

Greater London Authority (GLA)
**The cost of London's long-term
infrastructure**
Final report

REP003

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This report takes into account the particular instructions and requirements of our client.

It is not intended for and should not be relied upon by any third party and no responsibility is undertaken to any third party.

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13 Fitzroy Street
London
W1T 4BQ
United Kingdom

ARUP

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1 The Cost of London's long-term infrastructure

1.1 Background and scope

London is growing at its fastest rate in modern history. According to current estimates, its population is increasing by around one million individuals every ten years. This is equivalent to a rate of two thousand every eight days. Employment and economic activity are also rising.

Increasing demands are leading to pressing challenges for the city's infrastructure. These are coupled to rising expectations from Londoners, visitors, investors and businesses. The sustainability, quality and robustness of the city's infrastructure are increasingly under pressure and scrutiny.

Rising employment and population provide major opportunities for London government to lift the city's economic capacity and strengthen its competitiveness. There is a broad consensus that without optimal and increased infrastructure provision, the city will falter in its attempt to maintain and enhance its position amongst world cities. This view was reflected in the work of the independent London Finance Commission. One of the report's principal recommendations was to ensure that England's core cities gain the powers and fiscal autonomy to shape the provision of infrastructure and incentivize growth. These reforms would also improve accountability, the commission says, because decisions would be made by elected representatives closer to the people who put them in power.

Another recommendation of the commission was for the Mayor of London to develop an infrastructure plan for London in concert with other parts of London government. The GLA is now in the process of putting together a London Infrastructure Plan. This sets out the capital's strategic infrastructure investment requirements to 2050. This plan covers: transport; energy; waste; water; green; digital connectivity; and social infrastructure (including housing and schools).

Arup has been commissioned to provide an assessment of the costs associated with London's long-term infrastructure requirements and to provide an indication of the different ways in which this infrastructure development could be funded. Our work has included:

- Reviewing the projects identified to date and any additions (or other amendments) that should be considered;
- Arriving at high level costs and (broadly defined) benefits of the projects in question;
- Establishing an indication of the 'gap' between projected costs and available funding, focusing on areas of potential significant cost;
- Commenting on how projects could be delivered more efficiently; and
- Considering options for raising new or additional revenue sources.

This report summarises our findings. In the first chapter, we present an overview of costs by sector, focusing on projected capital expenditure requirements. We then consider each of the eight sectors identified, reviewing the costs associated with projected infrastructure requirements.

In section 10, we provide a preliminary assessment of the gap between projected costs and available funding in primary sectors, also discussing the potential impact of investment on some utility bills. In sections 11 and 12 we discuss options for reducing this gap, including the potential for savings through more efficient capital spending and mechanisms for generating additional or new sources of revenue. An appendix to this report provides additional detail to the discussion of our approach, inputs and assumptions.

1.2 Approach

The purpose of this study has been to provide a preliminary indication of the possible costs associated with the development of London's infrastructure. We have also considered existing and potential sources of funding for London's infrastructure development.

Cost projections are based upon Arup's understanding of potential future demand for different infrastructure types. At this early stage of development, the GLA has not developed a comprehensive set of candidate projects to be reviewed and considered for each and every infrastructure sector to 2050. However, the GLA has defined policy objectives across a range of sectors. High-level parameters, particularly the Mayor's own policy objectives, form the basis of our determination of the quantum of infrastructure required for each sector. Our analysis also has been based upon assumptions around London's forecast population growth, working in consultation with the GLA, TfL and other London government stakeholders.

In some sectors, Arup has assessed the potential level of demand for different types of infrastructure. We have adopted projected population growth as the main driver for infrastructure requirements in those sectors for which demand projections have been made. GLA Intelligence and other GLA population forecasts, as described in the appendix to this report, have served as the basis for future population growth projections. The process by which we have approached this study is shown in the figure below.

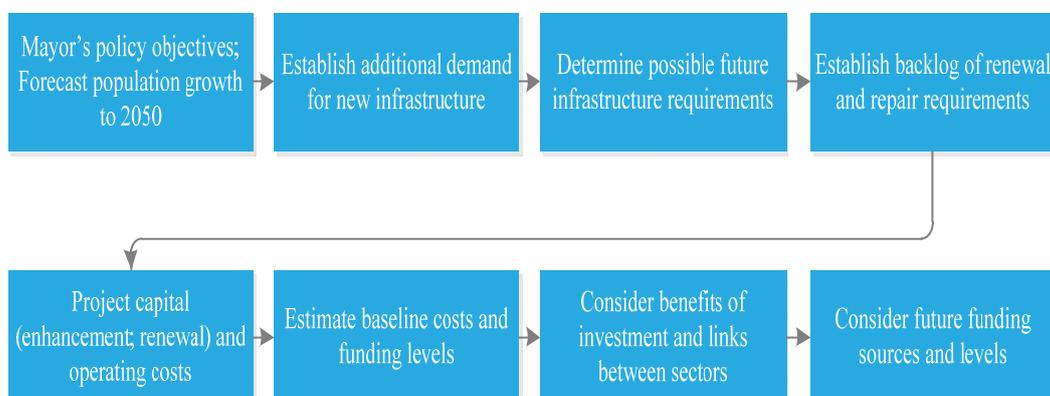


Figure 1: A schematic of Arup's overall approach. Source: Arup analysis

1.2.1 Cost projection approach

Below we highlight some important considerations including our approach to modelling costs for those sectors which represent some 90% of capital expenditure projected to be required in the period to 2050. We discuss our specific modelling approach in each of the infrastructure sector chapters of this report and in greater detail in the associated appendices.

1.2.1.1 Assessing capital and operating expenditure for each infrastructure sector

The primary focus of this assessment has been the investment required in order to provide new infrastructure supporting London's increasing population. Investment in capital enhancements (new projects) to London's infrastructure network represents an important component of long-term costs. Enhancement costs presented throughout this report related to the delivery of new infrastructure and housing units.

As London's infrastructure asset base grows, this new infrastructure also will require periodic renewal (sometimes referred to as renewals and/or capitalised maintenance). Specific assumptions around this type of capital expenditure vary across the sectors. In most sectors, including transport and housing, we have assumed that renewals expenditure related to newly constructed assets will represent a relatively modest percentage of projected cumulative enhancement expenditure over the study period. In both sectors, we have modelled renewals expenditure for newly constructed assets as one per cent of cumulative enhancement expenditure.

Our approach to modelling energy and digital connectivity renewals expenditure has differed. London's projected capital expenditure for energy generation will depend upon the level of 'decentralisation' (e.g. development of combined heat and power) that occurs. If this infrastructure is developed in the next decade or beyond, these assets are unlikely to require significant capital renewal within the study period. A large proportion of capital expenditure related to the electricity and gas distribution networks, however, is projected to relate to the renewal of assets.¹ In the digital connectivity sector, we have assumed that new assets are not renewed within the study period.²

The need for renewal expenditure extends beyond the new infrastructure London could require in the coming decades. Some of London's existing infrastructure faces a backlog of investment. Other parts are in the midst of on-going renewal and enhancement. A significant amount of renewals costs are projected to be associated with the transportation network. We have also included the potential costs associated with investment in London's existing education and housing infrastructure, addressing a backlog of capital maintenance in the city's schools

¹ The projected capital costs presented in the energy section of this report relate only to total capital expenditure, including both renewals and enhancements. Arup's modelling has relied upon more detailed analysis, as described in the appendix of this report.

² We explain this in greater detail in chapter 9.

and homes. We have modelled this expenditure in line with current requirements agreed with the GLA and other stakeholders.

In addition to periodic renewal, London's infrastructure assets will require on-going, routine maintenance. We have included these costs within operating expenditure projections. We have included the cost of operating London's new infrastructure assets, typically calculating operating costs as in relation to projected capital enhancement requirements.³

1.2.1.2 Cost projection periods

In order to avoid spurious accuracy, we have considered project delivery in five-year periods for each of the sectors. This approach is intended to reflect the fact that project delivery often changes in time (forward or backward). Throughout this report, we refer to costs in five-year periods. Each period refers to the five years prior to and including that year. For example, the period '2015' refers to the years 2011-2015 (inclusive), and the period '2050' refers to the years 2046 to 2050 (inclusive). In this report, "total" projected costs typically relate to the period 2016 to 2050 (inclusive).

1.2.1.3 Treatment of inflation

Price inputs have a base date of Q1 2014. In this chapter and throughout Arup's report, unless otherwise stated, projected enhancement and renewals costs are quoted in 2014 prices but with a 2% per annum underlying increase in construction costs. Technical change might be expected to drive down costs over time, but rising transaction and planning costs, material costs, labour costs, customer expectations, improved safety requirements and increasingly complex systems are expected to drive capital costs up in real terms.

Operating and maintenance costs are assumed to remain unchanged in real terms and unless otherwise stated are quoted in 2014 prices.

1.2.1.4 Gross value added (GVA) growth

In this report, we present calculations of projected costs as a percentage of GVA.⁴ The Office of National Statistics reports London's GVA to have been some £309 billion in 2012 (2012 prices).⁵ London GVA has been assumed to be some £325 billion in 2015. Our work has adopted GLA guidance that London's GVA will grow in real terms at a real rate of 3.5% per annum throughout the study period – once stimulation from infrastructure investment is accounted for⁶. The assumed rate of growth is roughly one percentage point higher than the average rate of growth exhibited by British economy since the Second World War.

Infrastructure typically is considered as an enabler of growth. Its development is correlated strongly with population growth and economic expansion. Investment

³ In the transport sector, operating costs for both new and existing assets are included.

⁴ GVA projections do not act in the model as a driver to any expenditure requirement projections.

⁵ Office of National Statistics via London datastore, Regional Gross Value Added, December 2013, available: <http://data.london.gov.uk/datastore/package/regional-gross-value-added>.

⁶ For clarity, the GLA's underlying GVA assumption used to define population growth is 2.5% per annum.

in infrastructure should have far-reaching, positive impacts on London's economy and society. There is reason to believe that investment in the capital's infrastructure will support economic growth above historical levels. Nonetheless, there is uncertainty around this assumption, and the level of growth seen in the future could be higher or lower than the assumed rate. Future study could incorporate different GVA assumptions.

1.2.1.5 Baseline costs and/or funding levels

Baseline and/or funding levels are presented in the period 2015 and the period includes funding for the years 2011 through 2015. These baseline funding levels are approximate estimates based on at times, limited publicly available information. Baseline costs are presented for comparison between future and existing expenditure. In most cases, the historical expenditure shown will vary from the actual outturn levels of expenditure seen in different sectors.

Arup's sector experts have worked with statements of accounts for the different infrastructure types to provide an indication of historical cost and/or funding levels. Arup has not completed a comprehensive review of current or historical expenditure levels, and, in particular, we have not reviewed infrastructure plan information for each of London's thirty-three boroughs in detail. This could form a useful further stage of analysis. The GLA has reviewed the historical figures presented in our report, providing guidance on historical public expenditure in many of the infrastructure sectors. Additional analysis may be required in order to ensure these baseline investment levels are more consistent with outturn costs across each of the infrastructure types.

1.2.1.6 Housing infrastructure approach

In the housing sector, the Mayor already has established the number of new homes that will be required in the capital over the study period. The GLA's recently published Strategic Housing Market Assessment (SHMA) states a need of 48,840 units per annum, roughly half of these units being affordable.⁷ We include both market-rate and below-market-rate projections in our cost assessment. We comment on these projections in relation to projected costs later in this section and in greater detail in the housing section of our report, also including costs for a "London Plan" scenario, delivering some 42,000 units to the London housing market each year. Unless otherwise stated, costs shown are for market-rate, affordable and social housing.⁸

We have included construction costs and the cost of land in our capital enhancement cost projections. Our construction costs are based upon a recent report from the Cabinet Office.⁹ We have added to these estimates professional fees associated with development and land costs. To project housing unit-related

⁷ Mayor of London, London strategic housing land availability assessment, 2013, available: <http://www.london.gov.uk/sites/default/files/FALP%20SHLAA%202013.pdf>.

⁸ Definitions of social and affordable housing may vary. Throughout this report, social and affordable housing together are referred to as affordable housing, encompassing all housing below the market rate.

⁹ Cabinet Office, Cost Benchmarks & Cost Reduction Trajectories to March 2013, 2nd July 2013, Table 22. The Cabinet Office report sets out costs on the basis of bedroom count rather than unit size. In order to calculate the cost per square metre associated with the construction costs found in the Cabinet Office report, we have assumed average sizes for each bedroom count.

land costs, we have assumed that they represent some 45% of total value and calculated land costs as a percentage of construction costs. In addition, we have included the land costs associated with the remediation of large development sites in our capital enhancement expenditure projections.

We have included the cost of major repairs and replacements in projected housing renewals capital expenditure. Renewals expenditure projections have been made for London's new housing units, including both market-rate and affordable housing units, as well as London's stock of existing affordable housing units. We have not included renewals costs for London's existing market-rate housing in our projections.

We have adjusted construction and operating costs in accordance with the Building Construction Information Services (BCIS) by the Royal Institute of Chartered Surveyors (RICS) guidance around cost estimation in London.

In some other sectors, including green, broadband and water infrastructure, these housing delivery targets have been considered as drivers for development requirements (and therefore cost).

We discuss our approach in greater detail elsewhere in this chapter, in which we also set out housing cost projections. Appendix A3 provides further discussion of housing model inputs and assumptions. In section 1.11.1, we consider the projected gap between projected housing costs and income sources.

1.2.1.7 Transport infrastructure approach

This section details our review and assessment of London's transport infrastructure needs to 2050. Working with the GLA and Transport for London (TfL), we have considered future requirements to provide a preliminary estimate of the capital expenditure and operating costs associated with the continued growth and renewal of the city's transport system. Our analysis is based upon:

- TfL's latest business plan and analysis of its historical expenditure;
- A review of trends and plans for the national rail network;
- London borough activities;
- Highways Agency expenditure;
- The Sir Howard Davies Airports Commission work;
- Analysis of high speed rail serving London; and
- Other expenditure planned at London's main airports.

We have developed a preliminary review of new schemes, based upon population projections and different development scenarios and have then undertaken a cost assessment for them. Different transport investment options for the capital have been commissioned by a range of local and central government agencies and commissions and private and public companies.

The scope of transport investment in London is broad. National, local and regional government bodies invest directly in transport in London. This is supplemented by private sector investment. Where spending is across a number of regions, we have deemed a "London share" based on the geographical spread

of the asset and its users and beneficiaries.¹⁰ We have worked closely with TfL and the GLA in order to establish an indication of London's future aviation, rail, road and other transport infrastructure requirements. In the first instance, we have relied upon TfL's own business planning documentation.¹¹ We have also sought to provide an independent view of future expenditure requirements. As a result, the list of projects contained in this report differs from the "long list" originally provided to us by TfL. We have prioritised, phased and structured the delivery of major projects according to current and emerging policy imperatives, guidance from the GLA and TfL and our professional opinion.

Policy drivers in the transport sector lie behind a significant share of London's future investment requirements and a significant increase in proposed capital enhancements over the next ten years. In particular, aviation capacity development is projected to require significant expenditure. The developed of new Underground lines and HS2 will add to this.

Because a preferred option for aviation capacity has not yet been determined, we have considered transport infrastructure schemes proposed during the study period according to several different spatial development scenarios, accounting for aviation capacity and other development options, as well as population growth.

These scenarios vary according to the location of development within or beyond London's current boundaries and the aviation scenarios that have been taken forward in the Davies Commission work. The Mayor's preferred development scenario is the creation of an airport in the Thames Estuary.

In line with instructions from the GLA, we have adopted the Mayor's preferred development scenario in presenting total costs in this report. Looking beyond these significant enhancements, we have independently considered the type and level of more incremental growth in infrastructure that could be necessary to support London's increasing population, including extensions to the Underground network and surface transport improvements. Detailed discussion of the different aviation scenarios and the costs projected for each is found in section 3.1 of this report.

We discuss our approach in greater detail in chapter 3, in which we also set out transport cost projections. Appendix A4 provides further discussion of transport model inputs and assumptions. In chapter 10, we consider the projected gap between projected costs and funding sources.

¹⁰ London borough spending on matters such as parking and concessionary fares has been excluded. Highways Agency spend other than the M25 Connect Plus PFI has not been estimated (nor that for Southend Airport). We have also not included TfL income or expenditure on interest on current account balances.

¹¹ We derive baseline capital estimates associated with aviation capacity development from the Airport Commission's reports. We have included in our estimates TfL estimates of additional capital requirements likely needed at Heathrow for the sake of comparing the option of developing a Thames Estuary Airport with expanding Heathrow.

1.2.1.8 Energy infrastructure approach

In the energy sector, we have modelled cost projections according to two scenarios for the industry's development: a 'hybrid' scenario and a 'centralised' scenario. Centralised electricity production and supply is likely to be based on new nuclear power, wind and Carbon Capture and Storage (CCS). In a hybrid model, cities will become increasingly more energy efficient and self-sufficient. Energy infrastructure will adapt to changing demands to deliver environmental benefits and lower energy costs. The Mayor's policy is to secure 25% of London's energy requirements according to a decentralised model by 2025.

The analysis uses the 2050 Pathways Calculator – originally developed by the Department for Energy and Climate Change (DECC) in 2010 and regularly updated since then – to develop a baseline energy supply/demand system. The Pathways Calculator allows users to develop their own combination of levels of change to achieve an 80% reduction in greenhouse gas emissions by 2050, whilst ensuring that energy supply meets demand.

We have modified the output of the calculator with London-specific ratios and factors to determine the amount and type of energy delivered by 2050 and capacity to be built. This modification enables sensitivities and scenarios to be developed around certain specific objectives, for example to achieve the Mayor's decentralisation target.

The model based on the calculator produces energy flows and capacity figures. Our analysis then assesses the investment in capital infrastructure associated with such energy flows and capacity. We use publicly available sources to estimate total investment expenditure, using costs of existing projects and projected unit costs.

We discuss our approach in greater detail in chapter 4, in which we also set out energy infrastructure cost projections. Appendix A5 provides further discussion of energy model inputs and assumptions. In section 10.3, we consider the effect significant capital expenditure could have upon energy and other utility bills, including the waste and water sectors.

1.2.2 Funding gap and revenue projection approach

In order to inform an understanding of future funding requirements, the GLA requested that Arup provide a preliminary indication of the 'gap' between projected costs and revenues. Informed by discussion with the GLA, its advisory group and other stakeholders, our analysis has varied across the different sectors considered. Given variation in our approach and some of the assumptions made, the gap estimated is intended for indicative purposes and should not be considered complete, as we discuss below.

We have focused upon the transport and housing sectors in particular detail, as these two sectors represent the large majority of projected capital expenditure over the study period and are likely to be funded in part by local government. Our approach has been to provide an indicative estimate of the gap between projected

expenditure requirements and projected revenues from taxes, grants, borrowing¹² and other such sources.

We have removed from consideration the costs associated with projects likely to be funded entirely by central government, such as national rail investment. We also have removed from consideration the costs associated with private-sector development. In the housing sector, this relates to market-rate housing. In the transport sector, this relates primarily to the costs associated with aviation capacity development, which we have assumed will be met by the private sector and recovered through user charging.¹³ In both the housing and transport sectors, we have differentiated between operating and capital funding requirements and made assumptions around the potential for revenues (from housing rents and transport fares) to address operating and capital expenditure requirements.

User charges, particularly in the utilities sectors, are likely to fund a significant portion of both operating and capital expenses. In the energy sector, for example, financing for generation and network infrastructure is put in place by the generation and network companies - primarily in the form of equity, bonds and bank loans – secured against the revenue generated through consumer bills. Because of this, we have agreed with the GLA to focus on the potential impact of projected expenditure on bills. In the energy sector, our analysis relies upon assumptions around changes in demand for energy, the types of projects likely to receive funding and the costs likely to be borne by the public sector.¹⁴

In the water sector, we have relied upon estimates published by Thames Water to understand the potential impact of significant capital investment. In the waste sector, we have considered changes to GLA estimates of local authority waste bills by estimating the effects projected expenditure will have on per capita and household user charging.

For the remaining infrastructure sectors, our approach has been to assume that projected costs at present are 'unfunded'. Expenditure requirements projected in these sectors are not linked to particular revenue streams, funded instead by a mixture of grants, private-sector contributions, other subsidies and via local authorities' general accounts. Any 'gap' will need to be funded by a combination of (re-allocating) existing resources, identifying new sources of revenue, accessing new capital receipts or through user charges.

In addition to considering the potential for reducing costs, the GLA requested that Arup consider a range of new revenue mechanisms that could support closing the

¹² As we later note, it has been agreed with the GLA that borrowing potential should be carried forward as a source of revenue but that debt servicing costs should not be included in our projections. This makes it likely that our estimate of the gap between costs and revenues is conservative, below the amount likely to be required in order to meet expenditure requirements and debt servicing costs.

¹³ Excluding aviation costs allows our analysis to focus on more certain future costs as the Davies Commission continues to address questions around the region's aviation capacity.

¹⁴ Our analysis relies upon central government assumptions around energy efficiency and consumption. We have assumed an improvement in energy efficiency and an overall reduction in energy consumption per capita, but we expect consumption of electricity to increase.

gap between projected expenditure requirements and existing revenues. We have considered a wide range of potential sources, providing a rough estimate of the potential revenues that could be generated. These projections are discussed below in section 1.12 and in chapter 12.

Addition discussion of our approach to estimating the funding gap is found in chapter 10 and in appendix A11.

1.2.3 Assessing the benefits of investment and links between sectors

The primary focus of this work has been to assess the potential costs associated with London's projected infrastructure requirements. We have also considered the potential benefits associated with investments, completing this analysis at a high level. Arup has reviewed some of the existing literature related to the different sectors in order to provide a preliminary indication of the benefits associated with infrastructure investment. Feasibility studies and/or cost-benefit analysis for individual projects have not formed part of the scope for this study. Projected capital requirements

Approximately £1,324 billion of capital expenditure (enhancements and renewals) is projected to be required between 2016 and 2050. Projected expenditure requirements include costs borne by both the public and private sectors.

Infrastructure type	Projected capital expenditure, 2016-2050 (£ billion) (2014 prices)	% total
Housing	547	42%
Transport*	466	35%
Energy	148	11%
Schools	68	5%
Water*	49	4%
Green*	22	2%
Waste	14	1%
Digital connectivity	8	1%
Total (£ billion)	1,324	100%
<p><i>*In order to more accurately reflect projected investment requirements associated with London's green infrastructure, portions of capital expenditure projected in the transport and water sectors have been re-allocated to the green sector in this summary chart. 10% of projected World City enhancement and renewal expenditure (including expenditure for projects identified by the Mayor's Roads Task Force), totalling £8.5 billion, has been moved from transport to green infrastructure. All flood risk mitigation enhancement capital expenditure, totalling £11.8 billion, has been moved from the water sector line to be included in green infrastructure. These figures are re-allocated back to the transport and water sectors in later charts and graphs in this section of the report and within the sector-specific cost and funding chapters.</i></p>		

Figure 2: Projected capital expenditure requirement by sector (including enhancements and renewals), 2016-2050 (£ billion). 2014 prices, including a 2% per annum underlying increase in construction costs. Source: Arup analysis

Enhancements to London's existing infrastructure asset base are projected to comprise some four-fifths of this cost, nearly £1,000 billion. Renewals expenditure, relating both to new assets and to the existing infrastructure, could total an additional £324 billion.

On average, these projections show that roughly £150 billion of capital expenditure for enhancements could be required every five years. An additional £50 billion is projected to be required each five-year period in relation to renewals of the asset base. These figures represent an increase relative to indicative estimates of recent infrastructure expenditure. In the most recent five year period, between 2011 and 2015, indicative estimates show that some £80 billion has been dedicated to capital expenditure.

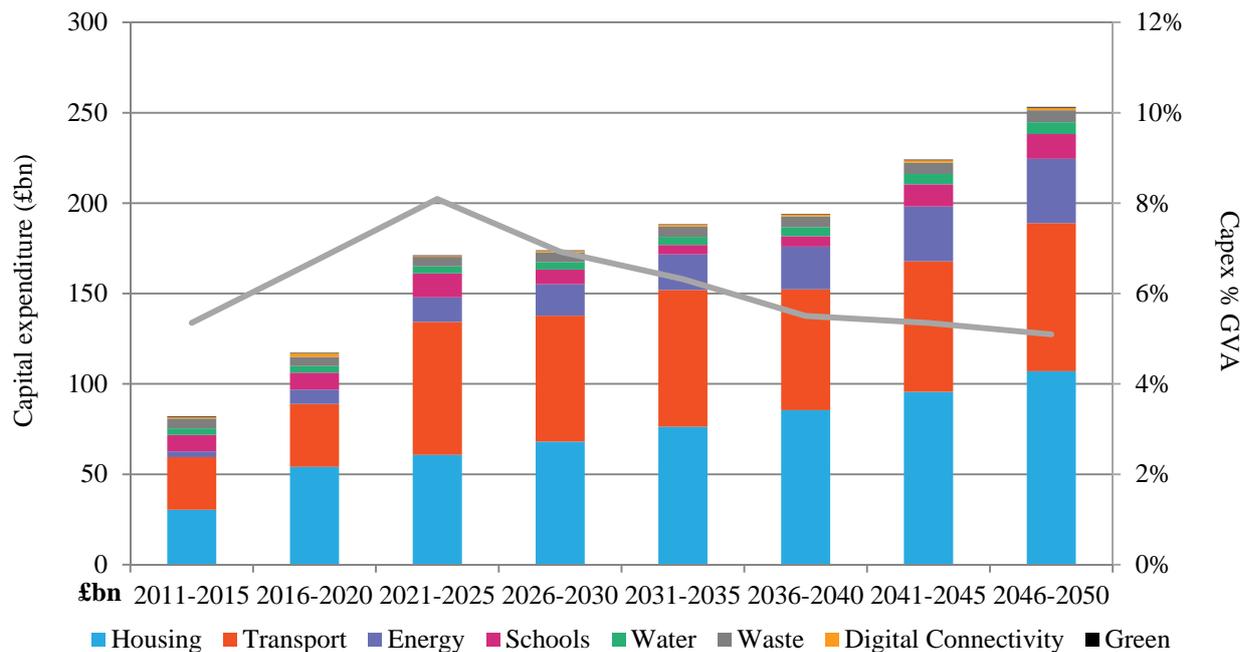


Figure 3: Projected capital expenditure (including enhancements and renewals) by five-year period, 2016-2050, and projected capital requirements as a percentage of estimated GVA (£ billion). 2014 prices, including a 2% per annum underlying increase in construction costs. Source: Arup analysis

Capital investment (including enhancements and renewals) requirements are projected to increase as a percentage of GVA by 2025. As shown in the figure above, capital expenditure requirements are projected to grow significantly in the early 2020s. Between 2021 and 2025, it is projected that capital expenditure (including both enhancements and renewals) will represent some 8% of GVA. A large portion of capital expenditure requirements projected in the early 2020s relates to transport system enhancements. These include the development of an airport in the Thames Estuary, London Underground renewal and enhancement plus London's share of the costs associated with HS2 and national rail enhancements.

