7: The economics of London's environment

7.1: Key points

- Natural capital – those elements of the natural environment which provide goods and services - has declined over time. However, maintaining natural capital is fundamental to ensuring continued economic development for London, given the context of globalisation, projected increases in population and employment, and climate change.
- Poor air quality is a significant environmental and public health issue for London, partly occurring due to the increased economic activity which has taken place in the capital over time. However, policy to improve London's air quality can be expected to lead to health improvements over time. For those born in 2025, exposed to 2025 emission concentrations compared to 2010 concentrations, the life expectancy benefits are modelled as up to 5 months through NO_2 reduction, and up to 1.5 months through $PM_{2.5}$ reduction, an annualised economic impact of £2.5 billion for NO_2 and £0.7billion for $PM_{2.5}$.
- Noise disturbance directly impacts on people's quality of life and wellbeing. The World Health Organization estimates that across Western Europe, prevailing levels of noise cost between 1.0 and 1.6 million disability-adjusted life years; a social cost of between £60 billion and £100 billion per year across Western Europe. Noise disturbance is a particular concern for London, as a result of increased economic activity in the capital, its major trunk road network, railway networks and airports.
- London's green infrastructure has the potential to lead to significant improvement of the natural capital account. The London i-Tree Eco assessment estimated that London's urban forest provides total benefits of £132.7 million per annum. The natural capital asset value for Beam Parklands, which has been designed to provide flood storage in addition to a healthy space for play and recreation, was estimated at £42 million in present value terms, significantly exceeding the long-term natural capital maintenance costs of £1 million.

- Climate change remains a significant risk to the London economy. Although, London's CO_2 emissions have fallen 17 per cent since 1990, global emissions continue to rise rapidly and this presents a risk to both London's economy and environment.
- There are around 570,000 properties in London that are at risk of flooding, however the vast majority of these are at the low risk level. London has a higher proportion of properties with at least a low chance of flooding compared to all other English regions.
- London has lower rates of recycling compared to England as a whole. Around one-third of households recycle, which is approximately 10 percentage points lower than the national average. Movement towards a circular economy in London with greater reuse, recycling and remanufacture can help address negative externalities associated with increased waste and provide opportunity for new economic activity in the capital.

7.2: The concept of natural capital accounting

The environment is a fundamental part of London's economy. It impacts upon the health and quality of life of Londoners, but also has an important role in the function of the London economy. Resources are used by people and businesses to produce and provide goods and services; therefore maintaining high environmental standards and ensuring infrastructure meets the needs of London's economy for the future is essential to ensure London's continued competitiveness.

The centrality of the environment in the nation's and London's life is reflected in the recent concern for natural capital. Like other forms of capital (such as manmade physical capital and embodied human capital) it provides a range of services, both directly and through enabling increased productivity on the part of other forms of capital. The goods and services to people include clean air, clean water, food and recreation.[1] Through industrialisation, population change and increased demands for goods and services, the stock of natural capital has declined over time, which could prove detrimental for future economic growth. For example, increased incidence of poor air quality impacts on the health of residents, which potentially causes costs through either lost work time or reductions in productivity.

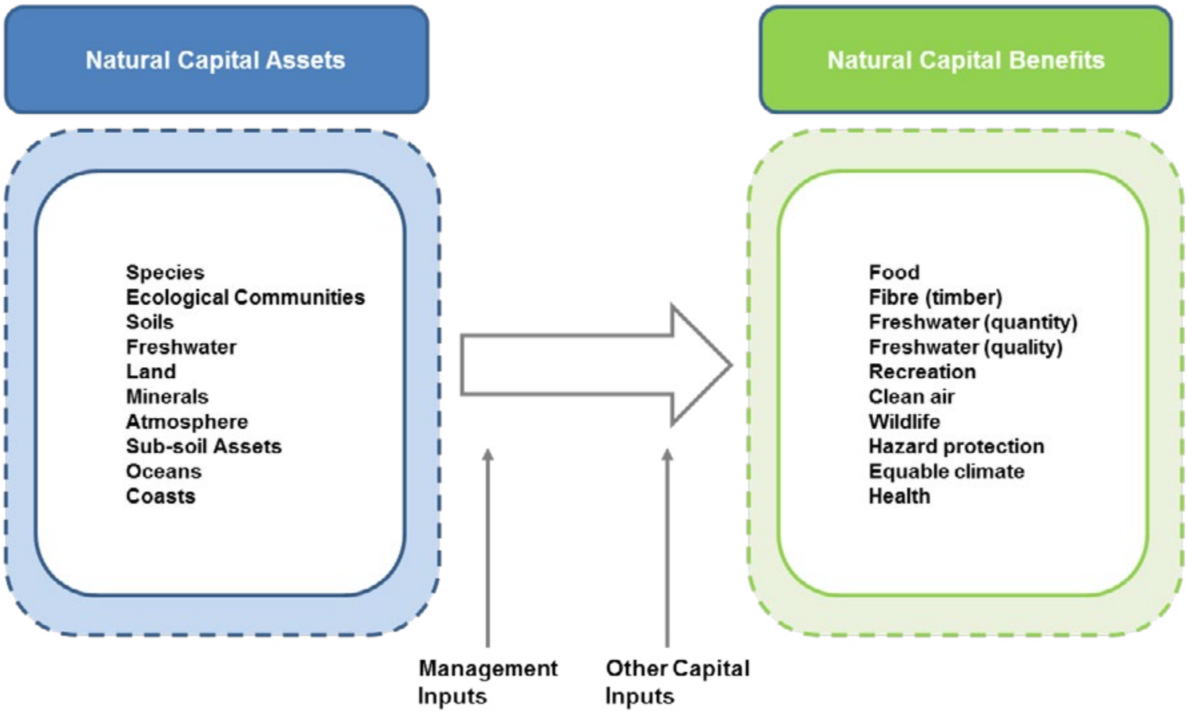
With population projected to grow in the next 30 years, the pressures on resources and natural capital will continue to grow; therefore to maintain and improve quality of life for Londoners, as well as safeguarding economic growth, interventions to protect the natural environment will need to be undertaken. In addition there is some evidence that the environment is a superior good, increasing in value as income per head rises.[2]

In recent times, exploration of the concept of natural capital has been undertaken by the Natural Capital Committee, with three reports on the 'State of Natural Capital' produced. These reports refined the concept of natural capital and explored valuation methods which can be used as part of project appraisal, to assess the potential value for the natural environment of different measures. Within their analysis, the Committee framed the concept in such a way that the benefits from natural capital are underpinned by the natural capital assets delivering them, as outlined in Figure 7.1. For example, by maintaining the atmosphere (the asset) free of pollution, the benefit that is derived is clean air, thereby mitigating the negative externalities (and hence costs) associated with poor air quality. It can therefore be summarised that elements of natural capital directly or indirectly provide value to society; economic benefits can be obtained from better protecting and improving our natural capital, in order to mitigate potential economic losses from failing to do so. For example, ensuring preservation of bees and other pollinators can mitigate the losses which may occur from reduced agricultural output.

The relationships between different natural capital assets and benefits are described as being "multiple, interacting, complex and evolving, …, but all are mediated both by human management of the assets, and by inputs of other capitals (manufactured and human)". An example given on this point is that the location of woodland determines how much it will be used and the benefits derived from it. However the "contribution of woodland to an equitable climate (via carbon sequestration) is mostly unaffected by its location and will instead be determined largely by its size (quantity) and to some extent by species composition (quality)."[3]

Such an example has particular consequences for the measurement of natural capital, the metrics that are used in assessing this, as well as valuation as part of project appraisal and national capital accounting. This is a point which the Natural Capital Committee advise further expert analysis be undertaken.[4]

Figure 7.1: Natural capital assets and type of benefits



Source: Natural Capital Committee[5]

The analysis of the state of London's environment is framed initially in terms of the benefits provided by natural capital in Figure 7.1. Thus, of the natural capital assets identified by the Natural Capital Committee, some are of considerably greater direct importance than others to London. This reflects the greater proportion of land devoted to buildings than is the case for other UK regions, and the absence of coasts except in estuarial form. Evidence of this effect is set out in Chapter 1 where evidence on employee jobs and total economic output from primary sectors reflect the preference of service sector activities in London's economy.

Less obviously from published data, the relative intensity of the built environment in London will imply a high value for the recreation benefits of green space.

The following sections build on these ideas as a basis for providing an outline of the current state of the environment in London across areas such as air quality, carbon emissions, energy usage, noise pollution, water, and climate change; with associated economic costs highlighted. Many of the areas explored in this chapter reflect the presence of market failure, typically through the existence of negative externalities.

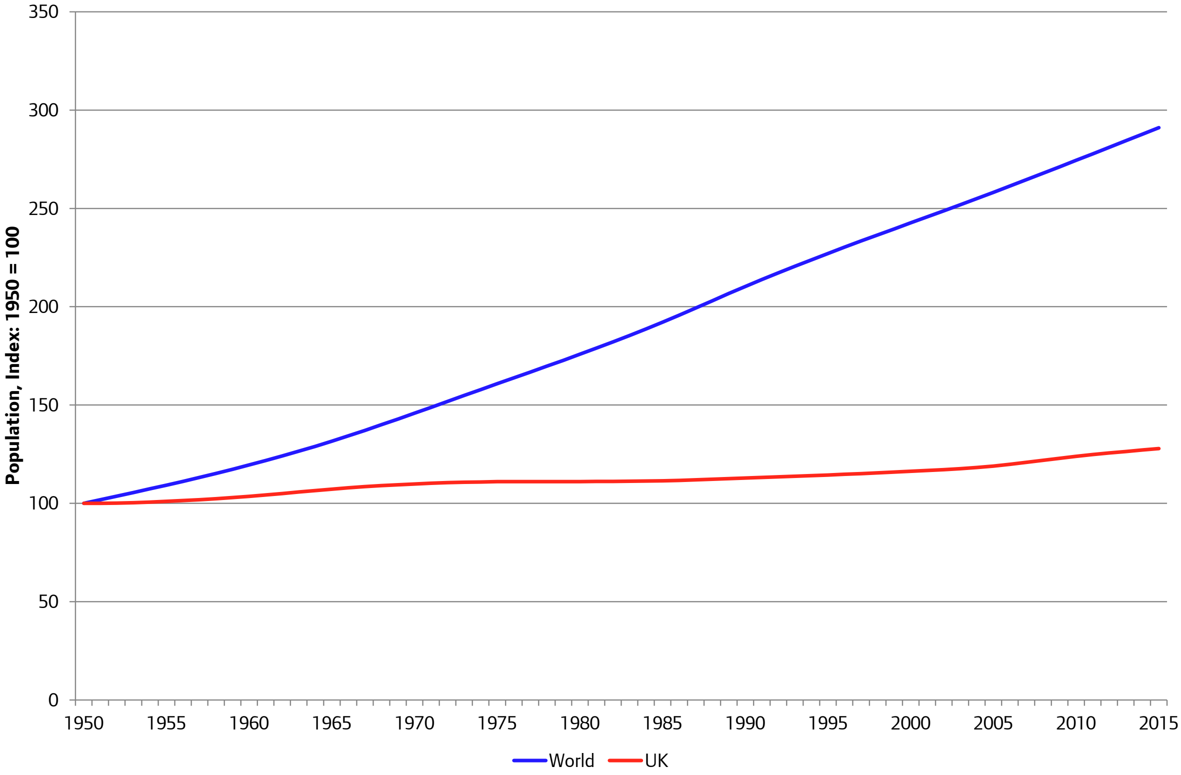
7.2.1: Future considerations – in the global context

In a discussion on the environment and natural capital it would be remiss not to consider the potential impact of future population and economic change; for example, how might projected increases in population place additional demands on natural capital? How might planned changes in regulations governing emissions enhance the stock of natural capital? It is likely that exogenous and endogenous changes may have impacts on the natural capital more generally, and would have a mixture of positive and negative impacts. This section provides an overview of some the key contextual issues before the remainder of the chapter looks at specific environmental areas.

a) The continued growth of the global and urban populations

In a global context, with population expected to continue to grow (as shown in Figure 7.2), and emerging economies expected to grow strongly; the natural capital account may be in a worse position despite efforts to improve the state of the natural capital in London.

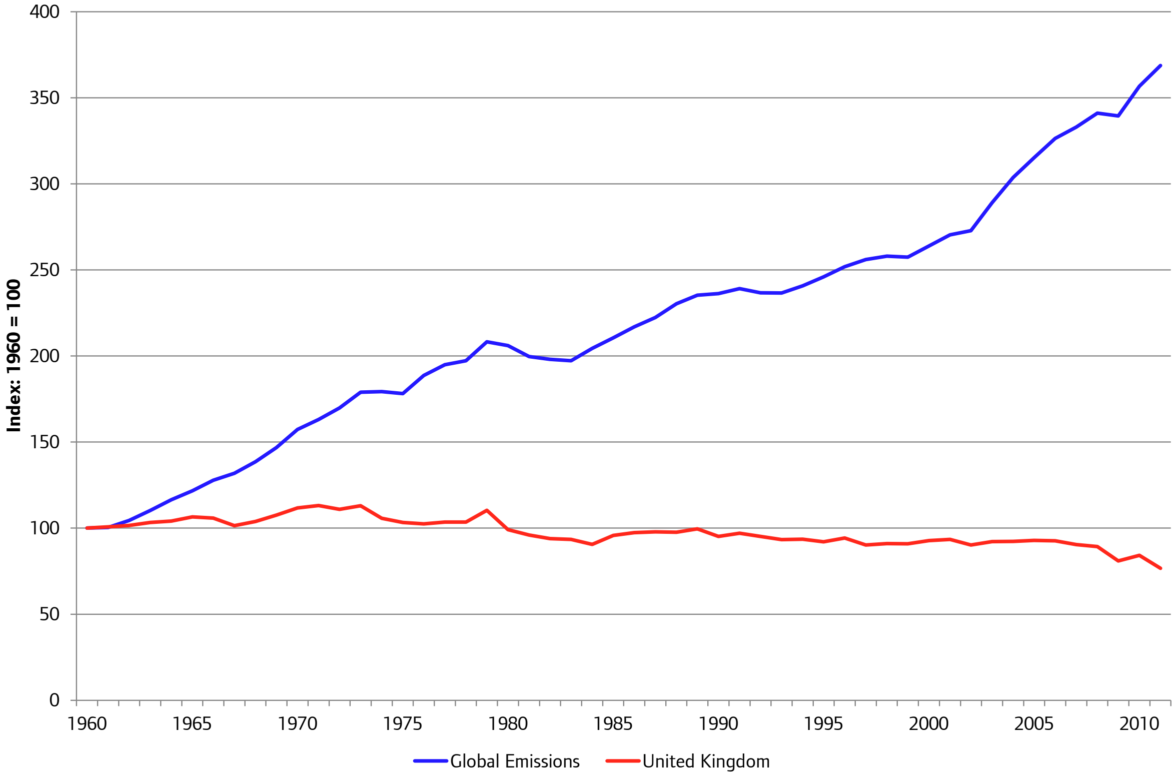
Figure 7.2: Global and UK population change, indexed to 1950



Source: United Nations

Increased global industrialisation has seen opposing trends in carbon emissions (Figure 7.3) which could lead to opposing policy positions, varying from stronger calls for international co-operation on the issue, to a more laissez-faire position where there could be limited incentive for major developed economies to act to reduce carbon emissions to address global emission increases.

Figure 7.3: Global and UK carbon emissions, indexed to 1960



Source: World Bank

In the London context, as illustrated in Chapter 8, London's population is projected to grow to over 10 million by 2041; one of the implications of this would be increased demand on services and infrastructure. Within the environmental context, there could be a wide range of impacts.

There will be an increased demand for energy for both businesses and residents. For London to maintain its position as a globally competitive destination, access to energy and infrastructure will be necessary for business, however increased energy production may lead to greater carbon emissions. Additional demands on the energy grid will be placed upon it by a growing population, so energy supply may be compromised. A potential mitigation against this could be the increased provision of decentralised energy, and/or a shift towards other renewable energy generation, and/or increased energy efficiency.

A growing population also increases the need for waste, reuse and recycling services. Positive and negative impacts can occur as a result of this; there is increasing pressure on London's waste sites in competition with other land uses and landfills accepting London's waste expect to close by 2025. Other industry that can treat London's waste may be shifted away from London (exacerbating trends towards increased industrial specialisation in service sector activities). However, increased demands on infrastructure may encourage shifts towards a more circular economy, where more materials are recovered for re-use, recycling or remanufacture. In turn, this may see growth in different areas of London's economy; available land may however be a constraint in the development of such activities going forward (a point referenced within Chapters 4 and 6 of the evidence base).

Issues of land use and its impacts on the natural capital account are relevant. Re-allocation of land towards development may impact upon the supply and quantity of green space available to residents, but can also impact on a wide range of other elements, such as flood protection, clean air, and biodiversity. Increased population, economic activity and trade therefore creates increased pressures on infrastructure and land use which have a potential range of negative environmental impacts (such as the possibility for new developments making London more vulnerable to urban heat island effects). However, through the use of mitigation during development, whether it be a commitment to energy efficiency or increased provision of innovative forms of green space (such as green roofs), impacts on natural capital can be offset and accounted for in future schemes.

Alongside population increase, London's continued economic development and connectivity see London's daytime population increase significantly. As seen in Chapter 3, net in-commuting to London stands at over 500,000, all of which means that there are increased calls on infrastructure, along with increased demand for activity to service the growing economy.

Over the last 30 years, London's economy has seen significant structural and spatial shifts. There has been the move away from manufacturing and primary activities towards the service economy. This potentially could be seen to have offsetting environmental impacts, moving away from higher emission activity in manufacturing, towards lower per capita emission activity within offices. There has been a shift away from more land intensive activity to economic activity that has agglomerated within the centre of London. It is not conclusive however that this has a specific impact on the natural capital balance. For example, increased activity in a particular area may have specific location based impacts on air quality, which in turn could disproportionately impact on more deprived areas or lower income groups.

However, some of London's economic success can enable the capital to be able to adapt to the future needs of the global economy, and also take the lead in areas which could promote the environment. For example, London's specialisation as a financial centre means it is well placed to diversify in areas such as low carbon finance; its status as a legal centre means it can be well placed to develop in areas such as environmental law; and its status as a high skilled location may mean that it can adapt to future economic development, such as in the green economy or circular economy. All of which may mean that London can continue to develop as a globally competitive city, whilst at the same time aid in the preservation of natural capital.

b) Continued increases in standards of living

Continued economic development is likely to increase the standards of living of the population. At its simplest level, this would mean that incomes would increase and consumption would increase as a result. To service the demand for increased consumption, more goods and products are manufactured. At face value, this is likely to worsen the current state of natural capital in a global context.

At the London level however, there may be offsetting impacts on the natural capital account. For example, with a growing population and increased disposable incomes, there will likely be a greater demand for goods and services, leading to greater economic activity to service this demand (increasing the call on energy and infrastructure). In addition, it may require increased distribution of goods, potentially having negative environmental impacts through poorer air quality and increased carbon emissions. However in light of these potential negative impacts, there is the potential for a shift towards products which are more energy efficient or environmentally friendly. For example, with higher incomes, households may be more inclined to purchase zero-emission cars, or have an increased demand for recreation activities (hence a need to supply more green space for such activities).

c) Continued globalisation and increasing travel

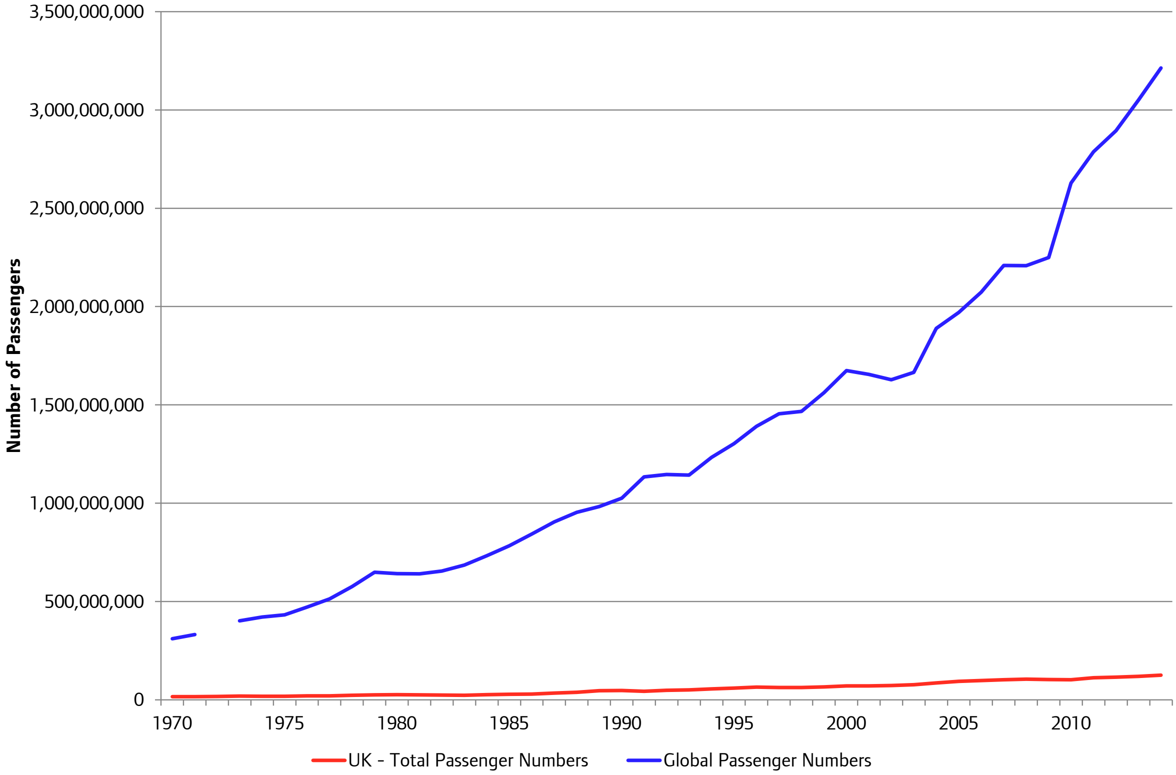
The growth in the global economy has led to specialisation from trade (as illustrated in Chapter 1). London in particular has developed into a truly global city, with trade links across the world. This in turn provides potential challenges and opportunities for the capital, and likewise, can potentially positively or negatively impact upon natural capital.

Increased industrialisation in the UK occurred in the 19th century; however it has been in recent times when London has developed as a global city, specialising in professional and business services. As shown in Chapter 2, agglomeration of activities and shared services (for example, a business locating in London may want to take advantage of lawyers, accountants, management consultants etc.) mean that business activity grew sharply, people were attracted to the capital as a place to live and work, and the population of the capital has grown significantly. This, and London's projected population and employment growth into the future, means that there will be greater calls for natural capital assets, increased need for capacity and infrastructure which could lead to a worsening environmental outcome.

However, in light of these concerns, there are incentives and opportunities for London to specialise and develop in areas which could help to mitigate against some of these risks. For example, as mentioned previously, there has been growth in London's low carbon finance sector; growth in low carbon and environmental goods and services; and development in activities relating to the circular economy.

It is clear that connectivity across the world has improved significantly (Figure 7.4), and this, alongside increases in global standards of living, has driven the growth of the tourism sector.

Figure 7.4: Global air passenger transport trends



Source: World Bank. Note: Break in series as data not available for 1972.

London is one of the most visited cities in world, and has seen growth in international visitor numbers of over 40 per cent in the last ten years as well as increases in domestic overnight and day visit tourism. This growth has two main impacts, firstly it increases the demand for travel services (such as air, railway, and road transport), hence in part leading to increased emissions and impacts on quality of life for residents (such as through increased noise pollution and congestion). Secondly, the tourism economy supports a wide range of business and employment; within London, it is estimated that the tourism economy supports 283,000 jobs and is worth around £10.0 billion of GVA to the economy.[6] This economic activity is likely to negatively impact on the natural capital account; that said, access to green spaces are one of the many contributory factors as to why tourists visit the capital. Therefore development of areas where people can access green space and improved air quality may have positive economic impacts for the capital.

