19.

4. From the scenario start date (2018/19) the key scenarios take 3 years to reach the optimum recycling rate based on roll out assumptions made for individual LAs.

5. The tailored “viable consistency” scenario is high performing although slightly lower in recycling rate than the optimum combined scenario . This is due to the slightly lower performing two stream options compared to current.

Conclusions – impacts on programme plans to support LAs

1. Key themes that will impact on recycling rate are the restriction on residual waste capacity by reducing frequency, expansion of separate food waste collections and intensive support to overhaul flats recycling
2. Due to high operational (staff) costs scenarios with reductions in residual waste frequency where and crews are saved offer the biggest financial savings (e.g. fortnightly or 3 weekly)
3. Other themes, such as adding in missing dry materials, offer little impact on recycling rate due to the good range of materials already collected and that missing materials are lightweight e.g. plastics
4. Levy/menu pricing and cases of limited sharing of avoided refuse disposal cost by disposal authorities has significant impact on the business case and provides low incentive for boroughs (collection authorities) to collect more
5. Performance and overall cost profiles depend on LAs adopting the scenario profiles detailed in the analysis before they commit to new systems. Otherwise LAs may be locked into service profiles that prevent them from achieving maximum performance in line with the scenarios in this study
6. The business case for adopting scenarios differs for each LA according to their starting point and disposal arrangements. However, targeted funding to relieve transition will improve the business case for key LAs adopting influential scenarios.

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