In later periods, it is projected that capital requirements will decline as percentage of GVA. By the middle 2030s, it is projected that capital expenditure requirements (enhancements and renewals) will fall to some 5.5% of projected economic output (GVA). This figure is roughly equivalent with estimates of current expenditure as a percentage of GVA.

In the 2040s, it is projected that capital expenditure will fall to some 5% of GVA. This decrease is projected despite a 'rolling forward' of enhancement expenditure (where appropriate); despite increasing capital expenditure requirements associated with the renewal of the growing asset base and despite the inclusion of underlying construction industry price growth in our cost estimates.

On average, these projections show that in broad terms, London will need to increase its level of expenditure relative to GVA output by some 1.5%, to meet its growing infrastructure requirements.

Projected ratios of capital expenditure to GVA may represent conservative estimates of costs relative to economic output from the perspective of the public purse. These figures include the costs of private sector housing development,

which could total roughly one half of all housing capital expenditure. Removing capital costs associated with private sector housing provision, total capital expenditure (including enhancements and renewals) peaks below 7% of GVA between 2021 and 2025, falling below 4% of GVA by 2050. Removing potential private sector capital expenditure, these projections show that London will need to increase its level of expenditure relative to economic output, on average, by around 1% in broad terms over the study period.

These projections of future capital expenditure exceed the amount associated with the current project pipeline identified by government. The National Infrastructure Plan (2013) sets out the costs associated with projects already in the planning process.¹⁵ Considering the current pipeline, HM Treasury has identified projects requiring some £36 billion of capital expenditure.¹⁶ Considering a long-term horizon and a wider range of infrastructure types, this work differs in scope and focus from the Plan. The Plan's focus is arguably far more immediate; identified projects to be delivered "to 2020 and beyond." Arup's higher projections reflect a longer term horizon and an approach based on an assessment of schemes required to underpin the long term prosperity of London and its rising population.

Our analysis indicates that investment in London's infrastructure will need to be maintained and increased in order to sustain population and economic growth. As with Arup's long-term projections, the UK government's projections show that a large portion of investment is accounted for by transport projects and programmes. These government projections do not include social infrastructure sectors.

1.2.4 Capital expenditure cost range

The level of investment achieved in the coming decades will reflect London government's choices around the capital's most pressing requirements and the prioritisation of different sectors and projects. There will be opportunities to deliver infrastructure more efficiently. Our review of HM Treasury analysis, other government sponsored analysis, industry trends and innovation and technological development shows that cost could be reduced by some 10% to 15%.

¹⁵ HM Treasury, *National Infrastructure Plan 2013*, December 2013, p. 24, available: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/263159/national_infrastructure_plan_2013.pdf.

¹⁶ HM Treasury, *National Infrastructure Plan 2013*, December 2013, p. 30.

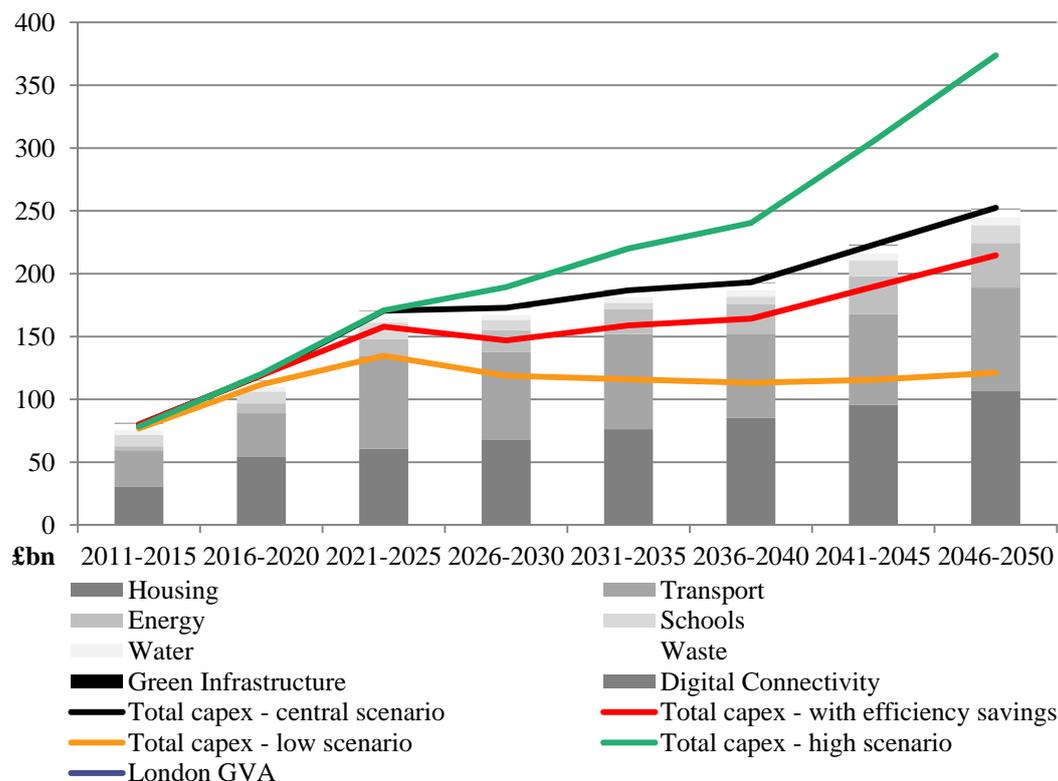


Figure 4: Projected capital expenditure required by five-year period, 2016-2050 and projected total capital expenditure. The red line indicates potential savings due to efficiency measures. (Savings from changes to individual projects are not included in the figure.) Source: Arup analysis

We have modelled cost savings such that they are achieved gradually over the coming decade, recognising that it would not be prudent to assume cost savings can be achieved spontaneously. Our projections assume that London will be able to achieve savings of some 7.5% relative to current cost projections by 2025 and some 15% by 2030, with savings then embedded in the supply chain. We discuss the potential for savings further in chapter 11 of this report.

In addition to considering potential savings achieved through efficiency measures and project coordination, the GLA requested that Arup consider a potential range of cost scenarios relative to the 'base case':

- Underlying construction cost inflation (1% per annum and 3% per annum);
- Population (low and high case); and
- Different efficiency gains (5% and 10% rising to 25%).

An illustration of how the capital costs diverge is presented in the figure below. Under a 'low' scenario the costs post 2020 remain relatively flat in real terms from 2030. Under a 'high' scenario, a combination of higher construction cost inflation and lower efficiencies increases capital costs in the early period, with a marked increase from 2040 driven by forecast population growth in the 2040s.

In the low scenario, capital expenditure is projected to increase to some £162 billion in the five years between 2046 and 2050. This figure compares with some £254 billion in the five years between 2046 and 2050 in the central scenario and some £411 in the five-year period in the high scenario. Whilst some £1,324 billion of capital expenditure is projected in the central scenario, it is projected that total capital expenditure between 2016 and 2050 could fall within a range of £1,000 billion and some £1,750 billion.

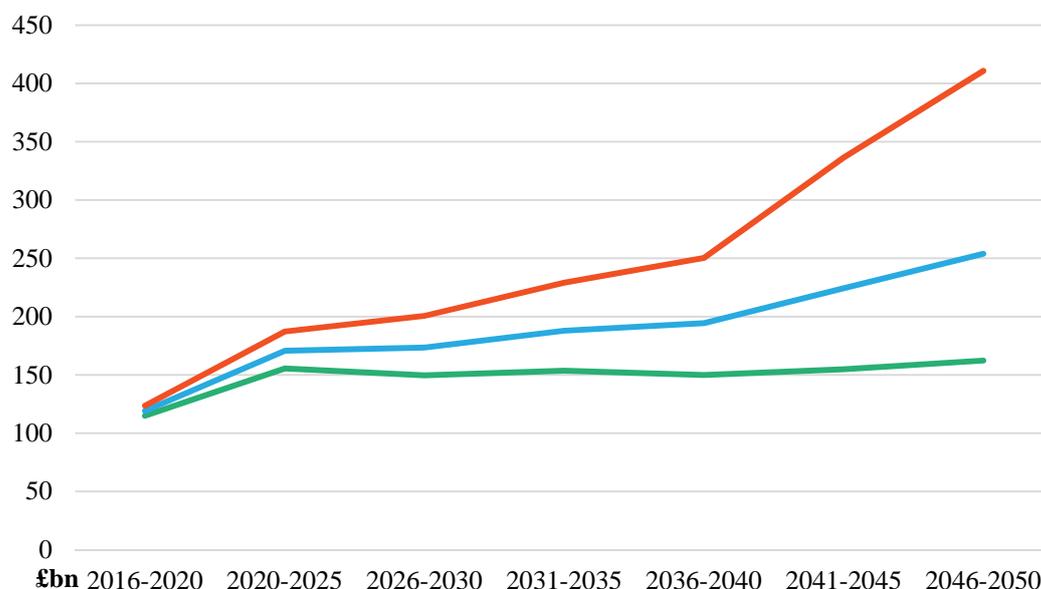


Figure 5: Low, central and high scenarios showing a range of projected capital expenditure required in each five year period. The central scenario corresponds with the capex totals shown previously (not accounting for efficiency savings). The high scenario relates to high population forecasts and high levels of construction inflation. The low scenario relates to the low population forecast, low levels of construction inflation and high efficiency savings (£ billion; 2014 prices). Source: Arup analysis

1.2.5 Projected operating investment requirements

Operating expense requirements are projected to align with capital requirements in the period. Between 2016 and 2050, approximately £970 billion of operating expenditure is projected to be required across London's different infrastructure sectors.

Infrastructure type	Projected operating expenditure, 2016-2050 (£ billion) (2014 prices)	% total
Transport	507	54%
Housing (all sectors)	253	27%
Energy	75	8%
Water	33	3%
Schools	77	5%
Waste	26	3%
Green*	0.4	1%
Digital connectivity	1.8	1%
Total	£973	100%
*Excludes operating costs associated with transport and water infrastructure assets; these costs are allocated to their respective sectors.		

Figure 6: Projected operating expenditure, 2016-2050 (2014 prices).

A large portion of operating expenditure is projected to relate to the city's transport system and housing stock. Transport operating cost requirements, including routine operating of the Underground, rail, bus networks, are projected to exceed £500 billion in the period. Housing operating expenditure requirements, projected to exceed £250 billion in the period, include routine maintenance costs for upkeep of buildings but not domestic utility bills (e.g. gas, electricity, telephone). All other sectors follow this general principle.

1.3 Housing infrastructure costs

A significant amount of detailed housing supply and demand modelling has already been conducted by the GLA. Most recently, the Mayor set out projections of London's current and future housing requirements in the 2013 London Strategic Housing Market Assessment (SHMA), released in January 2014.¹⁷ This work is in line with the government's National Planning Policy Framework (NPPF) and builds on similar previous analysis.¹⁸ These studies estimate the number of new homes needed in London by tenure and type and also includes detailed analysis of the housing requirements of important sub-groups of the

¹⁷ Mayor of London, *The London Strategic Housing Market Assessment 2013*, January 2014, available: http://www.london.gov.uk/sites/default/files/FALP_SHMA_2013_0.pdf.

¹⁸ Mayor of London, *Greater London Strategic Housing Market Assessment 2008*, April 2009, available: <http://legacy.london.gov.uk/mayor/publications/2009/docs/strategic-housing-report.pdf>.

population. Arup has not sought to replicate these studies, although we comment on risks around the delivery of projected housing units, and the potential effect under-delivery could have on projected costs, in the housing chapter of this report.

Arup has completed two cost scenarios for the housing sector. The first relates to the SHMA, assuming London's supply of new housing units will be 48,840 per year in all future years to 2050. The second relates to minimum requirements set out in the London Plan, assuming London's supply of new housing will be 42,000 units per year in all future years to 2050.

In this section, we present the costs projected for the SHMA scenario, assuming 48,840 units are delivered annually and roughly half of these units are affordable housing.

1.3.1 Overview of projected capital and operating expenses

Figure 7 overleaf shows capital (enhancements and renewals) and operating expenditure projected to be required for London housing, including both market-rate and affordable units, between 2011 and 2050.

Capital enhancement costs relate to the development of new housing units (both market-rate and affordable) and include land and construction costs.

Renewals costs relate to new market-rate and affordable housing units (after they are constructed) and to existing affordable and social housing.¹⁹

Operating expenses relate to routine maintenance expenses and exclude utility costs. They are presented for new housing units only. All costs projected are shown in 2014 prices, including a 2% increase per annum of capital costs (both enhancements and renewals) due to construction industry price growth.

¹⁹ Renewals costs have been estimated according to lifecycle renewal of structural elements, such as roofs, floors and ceilings, as well as replacement of significant fixtures and fittings, such as doors and windows. Costs associated with the renewal of existing market-rate housing have been excluded from our analysis.

£bn 2014 prices, five year period ending	2011-2015	2016-2020	2021-2025	2026-2030	2031-2035	2036-2040	2041-2045	2046-2050	Total 2016-2050	CAGR 2016-2050
Capex	30	54	61	68	76	85	96	107	547	2%
Enhancements	21	44	49	55	61	68	76	85	437	2%
Renewals	9	10	12	13	15	17	20	22	110	3%
Opex	3	7	13	21	32	44	59	76	253	8%
Housing total	33	61	74	89	108	130	155	183	800	4%

Figure 7: Projected capital and operating cost requirements by five-year period, 2011-2050, market rate and affordable housing. 2014 prices, including c.2% p.a. construction industry price growth for capital expenditure requirements. Source: Arup analysis

In the period from 2016 to 2050, using the assumptions noted above, we estimate housing-related expenditure, including both the private and public sectors, of some £800 billion. Capital expenditure, including enhancements and renewals, is projected to total some £547 billion in the period, representing some 68% of total projected housing costs. Of this capital expenditure, the costs associated with new unit delivery in the public and private sectors are projected to total some £437 billion, reflective of the large number of new units required.

Projected enhancement costs are split nearly evenly between market-rate and affordable housing, given the SHMA's assumptions about the future of London's housing market. In the SHMA scenario, affordable housing comprises about half of all new units built until 2050. Affordable housing enhancement costs (land and construction) are projected to total some £216 billion in the 35 years to 2050. In the same period, private sector housing construction costs (construction and land) are projected to total some £221 billion.

The on-going renewal of both new and existing housing in London is projected to require some £110 billion between 2016 and 2050. It is assumed that renewals costs will relate to on-going lifecycle renewals (such as replacing roofs and floors) as well as on-going investment in energy efficiency and other 'decent homes' type investment in London's existing affordable housing stock.²⁰ Capitalised renewal of London's affordable housing units is projected to total some £92 billion between 2016 and 2050. Our projections also include the costs estimated to be required for lifecycle renewal of London's new housing stock. The renewal of new housing (including both market-rate and affordable units) is projected to require some £18 billion between 2016 and 2050. Approximately half of these new unit renewals costs will relate to affordable housing units.

In total, some £253 billion of operating expenditure²¹ is projected to be required between 2016 and 2050, increasing from £7 billion in the five years between 2016 and 2020 to some £76 billion between 2046 and 2050. Maintenance expenditure is projected to increase significantly with the number of dwellings in London, rising at an average annual rate of 8% between 2016 and 2050.

²⁰ We have assumed London boroughs' existing housing stock totals some 410,000 units, whilst providers' housing totals some 391,000 units. We have estimated that the renewal of existing private registered provider housing to total some £21 billion in the period. The renewal of existing London borough housing is projected to total some £60 billion in the period.

²¹ Note that other operations costs, including utilities and cleaning, are excluded from these costs projections.

In the five year period to 2020, it is projected that capital expenditure (on new housing in addition to renewals activity) could grow from an estimated £30 billion to £54 billion (for the previous five year period), if London delivers the new housing requirements set out by the Mayor.²²

1.4 Transport infrastructure costs

Working with the GLA and Transport for London (TfL), we have considered future requirements to provide a preliminary estimate of the capital expenditure and operating costs associated with the continued growth and renewal of the city's transport system. Our analysis is based upon:

- TfL's latest business plan and analysis of its historical expenditure;
- A review of trends and plans for the national rail network;
- Highway Agency and London borough activities;
- The Sir Howard Davies Airports Commission²³ work;
- Analysis of high speed rail serving London; and
- Other expenditure planned at London's main airports.

We have developed a preliminary review of new schemes, based upon population projections and different development scenarios and have then undertaken a cost assessment for each of them. Different transport investment options have been commissioned by a range of local and central government agencies and commissions, and private and public companies.

Important questions about the future of aviation capacity in the region are currently being considered. Because a preferred option for aviation capacity has not yet been determined, we have considered transport infrastructure schemes proposed during the study period according to several different spatial development scenarios, accounting for aviation capacity and other development options, as well as population growth. These scenarios vary according to the location of development within or beyond London's current boundaries and the aviation scenarios that have been taken forward in the Davies Commission work.²⁴ The scenarios we have considered are outlined in section 3.1 of this report.

The analysis below focuses on the development of a new airport in the Thames Estuary, which is the Mayor's preferred strategy for increasing the region's aviation capacity. A summary of the costs associated with other aviation capacity development scenarios is found in section 3.2 of this report.

²² Please note that these are indicative costs rather than outturn costs. Arup unit rates (including construction and land costs) have been applied to the average number of units delivered over a typical five-year period.

²³ Airports Commission, Interim report, December 2013, available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/271231/airports-commission-interim-report.pdf

²⁴ Due to timing, our report does not take into account the consultation documents covering the Inner Thames estuary airport issued by the Davies Commission on 10 July 2014.

1.4.1 Overview of projected capital and operating costs

We have assessed London's transport requirements according to three expenditure areas. Figure 8, below details capital expenditure for enhancements, capital expenditure for renewals, and operating and maintenance expenses. Capital expenditure for enhancements includes major new projects. Capital expenditure for renewals includes the costs associated with major repair and replacement of the growing asset base. Operating and maintenance expenditure is for both new and existing assets.

£bn 2014 prices, five year period ending	2011-2015	2016-2020	2021-2025	2026-2030	2031-2035	2036-2040	2041-2045	2046-2050	Total 2016-2050	CAGR 2016-2050
Capex	29	35	74	70	76	67	72	82	475	2.9%
Enhancements	21	26	63	55	58	48	50	56	358	2.6%
Renewals	8	8	11	14	17	19	22	26	117	4.0%
Opex	49	52	60	71	77	78	82	87	507	1.7%
Transport total	78	87	134	141	153	145	154	169	982	2.2%

Figure 8: Projected capital and operating cost requirements by five-year period, 2011-2050. 2014 prices, including c.2% p.a. construction industry price growth for capital expenditure requirements. Source: Arup analysis

We project that London's transport system could require some £475 billion of capital investment (enhancements plus renewals) in the 35 year period to 2050. Total expenditure (including both capital and operating expenditure) could rise from some £78 billion over the five years to 2020 to some £169 billion in the five year period between 2046 and 2050.

Projected growth in expenditure is expected to be driven by a steady expansion of enhancements and renewals needed to get more out of London's existing transport system, along with substantial expenditure on new strategic rail links, road improvements and aviation capacity development. Renewals, operations and maintenance expenditure are estimated to ramp up as the overall asset base increases in size.

Projected expenditure arguably represents a manageable proportion of London's economic output. Capital expenditure is projected to total between 1.6% and 3.5% of GVA, per five year period, in the years between 2016 and 2050. This compares with an estimated 1.9% in the period to 2015.²⁵ Transport capital expenditure is projected to peak during the five-year period between 2021 and 2025,²⁶ when it could represent some 3.5% of the London's total economic output (GVA). By removing major schemes, projected capital expenditure would fall, at peak, from 3.5% of GVA, to 1.9% of GVA.

Higher expenditure in this period is projected to relate to construction costs of major schemes, including London's share of projects of national significance such as HS2 and the Estuary Airport (without accounting for benefits). Accounting for

²⁵ Based on Arup's review of expenditure within the period between 2011 and 2015. As this 'baseline' figure is likely to differ slightly from actual levels of expenditure, it is presented for indicative purposes only.

²⁶ This is the peak in terms of expenditure as % of GVA. The peak in terms of expenditure in absolute terms is later, between 2046 and 2050.

construction industry price growth during the study period, some £358 billion of enhancement expenditure is projected between 2016 and 2050. Aviation capacity development, TfL investment programmes and national rail investment together comprise the majority of this expenditure:

- It is estimated that a new airport in the Thames Estuary will require some £72 billion of enhancement expenditure between 2016 and 2050. In addition, some £24 billion of enhancement expenditure is projected to be required for non-Thames Estuary airports between 2016 and 2050.
- TfL's different enhancement schemes, detailed in section 3.4.1.1, are projected to require some £219 billion of expenditure in the study period, between 2016 and 2050. 'World City' enhancement expenditure is anticipated to require some £85 billion of expenditure over the study period, from 2016 to 2050. Expenditure proposed by the Mayor's Roads Task Force comprises a considerable share of World City enhancement expenditure requirements.
- London's share of HS2 enhancement expenditure has been factored in to our numbers for the first half of the next decade. Additional expenditure in London also is projected to be required in relation to national rail enhancements every five years. In total, rail enhancement investment is projected to require some £39 billion over the study period.

1.5 Energy infrastructure costs

The Mayor's carbon emissions and energy targets and their interaction with national objectives are fundamental drivers of the type of energy infrastructure investment that will be required and the costs associated with new infrastructure development. The Mayor's 2011 Climate Mitigation and Energy Strategy,²⁷ which covers the period up to 2025 and the route towards 2050 targets, advocates a move away from a reliance on national energy sources and supply towards a more London-centric approach. It argues that while London's energy future is inextricably linked to that of the UK as a whole, it stands to reap economic and environmental benefits from pressing ahead with its own energy demand reduction and energy supply programmes.

In developing scenarios for a 2050 energy infrastructure plan, Arup's review uses the objectives of the 2011 Mayor's Strategy for 2025 as its basis for analysis. Wherever possible, it remains consistent with the objectives and measures to achieve the strategy. At the same time, it also aims to be reflective of national energy policy assumptions and objectives. We have undertaken a preliminary cost assessment associated with a number of different scenarios. The cost projections set out in this chapter relate to two scenarios: a 'centralised' scenario and a 'hybrid' scenario.

- In a centralised scenario energy is primarily supplied via national networks with electricity production and supply likely to be based on new nuclear

²⁷ Mayor of London, *Delivering London's Energy Future: the Mayor's climate change mitigation and energy strategy*, October 2011, available: <https://www.london.gov.uk/priorities/environment/publications/delivering-londons-energy-future-the-mayors-climate-change-mitigation-and-energy-strategy>.

power, wind and gas-fired electricity generation with Carbon Capture and Storage (CCS), and a significant level of electrification of heat and transport.

- In a ‘hybrid’ scenario, cities will become increasingly more efficient and self-sufficient and therefore less reliant on national networks – even though national networks will retain a role in delivering energy supply.²⁸ This scenario would support Mayor plans to supply 25% of London’s energy requirements according to a decentralised model by 2025.

Below we present the costs associated with the hybrid scenario. We differentiate between direct and indirect investment. Indirect investment is expenditure for infrastructure to be built and operated outside London but which serves London. This is the generation, supply and transmission infrastructure which is necessary to supply London with energy for power and gas. In all scenarios, most of London’s energy will be connected to the national grid. The indirect investment in capital expenditure is modelled as London’s share of national investment.

Direct investment is expenditure in infrastructure to be developed and built within London, financed directly or indirectly by London consumers. In this category we can distinguish between three types of investment: distribution network investment; non-regulated infrastructure investment; domestic and small-scale commercial energy efficiency and low-carbon technology investment.

1.5.1 Overview of projected capital and operating costs

As can be seen below, Figure 9 shows capital and operating expenses projected to be required in the energy sector. Capital expenses include both renewals and enhancement costs. We discuss the assumptions guiding enhancement, renewal and operating expenditure projections in section 1.2.1.8 of this chapter, chapter 4 of this report and in appendix A5. Projections are shown in 2014 prices but with the inclusion of underlying construction price growth at a rate of 2% per annum for capital expenditure.

£bn 2014 prices, five year period ending	2011-2015	2016-2020	2021-2025	2026-2030	2031-2035	2036-2040	2041-2045	2046-2050	Total 2016-2050	CAGR 2016-2050
Capex	3	8	14	17	20	24	30	36	148	5.1%
Opex	8	9	10	10	11	11	12	12	75	0.9%
Energy total	11	17	23	28	30	35	42	48	223	3.5%

Figure 9: Projected capital and operating cost requirements by five-year period, 2011-2050. 2014 prices, including c.2% p.a. construction industry price growth for capital expenditure requirements. Source: Arup analysis

London’s energy infrastructure requirements are projected to total some £223 billion over the period between 2016 and 2050 (including capital and operating expenses). Capital expenditure requirements, including both enhancements and renewals, are projected to total some £148 billion, representing 66% of total

²⁸ Hence the name ‘hybrid’ given to this scenario: a further scenario, which has not been considered in this analysis could have seen a full ‘decentralised’ model being adopted with limited role for central networks and centralised energy supply.

projected expenditure. Operating expenditure is projected to total some £75 billion.

Of total projected investment, some 68% is projected to relate to indirect investment. Indirect investment is projected to total some £151 billion over the period to 2050 (including capital and operating expenses). This figure comprises £48 billion of projected capital costs (enhancements and renewals), with the remainder associated with projected operating expenditure requirements. Projected requirements equate to indirect annual capital expenditure of around £1.3 billion over the period.

Direct investment in London is projected to total some £72 billion over the period to 2050 (including capital and operating expenses). Almost half of direct capital expenditure projected is associated with electricity and gas network investment. Slightly more than one quarter of projected direct capital investment is associated with district heating networks and local combined heat and power (CHP). The remaining quarter of projected direct capital investment is associated with other renewable technologies, such as PV, heat pumps and solar thermal.²⁹ Approximately 16% of the total investment is expected to be delivered by 2025.