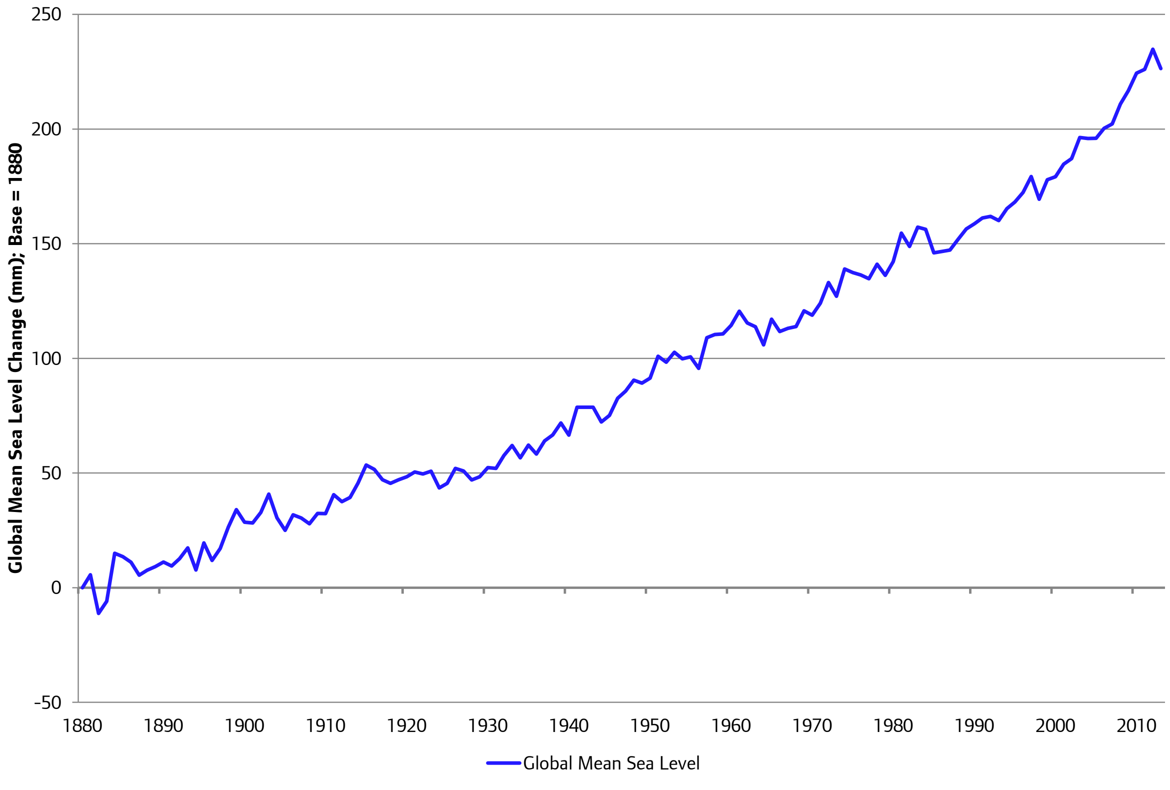
d) Climate change

As will be shown later in this chapter, the balance of evidence suggests that climate change is occurring and this represents a major economic risk for the global economy. Climate change also has significant impacts on the natural capital account, as a wide range of natural capital assets can be impacted through climate change. For example:

- Changes in ecology and species across areas can disrupt the natural wildlife and potentially have social and economic impacts across areas (e.g., declines in native bee populations impacting upon crop pollination; or more historically, the growth in numbers of grey squirrels compared to the native red squirrel);

- Climate change may mean that some land would become unusable for food production; rising sea levels (Figure 7.5) may impact on available land for economic activity;

Figure 7.5: Global sea level changes since 1880



Source: Adapted from Church, J. A. and White, N. J. (2011), "Sea-level rise from the late 19th to the early 21st Century". Surveys in Geophysics, Volume 32, Issue 4, pp. 585 – 602. Note: Chart does not include uncertainty bars

- Within the London context, climate change may impact on people's quality of life. A range of measures is likely to be needed to help mitigate the impacts, which could include improved flood risk management, more sustainable drainage, increased tree planting and green cover, measures to conserve water and improved building design.

7.2.2: Future considerations – conclusions

This section has sought to highlight the significant interactions between economic activity and natural capital. Changes in both the global and London context has specific impacts on elements of natural capital, it highlights the risks facing the capital but also the potential economic opportunities that could result from London building on its specific industrial specialisations and skill sets to look to balance continued economic development with protection of natural capital. Within later sub-sections of the chapter, some of these points are revisited, bringing together data on the trends on aspects of London's environment, but also drawing upon literature evidence on the economic importance of the environment.

7.2.3: The road map of the chapter

The following sections of this chapter look at a range of environmental areas in turn and consider how each relates to natural capital, the market failure underlying the issue, and a summary of the evidence on the economic costs and benefits associated with each issue. The remainder of this chapter considers the following areas:

- Atmosphere
- Noise pollution
- Climate
- Water
- Energy
- Waste
- Green infrastructure

7.3: Evidence on the state of London's environment

Within this section, detail on London's (and the UK's) current performance against environmental indicators are considered, as well as articulating the economic importance of each of these areas.

7.3.1: London's atmosphere

Clean air is a fundamental part of the natural environment and mitigation against poor air quality can lead to significant benefits to London's and the UK economy. London's air quality has implications for the health of Londoners, and by extension, this can impact on the productivity of London's workers and the potential for sustained economic growth. As with many aspects of the environment, poor air quality can be seen as a negative externality, where external costs are borne by people who are not directly the cause of emissions.

The existence of this can be easily observed. Economic activity within small geographic areas can lead to increased emissions – for example, businesses locating in a confined area all require a supply of goods and services, which may be transported by road; these businesses may also employ staff who travel by car or public transport. This, combined with other activities taking place in localised areas, such as education, healthcare, and leisure activities, can create hotspots of high air pollution. This will impact on the health of Londoners and the attractiveness of the capital as a place to live and work. Evidence on the state of London's air quality and the economic importance of it are provided in this subsection.

Economic development could be seen to have offsetting effects on the extent of emissions (both in terms of air quality and carbon emissions). Although this increased concentration of activity in localised areas can have negative impacts through poorer air quality; for major cities, in light of the benefits that clean air provides, there are incentives and opportunities to look to improve air quality, and opportunities for business to use a location as a hub to innovate in new technologies.

It is clear however that air pollution and carbon emissions are a significant risk to the global economy in the future, with the European Environment Agency stating that "air pollution is the top environmental risk factor for premature death in Europe; it increases the incidence of a wide range of diseases and has several environmental impacts, damaging vegetation and ecosystems".[7] In this context, it is important to distinguish those effects for which the impact is relatively localised and those (such as greenhouse gases) which affect the global (commons) ecosystem.

7.3.1.1: Evidence on London's air quality

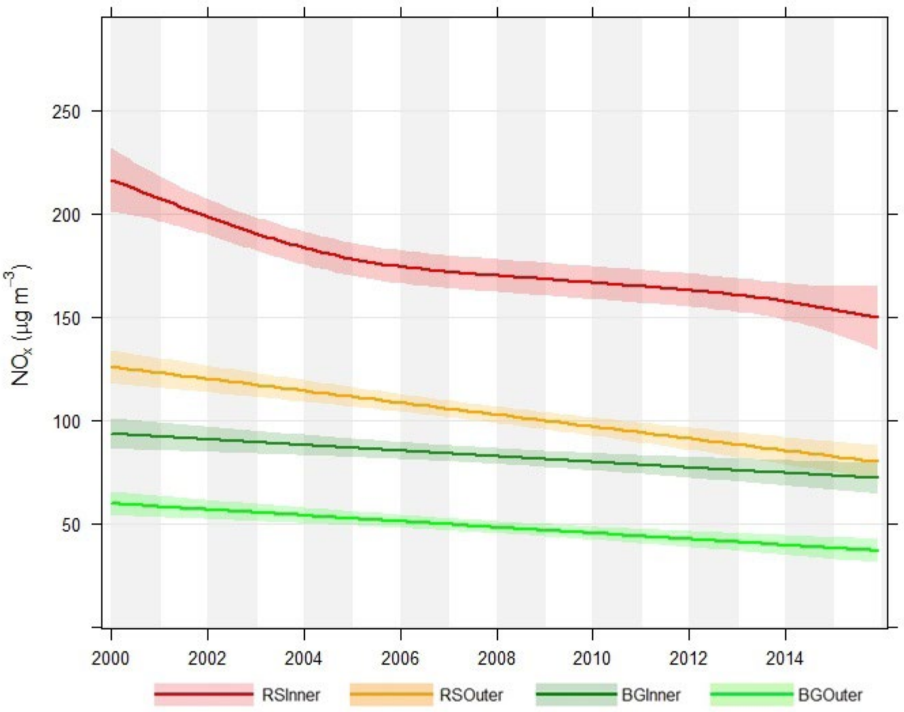
London has a large air quality monitoring network, funded by London boroughs, the GLA, TfL and Heathrow Airport. Many of these sites are part of the London Air Quality Network (LAQN)[8], managed by King's College London's Environmental Research Group.

Figures 7.6 – 7.9 show that overall, there has been a gradual reduction in all of the major air quality metrics, such as NO_2, PM_{10}, $PM_{2.5}$ and NO_x concentrations at background sites in inner and outer London and outer London roadside sites. Inner London NO_2 roadside sites have 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.

This is supported by analysis at most individual monitoring sites, although the dynamic nature of air pollution and the way it is affected by multiple factors (temporary issues like construction activity, weather, local road layouts etc.), means concentrations at some sites can go up while the overall trend across the city is improving.

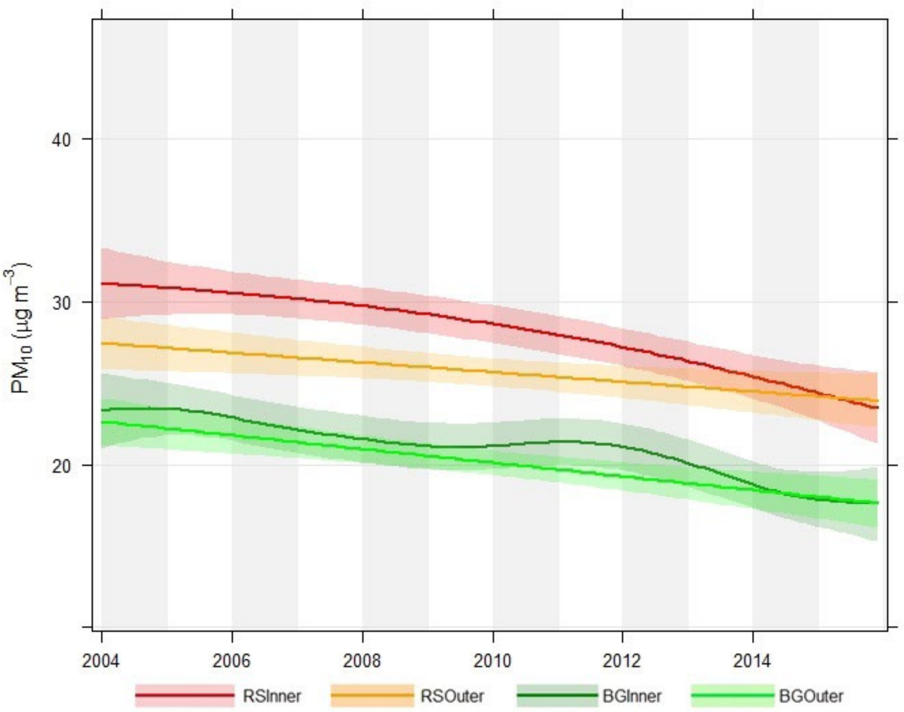
This network gives an opportunity to understand trends in London's air quality. One way to view air quality monitoring data is to group monitors based on their location and distance from the roadside and look at the average concentrations. For example, roadside monitors are within 5m of roads, whilst background sites are away from major sources.

Figure 7.6: Trends in NO_x, 1998 to 2015



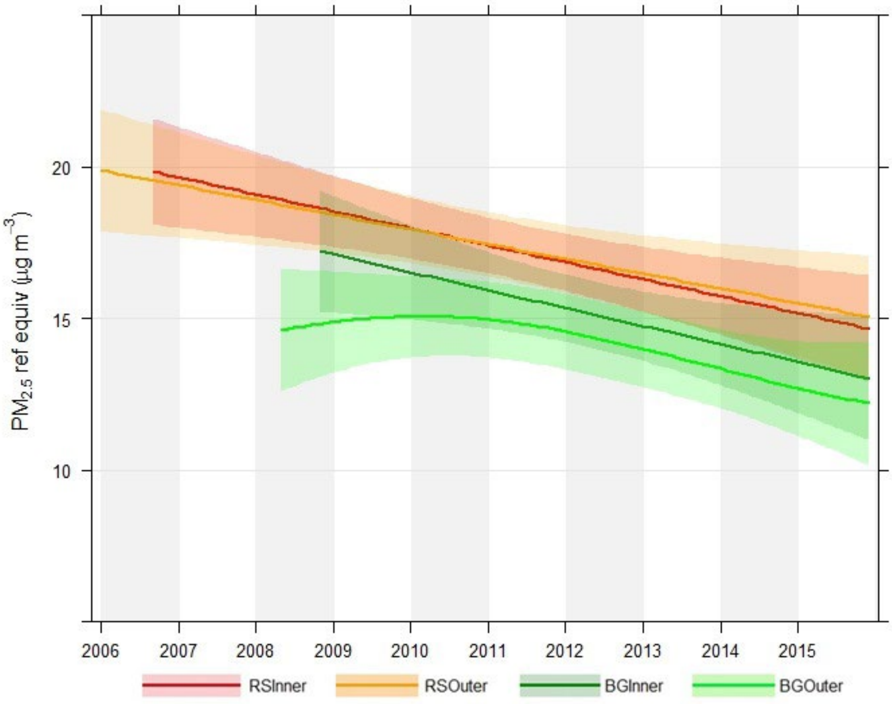
Source - the London Air Quality Network and analysis by King's College London (BG = "background", not next to a road. RS = "Roadside" and "Inner" and "Outer", refer to Inner and Outer London).

Figure 7.7: Trends in PM_{10}, 2004 to 2015[9]



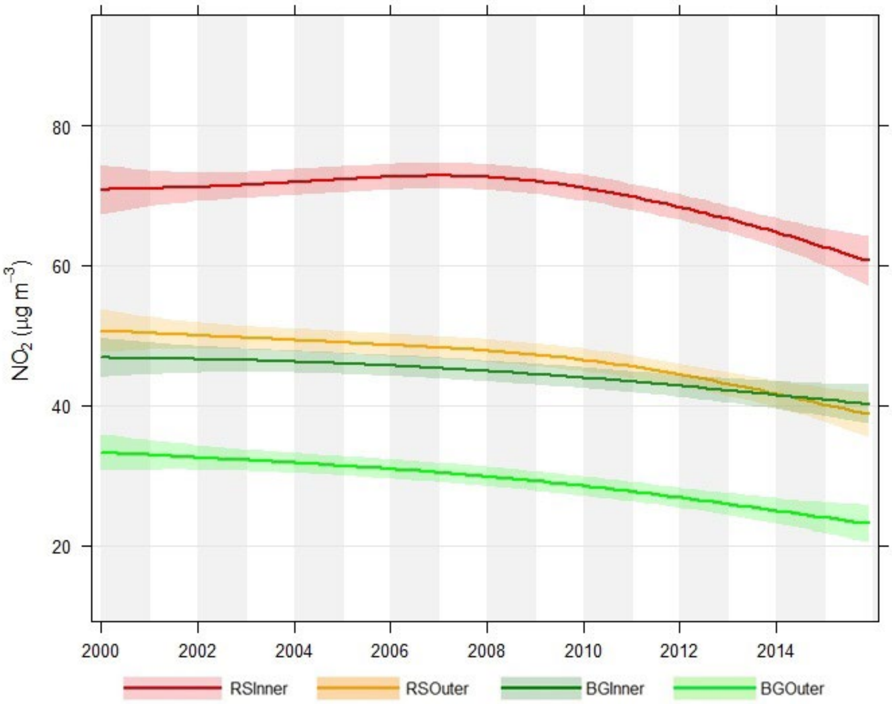
Source - the London Air Quality Network and analysis by King's College London. (BG = "background", not next to a road. RS = "Roadside" and "Inner" and "Outer", refer to Inner and Outer London).

Figure 7.8: Trends in $PM_{2.5}$, 2006 to 2015



Source - the London Air Quality Network and analysis by King's College London. (BG = "background", not next to a road. RS = "Roadside" and "Inner" and "Outer", refer to Inner and Outer London).

Figure 7.9: Trends in NO_2, 2000 to 2015



Source - the London Air Quality Network and analysis by King's College London. (BG = "background", not next to a road. RS = "Roadside" and "Inner" and "Outer", refer to Inner and Outer London).

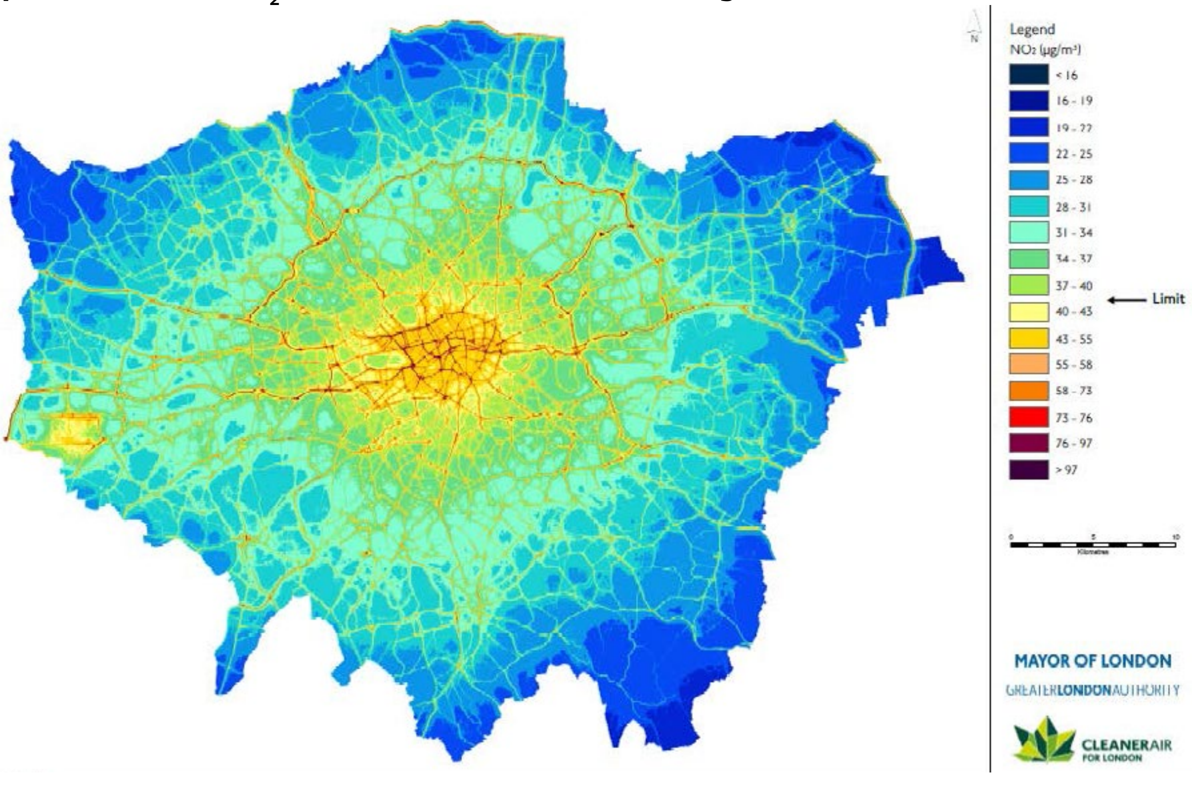
These averages do not however reflect the variability between individual site characteristics and trends. They do reflect all pollution sources experienced at a monitoring site and not just locally emitted pollution or road based pollution specifically.

Pollutant concentrations in London are affected by emissions in London, pollution from outside London and the UK, and other factors such as weather. Using sophisticated statistical models it is possible to 'remove' the weather effect from trends in concentrations of the main pollutants monitored at sites in the LAQN. This allows for the production of trends where the impact of variable weather conditions is reduced. This analysis was conducted by the Environmental Research Group at King's College and has shown the following trends from 2008 to 2013:

- NO_x roadside sites show a downward trend of 1.25 per cent per year, equating to a total reduction over the six year period of 7.5 per cent
- NO_2 roadside sites show a downward trend of 2.1 per cent per year, equating to a total reduction over the six year period of 12.6 per cent.
- PM_{10} roadside sites show a downward trend of 1.4 per cent per year, equating to a total reduction over the six year period of 8.4 per cent
- PM_{10} background sites show a downward trend of 0.65 per cent per year, equating to a total reduction over the six year period of 3.9 per cent
- $PM_{2.5}$ roadside and background sites show a downward trend of 2.2 per cent per year equating to a total reduction over the six year period of 13.2 per cent.
- Black Carbon[10] (only monitored at three sites) has shown small decreases but these are not considered statistically significant.

While the picture at the London level shows that air quality has improved, incidence of poorer air quality is observed where there is a greater agglomeration of business activity and particularly along transport links. Map 7.1 shows how air quality in general gets relatively poorer in areas closer to the centre of the city.