As we detail in chapter 4, our projections show that the difference between the two scenarios' total costs (capital and operating expenses) is some 10% over the study period, with the centralised model being the more costly of the two. This difference is a reflection of the significant changes needed to London's energy supply under both scenarios; even in a more traditional, centralised route, the considerable level of investment required. In the hybrid scenario, £223 billion of expenditure, including £148 billion of capital expenditure) is projected to be required between 2016 and 2050.

1.6 Water infrastructure costs

There are increasing pressures on the capital's water system, which arise from the dense urban environment that has developed in close proximity to the River Thames and its many tributaries. The forecast increase in population living in London means that there will be increased demand for drinking water in a region where there is arguably already scarce water supply. Climate change could exacerbate the potential imbalance between supply and demand, as patterns of rainfall change in the future. Adaptation of the existing water infrastructure will be required in order to address population growth and to cope with these changes.

Major investment projects in the water sector are reasonably well defined and understood, even though there is some uncertainty over the scale and timing of investments towards 2040. There will need to be on-going investments to maintain the existing water-related infrastructure such as the water and wastewater networks, treatment plants and the existing flood-defence assets. This investment requirement will also present an opportunity to improve the capacity and performance of these assets and, importantly, to identify the synergies between sectors that will help to optimise the investment.

²⁹ These figures include both enhancements and renewals.

1.6.1 Overview of projected capital and operating costs

Figure 10 below shows capital (enhancements and renewals) and operating expenditure projected to be required for London's water infrastructure between 2011 and 2050. All costs projected are shown in 2014 prices, including a 2% increase per annum of capital costs (both enhancements and renewals).

In broad terms, it is projected that water infrastructure expenditure will total some £95 billion between 2016 and 2050. In that period, it is projected that capital costs will comprise some two-thirds of the annual total, or £61 billion between 2016 and 2050.

Thames Tideway Tunnel, smart metering investment and flood defence expenditure comprise the majority of enhancement expenditure, in addition to the level of expenditure on maintaining and operating the existing assets. It is projected that operational expenditure will steadily rise with the water sector's growing asset base, with an average £34 billion over the period.

£bn 2014 prices, five year period ending	2011-2015	2016-2020	2021-2025	2026-2030	2031-2035	2036-2040	2041-2045	2046-2050	Total 2016-2050	CAGR 2016-2050
Capex	5	9	7	7	8	9	10	11	61	1%
Renewals	3	4	4	5	6	6	7	8	40	3%
Enhancements	2	6	3	2	2	3	3	3	21	-2%
Opex	4	4	4	4	5	5	6	7	33	2%
Operations	3	3	3	3	4	4	5	5	27	2%
Maintenance	1	1	1	1	1	1	1	1	7	2%
Water total	9	13	11	11	12	14	15	17	94	1%

Figure 10: Projected capital and operating cost requirements by five-year period, 2011-2050. 2014 prices, including c.2% p.a. construction industry price growth for capital expenditure requirements. Source: Arup analysis

Expenditure in the five year period between 2016 and 2020 is projected to be high given the construction of the Thames Tideway Tunnel. The project represents planned enhancement capital expenditure of some £4.2 billion in total.³⁰ It is assumed that £0.5 billion of that total will have been spent before 2015, with the remainder required between 2015 and 2020 based on our discussions with Thames Tideway team.

The £4.2 billion project (unindexed) is required to ensure that the UK complies with the obligations of the EU Urban Wastewater Treatment Directive (UWWTD) in relation to the discharge of untreated sewage into the River Thames from the combined sewer network. This currently happens sometimes after even relatively modest rainfall. Whilst the project continues to attract some criticism for not being the most cost-effective solution to dealing with the lack of capacity in the existing combined sewer, there is arguably no realistic alternative that will deliver the outcome required by the UWWTD, regardless of the level of population growth that occurs within the study period.

³⁰ Individual project enhancement figures are not indexed according to inflation, as they are inputs to the cost model.

In later years, enhancements comprise measures to increase flood resilience and the continued introduction of smart metering. Flood defence-related expenditure is projected to total some £0.9 billion of enhancement expenditure before 2050.³¹ Smart metering investment is projected to total some £1.3 billion of expenditure before 2050. We have estimated that both the need for additional fluvial, surface water and groundwater flood protection investment are delivered from 2020 onwards, in line with our comments above.

Arup's view of capital renewals in this sector includes expenditure both on below ground infrastructure and above ground assets such as treatment works and pumping stations. It is projected that renewals expenditure will total some £40 billion in the years between 2016 and 2050, increasing at a rate of 2.5% per annum in the period. The assumption of an increasing level of expenditure reflects the fact that the assets are ageing and it is likely that an increase will be required to maintain level of service, however there is the opportunity that this cost could be mitigated if other policies such as the introduction of Water Sensitive Urban Design (WSUD) can be successfully implemented.

1.6.2 The importance of water efficiency measures to cost requirements

As previously discussed, future supply/ demand balance relies on customers reducing their use of water. This is likely to arise in part from the introduction of wide-scale water metering but we recommend that the Mayor should continue to promote water efficiency measures and work with Ofwat to secure a compulsory metering programme for London. The Mayor could provide additional support to ensure that water companies are focusing on installing water meters in all properties which have previously been considered as uneconomic to meter (e.g. apartments).

If increasing water metering and other similar water efficiency measures are not possible or do not move forward quickly enough, then a large, new reservoir could be required within the study period (i.e. before 2050). Such a reservoir would have significant cost implications for the sectors' suppliers and major stakeholders. We believe that it could, indicatively, cost around £1 billion (not included in our estimates). Before investing in such a major project, we would argue that stakeholders should ensure that other options, such as continued reduction in leakage and demand management are exhausted. Over time, it is possible that technology could make such measures increasingly affordable and easy to implement.

1.7 Education infrastructure costs

London's school-aged population is projected to rise by around 20% over the study period. By 2050, the GLA has projected around 1.8 million individuals between the ages of four and eighteen will live in London. The future capital cost of the city's education infrastructure has been arrived at by estimating the costs of additional infrastructure required serve this growing population as well as the cost of renewing London's existing stock of education infrastructure. We also have estimated costs relating to the operation of schools and education facilities.

³¹ Individual project enhancement figures are not indexed according to inflation, as they are inputs to the cost model.

To model additional capital and operating expenditure associated with pupil growth, we have allocated marginal growth of the youth population to new infrastructure, making assumptions about the number of children different school types could accommodate. We have focused on primary, secondary and sixth-form schools, serving pupils aged four to eighteen over the study period.³² Other important education infrastructure, such as further education facilities, could be required³³. These facilities were outside the scope of this initial study, which focused on the primary requirements of the youth population.

Using GLA demographic projections, we estimate that London will require some 700 new schools over the period to 2050. The greatest share of need is projected to relate to school facilities serving children aged four to ten. It is projected that some 330 new primary schools will be required. In addition, some 170 secondary schools and some 196 sixth form colleges are projected to be required.

It may be possible for school-related capital expenditure to be made more efficient. For example, converting schools or increasing class sizes rather than constructing additional facilities could reduce capital expenditure requirements.³⁴

It was beyond the scope of this study for us to incorporate assumptions around such potential savings in our cost assessment. Similarly, we do not take into account how new population growth might be allocated to 'vacated' school places in existing infrastructure. This means that there is a risk that we have over-estimated the number of new school facilities and associated costs. Further refinements to the model could help to deal with this.

1.7.1 Overview of projected capital and operating costs

Figure 11 overleaf shows capital (enhancements and renewals) and operating expenditure projected to be required for London's schools between 2011 and 2050. Capital enhancement costs relate to the development of new school facilities and include land and construction costs. Arup has included the cost of renewing existing schools in our estimates. As in other sectors, some of these costs are projected to relate to taking care of new infrastructure once it has been built.

Other renewals costs relate to existing assets include major refurbishment costs. Arup has assumed lifecycle renewal costs of 3.5% of this existing asset base,

³² For indicative purposes. School need has been determined according to demographic trend as shown on the previous page, with each school type representing one of three age groups. Specific school types, such as VA Schools, may differ from those shown. At this early stage of analysis, with costs provided for indicative purposes, we assume nurseries are included in primary schools and 'specials' into both primary and secondary. This may have the effect of under-estimating expenditure requirements. Small additional assumptions have been made around other school types in relation to renewals costs. These are outlined in the appendix to this report.

³³ The Government, GLA and London LEP has included a programme for capital investment at Further Education colleges and other skills providers in London's recently agreed Growth Deal, see p3 of https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/327605/23_London_Enterprise_Panel_and_Greater_London_Growth_Deal.pdf

³⁴ For recent record of the manner in which authorities have disposed of land, suggesting it could be used more efficiently, please see the Education Funding Agency's listing of land disposals: <https://www.gov.uk/government/publications/school-land-decisions-about-disposals/decisions-on-the-disposal-of-school-land>.

reflecting conversations with relevant bodies and the GLA indicating a slightly greater need for investment in these assets.

All costs projected are shown in 2014 prices, including a 2% increase per annum of capital costs (both enhancements and renewals) due to construction industry price growth.

£bn 2014 prices, five year period ending	2011-2015	2016-2020	2021-2025	2026-2030	2031-2035	2036-2040	2041-2045	2046-2050	Total 2016-2050	CAGR 2016-2050
Capex	9	9	13	8	5	6	12	14	68	1.3%
Enhancements	6	6	9	4	0	0	6	7	32	0.4%
Renewals	3	3	4	5	5	5	6	7	36	2.4%
Opex³⁵	3	7	10	11	11	11	13	15	77	2.6%
Schools total	12	16	23	19	16	17	25	29	145	1.9%

Figure 11: Projected capital and operating cost requirements by five-year period, 2011-2050. 2014 prices, including c.2% p.a. construction industry price growth for capital expenditure requirements. Source: Arup analysis

As can be seen, education capital expenditure requirements are projected to total £68 billion. Approximately half of all capital expenditure is projected to relate to the development of new school facilities, labelled ‘enhancements’ in the figure.³⁶ These costs are projected to total £32 billion between 2016 and 2050. Renewals costs, including the capitalised maintenance of both newly built and existing (in 2014) education assets, are projected to total some £36 billion.

Operating expenses, calculated as a fee per school place per annum, are projected to rise as over the period. In total, operating expenses are projected to total some £77 billion between 2016 and 2050.

Overall our analysis indicates that new schools and colleges will require some £145 billion in the period between 2016 and 2050.

1.8 Waste infrastructure costs

The demand for waste infrastructure is primarily driven by the permanent and transient population in London both of which generate solid waste.³⁷ As in other sectors, we have examined demand in relation to the GLA’s central population scenario, which projects that the population will exceed 11 million in 2050.

The current waste management system is designed around the “take-make-use-dispose” linear economy. It is the responsibility of the 32 London boroughs and the City of London to collect, treat and ultimately dispose of household and some

³⁵ Opex costs include professional services such as teaching.

³⁶ We note that our projections include indicative estimates of the cost of land needed for development. We have assumed that building costs (including construction and ‘fit out’) comprise 40% of total costs, and that land costs comprise 60% of total costs. We also have assumed that 20% of total land requirements can be met through the use of land already owned by the relevant public authorities.

³⁷ A number of waste streams have been excluded from the waste infrastructure cost review including construction, demolition and excavation waste (CDEW), healthcare waste and hazardous waste. These waste streams are beyond the scope of this study and/or are relatively small.

commercial waste. Waste produced by businesses is largely serviced by the private sector.

The need for new waste infrastructure is expected to increase due to a rising population, waste volume growth and various policy imperatives which will shape how household and commercial waste are treated in the future. Household waste and commercial & industrial (C&I) waste are together forecast to increase from approximately 7.4 million tonnes per annum in 2010 to about 8.6 million tonnes in 2050 (see section 7.1).

Over the medium-term, there will be more pressure on London to treat its own waste within its boundaries.³⁸ Over the long-term, population growth will put increasing pressure on London's waste infrastructure assets. Moreover, public and corporate policy interventions are supporting a transition to a 'circular economy',³⁹ which will necessitate investment in new and different types of infrastructure, even as traditional means of treatment and disposal are maintained, renewed or enhanced. These shifts will change London's future waste infrastructure requirements. In particular, by moving to a circular economy model, there would be less need for landfill disposal of waste, as more resources are progressively reused, repaired or remanufactured.

For the purpose of this study, Arup has assumed that GLA recycling targets will be met by the dates set out in policy. However, we have modelled costs according to the central scenario for reuse, repair and remanufacture (20 per cent), which we believe more realistically reflects future potential.

Approximately 30 new facilities are projected to be required over the study period, between 2016 and 2050. The majority of new facilities projected to be will be either organic waste treatment facilities or secondary material sorting and bulking facilities. In addition to these new facilities, we have been asked to assume that existing and new waste facilities are replaced every 20 years.

1.8.1 Overview of projected capital and operating costs

Two separate approaches have been developed to estimate waste infrastructure costs. The first is based on a conventional estimate of capital and operational expenditure, and the second on using 'gate fees' reflecting the cost per tonne of waste treated. The figures presented relate to a 'conventional' approach.

The conventional approach of modelling waste infrastructure costs is based on using 'unit costs' for capital expenditure of providing the relevant waste infrastructure plus operational expenditure. Waste collection costs have been included as a separate expenditure to the waste infrastructure needs, but street cleansing costs are not included.

³⁸ This is in order to meet the "self-sufficiency" and "proximity" principles set out in government's Planning Policy Statement 10 (PPS10): Planning for Sustainable Waste Management. As detailed in the waste chapter of this report, the landfill tax plays an important role supporting recycling.

³⁹ "Linear" industrial and consumption processes are characterised as "take-make-use-dispose" practices, which result in waste in landfills or incinerators. A circular economy ("take-make-use-remake") is an alternative to a traditional linear economy, in which we keep resources in use for as long as possible, extract the maximum value from them whilst in use, then recover and regenerate products and materials at the end of each service life

Figure 12 overleaf sets out cost projections for the waste sector based upon our work with the GLA. These costs relate to the central population and central transition scenarios and are presented in 2014 prices. Projected costs are split between capital and operating expenses. (These projections are shown in real terms, including an underlying 2% annual uplift for construction industry price increases in capital costs.)

It is projected that waste infrastructure expenditure requirements, including capital and operating expenses, will total £40 billion between 2016 and 2050. Capital investment requirements including both enhancement (new facility) and renewals costs, are projected to total some £14 billion.⁴⁰ Renewals of the growing asset base, calculated as five per cent of enhancement costs, are projected to total some £3 billion over the study period, whilst new infrastructure development expenditure requirements are projected to total some £12 billion.

Operating expenses, shown including collection costs, are projected to represent more than half of total projected expenditure. Waste collection costs are projected to comprise a significant portion of total operating expenditure requirements, some £13 billion over the study period.

£bn 2014 prices, five year period ending	2011-2015	2016-2020	2021-2025	2026-2030	2031-2035	2036-2040	2041-2045	2046-2050	Total 2016-2050	CAGR 2016-2050
Capex	2	1	2	2	2	2	3	3	14	2.4%
Enhancements	2	1	1	1	2	2	2	2	12	1.9%
Renewals	0	0	0	0	0	0	1	1	3	5.2%
Opex (including collection costs)	4	4	4	4	4	4	4	4	26	0.1%
Waste total	6	5	5	5	6	6	6	7	40	0.9%

Figure 12: Projected capital and operating cost requirements by five-year period, 2011-2050. 2014 prices, including c.2% p.a. construction industry price growth for capital expenditure requirements. Source: Arup analysis

As waste treatment moves progressively ‘up the waste hierarchy’ towards reuse, benefits are seen in capital and operating cost efficiency relative to population growth and waste growth respectively. Operating expenses, calculated on a per tonne basis, are projected to remain constant (some £4 billion per five-year period) despite population and waste volume growth. It is projected that the operating costs associated with reuse and secondary facilities are some 60% to 70% less expensive than traditional treatment methods.⁴¹

⁴⁰ Enhancement capital expenditure is projected to include land costs, calculated as 45% of total facility development costs.

⁴¹ It is assumed that the operating cost per tonne for reuse and secondary material sorting and bulking facilities is some £20 per tonne per annum. Intermediate, thermal and landfill facilities are projected to require operating expenses of some £70 to £90 per tonne per annum.

1.9 Green infrastructure costs

Population growth could pose significant challenges to London's environment by 2050. Competition for land and the need for greater housing and commercial development are likely to place pressures upon the city's existing green spaces, whilst potentially reducing the supply of land within London's current boundaries available for creating any new green space.

Rethinking and restructuring the existing green space network to improve its performance, and greening the built environment, would enable the capital to address a number of environmental and social imperatives. These range from minimum green space requirements to a host of challenges potentially presented by a changing climate, from surface water management and urban cooling to ecological resilience. It will also yield a number of social benefits, linked to health improvements and community well-being.

Green infrastructure is more than parks and public spaces. It is increasingly understood as a network of interventions aimed at solving urban environmental problems by building with nature. These interventions can include efforts to increase biodiversity, strengthen air quality, improve sustainable energy production, provide clean water and better manage storm water. Arup has recommended a series of capital enhancements reflecting this understanding of green infrastructure, whilst also recommending the improvement of London's green spaces.

Our focus in this particular section is deliberately focused, including a select group of open space and other requirements identified by the GLA. Arup has recommended a series of capital enhancements whilst also recommending the improvement of London's green spaces. The capital enhancements included in this sector comprise green roofs, green walls, rain gardens, sustainable drainage, green corridors, increased tree canopy cover and the enhancement of other natural areas. In particular, we have considered:

- The improvement of London's existing parks and gardens (renewal);
- The adaptation of the green space network utilising green infrastructure (enhancement);
- The introduction of greener versions of 'Quietways' cycling infrastructure (enhancement);⁴²
- Review of the current level of funding for urban tree planting and establishment of future funding requirements to 2050 (enhancement); and
- Establishment of associated funding requirements for elements of green infrastructure, such as tree planting, sustainable drainage and green spaces, specific to future housing developments (enhancement).

There are opportunities to invest in green infrastructure across all of the sectors included in London's infrastructure investment plan. We note these opportunities in the different sector-specific sections of this report. We make other

⁴² Greater London Authority *The Mayor's Vision of Cycling in London – An Olympic Legacy for all Londoners*. Greater London Authority, 2013.

recommendations related to 'blue-green' infrastructure in the water sector chapter of this report. We also discuss green infrastructure investment in relation to the Mayor's Roads Task Force and other 'World City' transport investment in the relevant section.

In the capital expenditure summary presented earlier, we have grouped green infrastructure capital costs projected in the transport and water sectors with the other green infrastructure costs presented below. Such a re-grouping has the effect of increasing the capital expenditure estimated to be required. Re-allocating some transport and water-sector investment increases projected green capital expenditure from £2.1 billion to some £20 billion over the study period. The figures presented below are as sub-set of those presented earlier in this section.

1.9.1 Overview of projected capital and operating costs

Figure 13 below shows our estimate of costs for the open space and other new development requirements outlined in the previous section. Renewals expenditure projections relate to the improvement of London's existing parks and gardens. Enhancements relate to a series of housing-related tree planting, sustainable drainage and other new open space requirements. Operating expenditure is projected to relate to the upkeep of these assets, calculated as 5% of projected capital costs.

In the period between 2016 and 2050, it is estimated that some £2 billion of capital expenditure will be required. Of this, £1.6 billion is projected to be required for renewal of the capital's existing green spaces. Capital enhancements, including green Quietway enhancements and accessible green space within future housing developments, are projected to require some £500 million of expenditure between 2016 and 2050. In addition, some £400 million of operating expenses are projected to be required over the plan period. In total, some £2.4 billion will be required over the study period, between 2016 and 2050.

£bn 2014 prices, five year period ending	2011-2015	2016-2020	2021-2025	2026-2030	2031-2035	2036-2040	2041-2045	2046-2050	Total 2016-2050	CAGR 2016-2050
Capex	0.34	0.29	0.28	0.25	0.25	0.24	0.35	0.39	2.1	1.0%
Enhancements	0.02	0.04	0.07	0.07	0.08	0.08	0.08	0.08	0.5	2.0%
Renewals	0.32	0.24	0.20	0.18	0.18	0.17	0.27	0.31	1.6	0.7%
Opex	0.02	0.03	0.04	0.05	0.05	0.06	0.07	0.08	0.4	3.2%
Green total	0.35	0.32	0.32	0.30	0.30	0.30	0.42	0.46	2.4	1.3%

Figure 13: Projected capital and operating cost requirements by five-year period, 2011-2050. 2014 prices, including c.2% p.a. construction industry price growth for capital expenditure requirements. Source: Arup analysis

1.10 Digital connectivity infrastructure costs

The advent of the internet has heralded lifestyle and business change.⁴³ The number of devices connected to the network continues to increase. More and more consumers are ‘multi-tasking’, using multiple devices, and numerous services, at the same time. Tastes and markets are changing. The rise of video on demand, and virtual shopping, for example, are encouraging even greater use of telecommunications infrastructure. It is expected that the demand for data and faster broadband speeds will continue to rise. Future broadband infrastructure will be required to meet this increasing demand whilst maintaining adaptability to meet as yet unknown future uses.

The potential for innovation, coupled with limited existing knowledge of London’s digital connectivity infrastructure by London government, makes projecting future requirements difficult particularly when compared to other infrastructure sectors.

London’s telecommunications infrastructure is provided privately and regulated by the Office of Communications (Ofcom). A large portion of the capital’s existing broadband infrastructure is owned and/or controlled by BT Group (BT). Operators have not historically been required by the regulator to provide comprehensive, granular geographic information on the availability of their networks.

Our approach has been to project possible costs associated with the development of London’s ‘dark fibre’ network and other digital connectivity infrastructure, enhancing digital access and extending it to areas that are currently underserved and/or projected to be underserved.⁴⁴ In particular, this work has focused on the infrastructure required to provide:

- Access to Next Generation Access (NGA)⁴⁵ fibre broadband to every home by 2020 (i.e., an additional 150,000 underserved properties) – plus renewals thereafter;
- Public access Wi-Fi across London;
- 4G mobile access to the internet from nearly every part⁴⁶ of London (indoor and outdoor);
- 5G mobile access to the internet from nearly every part of London (indoor and outdoor) from 2020; and
- Related cyber security costs.

We have modelled the cost of providing digital connectivity infrastructure making a series of assumptions around the potential demand for the infrastructure and the

⁴³ Ofcom, *Infrastructure Report*, 2013, available: http://stakeholders.ofcom.org.uk/binaries/research/telecoms-research/infrastructure-report/IRU_2013.pdf.

⁴⁴ A dark fibre or unlit fibre is an unused optical fibre, available for use in fibre-optic communication.

⁴⁵ ‘Next Generation Access’ (NGA) infrastructure networks make use of technologies such as fibre-to-the-cabinet (FTTC) and fibre-to-the-premises (FTTP) network architectures in order to increase average connection speeds.

⁴⁶ For practical and technical reasons, it is virtually impossible and certainly not cost effective to provide coverage for every single part of London.

costs associated with its development. In the absence of detailed information provided by the regulator, private firms or other government agencies or bodies, these assumptions have been based on Arup analysis.

1.10.1 Overview of projected capital and operating costs

The figure overleaf sets out Arup's cost projections for digital connectivity infrastructure. Projected costs are split between capital and operating expenses. These costs relate to the central population scenario. These projections are shown 2014 prices, including a 2% per annum construction industry uplift for capital expenditure.

£bn 2014 prices, five year period ending	2011-2015	2016-2020	2021-2025	2026-2030	2031-2035	2036-2040	2041-2045	2046-2050	Total 2016-2050	CAGR (2016-2050)
Capex	0.8	1.9	0.5	0.8	1.0	1.1	1.3	1.4	8.1	-1.0%
Opex	-	0.1	0.2	0.2	0.2	0.3	0.4	0.4	1.8	4.1%
Digital connectivity total	0.8	2.0	0.7	1.0	1.3	1.4	1.6	1.8	9.9	-0.3%

Figure 14: Projected capital and operating cost requirements by five-year period, 2011-2050. 2014 prices, including c.2% p.a. construction industry price growth for capital expenditure requirements. Source: Arup analysis

As shown in the figure above, digital connectivity expenditure requirements, including both capital and operating expenses, are projected to total some £10 billion between 2016 and 2050.

Some 80% of this investment is projected to relate to capital expenditure requirements, totalling £8.1 billion between 2016 and 2050. Capital expenses are projected for each of the areas outlined in the previous section. Additional detail about the different investments proposed can be found in section 9.2.

Projected capital expenditure includes only enhancements to digital connectivity infrastructure and not for renewal of these assets. We have assumed that renewal of broadband assets is unlikely to occur within the study period and that other assets are likely to be replaced via investment in further enhancement capex.

Currently projected investment is concentrated over the short and medium-term, to 2030. Roll-out of super high-speed broadband, 4G and Wi-Fi connectivity are already underway. Given uncertainty after the 2030s, with the significant potential for future innovation and development in the sector, it is likely that further expenditure will be required.

In discussion with the GLA, we have 'rolled forward' projected capital expenditure requirements such that, on average, projected capital expenditure does not decline in real terms over the study period. On average, we have projected additional investment requirements of some £600 million (unindexed) each five-year period. Adjusting for construction industry price growth, we have included capital expenses of some £5,065 million in our projections between 2016 and 2050.

1.11 London's infrastructure funding gap to 2050

As we noted above in section 1.2.2 of this summary chapter, our analysis of the gap between projected costs and revenues, informed by discussion with the GLA, its advisory group and other stakeholders, has varied across the different sectors considered in the GLA's infrastructure investment plan.

We have focused upon the transport and housing sectors as these two sectors represent the large majority of projected expenditure over the study period and are likely to be funded with significant contributions made by London local government. Capital (enhancements and renewals) and operating expenses in these two sectors alone are projected to total some £1,782 billion in the study period, representing some 78% of all expenditure projected to be required between 2016 and 2050.⁴⁷

At this preliminary stage of analysis, we have not included in our estimate the potential funding gap associated with energy, waste or water infrastructure. User charges, particularly in the utilities sectors, are likely to finance a significant portion of both operating and capital expenses, which are likely to be met by the private sector rather than local government. Because of this, we have agreed with the GLA to focus on the potential impact of projected expenditure on consumer bills. We detail the results of this analysis in section 10.3 of chapter 10.

For the remaining sectors, we have assumed that projected costs are at present 'unfunded'. Capital and operating expenditure requirements projected for these sectors are not linked to particular revenue streams, funded instead by a mixture of grants, private-sector contributions and other subsidies, and via local authorities' general accounts. Any 'gap' will need to be funded by a combination of (re-allocating) existing resources, identifying new sources of revenue, accessing new capital receipts or through user charges. We have not included the costs associated with development in the funding gap projected.

Our preliminary assessment indicates that the gap between projected future costs and income sources in the housing and transport sectors alone could be approximately £135 billion in the study period, between 2016 and 2050 (2014 prices). As this figure does not include all of the infrastructure sectors, there is good reason to believe London's infrastructure funding gap could be considerably greater. This figure also does not account for potential debt servicing costs and/or other additional central overheads, and it likely represents a conservative estimate of the projected funding gap in the two sectors. We detail our housing and transport sector analyses below. Additional discussion of the funding available to other sectors is found in chapter section 10.4 of chapter 10.

1.11.1 Housing funding gap

Housing costs, including both market-rate and affordable operating and capital expenses, are projected to total some £800 billion in the period between 2016 and

⁴⁷ All figures quoted in this section are 2014 prices. Capital costs include 2% p.a. construction industry price growth.

2050. We have not considered the costs associated with market-rate housing in establishing the funding gap, projected to total some £363 billion over the study period, as these units will be built and maintained without subsidy. Affordable unit costs, including both operating and capital expenditure, are projected to total some £437 billion.

It is estimated that London government faces a funding gap of some £154 billion in order to meet projected affordable housing unit expenditure requirements, including renewals and new build costs.⁴⁸ This funding gap is comprised of renewals and new unit (enhancement) costs. This gap consists of £11 billion in relation to the capital renewal of estimated 'Decent Homes' type obligations, with the balance of £143 billion projected to relate to delivering new housing units.

Based on historical analysis, we have found that leveraged grant funding could reduce this gap. If £34 billion of capital funding were secured by London government, it could be used to leverage in the order of some £109 billion of private capital, reducing the total housing funding gap to the public sector to £45 billion.

We discuss operating, renewals and enhancement costs and funding in sections below.

1.11.1.1 Operating and renewals costs and funding

London's affordable housing operating and renewals costs are projected to comprise some £221 billion over the period. Based on precedent, we have assumed that rental income will meet all projected operating expenditure requirements and the vast majority of renewals expenditure requirements. However, it is assumed that funding comparable to previous 'Decent Homes' allocation will not be carried forward. This is projected to leave a shortfall in funding related to other capital renewals, including investment in energy efficiency, achieving and maintaining 'Decent Homes' standards and other estate regeneration. This renewals-related funding gap is projected to total some £11 billion over the study period.

1.11.1.2 New construction costs and funding

New construction costs related to affordable housing units are projected to total some £216 billion over the study period. An estimate of the future capital grant available has been made based on the GLA's historical expenditure, as shown in the National Affordable Housing Programme, equating to some £500 million per annum or £17 billion over the study period. In addition, private registered providers (PRPs) are projected to fund some £55 billion of capital enhancement expenditure for new housing units.

In total these funding streams would leave a gap of some £143 billion in relation to new unit capital enhancement expenditure. As noted above, leveraged grant

⁴⁸ Excludes debt service costs.

funding could help to reduce this gap. The shortfall in affordable housing grant/capital funding will need to be funded in from newly committed central government grant, access to new funding streams or access to new capital receipts, such as developer contributions or housing sales. It has been concluded that some £109 billion of private capital could be obtained via the leveraging of £34 billion of new grant. Therefore, the new housing capital funding gap is shown to be some £34 billion.

In this context, London could benefit from central government agreeing a more long-term and reliable funding stream for housing (similar to that secured by TfL in recent years), enabling the Mayor to get a better deal for Londoners and negotiate longer-term agreements with PRPs and boroughs to secure housing needed. Until then, PRPs and boroughs will continue to bid for the short-term 'pots' available and leverage borrowing headroom in the HRA to deliver new affordable homes and to balance this spend between new build and renewals of existing stock.

1.11.2 Transport funding gap

Transport costs, including both capital and operating expenses, are projected to total some £982 billion over the period between 2016 and 2050. We have assumed that all aviation costs, projected to total some £268 billion, will be covered by the private sector.⁴⁹ We also have assumed that central government, its agencies and other bodies will continue to provide for the transport infrastructure costs, projected to total some £172 billion that they have funded up to now.⁵⁰ London government's remaining share of estimated expenditure requirements, given these assumptions, is projected to total some £542 billion.

It is estimated that London government, including TfL and the boroughs, faces a gap of some £89 billion related to transport operating and capital costs (before debt service costs and other central overheads). As described below, an operating expenditure gap is projected to total some £12 billion between 2016 and 2050, and a capital expenditure gap is projected to total some £77 billion between 2016 and 2050.

1.11.2.1 Operating costs and funding

Our analysis of TfL's business plan and of future revenue potential shows that fares could meet TfL operating expenses and provide a significant contribution to

⁴⁹ Excluding complementary surface access infrastructure. It is likely that the Thames Estuary Airport could require at least some subsidy, but eliminating aviation costs allows our analysis to focus on more certain future costs as the Davies Commission continues to address questions around the region's aviation capacity. The funding gap therefore could be considered a "lower bound" in relation to the Estuary airport's development.

⁵⁰ This 'central government share', projected to total some £174 billion, includes national rail projects, High Speed 2 and Highways Agency projects. It is assumed that all remaining costs, including TfL project costs and other roads costs, will be addressed by London government.

capital investment requirements. No shortfall is projected related to TfL's operating expenses.⁵¹

Other projected operating costs related to borough road maintenance.⁵² These costs are projected to total some £12 billion over the study period. It has been assumed that these costs are 'unfunded'. In other words, the 'gap' identified will need to be funded by re-allocating existing resources, identifying new sources of revenue or accessing new capital receipts; we have not made assumptions on TfL's future budget making. In total, this leaves an operating expenditure funding gap of £12 billion between 2016 and 2050.

1.11.2 Capital costs and funding

Capital costs (enhancements and renewals) for transport projects funded by London government are projected to total some £269 billion over the study period, between 2016 and 2050.

Our analysis of the TfL business plan and of future revenue potential shows that fares will more than meet TfL operating expenses. We estimate a portion of projected capital costs - some £88 billion - could be met by surplus fare revenue. Other core sources of revenue funding include the General Grant from central government and TfL's Business Rates Retention (capturing a proportion of the growth in London's business rates), both of which we have assumed remain flat in real terms beyond TfL's business plan period.⁵³ Given these assumptions, we project a capital funding gap of some £77 billion between 2016 and 2050.

1.11.3 Policy implications

Whilst much of the infrastructure investment required in London is likely to be delivered and funded through the private and regulated sector, as well as central government, a significant element will fall to London government to find. It is clear that the funding gap between projected future costs and income sources in housing and transport of approximately £135 billion in the study period represents a significant challenge, in addition to the remaining sectors of the study where it is assumed that costs are "unfunded" at present.

In order to deliver the identified infrastructure requirements, London government will need to consider mechanisms for reducing the gap between projected costs and income. In part, as we have discussed, this could relate to driving efficiency savings in the delivery of major infrastructure projects.

It also is evident that additional sources of funding will need to be identified, be it through newly committed central government grant, access to new funding streams or access to new capital receipts. The London Finance Commission

⁵¹ We detail provide additional commentary around this analysis in chapter 10 and in the appendix to this report.

⁵² Borough roads exclude those which form part of the TfL Road Network or Borough Principal Road Network, both of which are managed by TfL.

⁵³ Both of these revenue streams could vary substantially over the period. In particular, the General Grant, negotiated directly with central government, could be subject to periodic/on-going reductions and uncertainty. The core capital funding stream also is negotiated directly with central government and could be subject to periodic/on-going reductions and uncertainty.

concluded that “London government needs fewer borrowing constraints and greater devolved tax powers to enable it to invest more comprehensively without the need for ad hoc, project-by-project financing arrangements.” As would be the case for Britain’s other major cities, London is likely to benefit from fiscal autonomy that matches continuous, stable funding streams with the ability to determine local need. Greater local control similarly should enhance political accountability, fiscal discipline and responsibility.

Should London government be permitted to retain a greater share of the tax revenues it generates, there is good reason to believe that central government funding could be reduced over time. In the short term, limited and modest proposals for fiscal devolution will not in themselves generate the financial resources to make a significant dent in the additional public capital investment requirements facing London. Over the long-term, with regular revaluations and year on year increases, the property tax base may yield more significant sums. Irrespective of fiscal devolution, additional powers to implement new revenue generating schemes will need to be granted in order to close the funding gap.

1.12 Options for reducing the gap: additional sources of revenue

There is considerable potential for London to raise the capital required to support infrastructure development. We have considered a range of new funding sources, including the traditional and the more radical.

Figure 15 below provides an illustrative estimate of the level of income each source could theoretically generate during the period of the plan.⁵⁴ It does not consider financial structuring implications, the potential impact on London’s competitiveness or willingness/capacity to pay. We discuss each option in more detail in chapter 12.

Potential additional source	Amount (£bn, 2014 prices, undiscounted)
Business Rate Supplement	3
Council Tax Supplement	2
London income tax share	33
South East income tax share (excluding London)	23
Motoring duty	48
Hotel tax	6
TfL fares increase	79
User charging (new roads)	Project specific

⁵⁴ Note as we discuss, in a number of cases this is not for the full thirty five year period 2016-2050.

Potential additional source	Amount (£bn, 2014 prices, undiscounted)
Property development	Project specific
Sponsorship and third party contributions	Project specific

Figure 15: Potential sources of revenue indicative amounts (£ billion). 2014 prices, undiscounted. Source: Arup analysis

Of the seven sources considered that are not project specific, we have identified revenues ranging from £3 billion to some £80 billion over the study period. For example, a cost neutral measure for employees would be to devolve a portion of the income tax collected nationally, based on the number of employees working within London. It is estimated that such devolution could generate £33 billion of revenues during the study period (undiscounted).

These projections have not included potential additional revenue from devolved property taxes. As noted in chapter 10, a 2.5% per annum real increase in property tax revenue would equate approximately to an extra £78 billion of income (on an undiscounted basis).

The potential revenues identified should be considered separately and on no more than an indicative basis. Competing demands for scarce resources would dictate that only a portion of future revenues, whether from property taxes or other sources, are likely to be available for infrastructure development. Moreover, changing London government's fiscal powers would be likely to have dynamic effects on the revenues generated by individual mechanisms, and there is uncertainty around the projections made. There is similar uncertainty around the composition of London government's overall income, which could change with the introduction of new taxes and other sources of revenue.

This discussion of revenue potential has not accounted for the profile of investment across the different infrastructure sectors the GLA is considering. Additional analysis (indeed a further study) would be required in order to understand the relationship between the investment programme and potential funding sources. In addition, future analysis would need to address the debt profile and financing costs associated with different investment proposals.⁵⁵ It is likely that such considerations would need to be addressed to achieve support for new revenue mechanisms. Most of the fiscal powers discussed in this report would require some form of central government support.

Notwithstanding these caveats, there is considerable potential to finance infrastructure via devolved revenue sources. A more local approach to funding infrastructure development could help to foster a virtuous cycle of efficient investment, growth and accountability, more effectively structuring incentives and decision-making. As the London Finance Commission (LFC) has identified, localised fiscal powers could level the playing field with other international cities that have greater control of local revenues and spending. Furthermore, there is no reason these funding mechanisms could not be used by other British cities, supporting existing initiatives such as City Deals, Community Budgets and efforts to increase the involvement of Local Enterprise Partnerships (LEPs) in spending decisions.

⁵⁵ As we have discussed, debt costs have not been included in our funding gap projections.

1.13 Conclusions

Arup's study of the costs associated with London's long-term infrastructure has shown that capital (enhancements and renewals) expenditure requirements in both the public and private sectors could be within a range of £1,000 billion and some £1,750 billion between 2016 and 2050.⁵⁶ In our central case, approximately £1,324 billion of capital expenditure (enhancements and renewals) is projected to be required between 2016 and 2050. Enhancements to London's existing infrastructure asset base are projected to comprise some four-fifths of this cost, nearly £1,000 billion. Renewals expenditure, relating both to new assets and to the existing infrastructure, could total an additional £324 billion.

Some £1,000 billion of all capital expenditure relates to the housing and transport sectors. Combined public and private investment in these two infrastructure sectors is projected to comprise more than 75% of capital (enhancements and renewals) expenditure required in the study period. Capital requirements are projected to grow significantly over the next decade. Between 2021 and 2025, it is projected that capital expenditure (including both enhancements and renewals) will represent some 8% of GVA, given a considerable increase in forecast housing unit delivery and in the initiation of major transport schemes. In later periods, it is projected that capital requirements will decline as percentage of GVA. By the middle 2030s, it is projected that capital expenditure requirements (enhancements and renewals) will fall to some 5.5% of projected economic output (GVA). This figure is roughly equivalent with estimates of current expenditure as a percentage of GVA.

Operating expense requirements are projected to increase with capital requirements in the period. Between 2016 and 2050, approximately £970 billion of operating expenditure is projected to be required across London's different infrastructure sectors. A large portion of operating expenditure is projected to relate to the city's transport system and housing stock. Transport operating cost requirements, including routine operating of the Underground, rail, bus networks, are projected to exceed £500 billion in the period. Housing operating expenditure requirements are projected to exceed £250 billion in the period, include routine maintenance costs.

Our preliminary assessment indicates that the 'gap' between projected future costs and income sources in the housing and transport sectors alone could be approximately £135 billion in the study period, between 2016 and 2050 (2014 prices). As this figure does not include all of the infrastructure sectors, there is good reason to believe London's infrastructure funding gap could be considerably greater. This figure also does not account for potential debt servicing costs and/or other additional central overheads, and it likely represents a conservative estimate of the projected funding gap in the two sectors.

In order to deliver the identified infrastructure requirements, the government will need to consider giving London government the powers and mechanisms for reducing the gap between projected costs and income. Driving efficiency savings in the delivery of major infrastructure projects may also contribute.

⁵⁶ Projected outturn costs will depend on a large variety of factors. This range relates to variation in forecast population growth, possible delivery efficiency and construction industry price growth.

To meet the needs of a growing population and enhance Londoners' quality of life, it is imperative policy makers find a way to deliver infrastructure for London on what will be an industrial scale across all types of infrastructure. Additional sources of funding will be needed – from central government grant, or access to new funding mechanisms and sources of finance. Fiscal devolution is elemental to delivering infrastructure success. Without bold and radical thinking, London risks losing its position as one of the world's most competitive and liveable cities. That would be to the detriment of the whole of the United Kingdom.

Ove Arup & Partners Limited.

July 2014

2 Housing infrastructure

This section details our consideration of the costs associated with the GLA's proposed housing strategy and associated investment. As we discuss below, a significant amount of detailed housing supply and demand modelling has been undertaken by the GLA. In January 2014 the Mayor set out projections of London's current and future housing requirements in the 2013 London Strategic Housing Market Assessment (SHMA).⁵⁷ These are in line with the government's National Planning Policy Framework (NPPF) and build on similar previous analysis.⁵⁸ The projections set out the number of new homes needed in London by tenure and type, and also include detailed analysis of the housing requirements of different parts of London's population.

Greater London Authority analysis form the basis of our review of the costs associated with London's long-term housing requirements. Although we comment on risks around the delivery of projected housing supply and the potential effect such under-delivery could have on projected costs, our figures adopt the targets outlined in the Further Alterations to the London Plan (FALP). These figures are subject to on-going review and consultation.

2.1 London's housing infrastructure requirements

The GLA has assessed housing requirements in order to meet newly arising need and to clear the backlog of new homes needed in its SHMA and Strategic Housing Land Availability Assessment (SHLAA). These studies form the foundation for the housing targets in the FALP and boroughs Local Plans.⁵⁹

These studies conclude that there is a need for some 50,000 to 60,000 additional homes in London per year.

- The 2013 SHMA (2014) sets out annual housing requirements to 2035. Current housing plans have not been developed beyond this period. The SHMA states annual need of 48,840 units per annum, with some 52% of these units being affordable.
- The FALP sets out 42,000 units per annum as the GLA's minimum target for overall delivery, with an aspiration of some 50,000 units. Current proposals - yet to be agreed - state that of these 42,000 units, 17,000 should be affordable.

Varying population and demographic projections inform these different projections. The GLA's figures are based on its own household projections, which are lower than those set out by the Department for Communities and Local Government (DCLG). The GLA states that its own projections of future housing requirements assume household size will fall. GLA intelligence has projected a slowing rate of population growth over the medium to long-term as compared to central government projections.

⁵⁷ Mayor of London, *The London Strategic Housing Market Assessment 2013*, January 2014, available: http://www.london.gov.uk/sites/default/files/FALP_SHMA_2013_0.pdf.

⁵⁸ Mayor of London, *Greater London Strategic Housing Market Assessment 2008*, April 2009, available: <http://legacy.london.gov.uk/mayor/publications/2009/docs/strategic-housing-report.pdf>.

⁵⁹ Mayor of London, *London strategic housing land availability assessment*, 2013, available: <http://www.london.gov.uk/sites/default/files/FALP%20SHLAA%202013.pdf>.

No projections have been made by the GLA for beyond 2036. For the purposes of this work we have rolled forward estimates to 2050, as detailed below.

2.1.1 Housing supply scenarios

Arup has completed two cost scenarios for the housing sector. The first relates to the SHMA, assuming London's supply of new housing units will be 48,840 per year in all future years to 2050. The second relates to the London Plan minimum requirements, assuming London's supply of new housing will be 42,000 units per year in all future years to 2050.

These two scenarios also rely upon the affordability levels set out in the FALP. In the first scenario, as in the SHMA, we have assumed approximately half of all units are affordable. In the second scenario, as in the London Plan, we assumed roughly 40% of all units are affordable. We discuss uncertainties around this unit delivery in the next section.

Projected future housing need per annum – by five year periods							
	2015- 2020	2020- 2025	2025- 2030	2030- 2035	2035- 2040	2040- 2045	2045- 2050
SHMA Scenario	48,840	48,840	48,840	48,840	48,840	48,840	48,840
London Plan Scenario	42,000	42,000	42,000	42,000	42,000	42,000	42,000

Figure 16: Projected future housing need per annum – by five year period. Source: Mayor of London, The London Strategic Housing Market Assessment 2013, January 2014; Mayor of London, Further Alterations to the London Plan, January 2014.

Arup has modelled unit cost, unit mix and unit sizes according to publicly available information and London Plan guidance, as set out in the appendix to this report.

2.2 Risks and uncertainties

2.2.1 New housing unit construction

Despite recent growth in the number of new housing units being built, over the last twenty or so years, the number of new homes built in London has not achieved the levels the Mayor is targeting for the future. As shown in Figure 17 overleaf, new home construction increased to 26,230 units in 2013, up 60% from the previous year, when some 16,300 units were registered. In 2011 and 2013, volumes were above pre-crisis levels. New home volumes have increased by some 5% per annum, on average, since the early 1990s.

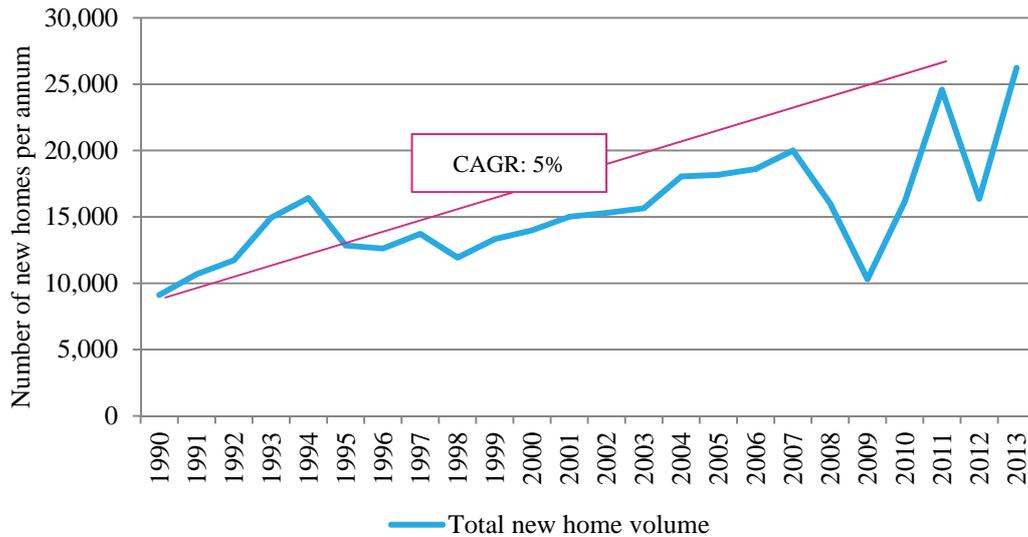


Figure 17: Total new home construction in the GLA, 1990-2013. Source: National Home Building Council, Annual new home statistics review (2013)

Perhaps inevitably, there is considerable uncertainty around the extent to which the volume of housing targeted for delivery over the long-term can be achieved. Historical delivery levels indicate that the industry may struggle to achieve the Mayor’s targets. The Mayor’s target of 48,840 units per annum represents a more than doubling of the average number of units delivered each year since 1990 and an increase of some 60% over the number of new homes built in 2013. Notwithstanding this, modelling of long-term trends based on more recent growth rates indicates that higher levels of delivery might be possible by the middle 2020s. Figure 18 below shows projected growth of housing unit delivery using an average annual rate of growth of 5% taking a base year of 2013.

If London’s housing construction continue to increase according to this trend, the capital could achieve delivery in excess of 42,000 units, (the Mayor’s minimum target), by 2025.

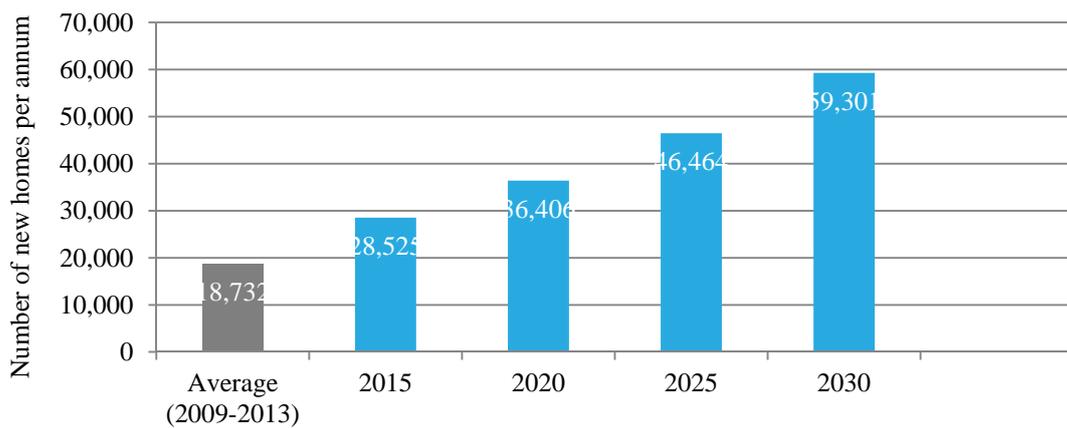


Figure 18: Projected delivery of new homes, assuming a constant rate of growth in line with the historical average rate (5%) is applied to 2013 figures.

2.2.2 Land costs

Land costs represent a significant proportion of overall housing development costs. We have therefore included the cost of land in our modelling. Whilst the historical trend for land values in London has no doubt been upwards, there is arguably uncertainty associated with estimating its value over the longer term. Population growth, given current density restrictions, serves to increase these values by generally increasing demand for a limited supply of land. Future land value growth could outpace historical levels. Actors in the market could affect values: for example, “land banking” could serve to slow development, whilst increasing values further. It is beyond the scope of our work to try and model dynamic change in land values.⁶⁰

2.2.3 Construction costs

Historically, the cost of construction has outpaced inflation. Arup has modelled construction costs in line with industry rates for London. The construction cost per square metre (excluding land) used in our modelling, averages some £1,200 per square metre, slightly above the national average. These assumptions are considered in greater detail in the appendix to this report.

2.3 Preliminary analysis of costs

The figure below sets out cost projections for the housing sector based upon our work with the GLA. The figures presented relate to both the public and private housing sectors. Approximately half of all costs are projected to be attributed to the private sector part of the market. Projected costs are split between capital and maintenance expenses. These projections are shown in 2014 prices⁶¹ as set out the annex to this report. These costs relate to the central population scenario. Note that each period represents a five-year period (not a single year); ‘2015’ covers the combined five year period of 2011-2015, ‘2020’ includes 2016-2020 and so forth.

2.3.1 SHMA scenario (48,840 units per annum)

Figure 19 overleaf shows capital (enhancements and renewals) and operating expenditure projected to be required for all London housing, including both market-rate and affordable units, between 2011 and 2050. Capital enhancement costs relate to the development of new housing units (both market-rate and affordable) and include land and construction costs. Renewals costs relate to new market-rate and affordable housing units (after they are constructed) and to existing affordable and social housing.⁶² Operating expenses relate to routine maintenance expenses and exclude utility costs. All costs projected are shown in

⁶⁰ Arup also has included separately the costs associated with the remediation of land at major regeneration sites. By benchmarking costs against sites in Stratford sites and drawing on other publicly available sources, we have estimated average requirements of some £400 per square metre for remediation. We assume that, on average, one two hectare site is remediated each five-year period, at a cost of some £8m.

⁶¹ Including an underlying increase of 2% per annum for capital expenditure.

⁶² Renewals costs have been estimated according to lifecycle renewal of structural elements, such as roofs, floors and ceilings, as well as replacement of significant fixtures and fittings, such as doors and windows. Costs associated with the renewal of existing market-rate housing have been excluded from our analysis.

2014 prices, including a 2% increase per annum of capital costs (both enhancements and renewals) due to construction industry price inflation.

£bn 2014 prices, five year period ending	2011-2015	2016-2020	2021-2025	2026-2030	2031-2035	2036-2040	2041-2045	2046-2050	Total 2016-2050	CAGR 2016-2050
Capex	30	54	61	68	76	85	96	107	547	2.3%
Enhancements	21	44	49	55	61	68	76	85	437	2.2%
Renewals	9	10	12	13	15	17	20	22	110	2.7%
Opex	3	7	13	21	32	44	59	76	253	8.4%
Schools total	33	61	74	89	108	130	155	183	800	3.7%

Figure 19: Projected capital and operating cost requirements by five-year period, 2011-2050, market rate and affordable housing. 2014 prices, including c.2% p.a. construction industry price growth for capital expenditure requirements. Source: Arup analysis

In the period from 2016 to 2050, we estimate total housing-related expenditure, including both the private and public sectors, of some £800 billion. Capital expenditure, including enhancements and renewals, is projected to total some £547 billion in the period, representing some 68% of total projected housing costs. Of this capital expenditure, the costs associated with new unit delivery in the public and private sectors are projected to total some £437 billion, given the high number of new units required. As we discuss in the next section of this chapter, these enhancement costs are likely to split near evenly between market-rate and affordable housing, given the SHMA's assumptions about the future of London's housing market.