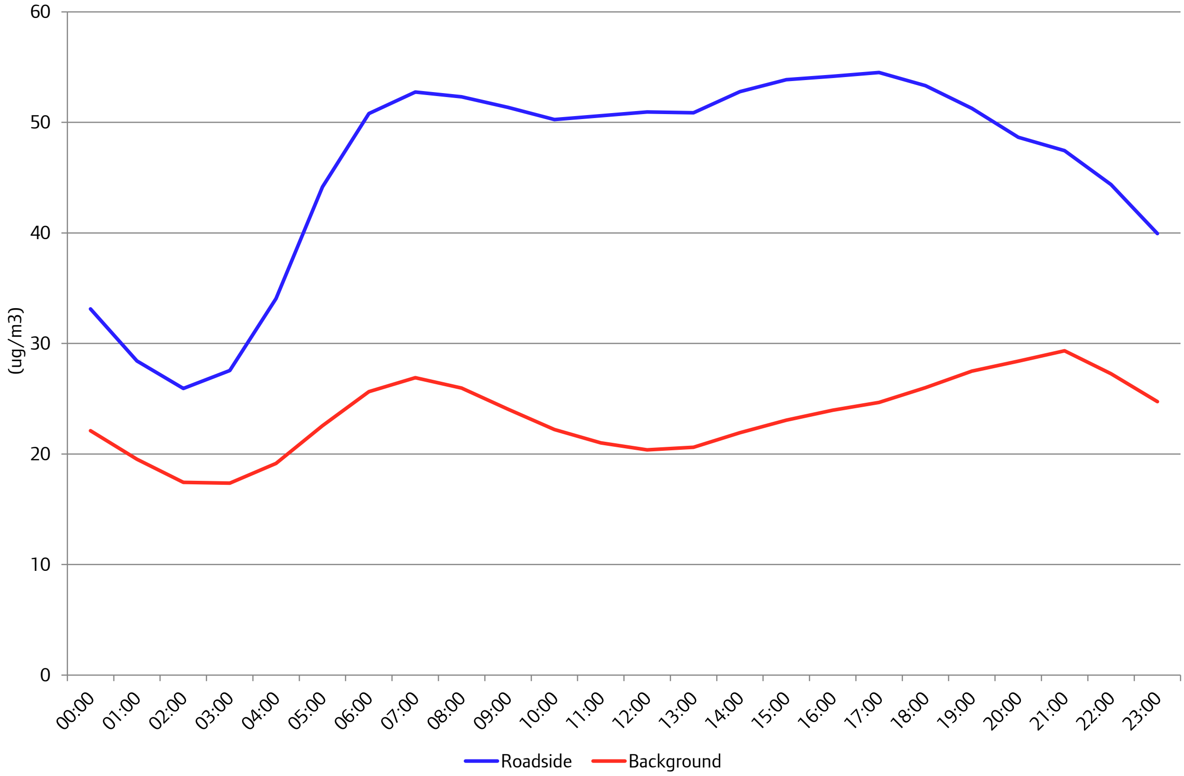
Map 7.1: Modelled NO_2 annual mean concentrations (µg/m³) for 2015 (baseline)



Source: Cleaner Air for London

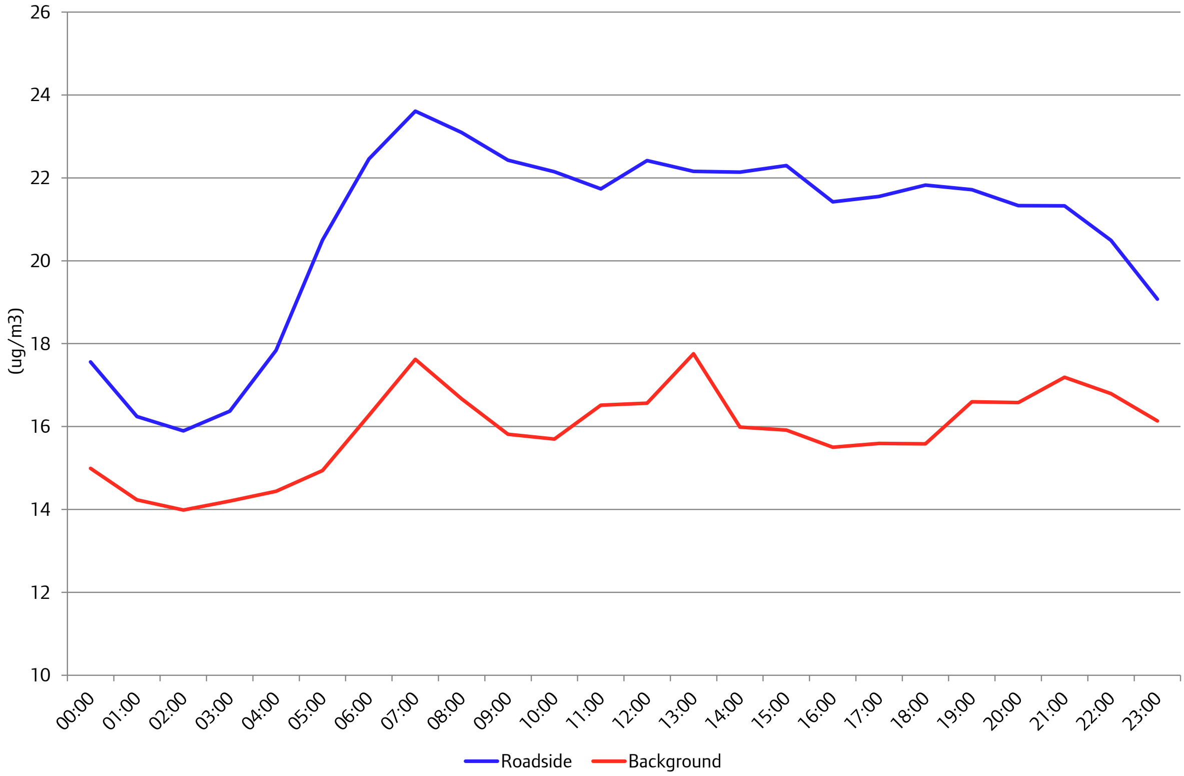
These data also highlight significant variations in pollution at certain times of the day. As would be expected, air quality is generally poorer in the rush hour periods and this may have significant impacts to certain groups, whether it is children walking to school or commuters going to work. Together, Map 7.1 and Figures 7.10 – 7.11 highlight the highly spatial and temporal nature of air quality in London.

Figure 7.10: Average NO_2 pollution by hour, London mean roadside and background, June 2016



Source: GLA Economics calculations; King's College London data (accessed at London Datastore)

Figure 7.11: Average PM_{10} pollution by hour, London mean roadside and background, August 2015



Source: GLA Economics calculations; King's College London data (accessed at London Datastore)

Looking forward, there are two offsetting effects which could impact on the environmental, medical and economic effects of air quality in London. While emission standards are more stringent, through implementation of standards such as Euro V and Euro VI[11], population increase and increased business activity may mean that congestion on London's roads could increase. Lower road speeds are associated with higher levels of pollution at traffic hotspots, which could create areas of comparatively poorer air quality.

7.3.1.2: Pollutant emissions by source

Data from the London Atmospheric Emissions Inventory (LAEI2013) provides an indication of recent trends in, and future projections of, emissions. A general theme emerges from the data, that much of the projected reductions in emissions will result from road transport and industry. However for individual pollutants, different sources have varying importance in contributing to future reductions in emissions.

It is important to note that future projections of NO_x and PM emissions do not take account of recent policy proposals put forward by the Mayor following the Mayoral election in May 2016, and are therefore subject to change.

i) NO_x emissions

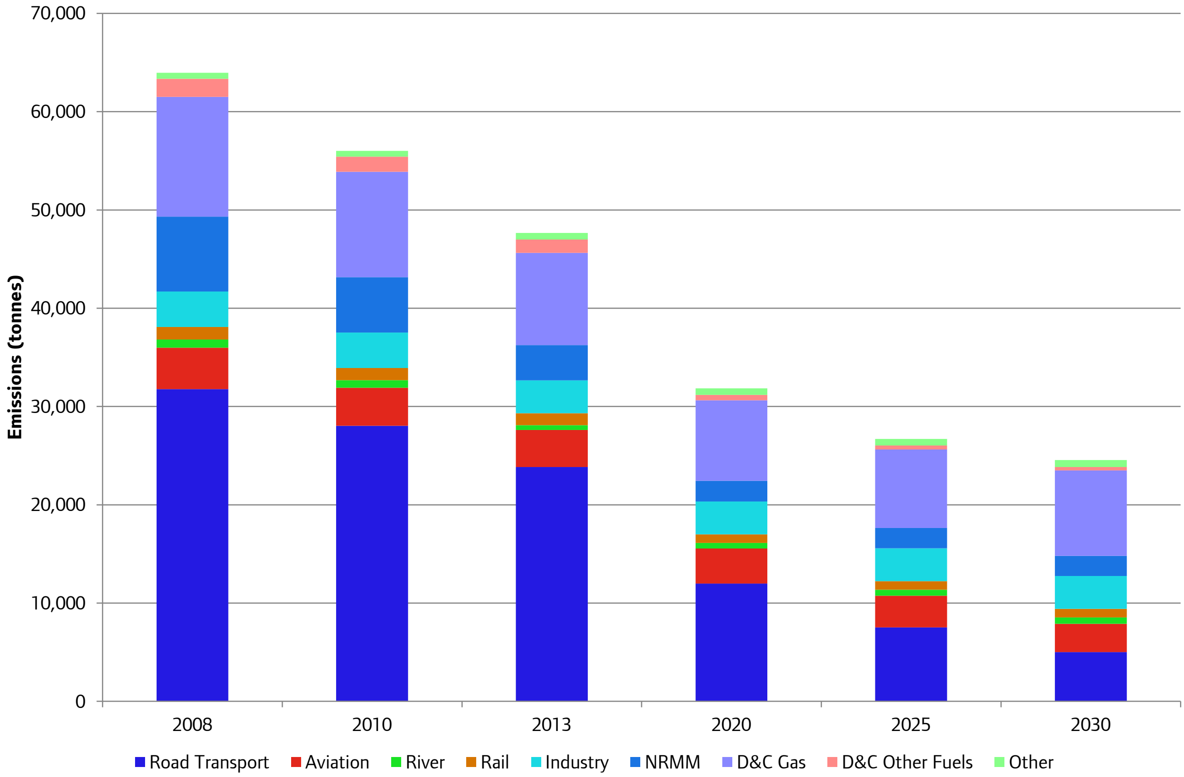
NO_x emissions are projected to fall considerably through to 2030, with the major driver in both absolute and proportional terms being from road transport – projected to fall by over 80 per cent. The other large absolute and proportional fall comes from "non-road mobile machinery" (NRMM), which comes from construction and industrial off-road machines, projected to fall by over 70 per cent (Table 7.1 and Figure 7.12).

Table 7.1: NO_x emission projections, London

Source	2008	2010	2013	2020	2025	2030	Reduction 2008-2030
Road Transport	31,774	28,049	23,853	11,995	7,535	5,018	-84.2%
Aviation	4,210	3,864	3,759	3,557	3,212	2,867	-31.9%
River	825	775	500	573	623	659	-20.1%
Rail	1,281	1,236	1,205	861	861	861	-32.8%
Industry	3,604	3,604	3,353	3,353	3,353	3,353	-7.0%
NRMM	7,625	5,638	3,571	2,117	2,057	2,057	-73.0%
D&C Gas	12,178	10,712	9,397	8,171	7,994	8,690	-28.6%
D&C Other Fuels	1,863	1,553	1,363	550	394	343	-81.6%
Other	599	580	661	676	679	704	17.5%
Total	63,957	56,011	47,661	31,852	26,708	24,553	-61.6%
Reduction	--	-12.4%	-25.5%	-50.2%	-58.2%	-61.6%	

Source: London Atmospheric Emissions Inventory

Figure 7.12: NO_x emission projections, London



Source: London Atmospheric Emissions Inventory

ii) PM_{10} emissions

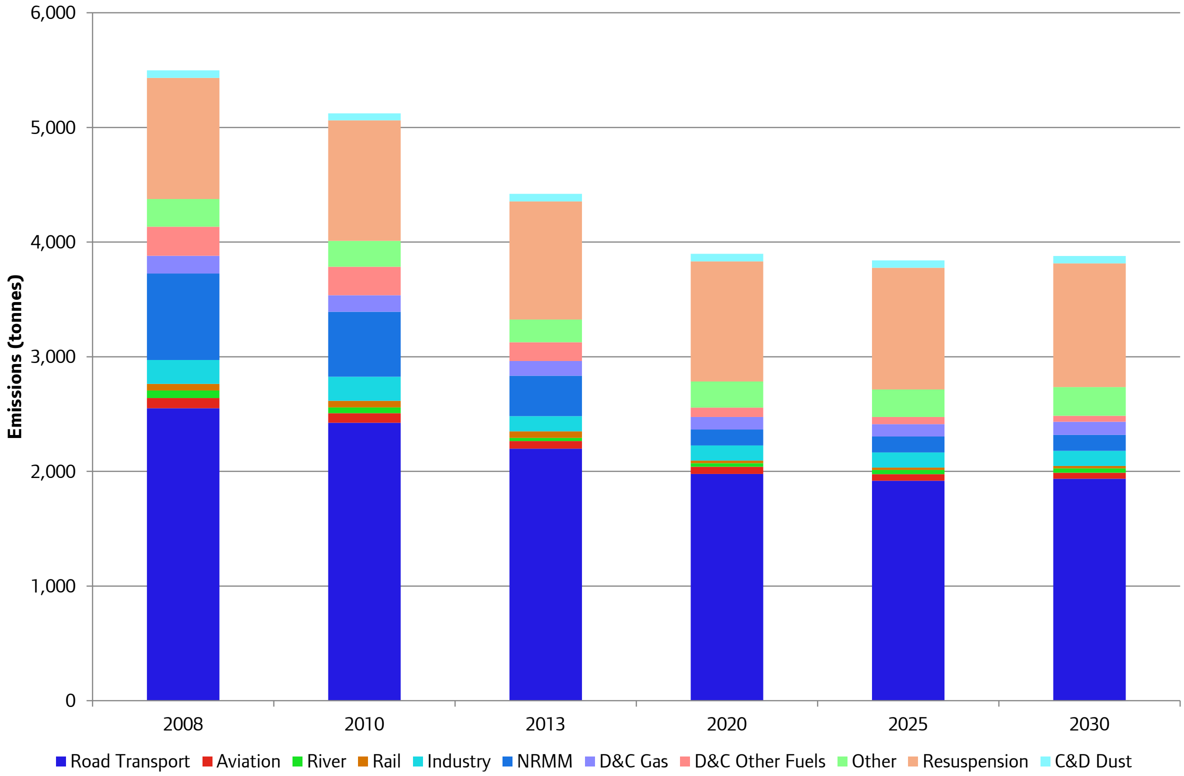
In absolute terms, much of the reduction again comes from road transport and NRMM, but proportionally. Table 7.2 and Figure 7.13 show that emissions reductions are projected to occur from a number of sources.

Table 7.2: PM_{10} emission projections, London

Source	2008	2010	2013	2020	2025	2030	Reduction 2008-2030
Road Transport	2,552	2,424	2,198	1,978	1,919	1,936	-24.1%
Aviation	88	84	66	63	58	53	-39.8%
River	66	50	28	31	35	37	-43.9%
Rail	58	58	57	22	22	22	-62.1%
Industry	207	210	132	132	132	132	-36.2%
NRMM	755	567	354	139	139	139	-81.6%
D&C Gas	154	143	128	110	107	115	-25.3%
D&C Other Fuels	254	249	164	82	62	52	-79.5%
Other	241	225	197	227	240	250	3.7%
Resuspension	1,057	1,051	1,031	1,048	1,062	1,078	2.0%
C&D Dust	66	61	65	65	65	65	-1.5%
Total	5,499	5,122	4,420	3,897	3,840	3,880	-29.4%
Reduction	--	-6.9%	-19.6%	-29.1%	-30.2%	-29.4%	

Source: London Atmospheric Emissions Inventory

Figure 7.13: PM_{10} emission projections, London



Source: London Atmospheric Emissions Inventory

iii) $PM_{2.5}$ emissions

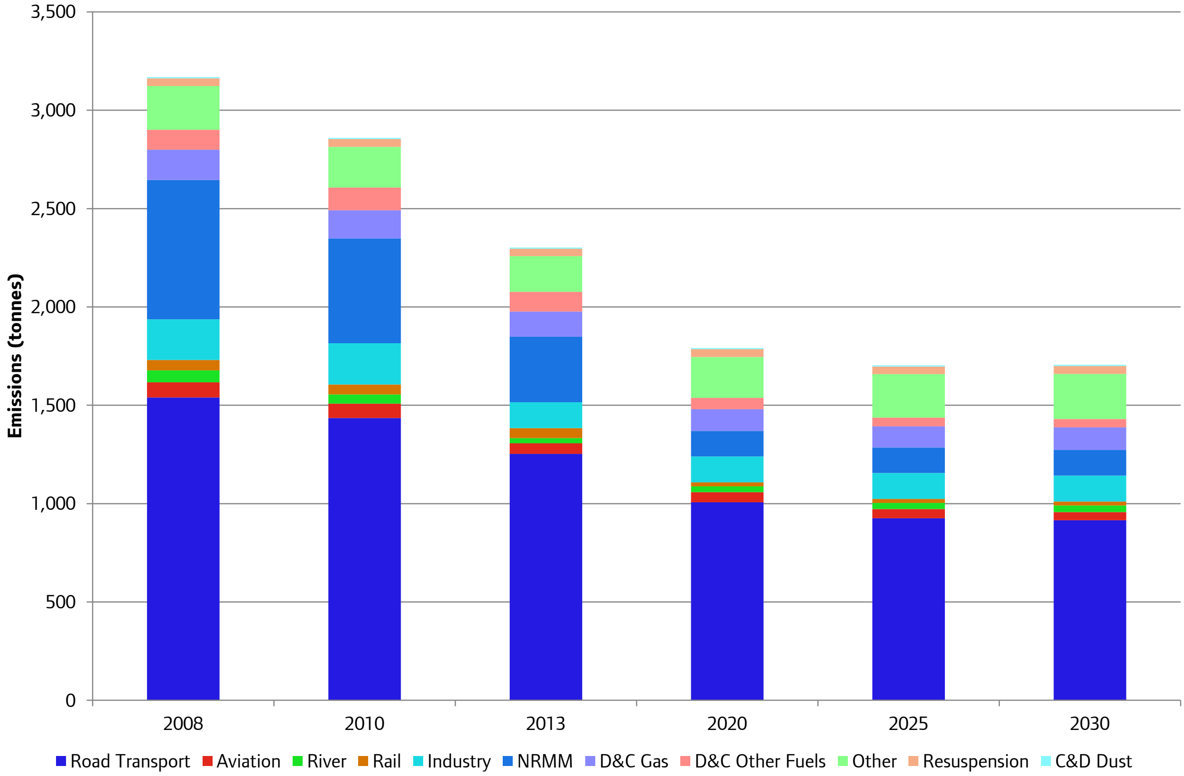
Major reductions in fine particulates are projected across most sources, with particular importance again in the road transport source. However major emissions reductions are projected across the other main transport types, such as aviation and rail, as shown in Table 7.3 and Figure 7.14).

Table 7.3: $PM_{2.5}$ emission projections, London

Source	2008	2010	2013	2020	2025	2030	Reduction 2008-2030
Road Transport	1,540	1,436	1,253	1,007	926	916	-40.5%
Aviation	77	73	54	52	46	41	-46.8%
River	61	46	26	29	32	34	-44.3%
Rail	52	51	51	20	20	20	-61.5%
Industry	207	210	132	132	132	132	-36.2%
NRMM	709	533	333	130	130	130	-81.7%
D&C Gas	154	143	128	110	107	115	-25.3%
D&C Other Fuels	101	115	100	58	45	42	-58.4%
Other	222	207	181	208	220	230	3.6%
Resuspension	39	39	38	39	39	40	2.6%
C&D Dust	7	6	6	6	6	6	-14.3%
Total	3,170	2,858	2,303	1,791	1,704	1,708	-46.1%
Reduction	--	-9.8%	-27.4%	-43.5%	-46.2%	-46.1%	

Source: London Atmospheric Emissions Inventory

Figure 7.14: $PM_{2.5}$ emission projections, London

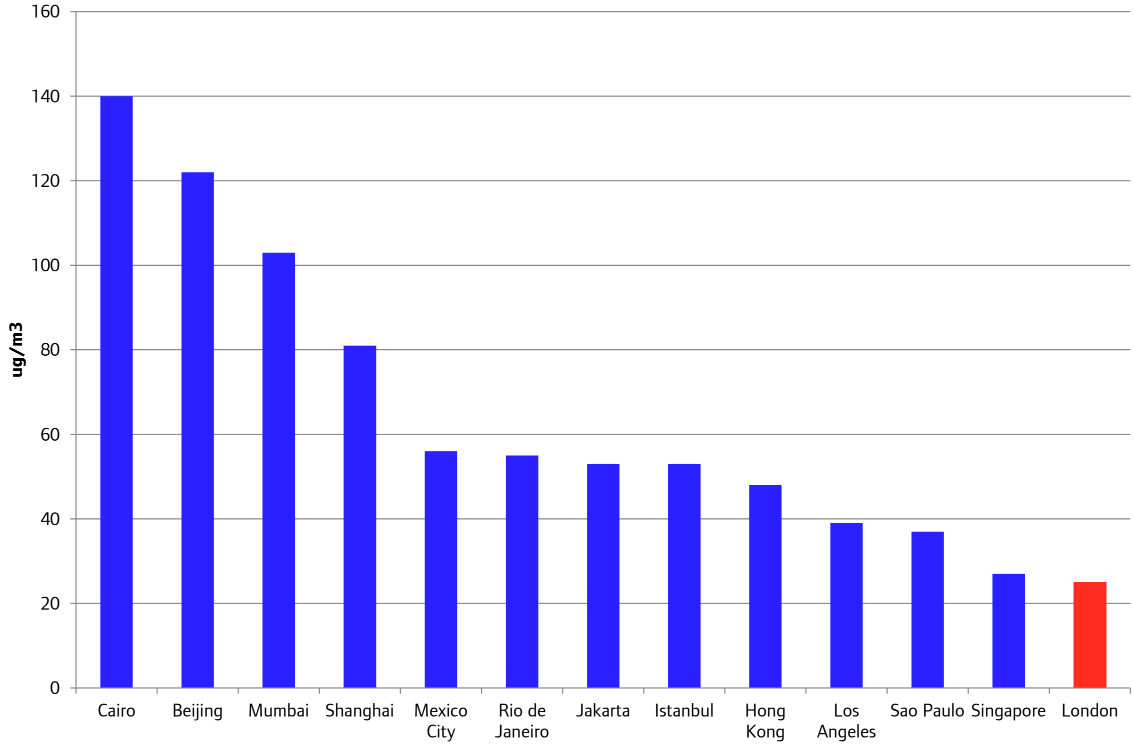


Source: London Atmospheric Emissions Inventory

7.3.1.3: International comparisons on air quality

Despite the UK being at risk of penalty from the European Commission due to poor air quality[12], London's air quality performs comparatively well compared to other major cities. Data compiled by AMEC Environment & Infrastructure shows that London's air quality is comparatively much better than many non EU cities, with many of the cities shown in Figure 7.15 being within emerging economies.

Figure 7.15: Five-year annual averages, PM_{10} pollution, 2008 – 2012, London compared to non-EU cities



Source: AMEC Environment & Infrastructure

Compared to other cities, London's air quality is similar to that of other major non-EU global cities, but does not approach the top of the rankings, as is shown in Table 7.4. This index developed by AMEC Environment & Infrastructure, for the GLA, has two elements; a traffic focussed index which prioritises the two main pollutants related to traffic, those being NO_2 and PM_{10}; and a health impacts index, which gives a higher priority to particulate emissions due to the severity of impacts from particulates compared to other pollutants. The combination of these two elements is known as the Citywide index.

Within the two components of this ranking, London performs worse on the traffic focussed index (placing 17th out of 36 cities), but performs better on health impacts (9th out of 36). The rankings shown in Table 7.4 are presented as an average of five years (2008 – 2012); for each individual year, London's position has held relatively constant, reaching a high of 12th position in 2012, but placed 17th in both 2010 and 2011.[13]

It should be mentioned that most of the cities which place above London in this ranking tend to have smaller populations and urban areas. When considering London against other major global cities of its size, London's air quality is assessed as poorer than Singapore and Paris, but better than New York, Hong Kong and Shanghai; as shown in Table 7.4.

Table 7.4: Citywide Index, five-year average 2008-2012

Position	City
1	Vancouver
2	Sydney
3	Stockholm
4	Vienna
5	Berlin
8	Singapore
12	Paris
15	London
17	New York
30	Hong Kong
34 (of 36)	Shanghai

Source: AMEC Environment & Infrastructure

7.3.1.4: Health and economic considerations

London's air quality has significant implications for the health and well being of Londoners, and by extension, this can impact on the productivity of London's workers and the potential for sustained economic growth. Air quality and wider environmental aspects such as access to green space are also important factors in attracting (and maintaining) people to live in the capital, as shown in a variety of city ranking indices (as outlined within Chapter 5).

Furthermore, analysis undertaken for the GLA shows populations living in the most deprived areas are on average currently more exposed to poor air quality than those in less deprived areas. Fifty-one per cent of the Lower Super Output Areas (LSOA - i.e. roughly wards) within the most deprived decile in London have average concentrations above the Nitrogen Dioxide (NO_2) EU limit value. Within the least deprived decile, only 1 per cent of LSOAs have an average concentrations above the NO_2 EU limit value.[14]

Owing to the large number of variables that influence the health impacts of air pollution, scientific understanding of this complex relationship is continually advancing. For this reason, in 2014 the GLA and TfL commissioned a study by King's College London to better understand the health impacts of air pollution in London based on the latest evidence. For the first time, the study included the health impacts of NO_2 as well as fine particles[15] ($PM_{2.5}$).

The health impacts were estimated for 2010 as this was the latest available 'base' year for the London Atmospheric Emission Inventory and associated air quality modelling[16]. The report estimated that for fine particles, the total mortality burden from long-term exposure was estimated at 52,630 life-years lost, equivalent to 3,537 deaths at typical ages and an estimated 88,113 life years lost for NO_2, equivalent to 5,879 deaths.

Short-term exposure to $PM_{2.5}$ and NO_2 were associated with 1,990 and 420 respiratory hospital admissions respectively, and 740 cardiovascular admissions associated with fine particulates. Within the report it is assumed that there is a 30 per cent overlap between NO_2 and $PM_{2.5}$ emissions, therefore total impacts of poor air pollution are estimated at 140,743 life-years lost, equivalent to 9,416 deaths at typical ages. To put these estimates in more context, $PM_{2.5}$ exposure is estimated to reduce female life expectancy by 9 months (increasing to 9.5 months for males), and NO_2 pollution reduces life expectancy by up to 15.5 months (17 months for males), on average across all of London's population.

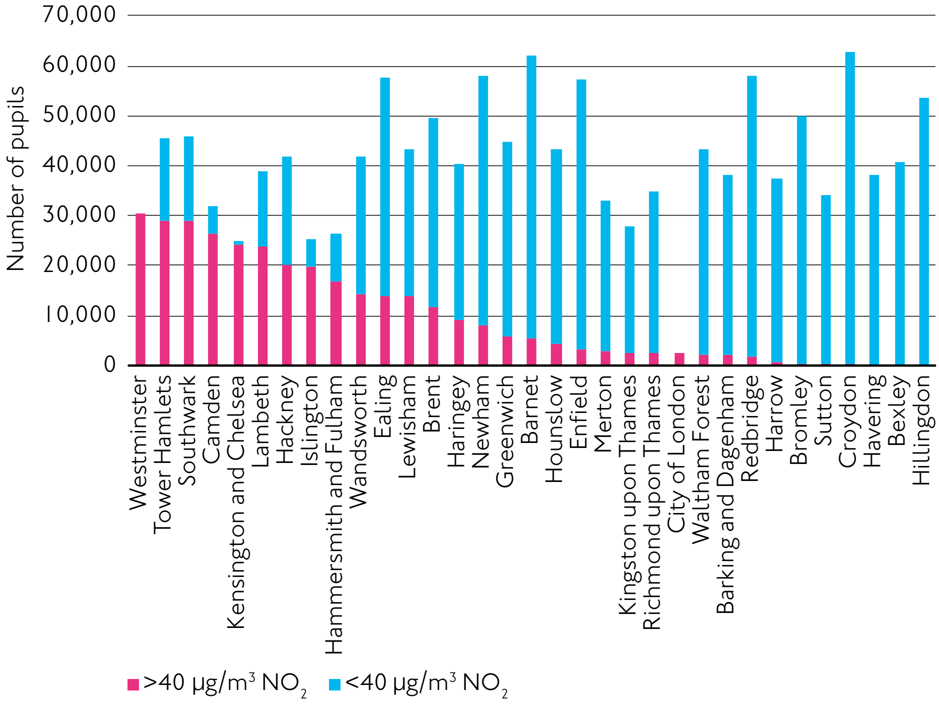
Pollution concentrations in London, and therefore the associated health impacts, can be attributed to broad emissions sources. Sources outside London make the largest contribution to the estimated mortality burden from long-term exposure to $PM_{2.5}$ in London as a whole, as well as being responsible for the majority of health effects associated with short-term exposure to air pollution in London. For instance, 75 per cent of the cardiovascular hospital admissions associated with $PM_{2.5}$ result from sources outside London. For NO_2, external sources are responsible for just under half of the mortality burden. This underlines the importance of coordinated national and European action to directly address sources of pollution and their transboundary effects.[17]

The estimated annual economic costs of the above health impacts for $PM_{2.5}$ was £1.4 billion, up to £2.3 billion for NO_2, and up to £3.7 billion for both pollutants.[18]

Research cited by the Policy Exchange notes the particular vulnerability that children face as a result of air pollution, in part "due to higher exposure" and "partly due to children being more susceptible to the effects of air pollution since they have incomplete metabolic systems, immature immune defences, and higher breathing rates than adults".[19] They also cite that living near main roads could account for 15 – 30 per cent of all new cases of asthma in children.

The risks faced by children from air pollution has been argued to be higher, since there is largely little choice of where children go to school. Schools tend to be located on main roads, therefore they face the risk of higher exposure. The Policy Exchange found that "around 328,000 children attend schools in London where NO_2 concentrations exceed the legal limit, representing just under 25 per cent of the total school population in London", (Figure 7.16) which are predominately located in inner London boroughs – where "58 per cent of pupils in Inner London boroughs are in schools in areas with harmfully high NO_2 levels".[20]

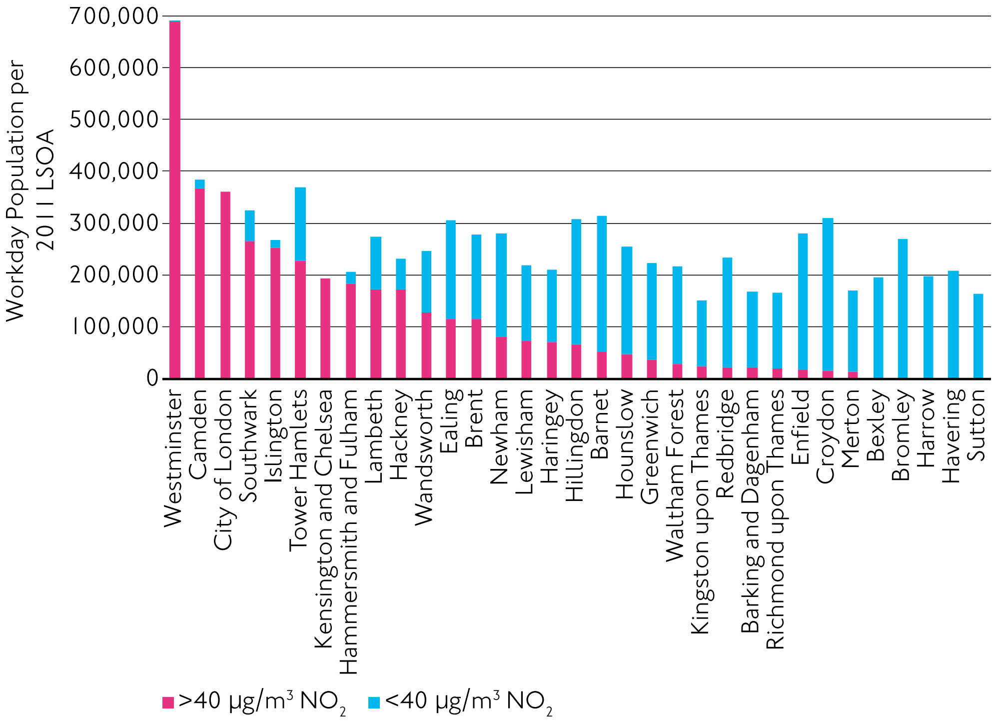
Figure 7.16: The number of pupils attending London schools where average NO_2 concentrations within a 100 metre radius of the school exceed the EU annual limit.



Source: Policy Exchange, drawing up Department for Education and Transport for London data

For the working age population, the Policy Exchange report finds that whilst adults may be less vulnerable than children in their response to air pollution, they can face very high exposure levels. This is especially the case within boroughs located within the CAZ, with Westminster most affected, as shown in Figure 7.17.

Figure 7.17: Workday population in LSOAs where the average NO_2 concentration is above or below EU legal limit



Source: Policy Exchange, drawing upon Office for National Statistics and Transport for London data

King's College London have undertaken analysis estimating the potential health and economic benefits that could result from projected improvements in air quality through to 2025, specifically the changes in life expectancy, total life years saved for the London population, and the annual change in economic costs of air pollution. Table 7.5 provides a summary of the life expectancy benefits that could occur from emissions reductions.

Table 7.5: Gains in life expectancy for those born in 2025, exposed to 2010 and 2025 emission concentrations for a lifetime

Pollutant	Scenario	Impact of life expectancy for those born in 2025	
		Males	Females
NO_2	2010 Concentrations	17.5 months	16 months
	2025 Concentrations	12.5 months	11.5 months
	Potential benefit	**+5 months**	**+4.5 months**
$PM_{2.5}$	2010 Concentrations	9.5 months	9 months
	2025 Concentrations	8 months	7.5 months
	Potential benefit	**+1.5 months**	**+1 month**

Source: Policy Exchange and King's College London.
Notes: For NO_2, figures are shown as up to a maximum value assuming NO_2 (rather than other traffic pollutants) are responsible for all the effects. A 30 per cent overlap with PM2.5 is already taken into account.

Following on from these life expectancy increases, these result in significant life-years gained. These equate to 1.3 million life years through reductions in $PM_{2.5}$ emissions, and 4.5 million life years through reductions in NO_2. Using Defra guidance on valuing changes in air quality, based on 2014 prices and an annual decrease in the value of future life years lost of 2 per cent per annum, finds total benefits of £0.7 billion for $PM_{2.5}$ and £2.5 billion for NO_2, as outlined in Table 7.6.

Table 7.6: Gains in life expectancy for those born in 2025, exposed to 2010 and 2025 emission concentrations for a lifetime

Pollutant	Scenario	Life Years Lost	Annualised Economic Impact (2010 prices)
$PM_{2.5}$	2010 Concentrations	9.2 million	£5.3 billion
	2025 Concentrations	8.0 million	£4.6 billion
	Potential benefit	**+1.3 million gain**	**+£0.7 billion gain**
NO_2	2010 Concentrations	16.8 million	£9.5 billion
	2025 Concentrations	12.2 million	£7.1 billion
	Potential benefit	**+4.5 million gain**	**+£2.5 billion gain**

Source: Policy Exchange and King's College London.
Notes: For NO_2, figures are shown as up to a maximum value assuming NO_2 (rather than other traffic pollutants) are responsible for all the effects. A 30 per cent overlap with $PM_{2.5}$ is already taken into account.

7.3.2: Noise pollution

Noise pollution can directly impact on people's quality of life, and in economic terms, is another example of a negative externality – such that high levels of ambient and background noise lead to external costs (i.e. on health and wellbeing) being borne by individuals who are not directly the cause of such noise. A practical example of this is that living under the flight path of a major airport would mean that people are exposed to higher levels of disturbance, leading to costs being borne on those who are not directly receiving the benefit (i.e. the flight to a location).

Noise impacts can be quite wide ranging, but the greatest impact is likely to be on people's health, quality of life and wellbeing. The health and wellbeing effects caused by exposure to higher levels of noise may well impact on workers' productivity. On a larger scale, exposure to higher levels of noise is likely to detract from a location's attractiveness as a place to live or work. Alongside other effects, noise pollution can impact on a person's decision to locate in a particular area.

Much attention is placed on air pollution as a negative externality, however noise pollution can be considered in the same way, resulting more generally from increased economic development. Agglomeration of businesses, residential, and public services all lead to specific spatial hotspots of noise pollution, which are considered in the following section.

7.3.2.1: Evidence on noise exposure and impacts

Noise can directly impact on people's quality of life and wellbeing, and by extension impact on productivity, the natural environment, and the attractiveness of a location to live and work. The analysis of the impacts of noise is particularly relevant in light of potential airport expansion in the South East.

Analysis undertaken by Defra on the impacts of noise on sleep disturbance, annoyance, hypertension and productivity looked to value each of these areas in turn, as well as providing a review of available literature on the topic. The most prominent of these was on sleep disturbance. The World Health Organization estimated that across Western Europe, prevailing levels of noise cost between 1.0 and 1.6 million disability-adjusted life years lost each year.[21] Using Department of Health estimates, the social cost would therefore be between £60 billion and £100 billion per year across Western Europe[22]. Sleep disturbance was the single biggest health impact (at 903,000 life years), followed by annoyance (654,000) and much smaller impacts on ischaemic heart disease, cognitive impairment of children, and tinnitus.[23]

Data from Defra shows the number of people in London exposed to noise levels beyond 55dB, through to greater than 75dB; by roadside, railway and for industry; and these data are shown in Table 7.7.

Table 7.7: Number of people exposed to roadside, railway and industrial noise above thresholds, Greater London, 2011

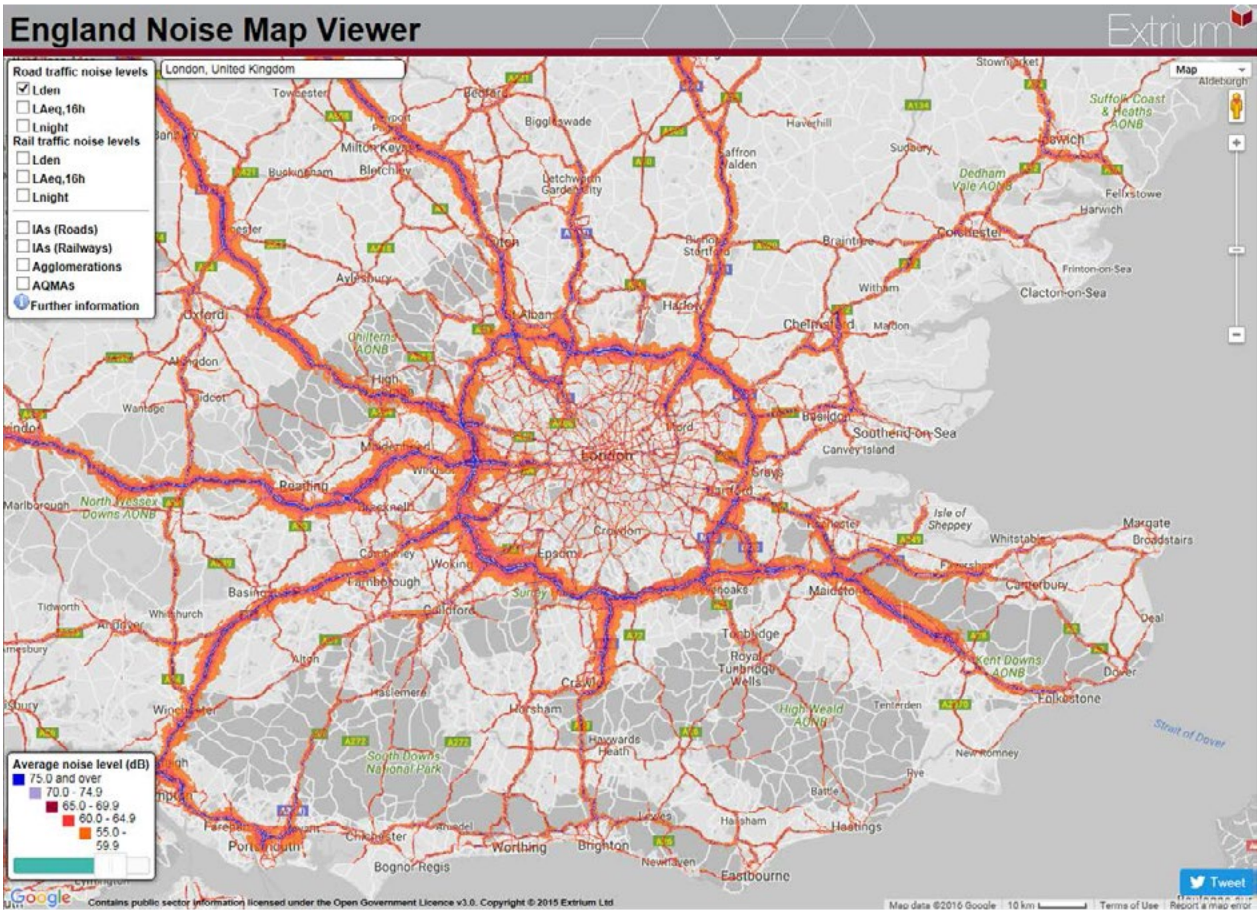
Type	>55dB	>60dB	>65dB	>70dB	>75dB
Roadside	2,387,200	1,426,100	1,027,200	597,800	99,200
Railway	525,200	308,500	158,100	59,800	15,200
Industrial	23,600	13,000	7,500	4,600	3,000

Type	>50dB	>55dB	>60dB	>65dB	>70dB
Roadside – Night	1,665,400	1,106,500	649,400	114,500	900
Railway – Night	388,700	214,200	95,100	29,700	6,400
Industrial - Night	20,500	11,300	6,700	4,000	2,700

Source: Defra

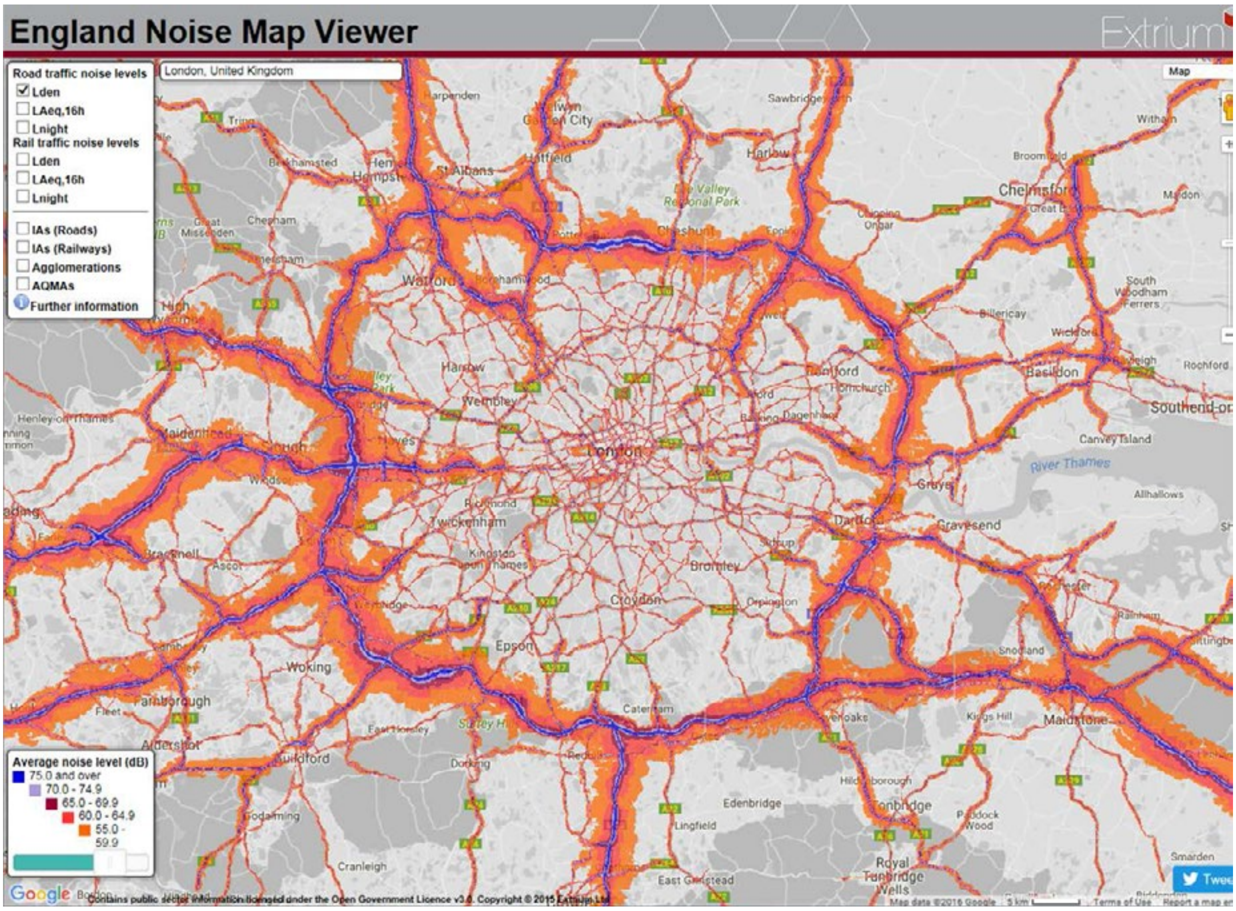
A more graphical illustration of noise exposure can be seen through mapping, specifically through the analysis of an open data source using strategic noise mapping exercise undertaken by Defra in 2012. Maps 7.2 to 7.5 are drawn from the open data viewer created by Extrium, and are snapshots of road noise exposure across London and the Greater South East. These maps clearly show the greater levels of exposure around the major trunks of the capital, but also on important routes within the M25 boundary.

Map 7.2: Noise exposure, Lden, London and the Greater South East



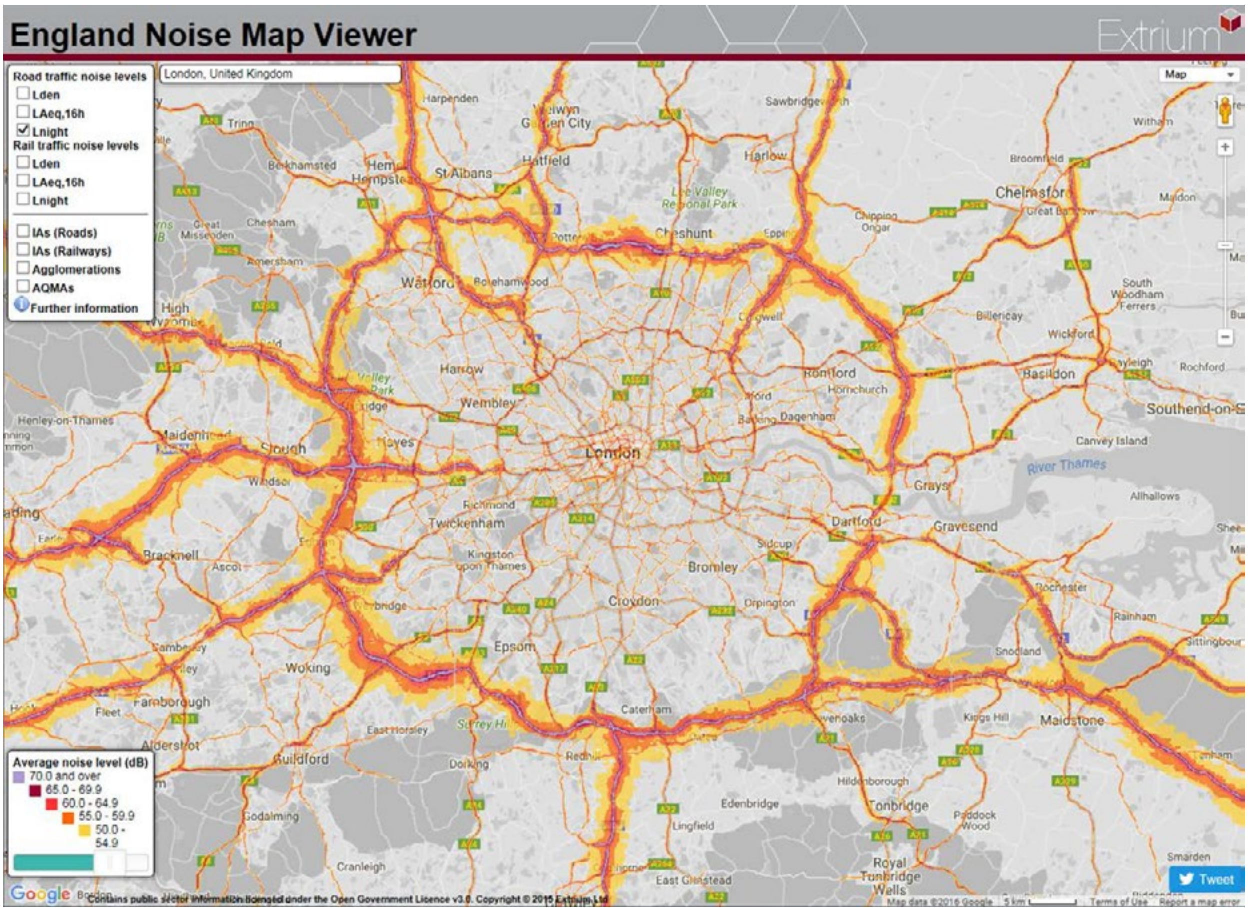
Source: Extrium, Google Maps; based on Defra data