The on-going renewal of both new and existing housing in London is projected to require some £110 billion between 2016 and 2050. It is assumed that renewals costs will relate to on-going lifecycle renewals (such as replacing roofs and floors) as well as on-going investment in energy efficiency and other 'decent homes' type investment of London's existing affordable housing stock.⁶³ The aforementioned renewals costs are projected to total some £92 billion between 2016 and 2050. Our projections also include the costs estimated to be required for lifecycle renewal of London's new housing stock. The renewal of new housing (including both market-rate and affordable units) is projected to require some £18 billion between 2016 and 2050.

In total, some £253 billion of operating expenditure⁶⁴ is projected to be required between 2016 and 2050, increasing from £7 billion in the five years between 2016 and 2020 to some £76 billion between 2046 and 2050. Figure 20 shows projected expenditure requirements by five-year period between 2016 and 2050. As can be seen, maintenance expenditure is projected to increase significantly with the number of dwellings, rising at an average annual rate of 8.4% between 2016 and 2050.

In the five year period to 2020, it is projected that capital expenditure (on new housing in addition to renewals activity) could more than double as compared to

⁶³ We have assumed London boroughs' existing housing stock totals some 410,000 units, whilst providers' housing totals some 391,000 units. We have estimated that the renewal of existing private registered provider housing to total some £21 billion in the period. The renewal of existing London borough housing is projected to total some £60 billion in the period.

⁶⁴ Note that other operations costs, including utilities and cleaning, are excluded from these costs projections.

the previous five years, growing from an estimated £30 billion to £54 billion, if London delivers the new housing requirements set out by the Mayor.⁶⁵

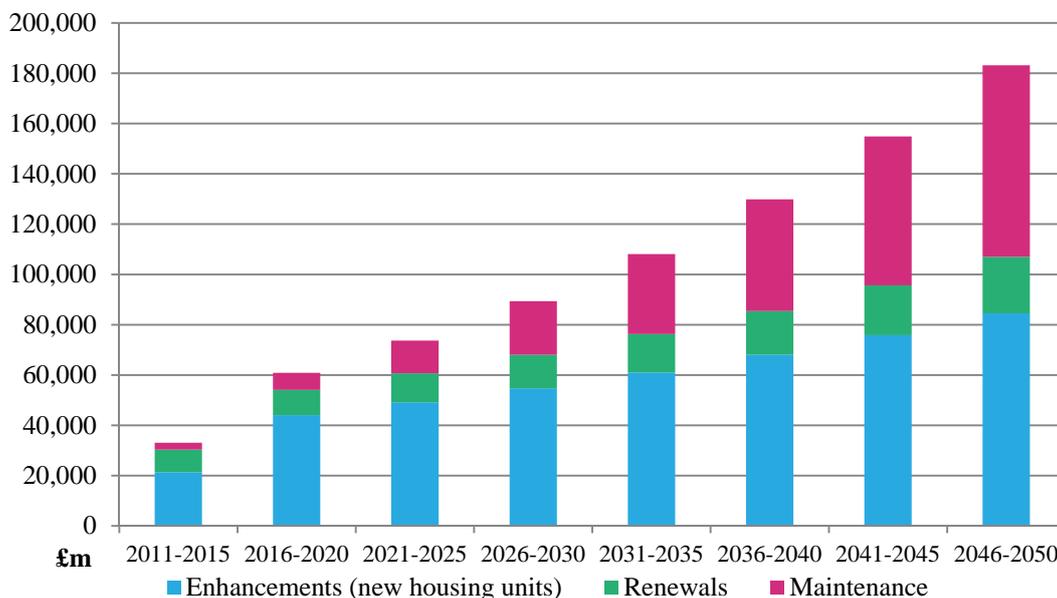


Figure 20: Housing expenditure, including both market rate and affordable housing, 2016-2050 (SHMA scenario). 2014 prices, including 2% p.a. increase to account for construction industry inflation for enhancements (new housing) and renewals. Source: Arup analysis. Land costs, assumed in to represent 45% of total new home delivery costs, are projected to total some £197 billion over the study period.

2.3.1.1 Affordable and market rate housing costs

In the SHMA scenario, affordable housing comprises about half of all new units built until 2050. Affordable housing enhancement costs (land and construction) are projected to total some £216 billion in the 35 years to 2050. In the same period, private sector housing construction costs (construction and land) are projected to total some £221 billion. Projections are shown in Figure 21 overleaf.

⁶⁵ Please note that these are indicative costs rather than outturn costs. Arup unit rates (including construction and land costs) have been applied to the average number of units delivered over a typical five-year period.

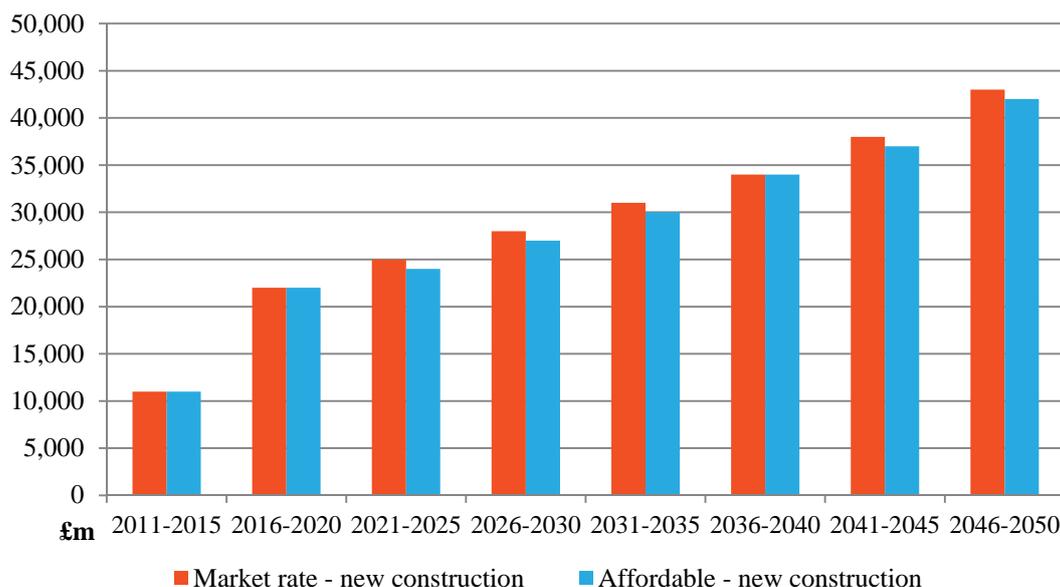


Figure 21: Affordable and market rate housing enhancement costs, including land and construction costs, for new units (SHMA scenario), 2016-2050 (£ million). 2014 prices, including a c.2% per annum increase for construction industry price inflation. Source: Arup analysis

As can be seen in Figure 22, significant investment is projected to be required in relation to affordable housing stock renewal. Some £100 billion of costs are projected to relate to affordable housing renewals. We have estimated that renewal of London boroughs' affordable housing will be more costly than that of private registered providers.

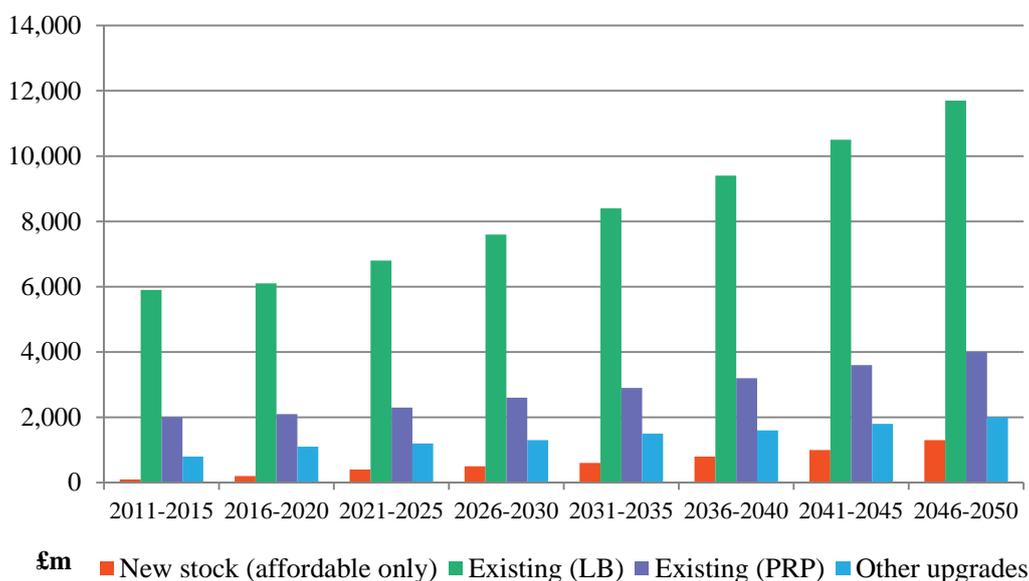


Figure 22: Affordable housing renewals costs for existing units (SHMA scenario), 2016-2050 (£ million). 2014 prices, including a c.2% per annum increase for construction industry price inflation. Source: Arup analysis

The renewal of existing private registered provider housing has been estimated to total some £21 billion in the period. The renewal of existing London borough housing is projected to total some £60 billion in the period. We have assumed

London boroughs' existing housing stock totals some 410,000 units, whilst providers' housing totals some 391,000 units.

The figures presented above exclude costs projected to be associated with the renewal of newly constructed affordable housing and those costs projected to be associated with the renewal of newly constructed market rate housing. New unit renewal is projected to total a further £29 billion, divided approximately in equal measure between market rate and affordable housing.

2.3.2 London Plan scenario (42,000 units per annum)

Using the London Plan to determine supply reduces projected costs in overall terms and those costs projected to be associated with affordable housing. In this scenario, some £487 billion of capital expenditure is projected to be required to 2050.⁶⁶ In total, including projected maintenance expenditure, some £715 billion of expenditure is projected to be required. This figure is roughly £85 billion less than under the SHMA scenario. These lower cost estimates reflect the fact that fewer units are anticipated under the London Plan compared to the SHMA (as discussed earlier in this chapter).

In the London Plan scenario, some £378 billion of capital enhancement expenditure for new housing units (including both market rate and affordable) is projected to be required. Figure 23 below sets out enhancement capital expenditure (including both land and construction costs) according to market-rate and affordable housing types.

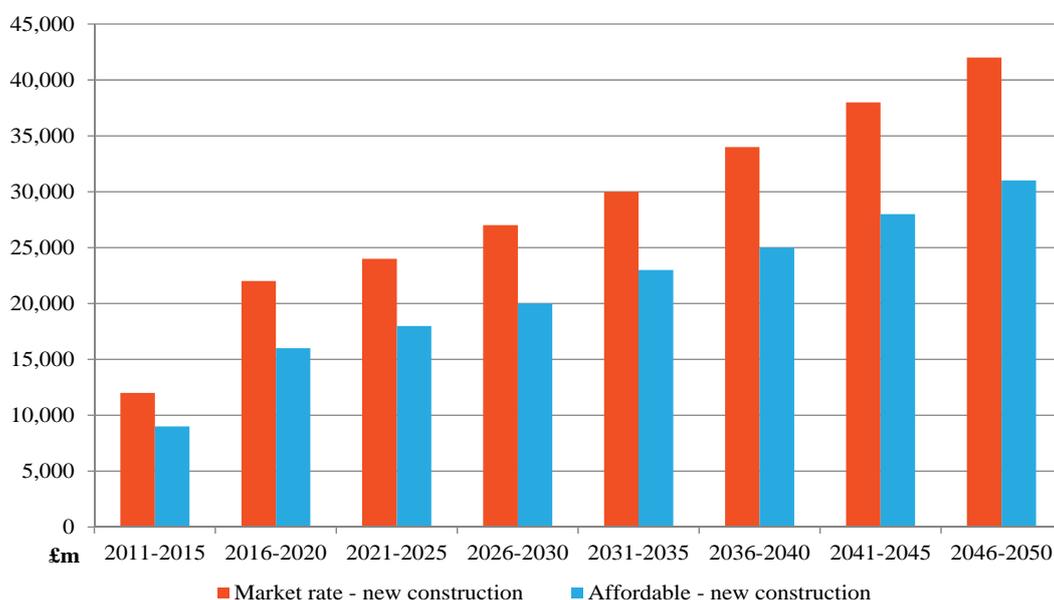


Figure 23: Affordable and market rate construction costs, including land costs, for new units (London Plan scenario), 2016-2050 (£ million). 2014 prices, including a c.2% per annum increase for construction industry price inflation. Source: Arup analysis

In the London Plan scenario, a higher proportion of costs - some 60% are projected to be associated with market rate housing. As shown in the figure above, some £217 billion of new housing construction costs are projected to relate to

⁶⁶ This compares with a figure of £547 billion under the SHMA scenario.

market rate housing. In this scenario, £161 billion of enhancement capital costs are projected to be associated with affordable housing.

2.4 Conclusions

The GLA has assessed housing requirements in order to meet newly arising need and to clear the backlog of new homes needed in its SHMA and Strategic Housing Land Availability Assessment (SHLAA). These studies form the foundation for the housing targets in the FALP and boroughs Local Plans. These studies conclude that there is a need for some 50,000 to 60,000 additional homes in London per year.

Arup has completed two cost scenarios for the housing sector according to GLA housing market analysis. The first relates to the SHMA, assuming London's supply of new housing units will be 48,840 per year in all future years to 2050. The second relates to the London Plan minimum requirements, assuming London's supply of new housing will be 42,000 units per year in all future years to 2050.

In the first scenario presented in this chapter, relating to the Strategic Housing Market Assessment (SHMA), it is projected that some 48,840 units will be delivered per annum until 2050. In the period from 2016 to 2050, we estimate total housing-related expenditure, including both the private and public sectors, of some £800 billion. Capital expenditure, including enhancements and renewals, is projected to total some £547 billion in the period, representing some 68% of total projected housing costs. Of this capital expenditure, the costs associated with new unit delivery in the public and private sectors are projected to total some £437 billion, given the high number of new units required.

In the first scenario presented in this chapter, relating to the London Plan, it is projected that some 42,000 units will be delivered per annum until 2050. Using the London Plan to determine supply reduces projected costs in overall terms and those costs projected to be associated with affordable housing. In this scenario, some £487 billion of capital expenditure is projected to be required to 2050. In the London Plan scenario, a higher proportion of costs - some 60% are projected to be associated with market rate housing. As shown in the figure above, some £217 billion of new housing construction costs are projected to relate to market rate housing. In this scenario, £161 billion of enhancement capital costs are projected to be associated with affordable housing.

Despite recent growth in the number of new housing units being built, over the last twenty or so years, the number of new homes built in London has not achieved the levels the Mayor is targeting. New home construction increased to 26,230 units in 2013, up 60% from the previous year, when some 16,300 units were registered. In 2011 and 2013, volumes were above pre-crisis levels. New home volumes have increased by some 5% per annum, on average, since the early 1990s. Historical delivery levels indicate that the industry may struggle to achieve the Mayor's targets. The Mayor's target of 48,840 units per annum represents a more than doubling of the average number of units delivered each year since 1990 and an increase of some 60% over the number of new homes built in 2013.

In order to encourage development and provide for a higher volume of private and social housing development going forward, choices around London's future spatial development will be necessary.

It may well be necessary to review development density and height restrictions in order to allow for additional, targeted growth within London's current boundaries. Development outside London's current boundaries, focused around transport nodes may need to be permitted in order to allow for an increase in supply.

3 Transport infrastructure

This section details our review and assessment of London's transport infrastructure needs to 2050. Working with the GLA and Transport for London (TfL), we have considered future requirements to provide a preliminary estimate of the capital expenditure and operating costs associated with the continued growth and renewal of the city's transport system.⁶⁷ Our analysis is based upon:

- TfL's latest business plan and analysis of its historical expenditure;
- A review of trends and plans for the national rail network;
- Highway Agency and London borough activities;
- The Sir Howard Davies Airports Commission⁶⁸ work;
- Analysis of high speed rail serving London; and
- Other expenditure planned at London's main airports.

We have developed a preliminary review of new schemes, based upon population projections and different development scenarios, and have then undertaken a cost assessment for each of them. Different transport investment options for the capital have been commissioned by a range of local and central government agencies and commissions, and private and public companies.

Important questions about the future of aviation capacity in the region are currently being considered.⁶⁹ Because a preferred option for aviation capacity has not yet been determined, we have considered transport infrastructure schemes proposed during the study period according to several different spatial development scenarios, accounting for aviation capacity and other development options, as well as population growth. These scenarios vary according to the location of development within or beyond London's current boundaries and the aviation scenarios that have been taken forward in the Davies Commission work.⁷⁰ The scenarios we have considered include:

- The development of a new airport in the Thames Estuary and development of Heathrow into a new town;⁷¹

⁶⁷ As we discuss in the funding section of this report, costs presented do not include financing costs. Fares income will continue to provide an important source of income to meet operating costs.

⁶⁸ Airports Commission, Interim report, December 2013, available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/271231/airports-commission-interim-report.pdf

⁶⁹ The Davies Commission has yet to report on its recommendation for increasing airport capacity, and we have assessed the costs of each of the options still under consideration separately. Airports Commission, *Interim report*, December 2013, available from:

https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/271231/airports-commission-interim-report.pdf. Due to timing, our report does not take into account the

consultation documents of the Inner Thames estuary airport studies issued by the Davies Commission on 10 July 2014.

⁷⁰ Due to timing, our report does not take into account the consultation documents covering the Inner Thames estuary airport issued by the Davies Commission on 10 July 2014.

⁷¹ A Heathrow 'new town' would be expected to at least partially accommodate population growth that would otherwise have taken place within other parts of London, or beyond London's boundary.

- Growth within London's existing boundaries, leaving the airports as they are currently (not taking into account any runway expansion that may result from the Davies Commission);
- Growth within London's existing boundaries, increasing Heathrow airport capacity by two runways by 2050;⁷²
- Growth within London's existing boundaries, expanding Gatwick airport capacity by one runway, followed by a runway at either Heathrow or Gatwick by 2050;
- Growth within London's existing boundaries, including the development of the 'Heathrow Hub' proposals to extend and split the runways to provide two extra runways by 2050;
- Growth beyond these boundaries, increasing Heathrow airport capacity by two runways by 2050;⁷³
- Growth beyond these boundaries, expanding Gatwick airport capacity by one runway, followed by a runway at either Heathrow or Gatwick by 2050; and
- Growth beyond these boundaries, including the development of the 'Heathrow Hub' proposals to extend and split the runways to provide two extra runways by 2050.

3.1 Costs associated with aviation and spatial development scenarios

Figure 24 overleaf shows capital (enhancements and renewals) and operating expenditure projected for the whole of the capital's transport system⁷⁴ to 2050 according to different population growth and aviation capacity development scenarios. Population growth scenarios relate to where London's incremental population is housed—within or beyond the capital's existing administrative boundary.⁷⁵ Aviation capacity development scenarios relate to the different options currently being considered by the Davies Commission.

A considerable portion of projected transport expenditure relates to London's existing system. This means that a large part of overall expenditure is not expected to change materially with different rates of population growth. However, in relation to new orbital links, new missing transport links, and schemes beyond London, the costs are potentially more scalable to the population that is expected to be accommodated. Similarly, the amount spent on new orbital links, new missing links, and schemes beyond London, is also expected to depend on where

⁷² The interim Davies Commission report from December 2013 (https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/271231/airports-commission-interim-report.pdf) 'sifted out' this four-runway option at Heathrow as part of the current Commission's recommendations, but it remains a longer term possibility.

⁷³ Ibid

⁷⁴ Projected costs include both public and private expenditure requirements.

⁷⁵ The 'Growth beyond London's boundaries' scenarios impact on our assessment of the enhancement spend needed as it alters expenditure on projects to expand the London rail and Tube system.

the new population is accommodated – whether within or beyond London’s boundaries,

In the following sections, we discuss the case for investment in the capital’s transport system; present an overview of projected costs; discuss enhancement, renewal and operating expenses in greater detail; and discuss the implications of our findings, including considering some of the benefits of transport system investment.

As shown in the figure below, changes to the aviation and spatial development scenarios therefore have a significant, material effect on capital and operating costs projected for the whole of the transport system. This figure shows the central population growth scenario only. The highest total costs, including both capital and operating cost requirements, are projected to relate to the expansion of Heathrow Airport with growth beyond London’s existing borders. As shown in this figure, cost requirements are projected to total some £1,054 billion, including £511 billion of capital (enhancement and renewal) expenditure.

Transport infrastructure cost summary – total costs, £ billion, 2016-2050 2014 prices, including a 2% pa underlying increase in capital costs ⁷⁶ Central population growth scenario									
Aviation scenario	Growth within London’s boundaries				New Estuary airport	Growth beyond London’s boundaries			
	No increase in aviation capacity	LHR R3 and R4	LGW expansion	Heathrow Hub		No increase in aviation capacity	LHR R3 and R4	LGW expansion	Heathrow Hub
Capital expenditure (enhancements and renewals)	401	497	471	480	475	415	511	484	494
Operating expenditure	478	537	505	510	507	483	543	510	515
Total (£bn)	879	1,034	975	990	982	898	1,054	995	1,009

Figure 24: Transport infrastructure cost summary. Total projected expenditure required by both the public and private sectors, 2016-2050. 2014 prices, including 2% construction industry cost uplift per annum. Source: Arup analysis

Projected transport costs associated with the proposed expansion of Heathrow are marginally higher than those required for the base case of the proposed Estuary Airport due to the inclusion of additional costs associated with Heathrow’s development which have been identified by TfL.⁷⁷ TfL has estimated that the

⁷⁶ Our work relies upon Davies Commission submissions, including those by TfL. We have not attempted to review the costs of the different airport expansion options in any depth.

⁷⁷ TfL has identified additional costs associated with Heathrow’s development in order for the airport to achieve an overall capacity similar to that proposed for an Estuary Airport. We have included these additional costs in our expenditure requirements for Heathrow, as shown in the figure above, both in the Hub and R3+R4 scenarios. TfL’s analysis has focused only on the direct comparison of an Estuary Airport with comparable capacity development at Heathrow. Arup has included other enhancement cost requirements for each of London’s existing airports during the study period in its cost assessment. Later in this chapter, these costs are referred to as “aviation—existing” costs within our discussion of enhancement expenditure requirements. We also have

additional cost associated with Heathrow, predominantly for surface access infrastructure enhancements, could total some £37 billion⁷⁸ above and beyond more routine capital and operating expenses. The base case of the Thames Estuary Airport transport development scenario is therefore projected to require a lower level of expenditure, totalling some £982 billion over the study period, including some £475 billion of capital (enhancements plus renewals) expenditure.

As might be expected, no increase in the region's aviation capacity shows the lowest capex and opex levels to 2050. This estimate ignores the potential inefficiencies that could be created through a lack of growth in aviation capacity.

The difference between the highest capital cost scenario ('Growth beyond London's boundaries, LHR R3 and R4') and the lowest ('Growth within London with no increase in aviation capacity') is £110 billion or 27% of the projected capital cost of the lowest cost scenario. Excluding additional costs for the Heathrow options identified by TfL would mean that development of a Thames Estuary Airport would be the most expensive option. This is due not only to the large costs of the airport itself, but also the redevelopment of Heathrow as a new town, with its associated additional transport costs.

3.2 Summary of costs according to the Mayor's preferred development scenario

As was shown the combined public and private expenditure, including both capital (renewals and enhancements) and operating expenses for the Mayor's preferred development scenario ('Growth within London's boundaries, new Estuary Airport') is projected to total some £982 billion.

Projected growth in expenditure is expected to be driven by a steady expansion of enhancements and renewals needed to get more out of London's existing transport system, along with substantial expenditure on new strategic rail links, road improvements and aviation capacity development. Renewals, operations and maintenance expenditure are estimated to ramp up as the overall asset base increases in size.

Significant expenditure is associated with major projects, including London's share of schemes of national importance. London's public and private sector contributions to nationally important schemes, including both capital and operating expenses, are projected to total some £280 billion. Included within the expenditure requirements associated with major schemes, London's share of planned high speed rail and aviation projects accounts for 30% of transport enhancement expenditure over the full study period to 2050.

We project that London's transport system could require some £475 billion of capital investment (enhancements plus renewals) in the 35 year period to 2050. Total expenditure (including both capital and operating expenditure) could rise from some £78 billion over the five years to 2015 to some £169 billion in the five year period between 2046 and 2050.

assumed that an Estuary Airport could require additional enhancement capital expenditure within the study period, as discussed later in this chapter of the report.

⁷⁸ Excluding construction cost uplift of 2% per annum used elsewhere.

3.3 The case for investment

Investment in London's transport infrastructure is critical in meeting the demands of its growing population, underpinning growth, competitiveness and employment in the wider economy and reinforcing London's position as a leading world city. New transport links play a pivotal role in opening up areas for regeneration and dealing with existing and anticipated capacity constraints. Transport infrastructure investment can be an important driver of land values⁷⁹, helping to secure a virtuous cycle of growth and investment that underpins wider funding of the city's infrastructure development.

As the Mayor's Transport Strategy outlines,⁸⁰ investing in transport benefits the wider economy by linking people to employment and products to markets. Alongside housing, London's transport infrastructure is perhaps the sector foremost in the minds of the public and policy makers when infrastructure investment is considered. This is perhaps because of the importance of transport within the Mayoral brief, the reliance on public transport by Londoners for accessing work, education, leisure and other opportunities, and the media observations that the existing system has historically suffered from under investment that has only relatively recently been addressed. Dealing with the backlog is anticipated to continue into the 2020s.

As new transport links allow for development growth and regeneration, financial mechanisms to be help pay for them can be deployed.⁸¹ Crossrail made some use of these mechanisms in order to contribute towards the funding of some of its capital costs, and Crossrail 2 is expected to do so to a greater extent.

There is considerable evidence to show that investment in London's infrastructure has far-reaching direct and wider economic benefits. As we discuss later in this section, correctly targeted, a contribution of £500 billion to these schemes could generate wider economic benefits of up to £1,500 billion.