Map 7.3: Noise exposure, Lden, London



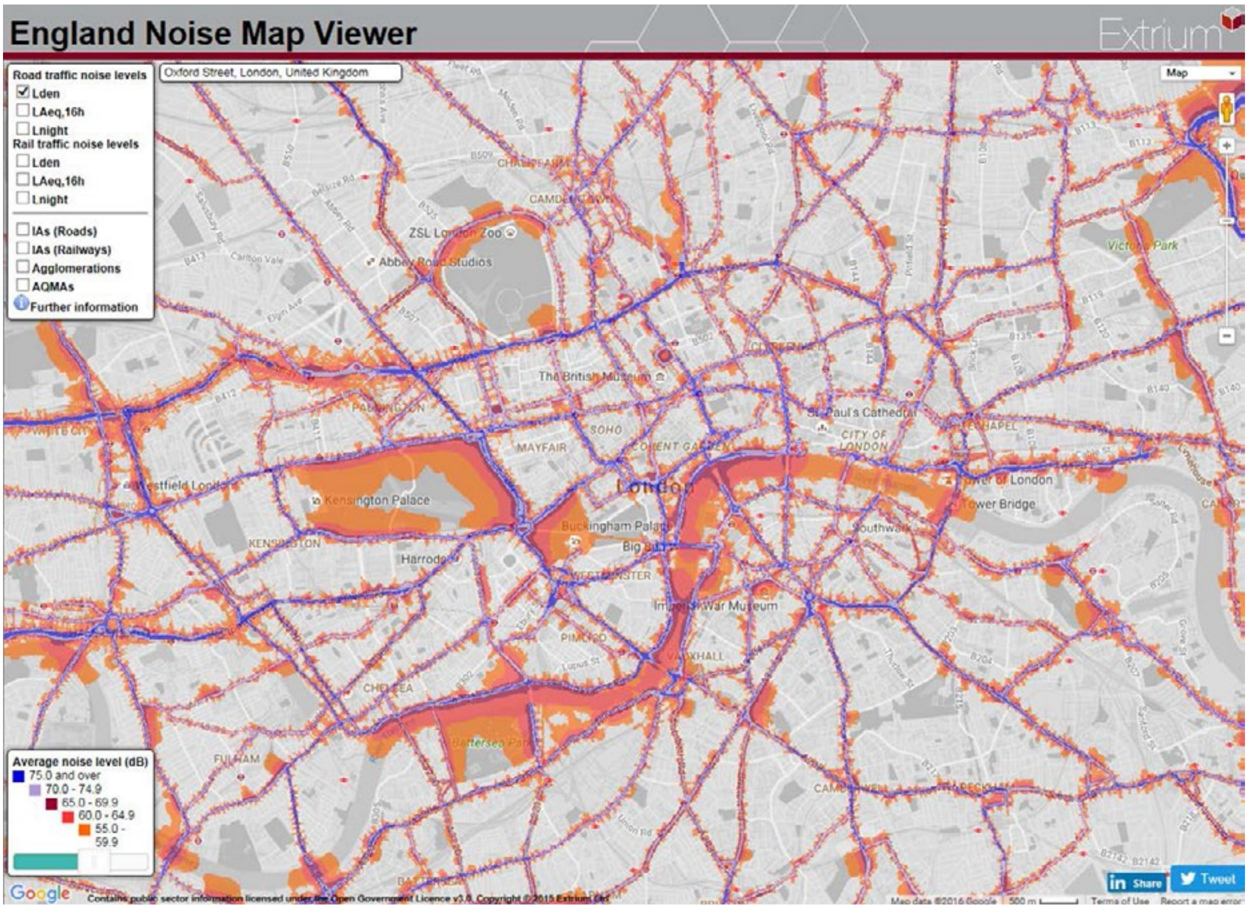
Source: Extrium, Google Maps; based on Defra data

Map 7.4: Night-time noise exposure, London



Source: Extrium, Google Maps; based on Defra data

Map 7.5: Noise exposure, Lden, central London



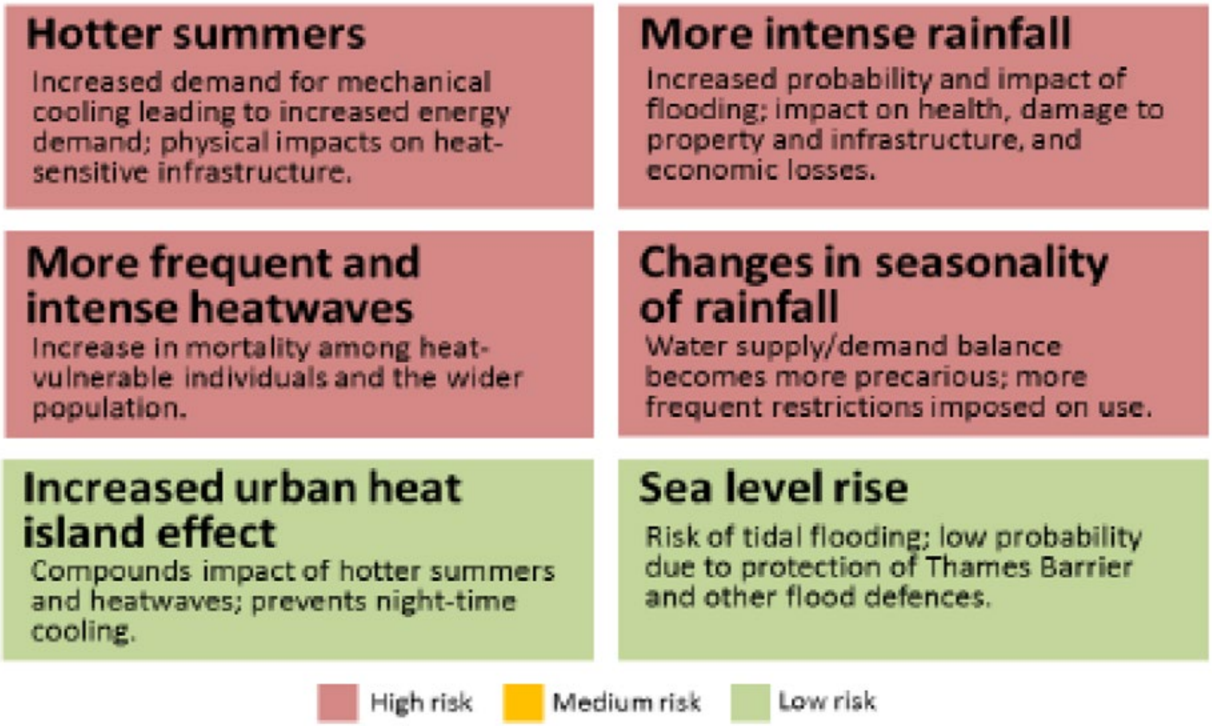
Source: Extrium, Google Maps; based on Defra data

Aviation noise also affects many people in London. A 2013 report from TfL noted that 766,100 people lived within the ≥ 55 Lden[24] contour of Heathrow[25]. At least another 17,800 people[26] are living within the ≥ 55 Lden contour of London city airport. This indicates that aviation noise is a significant environmental issue in London, particularly in light of the proposed expansion of Heathrow, which according to TfL could increase the noise exposure impact in London by £300 million per year (or £6.2 billion between 2030 – 2050) after accounting for annoyance, health and productivity impacts.

7.3.3: Climate

Changes to the climate represent major environmental and economic risks to the global economy. Similar to that referenced for air and noise pollution, climate change can be seen as examples of negative externality, such that the costs imposed on the population (or certain groups) are not those directly responsible for greenhouse gas emissions. Analysis from the Carbon Disclosure Project outlined six current and anticipated effects of climate change for London, which are shown in Figure 7.18.

Figure 7.18: Current and anticipated effects of climate change in London



Source: Carbon Disclosure Project, data provided for the CDP Cities 2013 report, GLA, 2013[27]

There are many examples of how climate change can lead to observable negative externalities for the population. Drawing upon the six areas outlined in Figure 7.18, with hotter summers comes the need to draw upon more mechanical cooling (such as air conditioning), however this leads to greater carbon emissions as a result of running these devices and in the increased energy supply requirement in order to manufacture and run them. More frequent and intense heatwaves can lead to health impacts for vulnerable groups, incurring costs on health services. With more intense rainfall there will be increased risks of flooding, leading to costs being incurred on homeowners, businesses and the public purse when these incidents occur. Changes in the seasonality of rainfall will make it harder to capture the water that we need for public supplies, leading to additional investment in large scale water supply infrastructure.

Adaptation against climate change can also allow us to observe the presence of market failures. For example, individuals (and businesses) would not likely to be able (or to be inclined) to address issues directly. For instance, if one business sought to instigate extra protection against flooding and sea level rise, other businesses would simply 'free ride' on them.

Each of these effects could be seen to impact on London's economy in different ways. For example, hotter summers and more frequent and intense heatwaves may act to reduce productivity and economic output as a result of heat-related illness, as well as effects on infrastructure, for example through buckling of train tracks or increased call on electricity and energy supplies for air conditioning. Increased rainfall and sea level rise could lead to a greater risk of flooding or a greater area exposed to flood risk (see Chapter 6). Finally, with increased economic activity and associated reductions in green spaces, urban heat island effects may reduce people's quality of life within their homes and on transport and create a greater reliance on household energy usage for air conditioning – the urban heat island effect can result in the centre of London being up to 10°C warmer than rural areas around London.

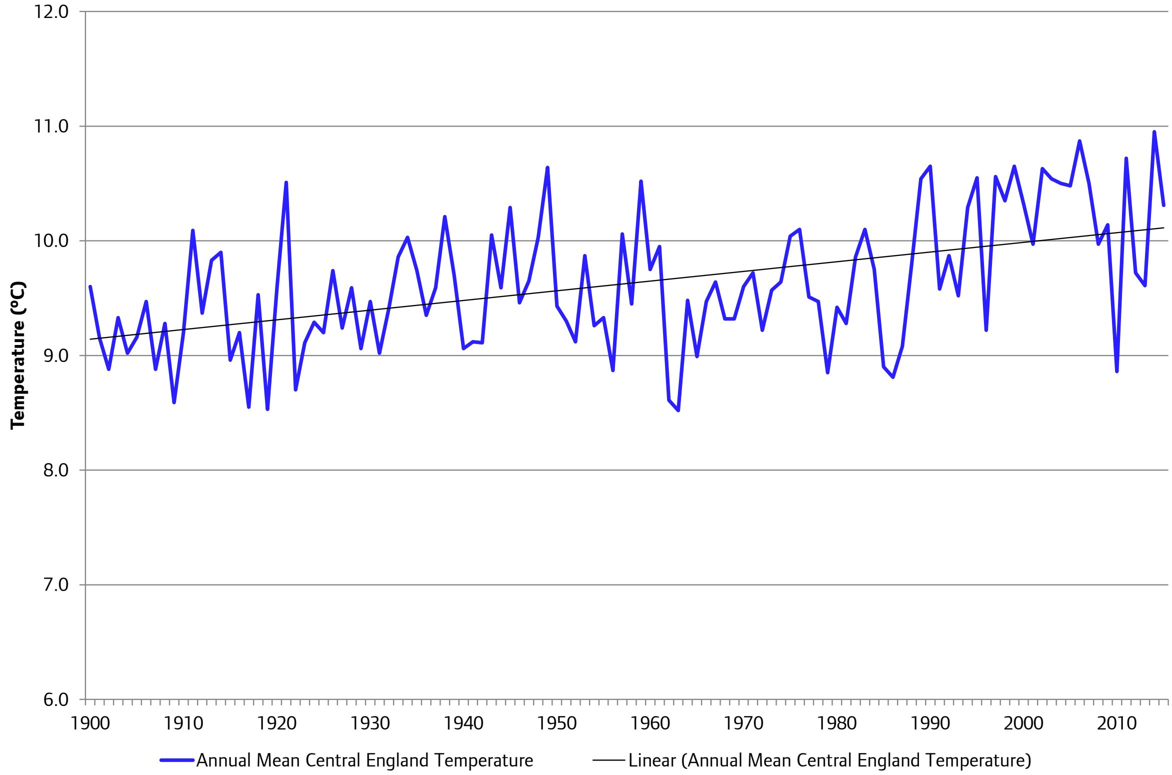
Evidence on climate change in the UK

The pre-eminent environmental risk to the global economy, and therefore by extension to the UK and London comes from climate change. This links directly to the concept of natural capital, since many of our natural capital assets are directly impacted by climate change. Within the UK, a major study on the potential impacts of climate change was produced by Lord Stern in 2006, where he summarised that "climate change will affect the basic elements of life for people around the world – access to water, food production, health, and the environment. Hundreds of millions of people could suffer hunger, water shortages and coastal flooding as the world warms". His review estimated that if no action was taken to reduce emissions, greenhouse gas concentrations "could reach double its pre-industrial level as early as 2035, virtually committing us to a global average temperature rise of over two degrees Celsius".[28]

The scale of the potential costs of not mitigating against climate change driven by anthropogenic emissions of greenhouse gases is large. The Stern Review estimated that the overall costs of not acting would be equivalent to 5 per cent of global GDP per year; whereas through acting to reduce greenhouse gas emissions, the costs could be limited to 1 per cent of global GDP a year.

To put climate change in context, Figure 7.19 outlines how average temperatures have changed here in the UK. Using historical data from Hadley Centre Central England Temperature (HadCET) dataset, over the course of the last 100 years, temperatures have increased gradually (with the linear trend line showing an increase of just under 1 degree Celsius between 1900 and 2015); and 2014 being the warmest year on record for mean HadCET.[29]

Figure 7.19: Central England temperature – mean annual data, 1900 – 2015



Source: HadCET, accessed from the Met Office

Economic opportunities through climate change mitigation and adaptation

With an increased risk of climate change, there may be opportunities for London's economy to lead in mitigation. For example, using London's highly skilled workforce to develop specialisation in low-carbon technologies, or building upon its pre-existing specialism for business and professional services (and shown by calculations of the Index of Specialisation, given in Chapter 1) by becoming a centre for low carbon finance and building in the development of the green economy. Research undertaken by kMatrix for the GLA estimated that the low carbon and environmental goods and services sector (LCEGS) in London comprised over 10,900 businesses and employed over 192,000 people, with companies in this sector achieving sales of £30.4 billion. Between 2007/08 and 2014/15, sales of companies in the LCEGS sector have grown by 45 per cent.[30]

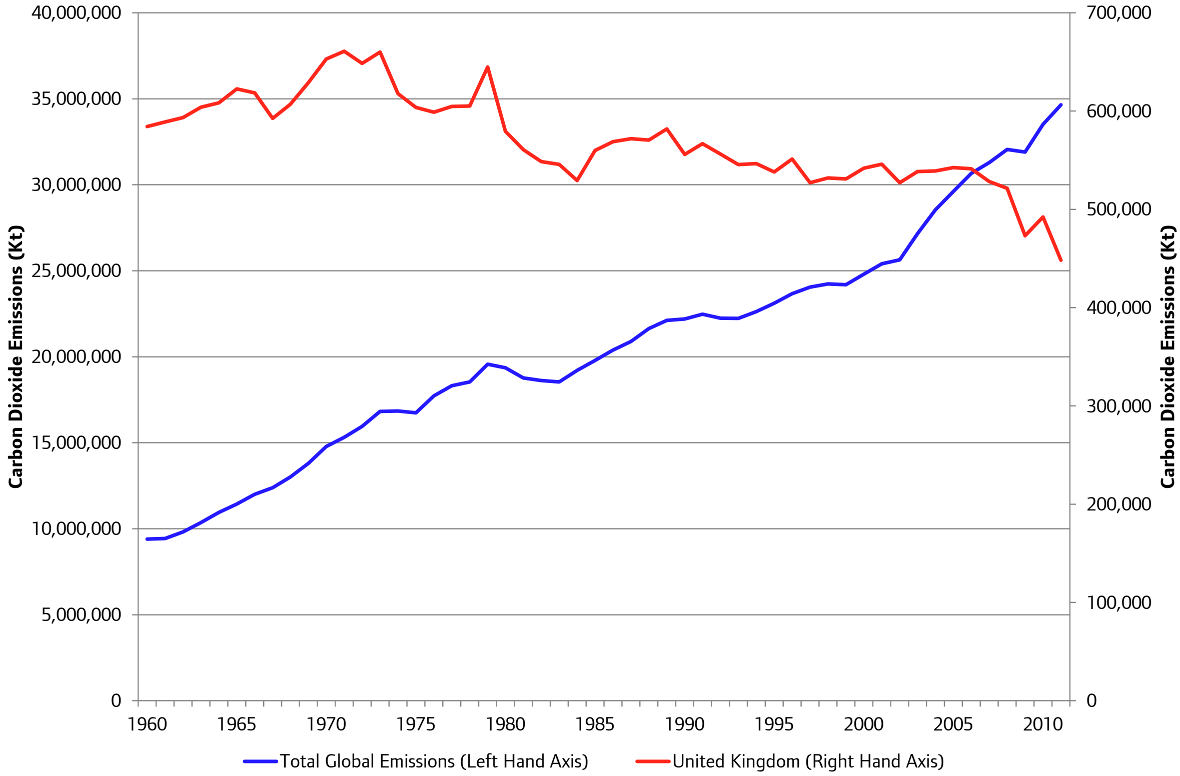
Within low carbon finance, the London Stock Exchange hosts the FTSE Environmental Markets Index Series markets; the FTSE Environment Technology Index has constituent companies with a market cap of $296 billion[31], and the FTSE Environmental Opportunities All-Share has a total market cap of $2.50 trillion.[32] It is however an area in which other global cities have looked to specialise, with for example, the growth of New York in green finance, and the Tokyo Stock Exchange being the first location to host a market for carbon trading.

However, as was referenced in the Stern Review, "climate change is the greatest market failure the world has ever seen, and it interacts with other market imperfections".[33] The impacts of climate change are therefore intrinsically linked with the notion of natural capital, since there are a number of natural capital assets which could be impacted through climate change, whether it is in the land, ecology or biodiversity. Also, climate change adaptation builds resilience to longer-term future threats and risks, such as flooding and increased temperature. Timely adaptation measures can reduce future damages to or overload on urban infrastructure such as transport and housing which can reduce costs and ensure that cities are resilient to the impacts of climate change.

Analysis of carbon emissions data

One of the major causes of global climate change has been through industrialisation, particularly over the last century. Data from the World Bank for the last 50 years show that global carbon dioxide emissions have more than trebled, due to the rapid industrialisation of developing economies (as well as for more advanced economies). For the United Kingdom, emissions have largely stayed constant and have fallen in recent times, as shown in Figure 7.20.

Figure 7.20: Comparison of trends in carbon emissions, global and UK emissions



Source: World Bank

Similar to trends for the UK, carbon dioxide emissions in London have been falling in both per capita and absolute terms, as shown in Tables 7.8 and 7.9 and Figure 7.21. Data on CO_2 emissions in the capital are drawn from the London Energy and Greenhouse Gas Inventory (LEGGI), which is produced by the GLA, incorporating sub-national energy and CO_2 equivalent data published by the Department for Business, Energy and Industrial Strategy (BEIS) for homes and workplaces, and data from the London Atmospheric Emissions Inventory (LAEI) for energy and CO_2 equivalent data for transport.

Between 1990 and 2014, total CO_2 emissions in London fell by 16.3 per cent; with emissions by industry type falling by 9.5 per cent for transport, 15.5 per cent for domestic, and 20.2 per cent for industrial and commercial.

There are a variety of reasons which could explain the falls in carbon dioxide emissions. These include a less carbon intensive national grid; a decline of capital intensive industries (partially shown by employment data in the manufacturing sector); the impact of energy efficiency programmes (both for industrial and residential property); personal choices in energy use (to become more energy efficient so as to guard against rising energy costs); as well as the improvements in the environmental performance of the transport system (through increased take-up of lower emission vehicles, implementation of emissions standards, and increased modal shift, such as to cycling and walking).

Table 7.8: Carbon emissions, 1990 – 2014, London

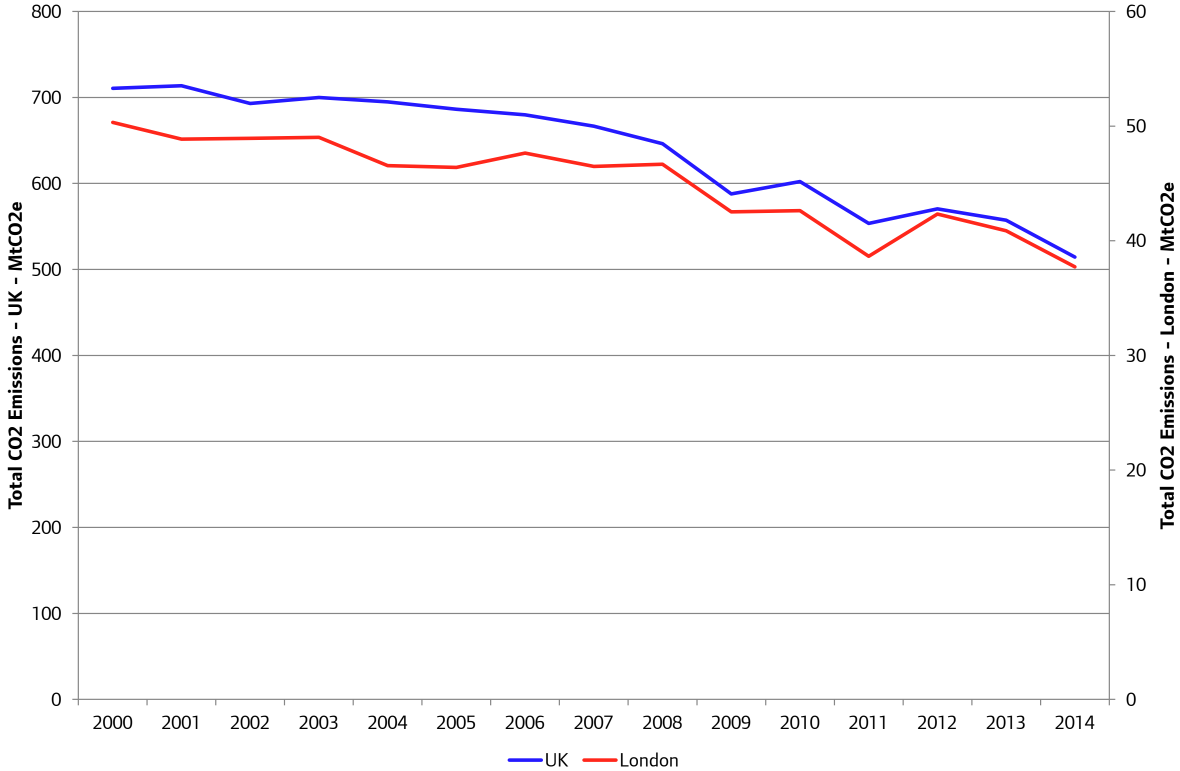
Year	Domestic	Industrial and Commercial	Transport	TOTAL	CO2 per capita
1990	15.84	19.74	9.47	45.05	6.63
2000	17.54	24.06	8.71	50.31	6.95
2001	17.79	21.76	9.31	48.86	6.67
2002	17.95	21.10	9.88	48.93	6.63
2003	18.11	20.45	10.45	49.01	6.63
2004	16.85	20.05	9.65	46.56	6.26
2005	17.31	19.23	9.86	46.40	6.17
2006	17.22	20.62	9.79	47.64	6.27
2007	16.84	19.85	9.79	46.48	6.04
2008	16.93	19.85	9.90	46.67	5.97
2009	15.25	17.38	9.90	42.52	5.35
GHG Emissions ($MtCO_2e$)					
2010	15.88	18.22	8.52	42.62	5.29
2011	13.94	16.12	8.58	38.64	4.71
2012	15.34	18.40	8.58	42.32	5.09
2013	14.91	17.29	8.68	40.87	4.86
2014	13.38	15.76	8.57	37.72	4.42

Reductions in emissions compared to baselines					
1990 baseline	-15.5%	-20.2%	-9.5%	-16.3%	
2000 baseline	-23.7%	-34.5%	-1.6%	-25.0%	

Source: LEGGI.

Notes: Data for 1990, 2000 – 2009 are data on CO_2, weather corrected; data for 2010 – 2014 are GHG emissions, non-weather corrected and CO_2e. 2014 are interim data.

Figure 7.21: Trends in UK and London CO_2 emissions



Source: DECC (UK data), LEGGI (London data)

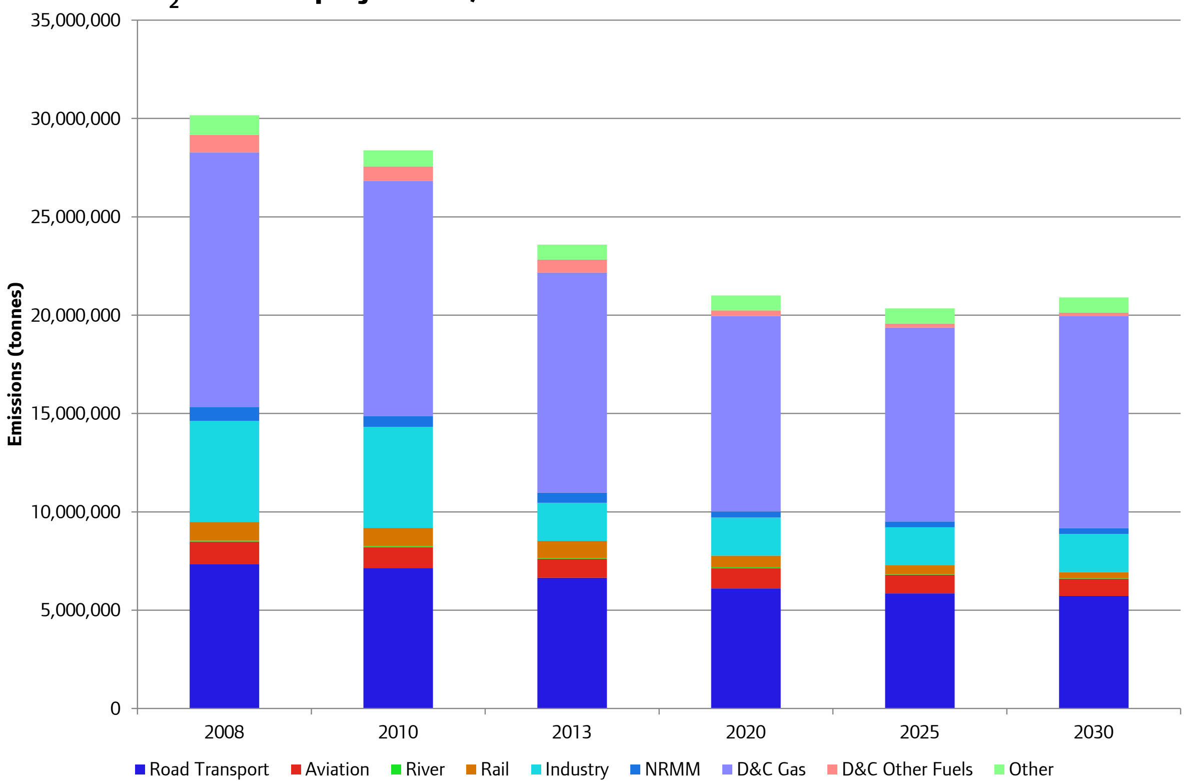
Data from the London Atmospheric Emissions Inventory (LAEI2013) provides an indication of recent trends in, and future projections of, emissions – however it should be noted that the LAEI does not include all the sources of CO_2 that are included within the LEGGI. Compared to 2008 levels, CO_2 is projected to fall by 30.7 per cent by 2030, with the major contributors in absolute terms being road transport, industry and domestic & commercial gas. In proportional terms domestic & commercial (other fuels), as well as rail, and industry will be major contributors.

Table 7.9: CO_2 emission projections, London

Source	2008	2010	2013	2020	2025	2030	Reduction 2008-2030
Road Transport	7,337,105	7,146,030	6,651,511	6,106,822	5,854,313	5,728,930	-21.9%
Aviation	1,150,455	1,054,417	969,357	1,034,119	952,887	871,654	-24.2%
River	46,867	49,843	30,630	35,270	38,282	40,485	-13.6%
Rail	958,455	937,052	876,001	598,833	433,666	293,405	-69.4%
Industry	5,127,617	5,127,617	1,935,825	1,935,825	1,935,825	1,935,825	-62.2%
NRMM	700,869	550,077	521,681	309,204	300,432	300,432	-57.1%
D&C Gas	12,959,735	11,956,119	11,186,471	9,941,950	9,854,826	10,777,333	-16.8%
D&C Other Fuels	878,019	738,171	657,321	281,622	207,274	184,927	-78.9%
Other	1,005,118	819,657	758,308	764,539	767,830	770,637	-23.3%
Total	30,164,241	28,378,985	23,587,104	21,008,184	20,345,335	20,903,628	-30.7%
Reduction	--	-5.9%	-21.8%	-30.4%	-32.6%	-30.7%	

Source: London Atmospheric Emissions Inventory

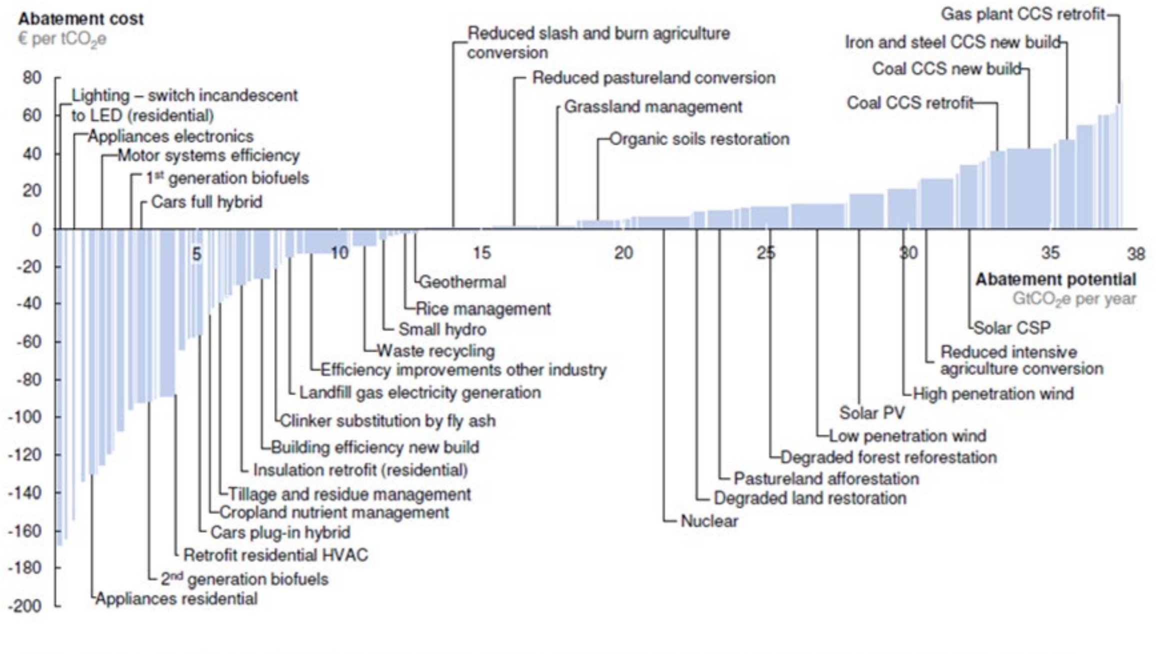
Figure 7.22: CO_2 emission projections, London



Source: London Atmospheric Emissions Inventory

Despite carbon emission reductions over time, for developed nations to meet reduction targets, a variety of programmes and activities are required, each of which will have different capacity to reduce carbon emissions at various levels of cost. The diagram in Figure 7.23 outlines the potential capability of measures to contribute towards emission reduction, comparing the abatement potential with the marginal abatement cost per tonne of carbon dioxide equivalent. However, it should be considered that these estimates were based on research published in 2010, therefore technological improvements could mean that certain measures may be more cost-effective now and potentially in the future. In addition, at a city level, individual measures may be more or less cost effective; for example, through the feasibility of retrofitting the existing housing stock.

Figure 7.23: Global greenhouse gas abatement costs curve beyond business as usual, 2030



Note: The curve presents an estimate of the maximum potential of all technical GHG abatement measures below €80 per tCO_2e if each lever was pursued aggressively. It is not a forecast of what role different abatement measures and technologies will play.
Source: Global GHG Abatement Cost Curve v2.1

Source: McKinsey & Company

7.3.4: Water

On topics relating to water, whether it be on water supply or flooding prevention, examples of market failure can vary.

The existence of public goods is not normally cited in the context of water supply, rather water networks currently act as a natural monopoly. It is an industry where there are such high entry costs for potential new suppliers (i.e. the development of infrastructure), that it is most efficient for just one business to operate in supplying water to residents in a particular area. This therefore provides some considerations when looking to address the needs of a growing population – i.e. regulation is put on service providers (and utility companies more generally who work in industries where natural monopolies typically operate) to ensure that the public are adequately served (whether it be in the environmental quality of drinking water, or in the market for private water service supply).

Market failures however may be presented in the choices made by consumers. For example, the presence of information failures are relevant to many domestic energy and water services. People may have a poor understanding of the amount of water that they use (since most customers are billed for their use based on the size of their property, therefore pay the same amount whether they use a little or a lot of water – only around 35 per cent of customers have water meters). Within this context, consumers may not be aware of the need for, or the benefits of, reducing their water usage, i.e. through cost savings through smart metering or ensuring their homes are more water efficient.

As previously referred to within the climate section of this chapter, flooding is an example where market failures can occur. Notwithstanding the importance of negative externalities, where the activities of people and business exacerbate climate change, or the role of development leading to reduced natural defences against all forms of flooding, significant costs can be borne by properties which are impacted.

Another important consideration is the presence of co-ordination failures. Flooding causes direct impacts on households and businesses, but the increased risk of flooding also has the potential impact of raising the costs of insurance against such events. Regulation over land use can help mitigate against the potential risk of flooding; for example, designation of areas as floodplain and the prevention of development may help to alleviate risk of flooding for nearby areas (as a result of an effective run off area for floodwater being maintained).

Evidence on economic and social impacts

Water is a fundamental part of the natural environment; it services households and industry through consumption and sewerage. The Thames has played an important role in the development of the capital as a centre for trade, through the import and export of goods and services, but also as a means of transport to and within the city.

i) Water supply

The South East of England is classified by the Environment Agency (EA) as being in "serious" water stress. This means that in an average year more water is abstracted from the environment to meet our demands than is sustainable in the long term. Many water companies in the South East have been set 'sustainability reduction targets' by the EA to reduce the amount of water they take from the environment. These, together with climate change and population growth, have led Thames Water to estimate that by 2050, without further action, London's demand for water will exceed the available sustainable supply by 522 million litres per day by 2050. Thames Water is therefore working to identify and assess the resilience of long-term water resource options to meet London's growing demand whilst at the same time being affordable and sustainable. These options include a new reservoir near Oxford, transfer of water from the River Severn Catchment to the Thames catchment and effluent reuse (treatment of water from sewage treatment works), and further desalination.

Most of London's water companies have also committed to reduce demand for water through:

- Installing smart meters to incentivise households to be more water efficient (Thames Water plan to install 900,000 meters over the next five years)
- Retrofitting homes to become more water efficient
- Using the new metering capability to better detect leaks
- Investigating 'smart' tariffs to further incentivise water efficiency when water resources are low.

ii) Sewerage

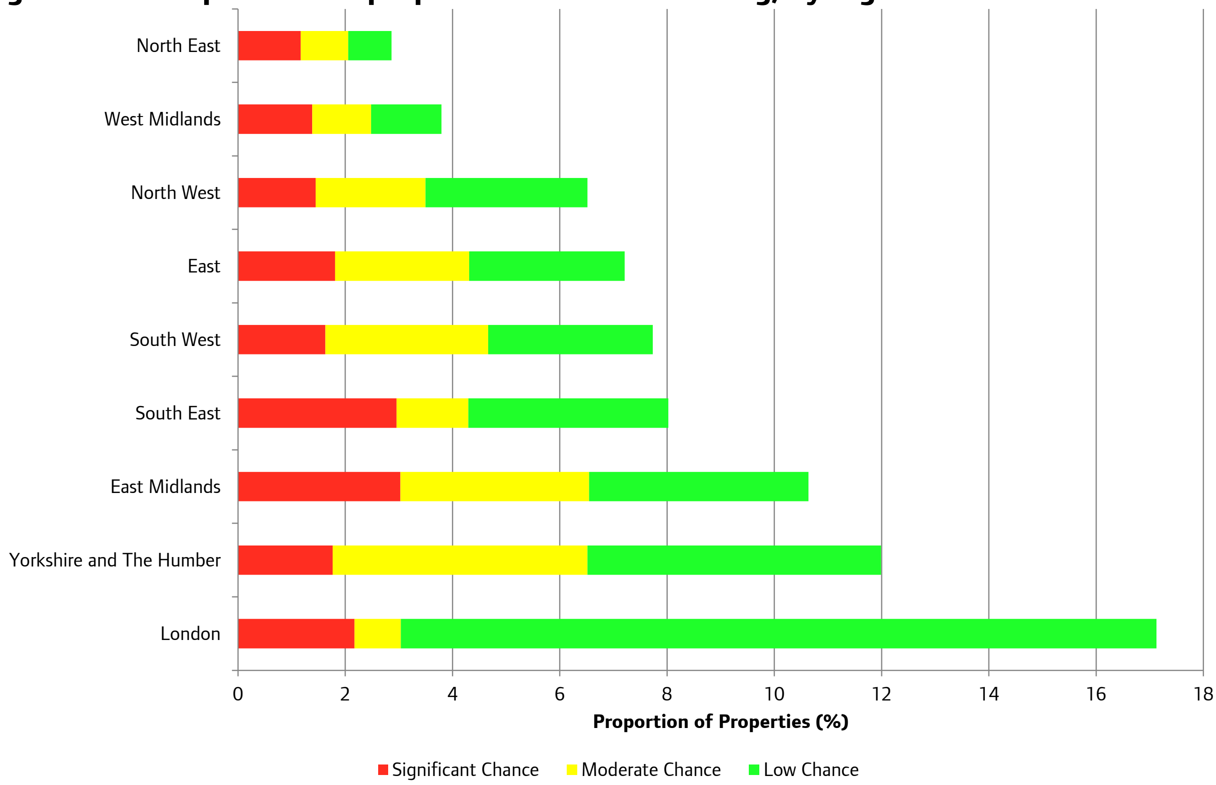
London's sewerage system has been developed over the past 150 years. The recent completion of the £650m Lee Tunnel in East London should prevent sewer overflows into the River Lee near Stratford. This will be complemented by the £4bn Thames Tideway Tunnel which is due to complete in 2023. Together these two projects alongside major upgrades at London's sewage treatment works that are either on-going or complete should mean that London's sewerage system can help to reduce pollution in London's waterways.

iii) Flood risk and drainage

Sixteen per cent of London's land area is within a flood plain and further areas are at risk of surface water flooding. Well over a million people are in these floodplains, although for the majority, the risks are actually low – see Figure 7.24. However, parts of the city are vulnerable to sea level rise. To address this risk, the Thames tidal flood defences protect over £200bn of property from tidal flood risk and the Environment Agency is progressing with the Thames Estuary 2100 project that will ensure this protection is maintained through the rest of the century.

With climate change predicting more intense patterns of rainfall, the risk of surface water and fluvial flooding will also increase. The understanding of the risk of surface water flood risk has improved greatly over the past five years through the Drain London project and updated Environment Agency risk mapping. Each of London's 33 Lead Local Flood Authorities are now exploring ways to manage and reduce surface water flood risk.

Figure 7.24: Proportions of properties at risk of flooding, by region



Source: NaFRA; Environment Agency; accessed on London Datastore

In terms of absolute number of properties within a floodplain, London has by far the highest number (at over half a million), as shown in Table 7.10.

Table 7.10: Numbers of properties at risk of flooding, England

Region	Significant Chance	Moderate Chance	Low Chance	TOTAL
London	72,000	29,000	470,000	573,000
Yorkshire and The Humber	48,000	129,000	149,000	327,000
South East	110,000	50,000	139,000	311,000
North West	47,000	66,000	97,000	211,000
East Midlands	60,000	69,000	81,000	211,000
East	46,000	64,000	74,000	188,000
South West	39,000	72,000	73,000	187,000
West Midlands	34,000	27,000	32,000	94,000
North East	14,000	11,000	10,000	35,000

Source: NaFRA, Environment Agency; accessed on London Datastore. Totals may not sum due to rounding.

When considering flood risk at a more spatial level, Hammersmith & Fulham, Southwark and Newham all rank within the top ten local authorities in England & Wales with the proportion of properties within a floodplain, as shown in Table 7.11.

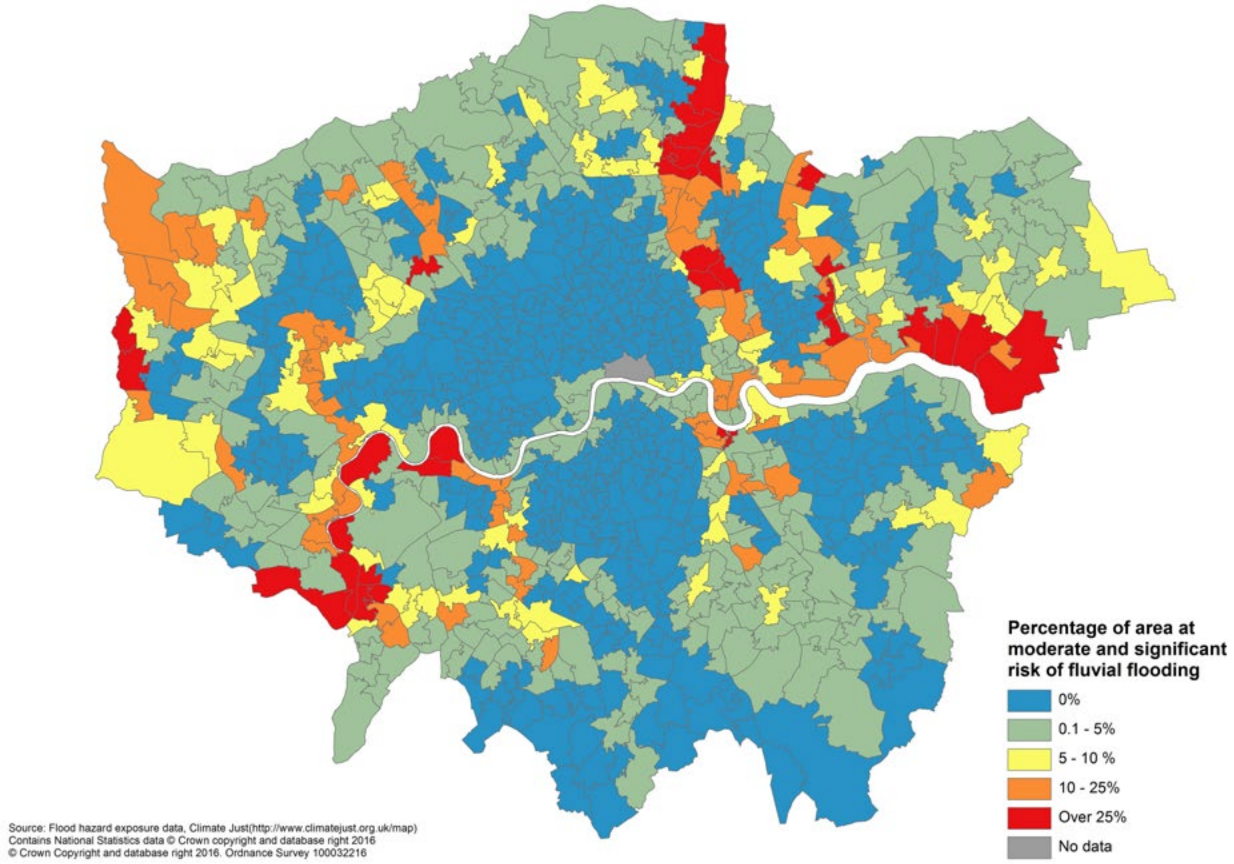
Table 7.11: Ranking of local authorities based on proportion of properties within a floodplain

Local Authority	Percentage of properties within a floodplain	Ranking within England & Wales (375 areas)	Percentage of properties with a significant chance of flooding	Percentage of properties with a moderate chance of flooding	Percentage of properties with a low chance of flooding
Hammersmith and Fulham	89	3	1.3	0.8	87.2
Southwark	68	5	0.0	0.0	67.9
Newham	50	8	1.9	0.6	47.7
Richmond upon Thames	43	11	4.2	6.7	32.4
Tower Hamlets	34	16	0.7	0.0	33.3
Wandsworth	30	19	2.4	1.9	25.8
Barking and Dagenham	25	29	4.1	1.7	19.3
Hounslow	25	30	2.5	1.3	21.0
Greenwich	23	33	0.5	0.1	21.9
Lambeth	22	39	0.5	0.0	21.2
Lewisham	17	53	2.8	0.8	13.2
Westminster	16	54	2.6	0.1	13.8
Enfield	16	56	7.9	2.2	5.5
Bexley	13	66	0.4	0.2	11.7
Merton	13	70	6.7	1.7	3.8
Kingston upon Thames	10	94	4.5	1.9	3.5
Haringey	9	102	3.9	3.3	1.8
Havering	8	113	1.2	0.4	6.5
Waltham Forest	7	132	4.0	0.7	2.2
Kensington and Chelsea	6	139	1.2	0.1	5.1
Hillingdon	6	141	3.8	1.3	1.0
Ealing	6	151	0.2	0.1	5.6
Bromley	6	158	2.3	1.0	2.5
Sutton	5	185	1.2	1.8	1.5
Redbridge	5	198	2.4	0.6	1.6
Brent	4	206	2.7	0.4	1.4
City of London	3	265	1.1	0.7	1.2
Croydon	3	268	1.9	0.1	1.0
Harrow	3	276	1.5	0.3	0.7
Hackney	3	285	0.2	0.0	2.4
Barnet	2	300	1.7	0.2	0.4
Camden	0	374	0.0	0.0	0.0
Islington	0	375	0.0	0.0	0.0

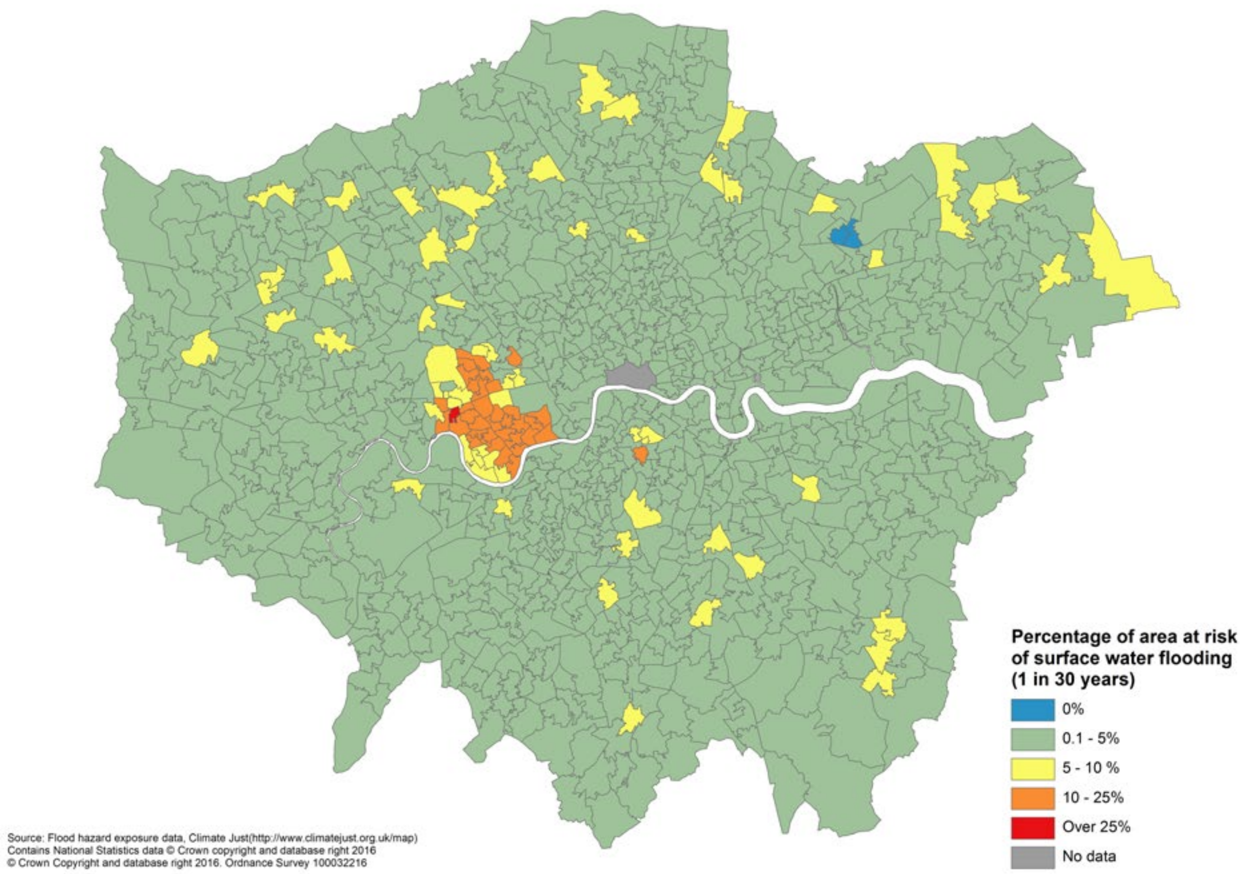
Source: London Datastore

Maps 7.6 and 7.7 provide an indication of the spatial risks of river/coastal flooding, and surface water flooding, each at MSOA[34] level. Map 7.6 provides data on the proportion of MSOAs covered by moderate or significant flood risk from river and coastal flooding, and Map 7.7 gives an indication of the proportion of the MSOA covered by extents of flood zones associated with a 1 in 30 year flood event.[35]