3.3.1 National policy

Government transport policy is framed typically around allocating resources towards improving the efficiency of travel. The primary mechanisms for increasing travel efficiency are increasing capacity and relieving congestion so that journey times for people and the movement of goods are made faster and more reliable. Much of the transport infrastructure currently in use today was built many decades ago, meaning that significant investment is therefore also need to renew existing transport infrastructure, ensuring it is kept in a serviceable condition.

New national transport projects are also aimed at opening additional routes for business, leisure and commuter travel. For example, the increase in aviation capacity currently under consideration by the Davies Commission, is proposed to

⁷⁹ See for example *Crossrail Property Impact Study*, GVA, October 2012. Available from: <http://www.crossrail.co.uk/news/articles/crossrail-predicted-to-increase-property-values-by-55-billion>

⁸⁰ *Mayor's Transport Strategy*, Greater London Authority, May 2010

⁸¹ See for example *Funding Crossrail 2*, London First, February 2014. Available from: http://londonfirst.co.uk/wp-content/uploads/2014/02/LF_CROSSRAIL2_REPORT_2014_Single_Pages.pdf

enable direct flights between the UK and potential new export markets in emerging economies. Similarly, the Government's proposals for High Speed 2 are justified on the basis of the line's ability to provide additional capacity and better link the economies of the north and the south of the country.

With respect to the environment, government policy is to reduce emissions from transport, where possible, by providing incentives and the infrastructure to support greater use of lower emission modes including electric vehicles. Policies are aimed at alleviating local congestion and reducing the adverse impacts of vehicle emissions, which can impact upon quality of life, particularly within urban areas.

3.3.2 London context

There are therefore obvious overlaps with these national policies, and the priorities for investment in London.

As an engine of the UK economy, a primary policy objective for the Mayor is for London to have a transport system which can allow a growing population to travel efficiently, safely and reliably, with minimal impact on the environment. There is a need to provide capacity not only for London's population but also for the considerable number of people who commute from the rest of the country and visit London for business and pleasure.

Against a background of increasing demand for many services, London's transport network often suffers from overcrowding and congestion. A key focus of expenditure is therefore to increase capacity on existing systems to meet the needs of the population today (including rising expectations) and to cater for future growth. For example, enhancements to the London Overground have helped to improve connectivity, have opened up access to employment and enabling housing development. Increasingly, policy attention is being paid to ensuring that the capital's roads contribute to an improved public realm—helping to ensure London remains one of the world's best cities in which to live as well as to do business. The Mayor's Roads Task Force has proposed an ambitious range of schemes over the study period. These are aimed at delivering more “liveable” safer streets, reduce the severance impact of major roads and in overall terms and improve the quality of the public realm around London's roads.⁸²

3.4 Preliminary analysis of costs and benefits

In the sections that follow, we discuss our findings related to the Thames Estuary Airport aviation capacity development scenario.⁸³ These findings also relate to the central population scenario, which assumes that more than 11 million people will live in the capital by 2050. We have assessed London's transport requirements according to three expenditure areas:

- Capital expenditure for transport enhancements, including major new projects such as Crossrail 2 and Crossrail 3, HS2, the Mayor's Roads

⁸² The Mayor's Roads Task Force also proposed investment in enhanced road links and additional river crossings, amongst others. See <http://www.tfl.gov.uk/corporate/about-tfl/how-we-work/planning-for-the-future/roads-task-force?cid=fs086#on-this-page-0>

⁸³ A list of the different development scenarios Arup has considered as part of its cost review is found in the introduction to this chapter. The capital and operating expenditure projected to be required for each of these different scenarios is presented in section 3.1.

Task Force programme of improvements and the new Estuary Airport (as well as other scenarios for new alternative new aviation developments following the outcome of the Davies Commission);

- Expenditure for renewal of the existing (and anticipated additional) transport asset base; and
- Operating and maintenance expenditure (again, for both existing and new assets).

3.4.1 Projected expenditure requirements

As can be seen in Figure 25 and Figure 26 below, for the transport scenario incorporating the Estuary airport some £475 billion of capital expenditure is projected to be required between 2016 and 2050. An additional £507 billion is projected to be required for operating costs.

Total expenditure (including both capital and operating expenditure) is shown to rise from some £87 billion over the five years to 2020 to some £169 billion in the period between 2046 and 2050.

Totalling some £358 billion, enhancement expenditure is projected to represent between one-third and one-half of projected total transport infrastructure costs in the study period. Renewals costs are projected to comprise smallest requirement within the sector, at a total of some £117 billion between 2016 and 2050.⁸⁴

£bn 2014 prices, five year period ending	2011-2015	2016-2020	2021-2025	2026-2030	2031-2035	2036-2040	2041-2045	2046-2050	Total 2016-2050	CAGR 2016-2050
Capex	29	35	74	70	76	67	72	82	475	2.9%
Enhancements	21	26	63	55	58	48	50	56	358	2.6%
Renewals	8	8	11	14	17	19	22	26	117	4.0%
Opex	49	52	60	71	77	78	82	87	507	1.7%
Transport total	78	87	134	141	153	145	154	169	982	2.2%

Figure 25: Projected capital and operating cost requirements by five-year period, summarising capital and operating expenses, 2011-2050 (£ billion). 2014 prices, including 2% construction industry cost uplift per annum. Source: Arup analysis

Projected expenditure arguably represents a manageable proportion of London's economic output. Capital expenditure is projected to total between 1.6% and 3.5% of GVA, per five year period, in the years between 2016 and 2050. This compares with an estimated 1.9% in the period to 2015.⁸⁵ Transport capital expenditure is projected to peak during the five-year period between 2021 and 2025,⁸⁶ when it could represent some 3.5% of the London's total economic output (GVA). Higher expenditure in this period is projected to relate to construction costs of major

⁸⁴ TfL includes some 'renewal' -type investment within its 'getting more out of the existing system' programme. We maintain this distinction.

⁸⁵ Based on Arup's review of expenditure within the period between 2011 and 2015. As this 'baseline' figure is likely to differ slightly from actual levels of expenditure, it is presented for indicative purposes only.

⁸⁶ This is the peak in terms of expenditure as % of GVA. The peak in terms of expenditure in absolute terms is later, between 2046 and 2050.

schemes, including HS2 and the Estuary Airport (without accounting for benefits). By removing these major schemes, projected capital expenditure would fall, at peak, from 3.5% of GVA, to 1.9% of GVA.

£bn 2014 prices, five year period	2011-2015	2016-2020	2021-2025	2026-2030	2031-2035	2036-2040	2041-2045	2046-2050	Total 2016-2050	CAGR 2016-2050
Capex (renewals plus enhancements)	29	35	74	70	76	67	72	82	475	2.9%
Of which: TfL projects	19	21	29	33	38	46	48	54	269	3.3%
National Rail projects	4	4	4	5	6	7	8	10	44	3.3%
High speed rail projects	0.1	0.1	14	1	1	1	1	1	19	9.4%
Non-TfL Roads projects	1	1	1	1	1	1	1	2	9	2.2%
Aviation projects	6	9	26	30	29	12	13	15	134	1.5%
Opex	49	52	60	71	77	78	82	87	507	1.7%
Of which: TfL projects	25	27	31	34	37	41	44	47	260	1.8%
National Rail projects	9	10	10	11	11	12	12	13	78	1.0%
High speed rail projects	0.1	0.1	1	3	3	3	3	3	16	11.0%
Non-TfL Roads projects	3	3	3	3	3	3	3	3	18	0.0%
Aviation projects	11	13	16	20	24	20	21	21	134	1.8%
Transport total	78	87	134	141	153	145	154	169	982	2.2%
Capex as % GVA	1.9%	2.0%	3.5%	2.8%	2.5%	1.9%	1.7%	1.6%		
Expenditure as % GVA	5.2%	4.9%	6.4%	5.6%	5.1%	4.1%	3.7%	3.4%		

Figure 26: Projected capital and operating cost requirements by five-year period according to area of investment, 2011-2050 (£ billion). 2014 prices, including 2% construction industry cost uplift per annum. Source: Arup analysis

Projected growth in expenditure is driven by a steady expansion of enhancements, along with the renewals needed to get more out of London's existing transport system and support on-going improvement.

As the asset base grows, renewals are projected to comprise a growing share of total costs. As was shown in Figure 25, it is estimated that renewals will increase from some £8 billion in the five years ending in 2020 to £26 billion in the five years ending 2050. This increase is being driven by the increasing size of the asset base and by real capital cost increases of 2% per annum. We have used a benchmark rate of 1% of cumulative enhancement expenditure to calculate renewal costs associated with looking after new assets.⁸⁷

Figure 27 sets out graphically a profile of transport expenditure. As can be seen, a step change in combined public and private investment will be required at the beginning of the 2020s, as projects of national significance are initiated. As these new projects are delivered, operational and maintenance costs also are projected to increase in aggregate. We have assumed that operations and maintenance costs represent 5% of capital enhancement values. Full details of the cost assumptions we have used are given in the transport cost appendix to this report.

⁸⁷ These figures are at the higher end of a range that we derived from a variety of benchmarks and sources. We conclude that projecting higher renewals and maintenance costs is prudent, as it reflects the intensity with which the capital's transport system and assets are used. Key benchmarks have been HS1, London Underground, Crossrail 1, and the National Rail network.

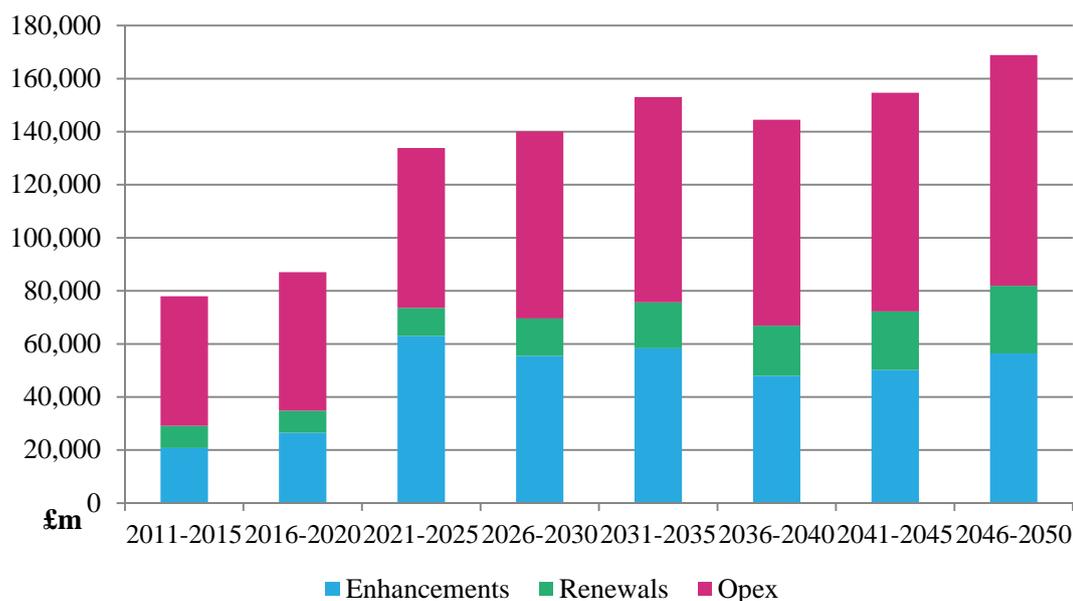


Figure 27: Estimated transport expenditure 2016-2050 (5-year period ending in year shown) (£ million). 2014 prices, including 2% construction industry cost uplift per annum for enhancements and renewals. Source: Arup analysis

3.4.1.1 Capital expenditure for enhancements

Figure 28 overleaf provides a breakdown of enhancement expenditure to 2050.⁸⁸

Aviation

As can be seen aviation expenditure, related to the new airport and to upgrades to the existing airports, comprises a significant proportion of total enhancement expenditure requirements during the study period. In total, it is projected that aviation infrastructure enhancements will require some £96 billion over the study period. This includes enhancements to existing airports. It is estimated that the Thames Estuary Airport will require some £52 billion⁸⁹ of enhancement expenditure over the study period.

After initial development, at a cost of some £46 billion⁹⁰, we have estimated that ongoing enhancement of the new airport is likely in the last decades of the study period, catering to further increases in demand. In total, we have assumed that the Thames Estuary Airport could require some £52 billion in the study period⁹¹. This would provide an airport with capacity for 150 million passengers per annum⁹². Accounting for construction industry price growth during the study period, it is

⁸⁸ As explained above, expenditure projections shown in this section relate to the Thames Estuary development scenario and the central population scenario.

⁸⁹ This figure is not indexed to account for real construction industry price inflation over the study period, estimated as c.2% p.a.

⁹⁰ Individual project enhancement figures are not indexed according to inflation, as they are inputs to the cost model.

⁹¹ *ibid.*

⁹² This figure is derived from the Airports Commission's Interim Report of December 2013

estimated that the new airport will require some £72 billion of enhancement expenditure between 2016 and 2050.⁹³

In comparison, the Mayor of London's estimate of the construction cost of a new Thames Estuary Airport is £44 billion⁹⁴, which also includes surface access costs but additionally includes an allowance for risk and optimism bias. However in the Mayor's case, an additional £12 billion of investment will be needed to allow the airport to expand in line with forecast demand growth to 150 million passengers per annum by 2050.

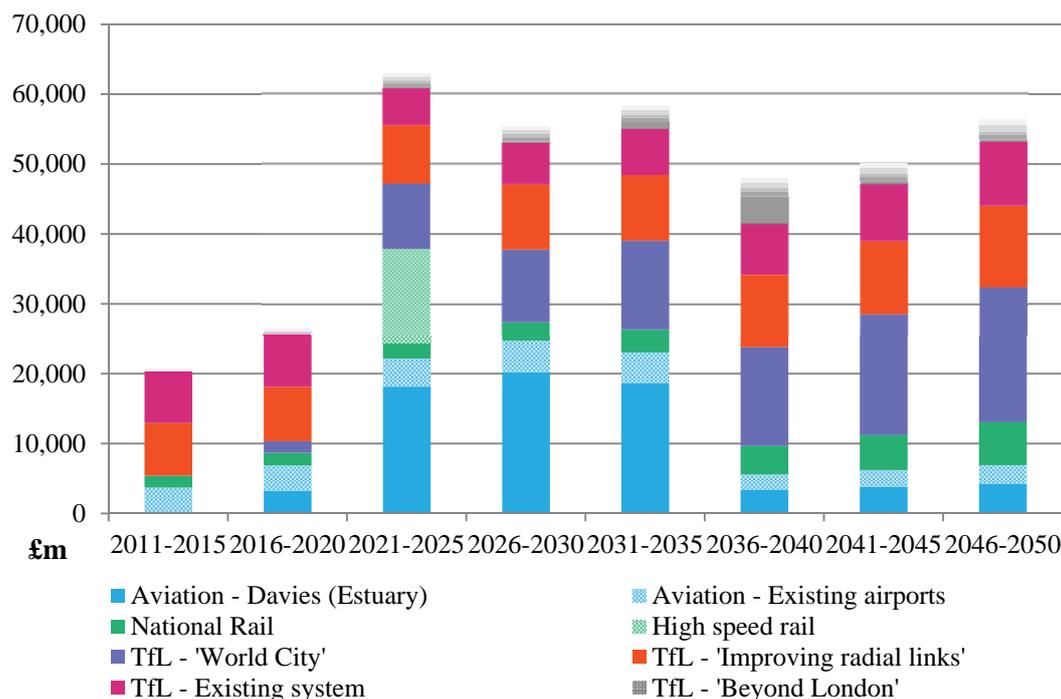


Figure 28: Capital enhancement expenditure by category, 2016-2050. 2014 prices (£ million) including 2% construction industry cost uplift per annum. We discuss the period of greatest projected capital expenditure, between 2021 and 2025, in greater detail in section 3.4.1.2. Source: Arup analysis

It is projected that enhancements to London's other airports will continue as a Thames Estuary Airport is developed and operated. As shown in Figure 28, enhancement expenditure related to London's existing airports is projected to occur throughout the study period. Heathrow enhancements are anticipated through the early 2030s and until its notional closure. Continued enhancement of other airports is projected until 2050. Some £24 billion of enhancement expenditure is projected to be required for non-Thames Estuary airports between 2016 and 2050.

⁹³ These enhancement costs exclude renewals cost requirements associated with the new airport. It is estimated that the new airport will require some £19 billion of renewals expenditure in the study period, between 2016 and 2050.

⁹⁴ Individual project enhancement figures are not indexed according to inflation, as they are inputs to the cost model.

TfL investment programmes

A large portion of projected enhancement expenditure in Figure 28 is shown according to the investment categories used by TfL. These categories encompass a wide range of proposed enhancements. As shown in Figure 29, these expenditure areas are projected to require some £219 billion over the study period.

'World City' enhancement expenditure is anticipated to require some £85 billion of expenditure over the study period, from 2016 to 2050. Expenditure proposed by the Mayor's Roads Taskforce, some £30 billion (unindexed), comprises a considerable share of total projected World City enhancement expenditure requirements.⁹⁵ We have assumed that the rate of Roads Task Force spend – originally earmarked for spending over 20 years – continues for the duration of the study period. Alongside road schemes, various cycling, river pier enhancements and other projects comparable to the Garden Bridge, make up the remainder of the 'World City' category.

In Europe and elsewhere, urban realm improvements are increasingly seen as an alternative to investment in more expensive, mechanised forms of transport. We expect a number of cities could follow this trend over the next several decades. Reflecting this view, we have modelled two increases in 'World City' investment in our central case, demonstrating the growing importance of green infrastructure.⁹⁶

Improving radial links (including the extension of existing Tube lines and the development of Crossrail 2 and Crossrail 3) is projected to require some £67 billion of expenditure between 2016 and 2050. Existing system enhancements are anticipated to require some £50 billion of expenditure over the study period.⁹⁷

Category	Project type included	Projected enhancement expenditure required (£ billion), 2014 prices
World city	Mayor's Roads Task Force; cycling schemes; river crossings; enhanced and additional river piers; schemes similar to the planned Garden Bridge	£85bn
Improving radial links	Crossrail; Crossrail 2; Crossrail 3; Extension of existing Tube lines	£67bn
Getting more out of the existing system	On-going enhancement to TfL's Underground and Rail existing assets	£50bn
Beyond London	Various new town enhancements given the closure of Heathrow Airport	£6bn

⁹⁵ Individual project enhancement figures are not indexed according to inflation, as they are inputs to the cost model.

⁹⁶ The first, of 10% on the per annum spend, is projected to occur from 2030 to 2040. An additional 10% is then included from 2040 to 2050. Correspondingly, we have reduced the 'Orbital links' and 'Radial links' amounts by 10% from 2030 (and a further 10% from 2040) as compared to TfL's own projections. Alternatively, additional 'World City' investment could be secured by a rephasing of Crossrail 3 – that has not been modelled in the central case.

⁹⁷ A detail of the different components of planned and proposed TfL expenditure is included at appendix A4.1.3.

Category	Project type included	Projected enhancement expenditure required (£ billion), 2014 prices
Complementary	Upgrades and re-alignments to support Crossrail enhancement	£4bn
Improving orbital links	Extension of light rail system	£4bn
Missing links	Connecting opportunity areas; New Tube stations	£3bn
Total		£219bn

Figure 29: Project TfL expenditure for major enhancements by category, 2016-2050. 2014 prices (£ billion), including 2% construction industry cost uplift per annum. Source: Arup analysis

National and high speed rail

London's share of HS2 enhancement expenditure has been factored in to our numbers for the first half of the next decade. Additional expenditure in London also is projected to be required in relation to national rail enhancements every five years. In total, rail enhancement investment is projected to require some £39 billion over the study period. In part because of the cost of HS2 projected to be required in London, enhancement expenditure is projected to peak between 2021 and 2025.

3.4.1.2 Projected enhancement expenditure requirements: 2021-2025

A large number of projects have been proposed as important to sustaining London's economy and fostering long-term growth. Many of these projects are initiated between 2021 and 2025. Enhancement spending is projected to peak at £63 billion between 2021 and 2025.⁹⁸

Figure 30 overleaf, details capital enhancement expenditure associated with projects initiated in the period between 2021 and 2025. Only the costs incurred for major projects in the five year period are shown.⁹⁹ In this period, the development of the new Estuary Airport, the construction of HS2 (including enhancements to other transport links at Euston and Old Oak Common), the building of Crossrail 2 and investment in the road network have been included. These projects represent some two-thirds of enhancement expenditure over the period in question.

We have used TfL's projected enhancement spend between 2014 and 2020¹⁰⁰ as the source of the costs of 'Getting more out of the existing system'. A portion of

⁹⁸ As explained above, expenditure projections shown in this section relate to the Thames Estuary development scenario and the central population scenario.

⁹⁹ For reference and comparative purposes, we include expenditure requirements for the Thames Estuary Airport development scenario and other aviation capacity development scenarios. All figures relate to the central population scenario, which forecasts a population of more than 11 million by 2050.

¹⁰⁰ Excluding Crossrail

these costs are projected only in the short-term, rather than over the entirety of the study period. For example, the Northern Line extension to Battersea is projected to be completed in 2019. Although TfL anticipates completing a significant portion of the backlog of Underground improvement works in the latter half of this decade, it is projected that some £5 billion of expenditure will still be required for enhancements to the existing system (2021-2025) especially the Underground.

As London's population grows, without sufficient investment, the level of overcrowding on the existing network is projected to increase. To offset overcrowding and to cater for growth at Euston generated by HS2, we have incorporated the cost of further Crossrail projects and other improvements, as suggested by TfL.¹⁰¹ These costs are included within the 'Improving radial links' category, which is anticipated to require some £8 billion of enhancement expenditure between 2021 and 2025.

A significant portion of expenditure projected to be required in the early 2020s relates to HS2. It is projected that London's share of HS2, the associated regeneration of Euston and Old Oak Common, coupled with ongoing costs of HS1 will total £13.5 billion on high speed rail expenditure in the period between 2021 and 2025.

There may be opportunities to reduce (or defer) expenditure in this period. Rather than concentrating on the development of new lines in the 2020s, more incremental growth of London's transport system might be an effective alternative. Longer development periods for major enhancements may also help ease construction industry capacity constraints as well as potential funding challenges.

Sector	Category	Enhancement expenditure (£billion), 2021-2025 only, 2014 prices
TfL	Getting more out of the existing system	£5.3bn
	Improving Radial Links	£8.3bn
	Improving Orbital Links	£0.6bn
	Missing Links	£0.4bn
	World City	£9.3bn
	Beyond London	£0.2bn
	Complementary	£0.5bn
National Rail		£2.2bn
High Speed Rail		£13.5bn
Non-TfL road projects		£0.5bn
Aviation	Existing	£4.0bn
	Davies	£18.2bn
Total (2021-25)		£62.9bn

Figure 30: Total enhancement expenditure projected between 2021 and 2025. 2014 prices (£ billion), including 2% construction industry cost uplift per annum. Source: Arup analysis

¹⁰¹ We have assumed Crossrail 2 and 3 are developed in 15 year intervals within the 'Improving radial links' investment category from 2020 onwards. We also have made allowances for Underground, Overground and light rail extensions within this same category.

Our central case, with Crossrail 2 and Crossrail 3 being built over 15 years, has transport capital investment (including both enhancements and renewals) taking the equivalent of 3.5% of London's GVA between 2021 and 2025. Taking an even longer-term approach to the development of new transport enhancements (by delaying Crossrail 2 completely until 2026 for example), would mean that transport capital expenditure in the five-year period would fall to 3.2% of London's projected GVA.

Technical change might be expected to drive down costs over time, but rising transaction and planning costs, material costs, labour costs, customer expectations, improved safety requirements and increasingly complex systems are expected to drive costs up in real terms. Hence, we have assumed that capital costs will increase at a real underlying rate of 2% per annum, reflecting recent historical real-terms increases.

3.4.1.3 Operation and maintenance (O&M) costs

In the Thames Estuary Airport scenario, operating expenditure is projected to total some £507 billion over the study period. Even so, as shown in Figure 31, the largest area of projected O&M expenditure relates to TfL's existing infrastructure.¹⁰² O&M of TfL's existing asset base is projected to total some £26 billion between 2016 and 2020, increasing to £33 billion by the five-year period between 2046 and 2050. O&M expenditure on national rail assets is forecast to rise from £10 billion for the five years to 2020 to £13 billion for the last five year period.

As with capital renewals, overall expenditure on operation and maintenance is expected to increase over the period to 2050 as new transport projects are delivered, increasing the portfolio of infrastructure which needs to be maintained.

We have adopted the view that expenditure to operate and maintain new assets could be more modest relative to the levels of expenditure required to maintain existing infrastructure. This is primarily because new infrastructure should not require extensive maintenance in the short to medium term and will be designed to be maintained more efficiently.¹⁰³

¹⁰² Operating expenses are calculated as 5% of capital expenditure, based on benchmarking against major transport projects. Further detail is provided in appendix section A4.2.1.4.

¹⁰³ For example through the application of 'RAMS' principles and the use of 'BIM'.

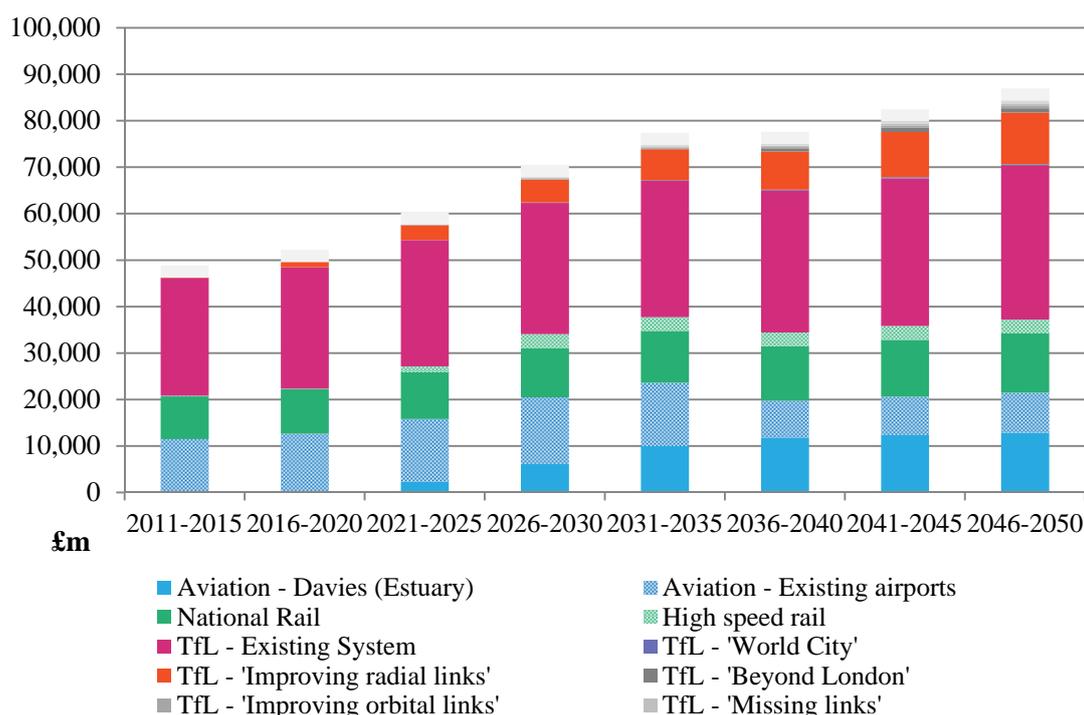


Figure 31: Projected operations and maintenance expenditure by category, 2016-2050. 2014 prices (£ million). Source: Arup analysis

We have estimated that because of the notional closure of Heathrow, O&M on existing aviation infrastructure – the five main airports serving London today – will reduce from £13 billion between 2016 and 2020 to just under £9 billion in the five years between 2046 and 2050. Estuary airport costs would be in addition to these.