Map 7.6: Proportion of MSOA area covered by either moderate or significant flood risk



Map 7.7: Proportion of MSOA area covered by extents of flood zones associated with a 1 in 30 year flood event

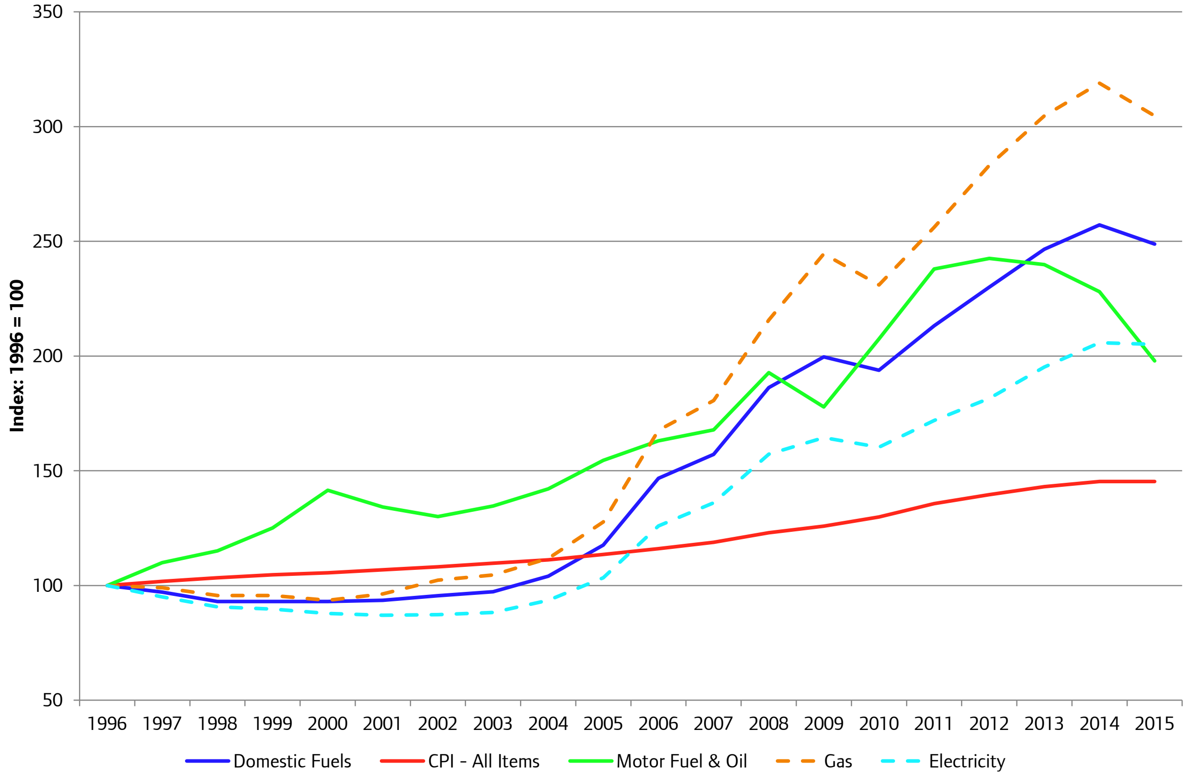


7.3.5: Energy

The generation of energy also has wider implications: greater energy generation may lead to increased carbon emissions, and following on from this, the potential for exacerbating climate change. From the consumer perspective, the presence of information failures about the potential financial and environment benefit of (for example) home energy efficiency measures is particularly relevant. Reduced domestic and industrial energy usage is consistent with mitigating against potential negative impacts of climate change. Such concerns, and pressures placed on the energy grid can explain the incentives for decentralised energy programmes for new developments.

Another concern in recent times (such as the last decade) has been trends in energy prices and the associated rises in total household energy costs (Figure 7.25). As a result of this, and other factors such as the rising costs of living more generally, there is a proportion of Londoners who are in fuel poverty (as described in more detail within Chapter 10).

Figure 7.25: Domestic fuel prices compared to inflation, current prices



Source: BEIS and Office for National Statistics; GLA Economics calculations
Note: Gas and electricity form part of the domestic fuel component (along with liquid fuels and solid fuels)

The implications of this can lead to significant impacts on public services. Insufficient heating may lead to an increased call on health services, and households may need to substitute between heating, food consumption, or other consumption. Households with families may be particularly affected, with children's life chances and health outcomes put at risk. Given the context of projected increases in population and employment in the coming decades, sufficient energy provision remains an important concern, especially as an increased call for energy means that the UK will be more reliant on international energy markets, which leads to risks to energy supply – all of which could potentially impact upon London's future competitiveness, but also the cost of energy for households more generally.

Evidence on energy usage in London

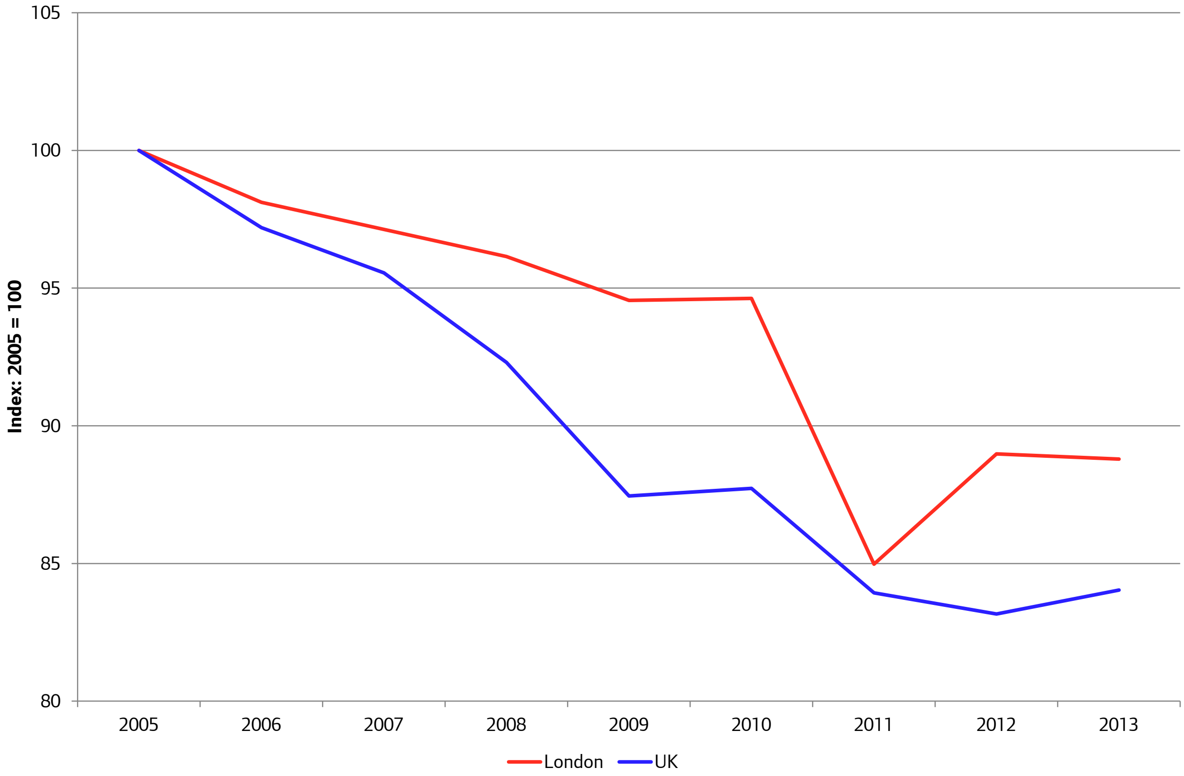
The UK is a net importer of gas and other fuels making London's energy supply reliant upon international energy supplies and markets. Over the last decade energy usage in London has fallen; between 2005 and 2013, total energy consumption in London fell by 11.2 per cent, as shown in Figure 7.26. Table 7.12 shows this decrease in energy consumption was consistent across the domestic, commercial and transport sectors.

Table 7.12: Energy usage, GWh, 1990 – 2014, London

Year	Domestic	Industrial and Commercial	Transport	TOTAL
1990	--	--	--	160,431
2000	68,056	68,767	32,518	169,341
2001	78,825	62,091	31,017	171,933
2002	*74,248*	*59,332*	*32,830*	*166,409*
2003	69,671	56,572	34,643	160,886
2004	69,051	58,519	35,270	162,839
2005	66,433	57,366	34,193	157,991
2006	64,474	55,308	35,230	155,012
2007	*64,239*	*54,413*	*34,804*	*153,457*
2008	64,005	53,518	34,379	151,902
2009	*63,462*	*53,448*	*32,479*	*149,388*
2010	62,918	53,744	32,838	149,500
2011	53,800	47,614	*32,838*	134,252
2012	57,459	50,288	*32,838*	140,585
2013	58,174	50,186	*31,920*	140,280
2014	53,490	47,747	32,829	134,066

Source: LEGGI.
Notes: Data for 1990, 2000 – 2009 are non-weather corrected. Data for 2010 – 20 14 are weather corrected. Data in italics are estimates.

Figure 7.26: Trends in UK and London energy consumption, 2005 – 2013



Source: DECC (UK), LEGGI (London)

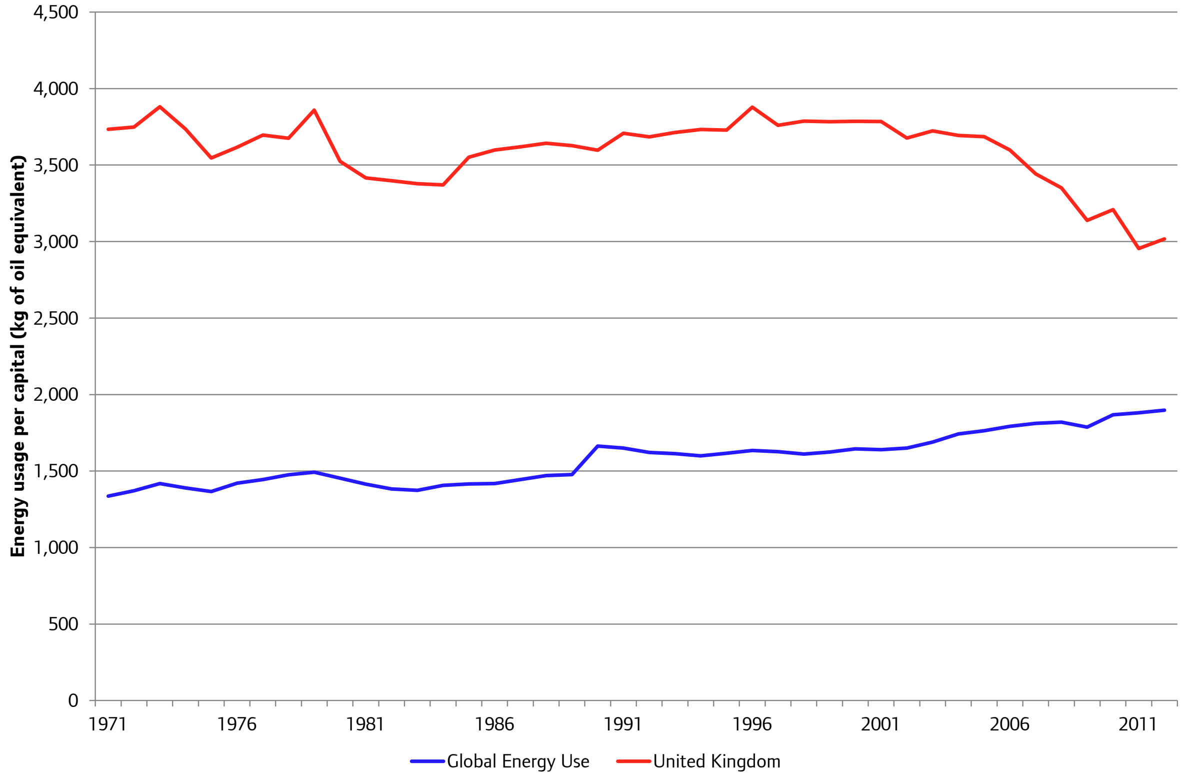
London comprises around 8.9 per cent of the UK's total energy consumption, which is considerably smaller than London's proportion of the UK population[36] (13.3 per cent) and of economic output (22.5 per cent); this is partially explained by density of London, with per capita energy consumption being lower in urban areas.

London's energy system is changing with an increasing demand for electricity and an increasing demand in the Central Activities Zone and during peak times. Currently, higher levels of development and recent increases in London's population are putting more pressure on an already stressed distribution network (40 per cent of London's electricity substations are already under stress). This is resulting in isolated incidents of demand exceeding supply (witnessed by blackouts in the West End for example). It is estimated that the electricity investment requirement to meet short-term new demand is £210 million (over eight to nine substations). The alternative to capital investments is to explore further the role of demand side management and load shifting.[37]

With London's population estimated to increase by around three million people, and add an additional 1.6 million homes by 2050, London's need for energy may increase with an expected 20 per cent increase in demand[38].

In a similar way to carbon dioxide emissions, energy emissions per capita for the United Kingdom have fallen. In contrast, there has been an increase in energy emissions per capita globally, as a result of globalisation and industrialisation. Figure 7.27 shows the trends over the last 40 years.

Figure 7.27: Energy usage per capita



Source: World Bank

7.3.6: Waste

The treatment of waste and recycling is a topic where different market failures can occur. Two main areas are typically raised; firstly of co-ordination failure and secondly the potential for free riding. If the collection and treatment of waste was borne on the consumer (or business), there may be insufficient provision and treatment of waste, impacting on environmental quality and the perception of a location to live and work.

As important is the presence of negative externalities. Similar to those previously referenced in relation to air quality and noise, negative externalties through waste may have very direct health impacts. Also visual blight through uncollected waste may also have impacts on people's quality of life, wellbeing, and the perception of a location to live, work and visit. For materials and products that may have significant long-term impacts (such as industrial waste), these effects may be very significant.

Analysis on waste and recycling

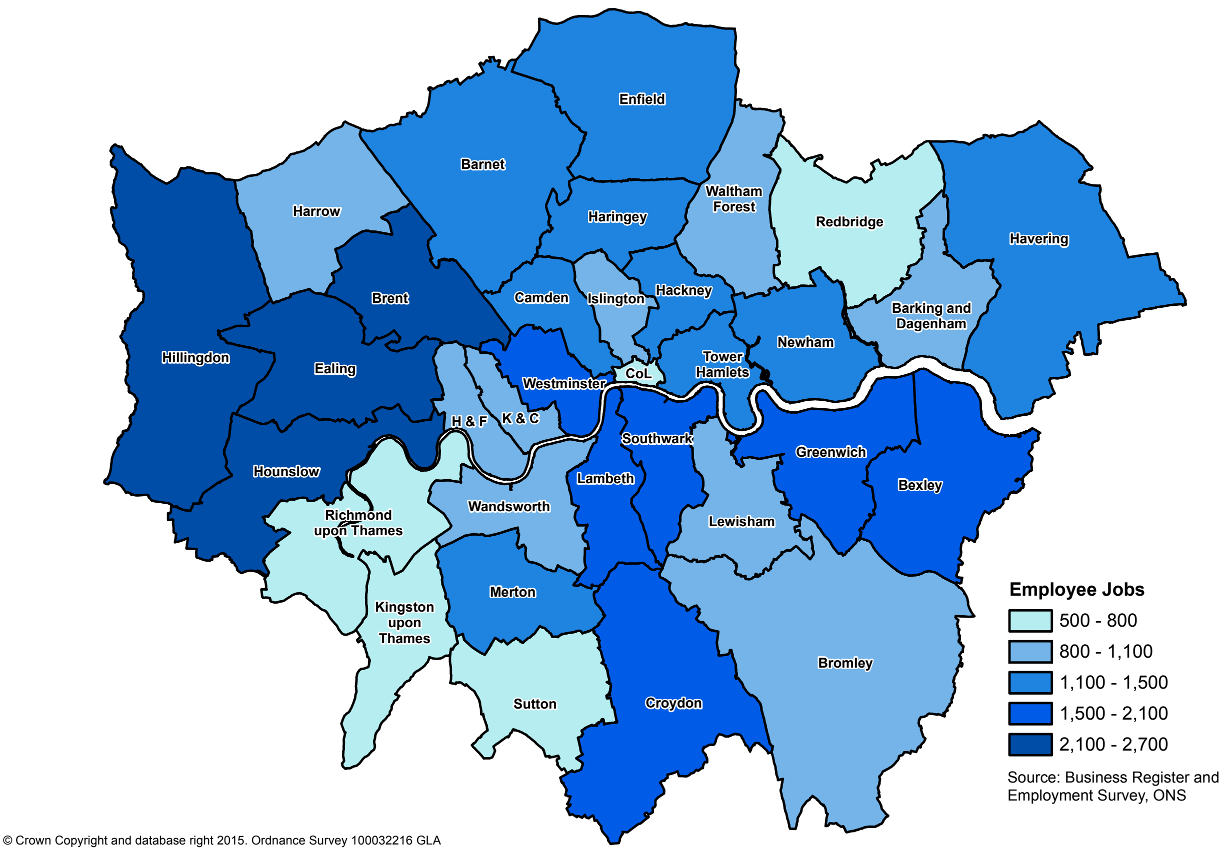
As a major population centre, London produces a significant quantity of waste – around 15 million tonnes per year; including 3.1 million tonnes of household waste and around 4.7 million tonnes of commercial and industrial waste, the latter of which has been in decline with an increasing shift towards a service led economy. The remaining 7 million tonnes of waste generated each year comes from construction, demolitian and excavation activities. London manages around half of the waste produced within its boundaries, with the remainder exported to other parts of the UK and beyond.

London comprised 13.3 per cent of the total UK population and 22.5 per cent of total economic output, yet contributed only 7 per cent of total UK waste arisings of 200 million tonnes in 2012. In addition, London only contributed around 10 per cent of the UK's total commercial waste.[39]

How London produces and services waste has significant implications for London's natural environment. Resources (such as land, water etc.) are used in the production of goods and services, therefore consideration needs to be given to how industrial activity impacts upon London's natural capital and achieving higher reuse and recycling performance to reduce reliance on manufacturing virgin materials. A growing population and increased business activity also has implications in where waste remediation, reuse and recycling activity can take place in the capital, especially in the context of the competition and cost of land (as highlighted in Chapter 4). It may be increasingly common for London's waste to be transported further towards the periphery of the capital or even outside. The implications of this include increased emissions related to the transport of waste via greater distances.

In this regard, there are opportunities for London to change how it treats waste – recovering value from more waste and reducing the scale of waste going to landfill and incineration (therefore depleting London's natural capital), and encouraging other uses of materials. One particular example where London's economy can adapt to changes in land use, business activity and the future needs of London's population is through the movement towards a more circular economy. A circular economy is one that keeps products, components and materials at their highest use and value at all times. It is an alternative to the current linear economy where we take make, use and dispose of product, components and materials. If the costs of materials rise, including the costs of treating or disposing of such materials, then there may be an increased economic incentive to reuse the materials. A circular economy can stimulate innovation in areas like product design, re-use and remanufacturing facilities, business models as well as new forms of finance. In this scenario, the implications are a reduced demand for landfill, an increased demand for repair, re-use, re manufacturing and recycling (and hence infrastructure). Analysis undertaken by WRAP for the London Sustainable Development Commission, the London Waste and Recycling Board, and the GLA[40], estimates that total employment in the circular economy was 46,700 in 2013 (Map 7.8). Modelling from GLA Economics estimates that the total GVA in the circular economy would be approximately £2.8 billion in 2012.[41] In addition, analysis undertaken for LWARB outlines that the movement towards a more circular economy could lead to 12,000 net new jobs in the capital by 2030.[42]

Map 7.8: Employee jobs in the circular economy, 2013



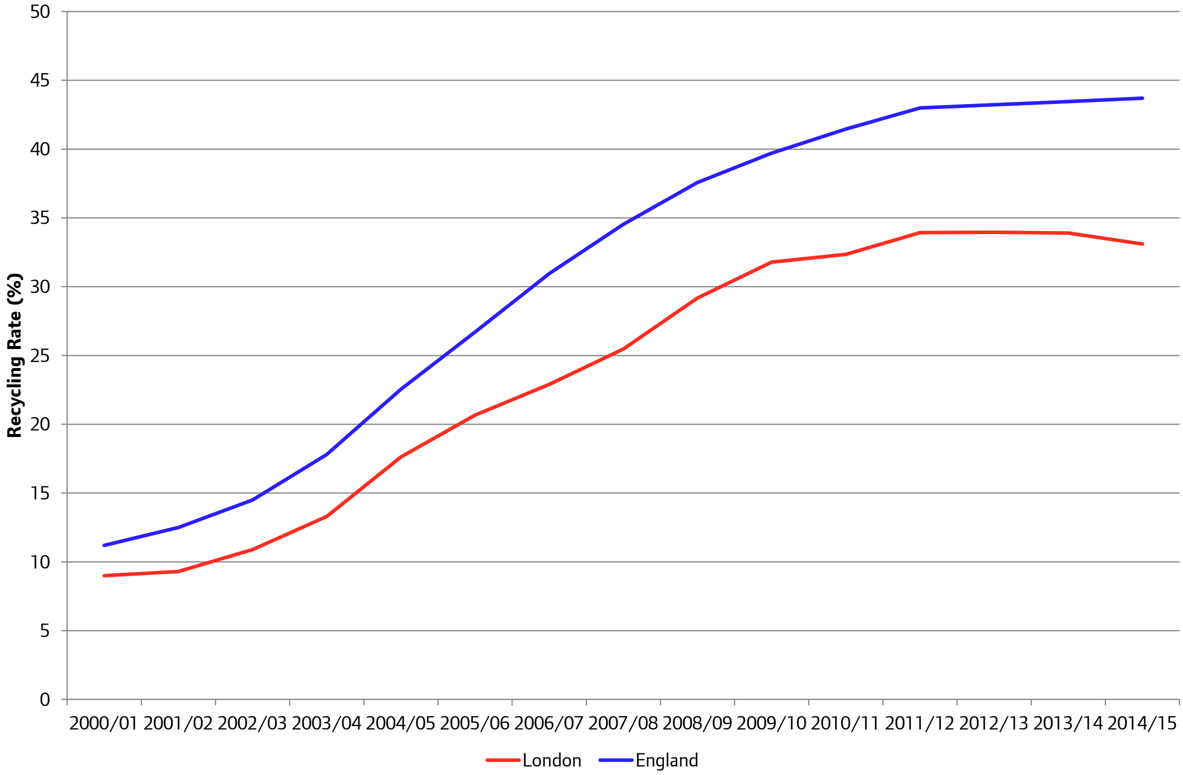
Source: Business Register and Employment Survey, ONS

Data on local authority controlled waste, including household waste, is reported to Defra, verified and published annually. However data on commercial waste is not collected in the same way and therefore for the purposes of modelling and plan making, Defra survey data collected at a London level is used and the latest projections can be found in the London Plan.