3.4.2 Potential benefits of investment

Traditionally, the primary drivers for transport investment in London are to provide additional capacity to relieve existing congestion, and to meet future demand. Wider economic benefits are typically considered as a separate increment to the primary appraisal. Most transport projects are assessed against the benefits they will bring to transport users. These include faster journey times and relief from crowding and further benefits through reducing road accidents by encouraging people to move to safer modes of transport. Schemes benefit non-users as well. For example, they are likely to yield benefits in terms of decongestion and for projects that encourage transfer to more environmentally friendly modes, harmful emission reductions. The projects identified by the Mayor's Roads Task Force are designed at least in part to improve the environment for pedestrians, cyclists and public transport and enhance the safety of London's streets.

3.4.3 Estimating direct benefits of expenditure

As a rule of thumb, major transport investment schemes that typically secure government approval tend to have a benefit-cost ratio (before wider economic benefits) of at least 2:1, meaning that society benefits by £2 for every £1 that is invested. Sometimes schemes have higher benefit values. In 2012, every project

that was approved by the Department for Transport had a benefit-to-cost ratio that was above 2:1.¹⁰⁴ Crossrail has been shown to have a benefit-to-cost ratio of around 2:1 (before taking wider economic benefits into account).¹⁰⁵

We would expect the major benefits (in terms of their monetised value) of transport investment in a dense, congested city such as London to be journey time savings, road decongestion benefits (and wider economic benefits from agglomeration effects). Benefits will include journey quality benefits, which would be of particular relevance to some Roads Task Force projects, and prevention of accidents, through passengers moving to a safer mode (usually away from cars and onto public transport).

3.4.4 Estimating wider benefits of expenditure

Transport projects have a beneficial impact on the economy by providing new or improved links between centres of economic activity, generating employment opportunities and opening new markets.¹⁰⁶ Wider economic benefits include giving firms better access to (deeper and/or broader) labour markets and enhancing competition. Agglomeration benefits are particularly relevant to a large, relatively dense urban area such as London. Once these are added into a conventional scheme appraisal, the benefit-costs ratio can increase substantially. Crossrail's benefit-cost ratio including wider economic benefits has been estimated as 3.1:1.

For Crossrail, the overall public sector contribution has been around two-thirds of the total cost, with the remainder coming from user charges. For similar schemes, we might expect the private sector contribution to be marginally lower across the range of projects that we have considered. It would be reasonable to suggest that the public sector might contribute around half of the costs towards the projects in our portfolio, constituting around £500 billion of the £1,000 billion of transport costs over the plan's period. With a benefits-to-cost ratio of 2:1, this would be expected to generate £1,000 billion of return for the public sector contribution; with a benefits-to-cost ratio of 3.1:1, this would be expected to generate in excess £1,500 billion of wider benefits.

3.5 Risks and uncertainties

Some projects that are planned for the next few decades are already in some stage of development. TfL holds detailed budgets for the period until the early 2020s. It is developing plans for Crossrail 2 and has outline budget plans for the period to around 2030. Furthermore, national rail has an established funding settlement for a new control period (2014/15 to 2019/20), High Speed 2 is planned to open in stages to 2033 and the M25 has a long-term PPP arrangement to 2039.

¹⁰⁴ *Percentage of DfT's appraised project spending that is assessed as High or Very High value for money*, Department for Transport, August 2013. Available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/230918/vfm-indicator-jan-dec-12.pdf

¹⁰⁵ See for example *Crossrail*, National Audit Office, January 2014. Available from: <http://www.nao.org.uk/wp-content/uploads/2014/01/Crossrail.pdf>

¹⁰⁶ In theory, transport schemes with high ratios of benefit to cost could contribute to GVA growth beyond historical levels.

More uncertainty exists around the development of London's aviation infrastructure and the outcome of the Davies Commission. Furthermore, there is a broader related question over the extent to which London will be able to grow outwards. An estuary airport (or indeed one that put additional capacity into Gatwick) may shift London's development towards its peripheries. Whatever the outcome of Davies, the overall cost of aviation capacity development will be very substantial. For example, before indexation the largest scheme – the Estuary airport - had a mid-point capital cost of £46 billion in real prices.

Some work has been undertaken by TfL on the additional costs of some Davies Commission recommendations; it is at a preliminary stage. Cost uncertainty in this area has a material impact on overall transport expenditure projections. For example a 10% increase or decrease of expenditure of £46 billion is equivalent to around one-third of the capital cost of Crossrail 1.¹⁰⁷

Whatever the outcome of the airport review, not all of the costs of new and improved airports will be borne by London, as a large proportion of the cost of projects will be funded by the private sector. These charges will be passed onto airlines and passengers from across the UK and beyond.

Spatial planning scenarios themselves contain uncertainties. For new town development scenarios in which growth is accommodated beyond London's boundaries and the Estuary airport (Heathrow new town) options, we have included the costs for a new rail link and stations (or in Heathrow's case, conversion of the existing), and for developing a local public transport (light rail and bus) system. The costs have been derived from planned TfL projects.

3.6 Links with other sectors

Significant progress has been made in London towards developing sustainable, green transport. For example, there are new walking and cycling routes in the Queen Elizabeth Olympic Park; the cycling network continues to expand. In future, London's reputation as a world class place to live, work and do business may depend to a much greater extent on the successful delivery of such schemes than it has done previously. To account for these opportunities, we have factored in increased projected expenditure on 'World city' schemes from 2030, and offset this with lower expenditure on 'Radial' and 'Orbital' links after that point.

The Mayor's Roads Task Force¹⁰⁸ suggests that it will work towards providing "great places which contribute to the look, feel and reputation of the city". Many of the Task Force's recommendations (in particular the aspiration to provide greener, cleaner, quieter streets and a healthier more active city) could at least in part be considered as green investments. The additional cost of providing green "Quietways", dedicated cycling routes, has been included separately in the green infrastructure category.

¹⁰⁷ If Heathrow was to be decommissioned, there would no doubt be significant costs associated with transitional arrangements for moving to a new purpose built airport to the east. It is beyond the scope of this report to attempt to quantify them.

¹⁰⁸ *Roads Task Force Report*, Transport for London, July 2013. Available from: <http://www.tfl.gov.uk/corporate/about-tfl/how-we-work/planning-for-the-future/roads-task-force?cid=fs086#on-this-page-0>

The effect of the roll-out of electric car infrastructure and the demand that it will place on the grid requires careful consideration.¹⁰⁹ If London's achievement of rolling out 1,300 charging points is built upon, such that the city becomes a world leader in charging points and take up of electric cars, it would create significant additional demand for electricity from the grid. The impact of a faster, more intense roll-out of electric car infrastructure on the demand from the grid and the consequent required rate of power station building would affect substantially the energy sector.

3.7 Opportunities for consolidation

There are interdependencies between some of the major enhancement projects. These would benefit from more detailed analysis. In particular, HS2 and Crossrail might both serve a new station at Old Oak Common, and efficiencies may be possible through the way work is phased between the two projects. Similarly, there will be linkages between HS2 and the proposed Crossrail 2 line, at Euston station.

For all of the major schemes, there are opportunities to integrate transport with the wider cityscape to improve quality of life. London has a strong track record in this area, including the high quality environments created by the Jubilee Line Extension at Canary Wharf and more recent development at King's Cross station and that which is planned to take place following Crossrail and HS2. Chapter 11 of this report presents further analysis of potential cost savings and efficiencies.

3.8 Conclusions

The ambitious programme of transport investment forecast for the next few decades is unprecedented in London's recent history. Until the turn of the century, investment has been characterised by a stop-start flow of enhancement expenditure. Enhancement investment has unquestionably been held back by a post-war reluctance to invest during the years when the city's population and public transport usage was declining.

Catering to economic development and population growth has been shown to require a reversal of such historical trends. London's ambitions to begin to build two new airport runways (either as part of a new Estuary Airport, or elsewhere), to commence work on a new high speed line and further Crossrail schemes, to implement the Roads Task Force recommendations and to invest in linking up development areas, would require a step-up in transport spending. As has been demonstrated with Crossrail (and imminently, with the extension of the Northern

¹⁰⁹ There is significant overlap of the transport and energy workstreams, with many of the transport investments requiring additional electrical power, and putting additional strain upon the grid. This is perhaps most strongly seen in the field of electric vehicles (EVs). We have been informed by TfL that there are no plans to expand the publically available electric vehicle network in London beyond the 1,300 points that have already been provided. We have not included additional costs of further expansion of that network. With this in mind we have assumed for this report that any future EV charging point expansion will be privately, rather than publically led, and is perhaps more likely to be on the micro-scale (such as the organic growth of individual private charging points at home and at fuelling stations), rather than at scale (such as a planned network of charging points across London). There is, of course, a risk that the delivery mechanism for future EV expansion tends more towards the latter approach, which would trigger additional costs and put pressure upon planned spending elsewhere.

Line) this investment will probably be more likely to happen if innovative funding mechanisms and fiscal devolution are implemented.

The primary focus of our analysis has been the costs associated with London's transport system given the development of an airport in the Thames Estuary and the creation of a new town at Heathrow. In this scenario, London's transport system could require some £982 billion¹¹⁰ of capital (enhancements plus renewals) and operating expenditure by the private and public sectors between 2016 and 2050. Some £475 billion of capital expenditure is projected to be required for capital expenditure, and some £507 billion is projected to be required for operating expenditure.

When projected costs peak as a percentage of London's GVA in 2021-2025, it is estimated that total transport expenditure will be some £134 billion, including capital (enhancements plus renewals) and operating expenses. In this five year period, it is projected that capital expenditure will represent 3.5% of projected GVA. In the five years between 2011 and 2015, capital expenditure is estimated to have totalled some £78 billion, representing 1.9% of GVA. In overall terms, projected capital expenditure for new transport enhancements arguably represents a manageable proportion of economic activity.

¹¹⁰ 2014 prices including a 2% pa underlying increase in capital costs due to construction industry price increases.

4 Energy infrastructure

This section details our review of the GLA's energy infrastructure investment plan. Working closely with the GLA we have considered future requirements in order to provide a preliminary estimate of the capital and operating costs associated with future growth. Our work is based primarily upon two different models of potential long-term energy supply: a centralised scenario and a 'hybrid' scenario.

The Mayor's own carbon emissions and energy targets and their interaction with national objectives are fundamental drivers of the type of energy infrastructure investment that will be required and the costs associated with new infrastructure development. We have undertaken a preliminary cost assessment associated with a number of different scenarios. The cost projections set out in this chapter relate to two scenarios: a 'centralised' scenario and a 'hybrid' scenario.

- In a centralised scenario energy is primarily supplied via national networks with electricity production and supply likely to be based on new nuclear power, wind and gas-fired electricity generation with Carbon Capture and Storage (CCS), and a significant level of electrification of heat and transport.
- In a 'hybrid' scenario, cities will become increasingly more efficient and self-sufficient and therefore less reliant on national networks – even though national networks will retain a role in delivering energy supply.¹¹¹ This scenario would support Mayor plans to supply 25% of London's energy requirements according to a decentralised model by 2025.

Our projections show that the difference between the two scenarios' total costs (capital and operating expenses) is some 10% over the study period, with the centralised model being the more costly of the two. This difference is a reflection of the significant changes needed to London's energy supply under both scenarios, even in a more traditional, centralised route, the considerable level of investment required. In the hybrid scenario, £223 billion of expenditure, including £148 billion of capital expenditure) is projected to be required between 2016 and 2050.

4.1 The case for investment

There are a number of challenges facing London with regard to energy supply in the medium and long term. These include the future availability and price for the supply of fuels, particularly gas for heating (and to a smaller extent, power generation) and the amount of infrastructure required for power generation, transmission and distribution to meet London's expected growing demand. Furthermore, London is currently heavily reliant upon the national grid for electricity and for gas, and its supply is inextricably linked to national energy infrastructure and national energy policy. Therefore costs and security of supply challenges at the national level will directly affect London's resilience and its

¹¹¹ Hence the name 'hybrid' given to this scenario: a further scenario, which has not been considered in this analysis could have seen a full 'decentralised' model being adopted with limited role for central networks and centralised energy supply.

customers, potentially exposing them to risks that are beyond the direct control of London's authorities.

The interaction between national and regional/local objectives will be one of the most important dynamics that will drive the type of infrastructure investment in London in the future.

4.1.1 National factors

National energy policy, which is driven by the interlinked objectives of decarbonisation, security of supply and affordability, is moving to a more complex interaction of fuel sources. The decarbonisation of UK national energy supply will likely lead to a more expensive energy system with significant investment required in infrastructure over the next 20 years, for example for the investment in electricity generation assets such as the new nuclear programme and deployment of offshore wind. At the same time, maintaining security of supply will require investing in additional infrastructure to ensure reliability in the face of more intermittent sources of generation in the power sector, and to ensure reliability of gas supply in the face of potential supply (or price) shocks in the international commodity market.

Whilst energy supply interruptions (for gas or power) remain unlikely, the costs associated with unplanned interruptions and/or shocks, and the associated spikes in wholesale energy prices, are likely to have a significant downstream impact on retail gas and electricity prices for businesses and domestic customers.

The scale of this infrastructure requirement is very significant – and occurs in a short timeframe. The government regulator, the Office of Gas and Electricity Markets (Ofgem), estimates that up to £200 billion over the next ten years – more than twice the amount spent over the last decade — will be needed to replace the UK's ageing infrastructure to meet the UK's energy needs. This before investment to comprehensively 'decarbonise' the power sector, electrify the heating and transport sector after 2020.

4.1.2 London policy imperatives

The Mayor's 2011 Climate Mitigation and Energy Strategy,¹¹² which covers the period up to 2025 and the route towards 2050 targets, advocates a move away from a reliance on national energy sources and supply towards a more London-centric approach. The Mayor's Climate Change mitigation and Energy Strategy argues that while London's energy future is inextricably linked to that of the UK as a whole, it stands to reap economic and environmental benefits from pressing ahead with its own energy demand reduction and energy supply programmes. These programmes have the potential to reduce the vulnerability of the capital to supply and price shocks.

The Mayor's strategy sets out a number of policies and programmes aimed at reducing energy consumption and encouraging local supply of energy, within

¹¹² Mayor of London, *Delivering London's Energy Future: the Mayor's climate change mitigation and energy strategy*, October 2011, available: <https://www.london.gov.uk/priorities/environment/publications/delivering-londons-energy-future-the-mayors-climate-change-mitigation-and-energy-strategy>.

London. The strategy includes the Mayor's objectives for the delivery of sustainable energy to London, as outlined below.

Energy efficiency and emissions

- Energy supply should be low carbon, in line with the supply contribution to the Mayor's target to reduce CO₂ emissions from all targeted sources by 60 per cent on 1990 levels by 2025 and 25% of London's energy supply from DE.
- By 2025, retrofit 2.9 million homes through the 'RE:NEW' programme - 15.7 million easy measures installed, 1.7 million installations of loft and cavity wall insulation and 731,000 installations of solid wall insulation.
- Retrofit through the 'RE:FIT' programme 11 million m² of public sector floorspace, and 44 million m² of private sector floorspace.

Decentralisation of energy supply

- The Mayor has a target to deliver 25 per cent of London's energy supply from decentralised energy by 2025. Decentralised energy is defined as local generation of electricity and the recovery of heat, where appropriate, for use in building space heating and domestic hot water production. This includes microgeneration, such as photovoltaics on individual buildings, through to large-scale combined heat and power operating with heat networks.
- The GLA's Decentralised Energy Capacity Study (2011) showed that over half of the overall opportunity for decentralised energy in London is through medium and large-scale heat networks. In addition the study found that a significant proportion of the opportunity for decentralised energy in London will be powered through Combined Heat and Power (CHP) generation.
- The GLA's Decentralised Energy Capacity Study (2011) also investigated the potential for renewable sources of energy for London. It estimated that by 2025, these sources could supply more than 10,000 GWh of energy, equivalent to 12 per cent of London's total energy supply.

Investment in a smart network

- London's existing electricity distribution network will require significant investment to be fit for purpose by 2025. The network is intended to become a 'smart' grid, making use of decentralised electricity generation at all scales. The network will need to be able to accommodate intermittent wind generation at the national scale, and manage demand associated with electric vehicles, heating, and energy hungry locations at vulnerable points on the network.
- The Mayor supports central government plans to accelerate the development of responsive, robust and accessible electricity grids. The Mayor is working with Ofgem's Smart Cities programme and in conjunction with London's electricity distribution network operator (UK Power networks) and a range of commercial and academic partners, on a major project to understand the

demands of a London smart grid. The project will pilot smart grid technologies that improve access to decentralised generators and accelerate the deployment of smart meters and demand management incentives and mechanisms.

- The Low Carbon London programme (of which the GLA is a steering group member) is trialling demand management on the local distribution network with UK Power networks. It has a target of securing 25 MW of demand response on the London grid (companies that are provided with a financial incentive to reduce their electricity consumption at times of network ‘stress’).

4.2 Infrastructure Plan development scenarios modelling

In developing scenarios for a 2050 energy infrastructure plan, Arup’s review uses the objectives of the 2011 Mayor’s Strategy for 2025 as its basis for analysis. Wherever possible, it remains consistent with the objectives and measures to achieve the strategy. At the same time, it also aims to be reflective of national energy policy assumptions and objectives.

Heating for buildings (both residential and commercial) gives rise to a significant share of CO₂ emissions. Decarbonisation through energy efficiency and supply measures is therefore a priority that will drive a large proportion of new infrastructure requirements. Changes to the way heat is produced and delivered are included in all the scenarios that we have generated.

In addition to changes to population and industrial and commercial activity, there are three policy factors that are anticipated to drive the shape of future energy demand and supply in London and therefore the requirement for new infrastructure:

- The degree of success of energy efficiency measures to further reduce energy intensity;
- The extent to which transport and heat generation become ‘electrified’; and
- The degree to which energy generation is decentralised;

The scenarios for this study assume national energy policy and the impact it has on London broadly as given. They then reflect flexibility around how the three factors above may influence the final investment decisions. Government has run a number of scenarios with regard to the three policy factors above. It is difficult to provide an accurate estimate of the likelihood that any of these scenarios will materialise. For example we believe that some electrification of heat and transport will occur between now and 2050 although the degree and extent of it remains uncertain. The most relevant issue for London is the degree of additional (or reduced) effort that London will undertake to promote such policy. In the two illustrative scenarios we analyse in this study we make assumptions with regard to this ‘relative London’ effort and the implications that it will have on London’s infrastructure requirement and therefore, for example, on the need for further encouragement or incentives to be provided for certain technologies.

The analysis uses the 2050 Pathways Calculator (originally developed by DECC in 2010 and since then regularly updated) to develop a baseline energy supply/demand system for the UK to achieve Government 2050 emissions objectives. The Pathways Calculator allows users to develop their own combination of levels of change to achieve an 80% reduction in greenhouse gas emissions by 2050, whilst ensuring that energy supply meets demand.

The output of the calculator has been modified with London specific ratios and factors to determine the amount and type of energy to be delivered by 2050 (and capacity to be built). The modification allows sensitivities and scenarios to be developed around certain specific objectives, for example to achieve the Mayor's Strategy Decentralisation targets. A capital infrastructure associated with such energy flows and capacity can then be estimated. We use publicly available sources to estimate total investment expenditure (using costs of existing projects and projected unit costs).

4.2.1 Scenarios

As noted earlier, we have focused on two alternative scenarios: a 'centralised' scenario and a 'hybrid' scenario. We describe these two scenarios below.

4.2.1.1 Centralised scenario

Centralised electricity production and supply is likely to be based on new nuclear power, wind and gas-fired electricity generation with Carbon Capture and Storage (CCS). A significant level of electrification of heat and transport is also assumed. However, this scenario may entail an amount of fossil fuel (natural gas) in building heating due to delay in progress on new nuclear and the current interest in developing indigenous unconventional (shale) gas. In general accordance with Government's 2050 decarbonisation pathway, this model is supported through Electricity Market Reform (EMR) which provides market certainty for new nuclear and wind investment through the introduction of the Contract for Difference Feed-in Tariff (CfD FiT).

The implication for buildings in this scenario would be in the decline in the use of gas for heating and its replacement with electric heat pumps (e.g. air-source in the case of the centralised scenario). The exception would be in areas where heat networks have been developed as a result of the Mayor's policies and strategies. In these cases industrial heat pumps would replace existing energy production technologies at the appropriate point in the investment cycle using local waste and natural heat sources.

4.2.1.2 Hybrid scenario

In a 'hybrid' scenario, cities will become increasingly more efficient and self-sufficient and therefore less reliant on national networks – even though national networks will retain a role in delivering energy supply. Through a larger role for Smart solutions, such as Smart Grids, and for example Time of Use Tariffs, energy infrastructure and consumers will intelligently adapt to changing demands to deliver environmental benefits and lower energy costs. In this scenario the

Mayor's target to supply 25% of London's energy requirements according to a decentralised model by 2025 would be delivered.

Starting with combined heat and power (CHP) with larger schemes incorporating heat networks, such schemes would in time, increase in size and then interconnect. Later evolutions would deploy 'smart' systems, heat storage, and active electricity network control to allow optimum system utilisation and operation. Policy changes would bring about new market structures and new entrants. CHP technology would be replaced with industrial heat pumps operating with the same heat networks as the grid decarbonises.

The evolution of London's energy infrastructure over the next 36 years is likely to involve a combination of centralised and decentralised models. The hybrid model assumes the decentralised model would achieve a 25% penetration by 2025 and this would increase, where DE is economically competitive, towards 2050 to closer to a 50% penetration. A centralised model would make-up the balance of the energy requirement.

4.2.1.3 Common assumptions in the two scenarios

We expect significant end-user energy efficiency to be achieved over the period with demand for power and heat by 2050 to be not more than 20% higher compared to today's (2011) levels.¹¹³

Following government core scenarios and pathways, we estimated that gas consumption for heating domestic homes by 2050 will be limited and replaced by a combination of new technologies and solutions, for example electric heat pumps, district heating, or solar thermal – although gas supply will continue to play a role as a supply fuel for CHP and industry.¹¹⁴ This assumption is pivotal to the scenarios. A shift in heat supply from gas to either electric heat pumps or district heating networks is the most significant and consequential choice over the period. It will require considerable planning – many years ahead of potential heating supply switchover, particularly in the residential sector and for existing homes. Gas transmission network and gas distribution network operations will be affected. Regulatory decisions at national level will need to be closely coordinated with any London's policy that aims to drive such a shift.

In line with central government assumptions for the core scenarios in the 2050 Pathways analysis, we estimated a considerable electrification of the transport sector. In particular the passenger vehicle fleet is expected to be two thirds low carbon (hybrid, plug-in hybrid or fully electric) by 2050, with the commercial fleet almost fully low carbon.¹¹⁵

Primary differences between the two scenarios are outlined below.

¹¹³ In our analysis we have assumed that energy efficiency targets set by the UK Government and/or the EU Commission area achieved and policies designed by UK Government to deliver such savings are successful – for example with regard to building standards, products standards, the Green Deal etc.

¹¹⁴ This is an assumption based on current government scenarios.

¹¹⁵ In this study, as we have based our assumptions on the DECC 2050 Pathways work, we have focused on electric vehicles technologies, though we recognise that Hydrogen fuel cells may also be a possible alternative means of powering transport in 2050.

Centralised model

- By 2025 decentralisation of energy does not meet the 2011 London plan figures.
- By 2050 heat pumps achieve more than 60% of heat demand.
- There will still be limited decentralised energy by 2050 – 8% of total heat demand (with gas still taking up the remaining share).

Hybrid model

- By 2025, decentralisation of energy as per London 2011 plan (18.6TWh of decentralised heat and 2TWh of PV).
- By 2050, further decentralisation of heat (including through heat networks) to achieve 50% of demand.
- There will be significant use of individual heat pumps in the residential/small commercial sectors by 2050 – 16% of total heat demand.

The two scenarios illustrate the impacts of two quite different models (though in both scenarios we assume gas for heating in residential sector to fall significantly and we assume a role for alternative technologies).

4.3 London's energy infrastructure requirements

In line with the scenarios outlined above, we have modelled demand and infrastructure requirements, balancing supply and demand. In the remaining analysis we use the term 'energy' to refer to heat and electricity demand. We have excluded from the analysis transport demand except where it affects electricity demand – i.e. electric vehicles. We have not therefore included in our analysis demand for oil or petroleum products or their supply infrastructure. The table overleaf summarises demand. The analysis of the drivers of demand follows.