Data for 2014/15 shows that 3.66 million tonnes of waste were collected by local authorities in London (about 80 per cent of waste is from households). Total household waste has fallen by 11 per cent in London since 2000/01, and despite a growth in population, total waste arisings have, year-on-year, steadily declined by 18 per cent over the same period except for a slight increase from 2013/14 to 2014/15. London has the lowest waste arisings per head of any region (359kg per person), which has been in steady decline over time.[43] A downward trend is expected to continue due to a mixture of light weighting of goods and packaging, and increased numbers living in houses in multiple occupation.[44]

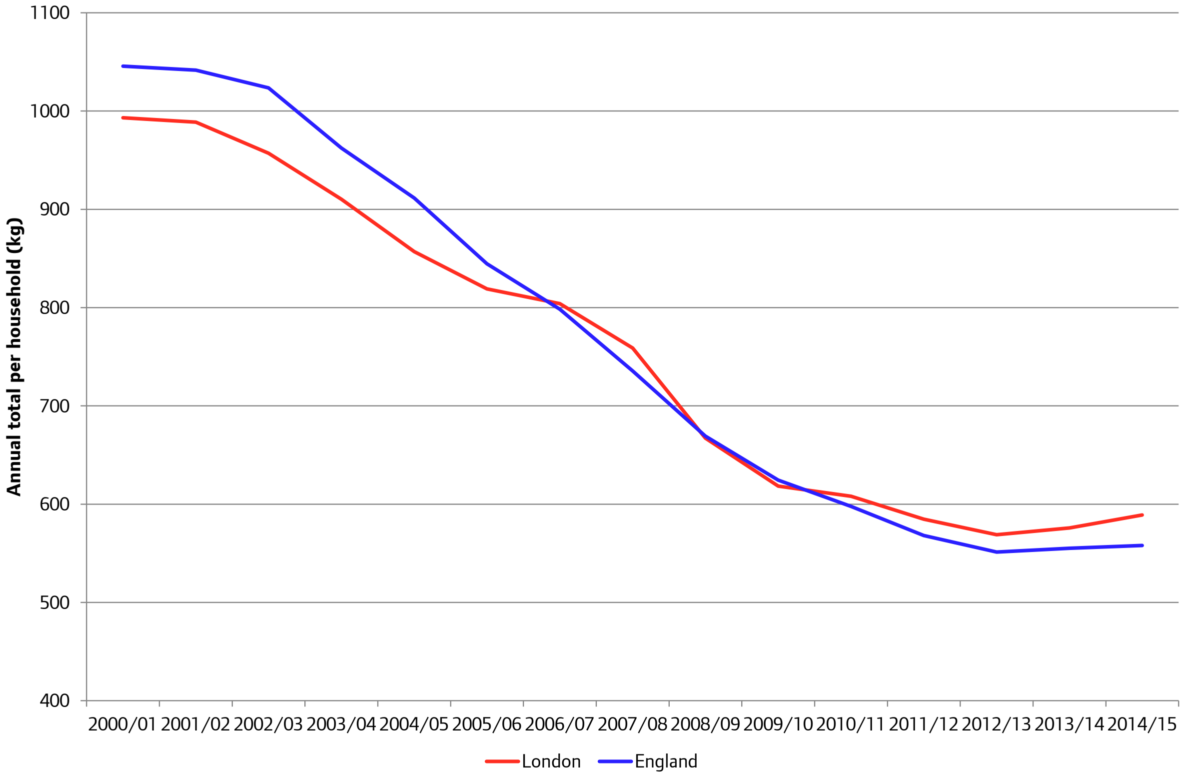
Data shows that London typically lags behind other regions in the proportions of household waste sent to recycling; in 2014/15, household recycling rates were just over ten percentage points lower than the average for England as a whole (Figure 7.28). At the same time though, London has higher than average levels of household waste per household (Figure 7.29) – despite having the lowest levels of household waste generated per person. A combination of light weighting materials, and measures to encourage households to reduce waste levels have made an impact, with average household annual waste falling by 42 per cent since 2000/01.

Figure 7.28: Household recycling rates in London and England as a whole; 2000/01 – 2014/15



Source: Defra

Figure 7.29: Annual household waste totals per household



Source: Defra

With increasing trends in incineration and recycling flatlining in recent years, there has been a decreasing trend in the amount of waste sent to landfill. This has important implications for London and its infrastructure needs to manage waste. Table 7.13 shows the trends of household recycling, household waste and waste sent to landfill over the last six financial years:

Table 7.13: Data on household and local authority waste indicators, London

	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15
Household Recycling Rate	31.8%	32.4%	33.9%	34.0%	33.9%	33.1%
Percentage of local authority waste sent to landfill	48.7%	44.7%	30.6%	25.5%	24.4%	20.6%
Percentage of local authority waste incinerated	20.8%	23.6%	35.7%	40.9%	41.9%	45.9%
Residual household waste per household	618kg	608kg	585kg	569kg	576kg	589kg

Source: Defra

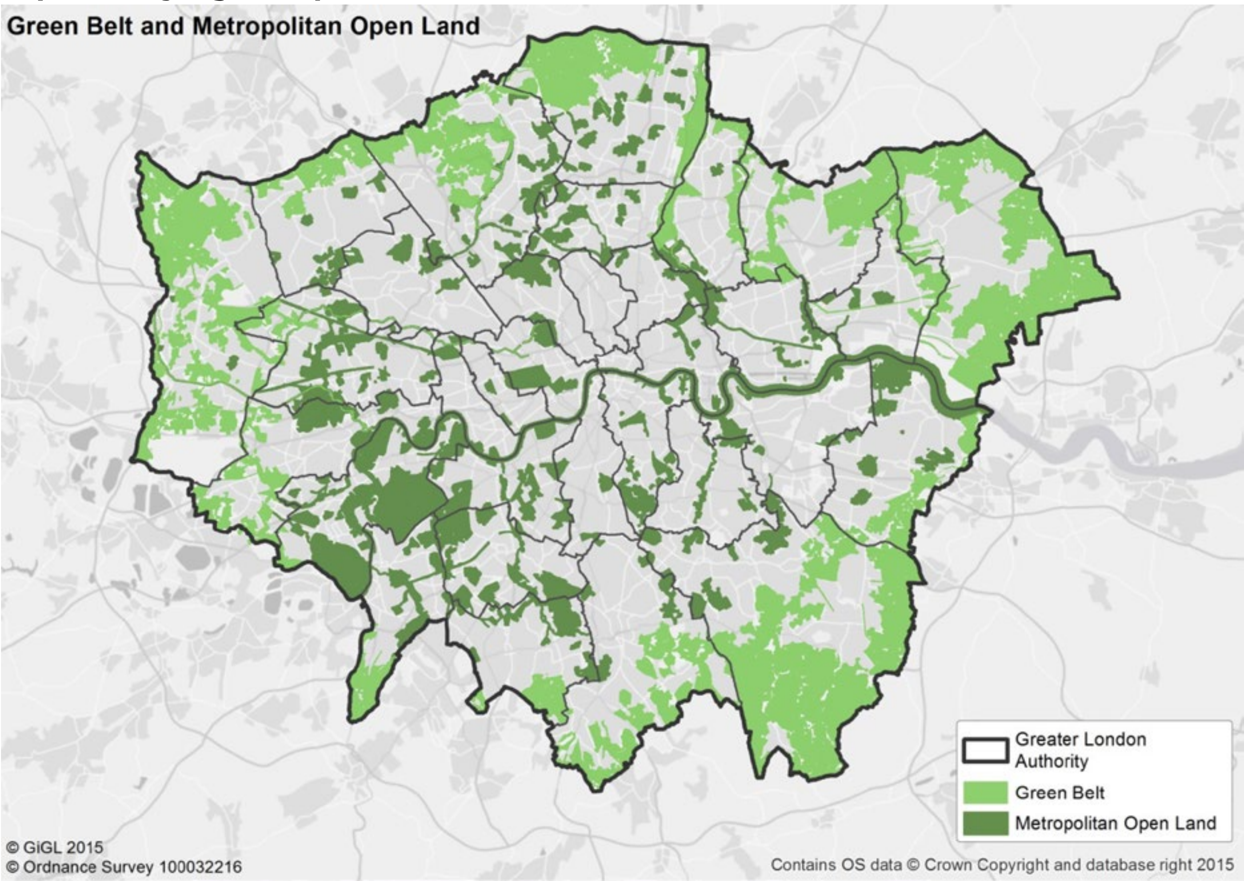
7.3.7: Green infrastructure

The previous sections of this chapter have looked at environmental areas where market failures are observed, but an area in which market failures can be mitigated into the future is through the provision of green infrastructure. This can be considered as the network of green spaces (as well as features such as street trees and green roofs) that is planned, designed and managed to deliver a range of benefits, including:

- healthy living;
- mitigating flooding;
- improving air and water quality;
- cooling the urban environment;
- encouraging walking and cycling; and
- enhancing biodiversity and ecological resilience

London is already a green city, with over 47 per cent of its total area classified as green or blue, and has over 8 million trees (Map 7.9 provides an overview of the major green spaces in the capital). As set out by the NCC, green infrastructure is an integral part of the urban environment upon which the prosperity and viability of the capital depends.

Map 7.9: Major green spaces in London



Source: GLA Intelligence Unit. Note: This map only includes Green Belt and Metropolitan Open Land, not all green spaces in London.

Activities relating to green infrastructure are designed to provide a range of both environmental and social benefits, and look to address specific market failures. These market failures are more wide ranging than solely negative externalities which are the pre-dominant example of where market failure occurs in the context of air and noise pollution. Focussing on London's population, there are examples of where green space provision provide positive externalities to residents, such as the wellbeing impact that green space can have on quality of life. Access to green spaces also provide a place for health, fitness and recreation activities (therefore potentially mitigating against the negative externalities resulting from poorer health outcomes), as well as positive impacts on communities (on aspects such as social cohesion – as a place where people can meet).

In addition, green infrastructure can ameliorate a range of potential negative impacts caused by climate change and urban development. For example, trees and vegetation can absorb rainwater and open spaces can store flood water thus reducing damage to buildings and infrastructure during flood events. Tree canopies can have cooling effects for buildings and at ground level. The range of economic impacts is extensive and the following sections explore some of the literature on the economic impacts that green infrastructure can have.

Green infrastructure is also an example of a public good. In economic terms, public goods are example of products which are non-rival and non-excludable. In the environmental context for example, National Parks are generally considered to be public goods, they are typically non-rival due to their size, such that one person's enjoyment of the park should not impact another person's enjoyment. They are also non-excludable, since access to them is provided free of charge (in part because their geographic scale means that monitoring and charging for entry across the entire border of the park would likely be impractical).

In its intent (to a large extent), green infrastructure is designed to be non-rival and non-excludable. Due to the nature of public goods, these tend to be areas which are provided by the public sector as typically private sector businesses will not invest in public green space provision since they cannot derive profit. However, businesses may well invest in green spaces for their staff as there may be productivity benefits for them by having staff that experience the wellbeing benefits that green spaces provide. Another limiting factor on private sector provision relates to ownership of land; publicly owned land would likely need agreement from local authorities to increase provision (such as planting trees in public spaces).

Economic and social impacts of green infrastructure

Comprehensively valuing the services and benefits provided by green infrastructure is necessary so that these are properly accounted for when deciding, for example, how to enhance resilience or improve public health.

The economic benefits are wide ranging. 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 £2.1 billion per annum.[45] 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[46].

Within an environmental context, the scale of economic impacts is potentially much higher. The natural capital account for Beam Valley Parklands (Box 7.1), for example, indicate 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 £42 million in present value terms, and it 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[47].

Programmes of planting trees in urban areas provide a range of both environmental and wellbeing benefits. These include aesthetic improvements to areas and these becoming a focal point for residents. They can also act as a means of carbon storage, improve biodiversity, help to reduce localised flooding, and potentially enable reductions in energy usage through helping to cool areas in the summer and provide insulation in the winter. The London i-Tree Eco assessment has looked to provide monetised costs for the environmental benefits and replacement costs of trees currently in the capital, estimating that London's existing urban forest provides total benefits of £132.7 million per annum.[48]

Box 7.1: Practical application of natural capital accounting – Beam Parklands case study

Introduction:

One of the aims of the Natural Capital Committee is to encourage the take-up and use of natural capital accounting for individual projects, and more widely, for the UK as a whole. For the GLA, an important concern in decision making is to address the potential negative impacts on the stock of natural capital, resulting from pressures of population increases, economic activity and global warming; net of the possible improvements to natural capital resulting from environmental improve. To improve decision making, it is important to develop a better understanding of the costs associated with degradation of the environment, net of the value resulting from environmental improvements.

To illustrate how natural capital accounting can be used in project appraisal, this box provides a case study of the Beam Parklands in the London Borough of Barking & Dagenham. This appraisal attempted to address both accounting for natural capital assets and estimation of the some of the values required for decision making.

Natural capital improvements – Valuing environmental services:

As part of the natural capital appraisal, the positive impacts in aspects of the environment are considered; net of the environmental, economic and financial costs. For example, the following environment services were considered:

i) Flood regulation

The value generated from flood prevention was calculated by estimating the number of properties at risk of a 1 in 25 year flood event, and estimating the associated damages resulting. The expected value was given by:

Likelihood of flood event * Estimated damage to properties

This was estimated at £591,000 per annum; with a discounted present value of £19 million over a 99 year appraisal period.

ii) Local community benefits

In the Beam Parklands, these would be expected to include:

- Recreation and amenity
- Education opportunities
- Improved health outcomes
- Reduced community severance
- Volunteering

The flow of these is underpinned by the site's natural capital assets. In the event, a broad approach to the valuation of the community benefits was adopted. This made use of data on amenity values as reflected by residential and non-residential price uplifts in the vicinity of the site. However, it is important to understand the potential for differing approaches to valuing individual benefit streams and some of the issues associated with them.

The approach adopted to estimate amenity values does not directly reflect health benefits. On health, the physical benefits associated with greenspace are generally well evidenced. However, the link between greenspace and improved mental health is less well established in the empirical evidence. In any case, health effects suffer from one of the common problems with benefit estimation in this context; that of potential overlap and resulting double counting.

Studies assuming the relationship between greenspace and property price in London and the wider UK are generally in the range of 1 per cent to 5 per cent uplift. For the Natural Capital account aspect of this study, a 3 per cent uplift has been used. Local community benefits are calculated by applying the 3 per cent uplift to the estimated number of properties in the vicinity of Beam Parklands.

The number of properties are calculated based on the Access to Natural GreenSpace Standard (ANGSt; Natural England, 2010), but using the more conservative residential property value. This was based on mean property value for dwellings in the wards within the catchment area (ANGSt standard 1 catchment; Land Registry). Non-residential property was calculated on total rateable value in the Middle Layer Super Output Areas contained within the location.

However, net of these benefits, the maintenance costs of physical capital relating to community benefits are also estimated. No baseline information for this is readily available, so a proportion of the valuation estimate for 2014 is allocated to the baseline. Half of the property price uplift (that being 1.5 per cent) is allocated to the baseline; totalling £316,000 per annum. This is reported net of the physical maintenance costs of £19,000; therefore total net benefits sum to £297,000.

Revaluations and adjustments capture the real change in property value between 2011 and 2014 of £184,000 per annum; which accounts for the real increase in the number of residential properties. This calculation also includes a small reduction in the physical maintenance liability of £1,000 per annum.

The present value of local community benefits, discounted over the 99 year appraisal period is estimated at £26 million.

iii) Caveats in the calculation of local community benefits
The report makes clear that the approach to valuing local community benefits is indicative and assumes a general local amenity benefit provided by Beam Parklands. It requires a number of key assumptions:

- Size of beneficiary population and catchment area
- Property price uplift
- Keeping uplift values constant in catchment area as the distance from the site increases
- Attribution of a proportion of the property price uplift to the baseline value – information to support a more detailed assessment is not available
- The underpinning assumption is that the amenity value of Beam Parklands will be reflected in local property values. This effect is well evidenced in the empirical literature but is deemed to reflect the higher health outcomes and wellbeing improvements that result.

iv) Liabilities and other costs
The key task for the study was to allocate share of maintenance costs to natural and to physical capital. The key categories included were:

- Staff costs
- Management costs
- Volunteer costs – valued in terms of the hourly wage of equivalent work.[49]

A key assumption was that natural capital maintenance costs are constant in real terms over a 99 year appraisal period.

Conclusions and lessons for future learning

Through the appraisal, the calculated natural capital asset value for Beam Parklands was estimated at £42 million in present value terms, which significantly exceeds the long-term natural capital maintenance costs of £1 million.

The study has provided important insights into the application of Natural Capital Accounting and the approach to valuing important benefits and costs for decision making on Natural Capital issues. A number of specific lessons emerge:

- The amenity value of green space is extremely context specific: it will reflect the (unique) characteristics and size of the green space itself; the numbers and socioeconomic characteristics of those living and working in the "catchment" of the green space (and by extension, the number and characteristics of "competing" amenity spaces); and, integral to the last, the ease of access for those living or working in the catchment.

- The damage costs of flooding (or benefits of flooding damage avoided) also reflect a number of context specific characteristics, as well as some "exogenous" factors. The characteristics of the immediate area at risk will also have substantial implications for risk and the extent of damage (costs) associated with a flood event. As for amenity, the number and socioeconomic characteristics of residents and dwellings will be very important, and the amount and nature, especially use, of non-residential property will often be highly relevant.

Chapter 7 endnotes

1 Natural Capital Committee, 2015, "The State of Natural Capital, Protecting and Improving Natural Capital for Prosperity and Wellbeing: Third Report to the Economic Affairs Committee"

2 "Demand for environmental quality is a superior good,…[having] an income elasticity greater than one" See, for example, Beckerman, Wilfred, 1992, "Economic Development and the Environment: Whose Growth? Whose Environment?", World Development 20 (4) pp481-496

3 Natural Capital Committee, 2015, "The State of Natural Capital, Protecting and Improving Natural Capital for Prosperity and Wellbeing: Third Report to the Economic Affairs Committee", page 19.

4 Natural Capital Committee, 2015, page 19 – 20.

5 Natural Capital Committee, 2015, page 19

6 "The Value of Cultural Tourism to London", GLA Economics Current Issues Note 44.

7 Drawn from Natural Capital Committee, State of Natural Capital, 3rd Report

8 www.londonair.org.uk

9 Due to monitoring methodological changes a time series can only be derived for PM_{10} from 2004

10 Black carbon is formed through the incomplete combustion of fossil fuels, biofuels, and biomass. It is emitted directly into the atmosphere in the form of fine particles ($PM_{2.5}$). Source: United States Environmental Protection Agency.

11 Euro V and Euro VI refer to the most recent European emission standards for exhaust emissions of new vehicles sold in EU member states. These apply separately for diesel and petrol engines, as well as for passenger vehicles, commercial vehicles, trucks, and buses

12 The UK was taken to court by the European Commission for persistent air pollution problems: http://europa.eu/rapid/press-release_IP-14-154_en.htm. It is unclear what penalties the UK could receive if found guilty, although they are likely to be financial.

13 "Comparison of Air Quality in London with a number of world and European cities", AMEC Environment & Infrastructure, Table 10.6, page 61.

14 Aether, "Analysing Air Pollution Exposure in London", page 8.

15 $PM_{2.5}$ and PM_{10} refer to particulate matter (PM). This is the term used to describe condensed phase (solid or liquid) particles suspended in the atmosphere. Their potential for causing health problems is directly linked to the size of the particles. $PM_{2.5}$ refer to particles that are smaller than 2.5 micrograms in diameter; these are considered to have more harmful health effects than PM_{10}, which refer to particles at 10 micrograms in diameter.

16 As such, the analysis does not reflect the impact of many of the interventions outlined in the Mayor's Air Quality Strategy (published in 2010) and implemented since this date, such as tighter Low Emission Zone standards and age limits for taxis introduced in 2012.

17 Walton, H. et al, (2015), "Understanding the Health Impacts of Air Pollution in London", King's College London for GLA and TfL.

18 The estimated impact for NO2 are stated as "up to £2.3 billion" since the Committee on the Medical Effects of Air Pollutants (COMEAP) are currently considering how best to quantify these impacts. For this referenced study, a previous study from King's College London on the health impacts of air pollution in London from 2010 is cited, where a range of methods were used to estimate the health impacts associated with NO2 pollution in London. Source: Walton, H. et al, (2015) "Understanding the Health Impacts of Air Pollution in London", King's College London for GLA and TfL.

19 Policy Exchange, (2016), "Up in the Air, How to Solve London's Air Quality Crisis: Part 1"

20 ibid

21 "Burden of disease from environmental noise: Quantification of healthy life years lost in Europe", World Health Organisation; Executive Summary page xvii.

22 Calculation on economic impact undertaken by Defra on World Health Organisation analysis of disability-adjusted life years lost through environmental noise "Environmental Noise: Valuing impacts on: sleep disturbance, annoyance, hypertension, productivity and quiet", page 9.

23 "Burden of disease from environmental noise: Quantification of healthy life years lost in Europe", World Health Organisation; Executive Summary page xvii.

24 Lden – is the A-weighted long-term average sound level for the day-evening-night noise indicator in decibels (24 hours).

25 TFL, Airports Commission Discussion Paper 05: The Mayor of London's Response

26 London City Airport, Noise Action Plan, 2010-2015

27 "Weathering the Storm: The Impact of Climate Change on London's Economy", London Assembly, 2015; page 10

28 "Stern Review: The Economics of Climate Change", 2006; page vi

29 Parker, D. E.; Legg, T. P. and Folland, C. K., 1992, "A new daily Central England Temperature Series, 1772-1991"; International Journal of Climatology, Volume 12, pp. 317 – 342. Full dataset for 1659 to 2015 accessed at www.metoffice.gov.uk/hadobs/hadcet. The temperature data are based on a "roughly triangular area of the United Kingdom enclosed by Lancashire, London and Bristol".

30 "London's Low Carbon Market Snapshot 2015", kMatrix, page 4.

31 "FTSE Environmental Technology Index Series", Factsheet, 30 November 2015

32 "FTSE Environmental Opportunities Index Series", Factsheet, 30 November 2015

33 "Stern Review: The Economics of Climate Change", 2006; page viii

34 Middle Super Output Area

35 Full dataset available on the London Datastore: http://data.london.gov.uk/dataset/climate-just-data

36 Based upon 2015 ONS mid-year population estimates.

37 Such examples include the London Energy Plan Tool launching in February 2016 which will look at a number of scenarios that can deal with this issue.

38 https://www.london.gov.uk/what-we-do/business-and-economy/better-infrastructure/london-infrastructure-plan-2050

39 "Digest of Waste and Resource Statistics – 2015 Edition", Defra

40 "Employment and the Circular Economy: Job creation through resource efficiency in London", WRAP.

41 This has been calculated using the methodology established to calculate GVA and GVA per job for specific industries based on the selection of specific SIC codes, first referenced in GLA Economics Current Issues Note 44; alongside the selection of SIC codes relating to the circular economy.

42 LWARB, "London – The Circular Economy Capital: Towards a circular economy – context and opportunities", 2015.

43 'Local Authority Collected Waste Statistics', Department for Environment, Food and Rural Affairs.

44 Definition of houses in multiple occupation available at: https://www.gov.uk/private-renting/houses-in-multiple-occupation

45 Natural England, (2009), "Our Natural Health Service: The role of the natural environment in maintaining healthy lives".

46 Valuing Greenness Green spaces, house prices and Londoners' priorities https://www.london.gov.uk/sites/default/files/valuing_greenness_report.pdf

47 Beam Parklands Natural Capital Account

48 Treeconomics London, (2015), "Valuing London's Urban Forest: Results of the London i-Tree Eco Project" http://www.forestry.gov.uk/pdf/2890-Forest_Report_Pages.pdf/$FILE/2890-Forest_Report_Pages.pdf. Monetised annual benefits outlined on page 10; benefits of tree planting provided on pages 16 and 17.

49 Parish, A., Heath, J., and Hassan, M., 2003.. Changing the face of social services – volunteers adding value in service delivery. The National Centre for Volunteering. Available at: http://centreonphilanthropy.com/files/kb_articles/1250260224Volunteering%20in%20Social%20Services.pdf