Hybrid model selected outputs, energy flows	Centralised model selected outputs, energy flows
<p>Demand</p> <p>Energy (electricity and heat) demand – increases by 11% by 2050 (0.3% CAGR¹¹⁶), although energy consumption per capita falls by 19%</p>	<p>Demand</p> <p>Energy (electricity and heat) demand – increases by 20% by 2050 (0.5% CAGR), although energy consumption per capita falls by 13%</p>
<p>Electricity</p> <p>Electricity demand increases by 43% (0.9% CAGR)</p> <p>Electricity to meet electric vehicle demand is 8% of total electricity demand</p> <p>Peak capacity on the distributed network will need to increase by at least 125% from 5.4GW in 2011 to more than 12GW in 2050</p>	<p>Electricity</p> <p>Electricity demand increases by 66% (1.3% CAGR)</p> <p>Electricity to meet electric vehicle demand is 7% of total electricity demand</p> <p>Peak capacity on the distributed network will need to increase by at least 200% from 5.4GW in 2011 to more than 17GW in 2050</p>
<p>Heat</p> <p>Gas demand (to final users) share of total demand falls from 61% to 15% by 2050.</p> <p>Gas share of heat demand in 2050 is 30% (in 2025 is 60%; in 2011 it was 98%)</p> <p>Electric heating (heat pumps) share of heat in 2050 is 16% (in 2025 is 8%)</p> <p>Decentralised (District Heating, solar thermal and CHP) share of heat in 2050 is 53% (in 2025 is 32%)</p>	<p>Heat</p> <p>Gas demand (to final users) share of total demand falls from 61% to 13% by 2050.</p> <p>Gas share of heat demand in 2050 is 25% (in 2025 is 73%; in 2011 it was 98%)</p> <p>Electric heating (heat pumps) share of heat in 2050 is 64% (in 2025 is 14%)</p> <p>Decentralised (District Heating, solar thermal and CHP) share of heat in 2050 is 8% (in 2025 is 3%)</p>

Figure 32: Arup assumptions used to calculate costs in each of the two energy scenarios.
Source: Arup analysis

Overall energy demand in 2050 is lower in the ‘hybrid’ model. This is the result of the difference between scenarios in terms of energy utilised by different supply technologies. For example, on the coldest winter days, heat pumps as part of a heat network have higher efficiency than individual air source heat pumps installed in domestic homes. This lower efficiency for individual heat pumps leads to a higher electricity demand (that impacts on upstream electricity distribution, transmission and generation capacities) consumption. In the centralised scenario there is a significantly higher level of individual heat pumps installed and lower number of ‘network’ heat pumps’.

Analysis of the modelled scenarios also indicates differences around the role of gas in the energy supply and the speed of change in provision. Compared to the centralised scenario, the hybrid scenario assumes, and therefore shows, a much

¹¹⁶ Compound Annual Growth Rate – the year-over-year growth rate of an investment or metric over a specified period of time.

more ambitious change in the period up to 2025 – as illustrated in figure 17 below. There is more decentralised energy by 2025 and a lower share of gas in the final energy supply, although gas is still used in the transformation process in the power sector, CHP and district heating.

By 2025, heating technologies in the hybrid scenario progressively shifts from network connected gas boilers to decentralised energy solutions (district heating and CHP). After 2025 decentralised energy continues to increase its share of the heating market, but at a much slower rate. Electric heating in the domestic sector via heat pumps begins to increase after 2025 in this scenario too. However, it never reaches the levels assumed in the centralised scenario. Finally, in the hybrid scenario we also see a higher level of deployment of solar PV installations in London.

In the centralised scenario, decentralised energy does not reach the same level of deployment by 2025 (and therefore fails to meet the Mayor’s 2025 target). Investment in decentralised energy such as district heating, CHP and solar PV is very limited over the period to 2050. Whilst deployment of individual air source heat pumps starts around 2015, the significant programme of electrification of heat is carried out between 2025 and 2050.

The combination of the two factors means that the centralised scenario implies a lower level of investment and fuel supply shift in the shorter term to 2050 and a much more significant level of change in the investment and energy supply post-2025. These differences are then reflected in the level, type and amount of investment required over the period to 2050.

Figure 33 below and Figure 34 overleaf illustrate the energy flows for the two scenarios. The figures show the annual energy flows in each of the years included.

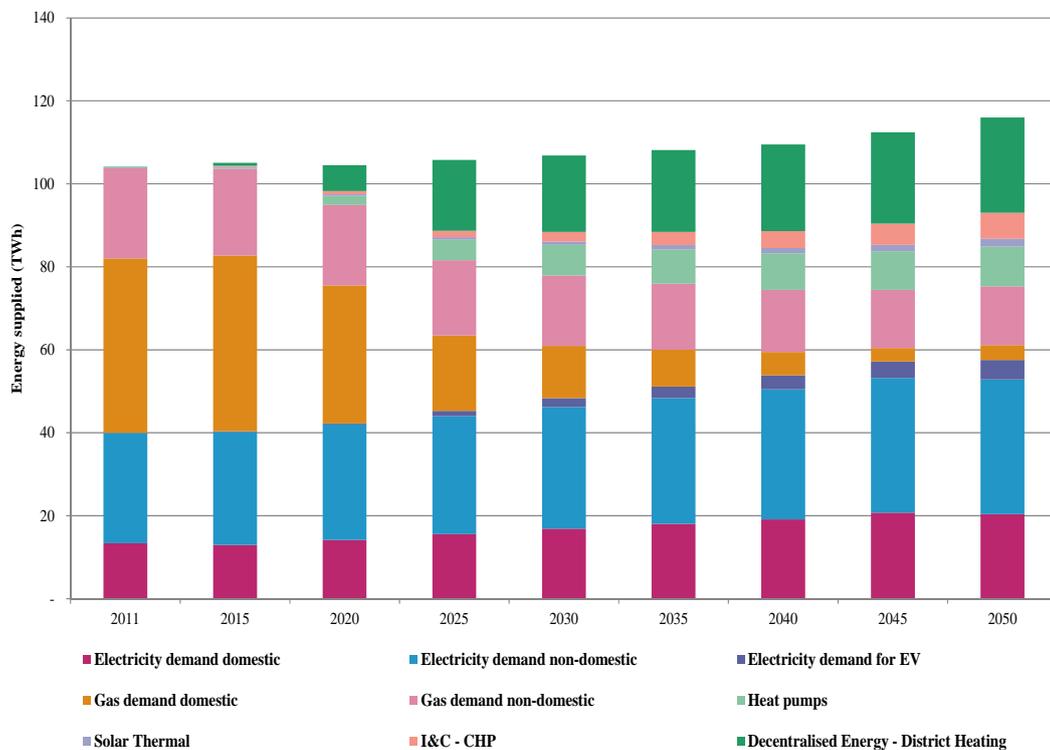


Figure 33: Energy flows - hybrid scenario. Source: Arup analysis

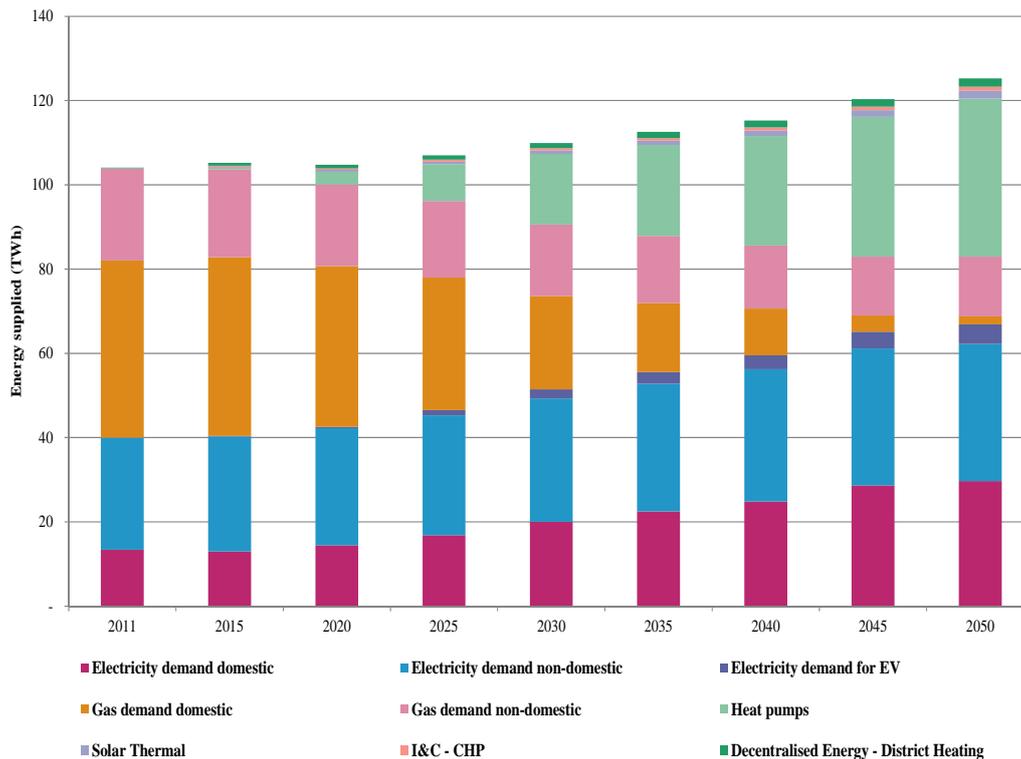


Figure 34: Energy flows - centralised scenario. Source: Arup analysis

4.4 Projected costs –investment requirements

It is possible to classify investment in two categories: indirect investment and direct investment.

4.4.1 Indirect investment

Indirect investment is expenditure for infrastructure to be built and operated outside London but which serves London. This is the generation, supply and transmission infrastructure which is necessary to supply London with energy for power and gas. In all scenarios, most of London's energy will be connected to the national grid. The indirect investment in capital expenditure is modelled as London's share of national investment.

This cost is borne by utilities and other energy companies (gas suppliers, electricity generators, other energy suppliers and transmission network companies). It is passed through to London consumers, connected to grids, through their energy bills. Such costs will be reflected in the wholesale costs for electricity and gas, in the transmission network charges and in other third party charges (i.e. environmental charges to meet renewable and low carbon standards, and, following the introduction of the Electricity Market reform, capacity mechanisms charges).

4.4.2 Direct investment

Direct investment is expenditure in infrastructure to be developed and built within London, financed directly or indirectly by London consumers.

Distribution network investment: funding for investment in electricity and gas network infrastructure is raised through distribution and new connection charges, which are paid to the network operators. The price that the companies can charge is regulated by Ofgem and included as separate item in domestic and non-domestic energy bills.

The regulator sets the maximum amount of revenue the operators can receive through charges they levy on users of their networks to cover their costs and earn them a return in line with agreed expectations. Ofgem's price control reviews will reflect the new regulatory framework (the 'RIIO' model) which aims to put more emphasis on incentives to drive innovation.

Non-regulated infrastructure investment: this investment for new infrastructure in the non-regulated market, i.e. anything outside the transmission and distribution gas and electricity national network. It can include generation infrastructure connected to the national grid as well as local generation and decentralised heating networks (industrial CHP, district heating networks etc.).

This investment is currently expected to be funded as project finance via private sector investment, though in some circumstances public sector support acting as catalyst may be used. Based on the current market framework and market conditions, all such infrastructure may not be always commercially viable in its own right in the near term, but rather will deliver long-term returns over 15-40 years.

Domestic and small scale commercial energy efficiency and low carbon technology investment: this investment is generally undertaken at individual households and buildings level and is financed via specific central government (and local) support schemes, for example the Renewable Heat Incentive, Feed in Tariff, the Green Deal or Energy Company Obligation.

We discuss funding options for the energy sector in section 10.3.

4.4.3 Investment requirement—hybrid scenario

The figure below illustrates the total investment required over the period. Each period quoted represents a five-year period. Projections are shown in 2014 prices but with indexation of capital expenditure by an underlying rate of 2% per annum.

Total expenditure over the period 2016-2050 is projected to amount to £223 billion, of which around 68% is for indirect investment paid through customer bills. Looking more specifically at the capital investment, this will be around £4.2 billion per annum over the period, mostly for electricity generation capacity.

Total direct investment in London, including London networks, decentralised energy and other London investments, is projected to comprise some £74 billion over the period to 2050. This figure is comprised of £48.3 billion of projected capital costs (enhancements and renewals), with the remainder for operational costs. This equates to an annual capital expenditure of around £1.3 billion per

annum over the period. Figure 35 illustrates total investment (capital and operating expenses) over the period, split by type of investment, which totals some £47 billion in the years 2016-2050. Figure 36 shows projected direct investment over the period, totalling some £17 billion from 2016 to 2050. Overall, almost half of direct capital expenditure projected is required for electricity and gas network investment, slightly more than one quarter for district heating networks and local CHP, and the remaining quarter for other renewable technologies (PV, heat pumps, solar thermal). About 16% of the total investment is expected to be delivered by 2025.

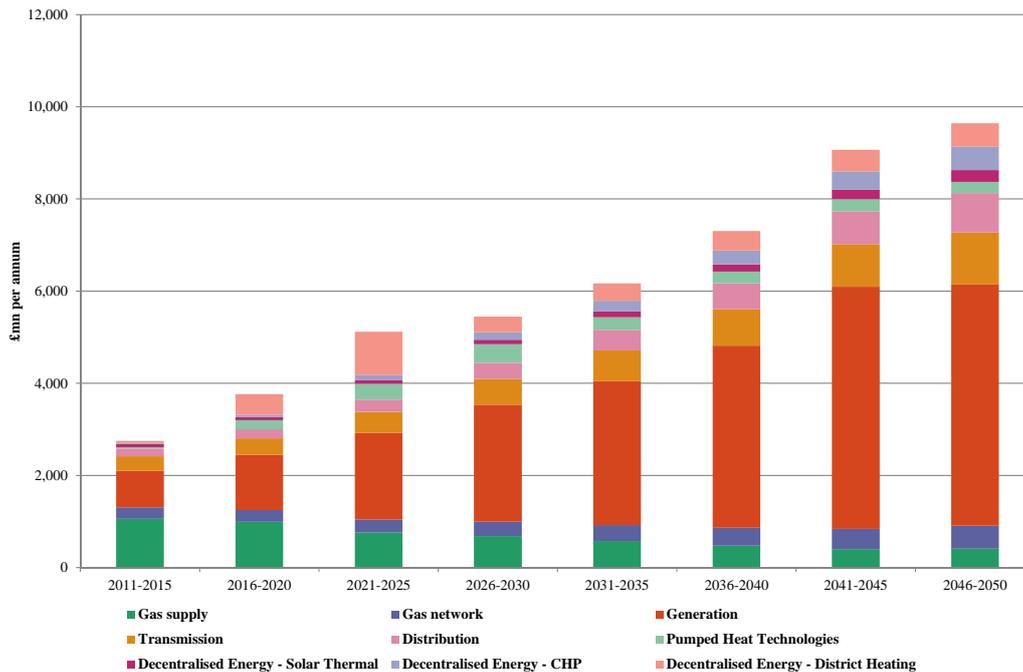


Figure 35: Total investment (annual), 2011-2050 – hybrid scenario. Source: Arup analysis

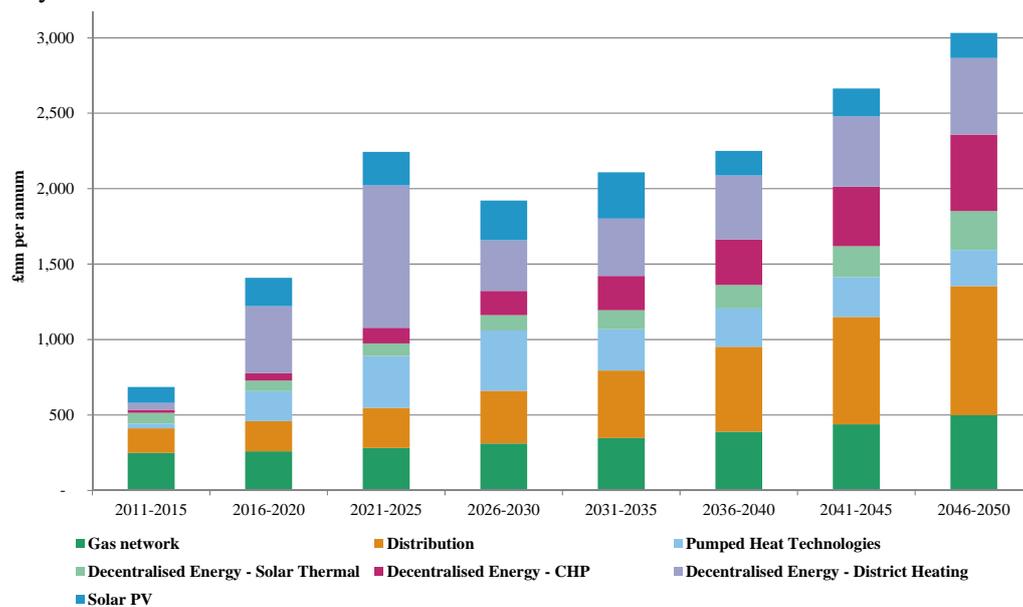


Figure 36: Direct investment 2011-2050 (annual) – hybrid scenario. Source: Arup analysis

4.4.4 Investment requirement—centralised scenario

Figure 37 below illustrates the total investment required over the period. Projections are shown in 2014 prices but with indexation of capital expenses (enhancements and renewals) by an underlying rate of 2% per annum.

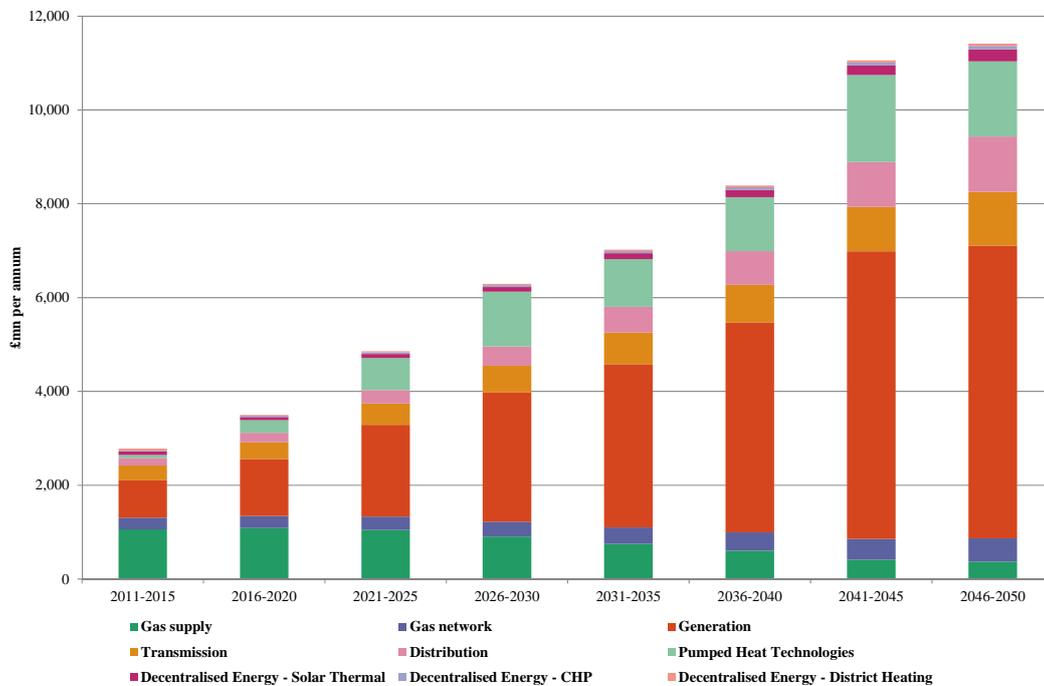


Figure 37: Total investment, 2011-2050 – centralised scenario. Source: Arup analysis

Total expenditure over the period 2016-2050 amounts to £245 billion, of which around 66% is for indirect investment paid through customer bills. Capital expenditure requirements are projected to be some £4.8 billion per annum over the period, mostly for electricity generation capacity. The direct investment in London, including London networks, decentralised energy and other London investments, is projected to total £79 billion over the period to 2050. This equates to annual capital expenditure requirements of some £1.6bn over the period.

Figure 37 illustrates the total investment (including capital and operating expenses) over the period, split by type of investment. Figure 38 shows projected direct investment over the period. Overall, almost half of projected direct capital expenditure is required for electricity and gas network investment, about 5% for district heating networks and for local CHP and the remaining 45% for renewable technologies (PV, heat pumps, solar thermal). About 12% of the total investment is expected to be delivered by 2025.

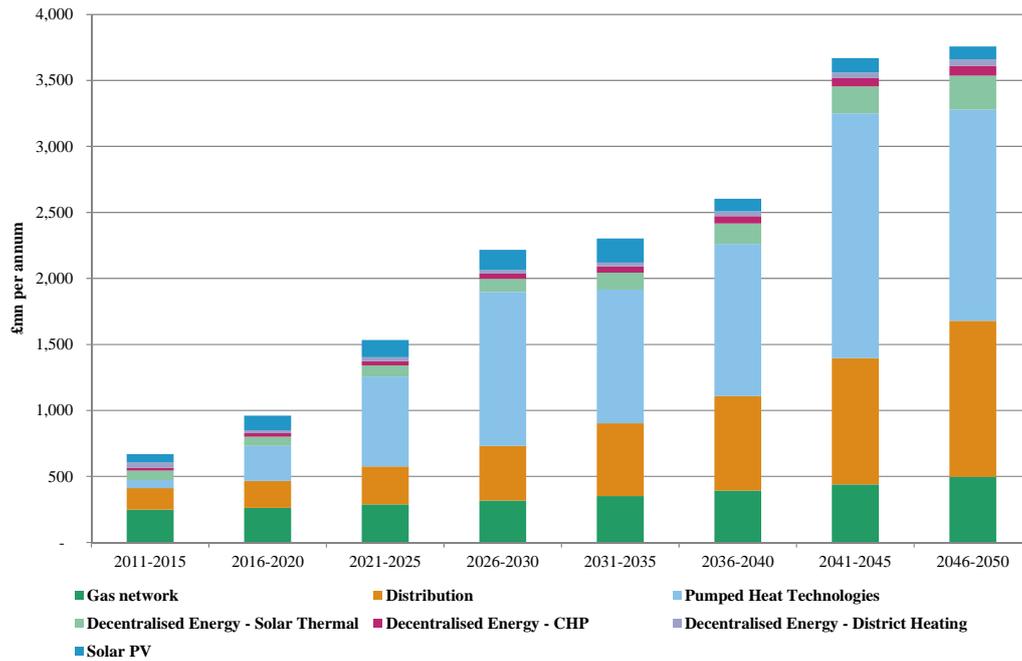


Figure 38: Direct investment 2011-2050 – centralised scenario. Source: Arup analysis

4.5 Scenarios costs comparison

When we compare the two scenarios we found an overall difference of around 10% in total costs over the period. This is a reflection of the significant changes needed in London’s energy supply under both scenarios and therefore the considerable level of investment required. Both scenarios achieve a similar level of decarbonisation and end-user energy consumption efficiency (i.e. efficiency achieved at the consumer end, whether residential or commercial). However, the differences in technologies deployed, , lead to the decentralised scenario implying higher costs overall and in particular in the longer term.



Figure 39: Direct investment 2011-2050 – centralised vs. hybrid scenario. Source: Arup analysis

There is in fact quite a significant difference in the profile of costs over time (Figure 39 above illustrates this for direct costs). The hybrid scenario involves higher costs in the shorter term (the 2014 to 2025 period) and lower costs in the 2025 to 2050 period. By 2050 the difference in annual costs is about 19% in total costs and 29% in direct costs. In the shorter term costs are higher, particularly to achieve 2025 targets. Once the major capital investment in the decentralised infrastructure has been completed costs are lower after 2025 and are likely to remain consistently so.

These costs reflect capex and opex costs and do not take into account security of supply costs and risks and exposure to energy prices – commodity and electricity costs. By achieving a higher level of decentralised energy supply, the hybrid model reduces the exposure to two types of risks that may arise in the longer term with regard to the national energy supply:

- Security of supply;
- Volatility in commodity prices.

The hybrid scenario will reduce the exposure to both risks above – although it is not currently quantified. The risks from supply interruptions are very limited at present – the UK has experienced one of the lowest levels of interruptions across all European countries over recent years. However, as the generation mix changes and the UK level of reliance on international energy markets also changes (e.g. more international exposure in the supply of fossil fuel, though their role will diminish in the overall energy mix) it is difficult to assess how such risks may change. Costs of interruption are high and are likely to be even higher in London – due to the concentration of population and level of economic activity. Therefore, even a modest reduction in risks may yield significant benefit in the future.

Scenario	Type of costs	Metric	2014-2050	2014-2025	2025-2050	2050 annual
Hybrid	Total	Costs (£mn)	222,608	40,257	182,351	9,807
		Annual average (£mn)	6,360	4,026	7,294	9,807
		Annual average costs per capita (£)	630	440	707	878
	Direct	Costs (£mn)	64,968	12,608	52,361	2,867
		Annual average (£mn)	1,856	1,261	2,094	2,867
		Annual average costs per capita (£)	184	137	203	257
Centralised	Total	Costs (£mn)	245,415	37,659	207,756	11,514
		Annual average (£mn)	7,012	3,766	8,310	11,514
		Annual average costs per capita (£)	692	412	803	1,031
	Direct	Costs (£mn)	73,193	9,269	63,924	3,659
		Annual average (£mn)	2,091	927	2,557	3,659
		Annual average costs per capita (£)	205	101	247	328

Figure 40: Energy sector scenario analysis - summary. Source: Arup analysis

Volatility in commodity and electricity prices is also expected to increase in the future. In the centralised scenario about 62% of the market is exposed to volatility of wholesale prices (primarily electricity prices accounts for 51% of this total price volatility); whilst in the hybrid scenario about 59% is exposed to wholesale energy prices volatility (again primarily electricity prices, 48%). Therefore any increase in electricity price – due for example to security of supply issues – will have a greater impact in a centralised scenario.

4.6 Risks and uncertainties

There are a number of drivers that will compound and impact future infrastructure requirements in terms of the amount of energy consumed, how and when such energy consumed, and where infrastructure could be more efficiently located.

4.6.1 Spatial considerations

Spatial considerations relate to the likely locations of energy demand and potential synergies with investment in other sectors. Significant demand for new energy infrastructure will occur in development areas, including London Plan Opportunity Areas, and the location of other major building projects. Although it is not certain, we would expect investment in decentralised energy (district heating) initially to be located “on site,” given the considerable re-generation effort related to new developments. Investment would be likely to occur at the same time as other essential utilities, including water, telecommunications infrastructure, opening the opportunity for synergies that may potentially reduce costs.

At the same time, investment in a specific technology or fuel supply (for district heating and CHP) may be location dependent. The necessity of being close to a particular source of fuel, such a waste disposal facility or renewable/secondary heat source, may prove a challenge in relation to development requirements.

4.6.2 Changes in energy demand behaviour

There may be uncertainty around future energy demand. Building-specific demand increases from commercial redevelopment, due to modernisation and refurbishment in response to tenant requirements. Investments typically include air conditioning, increased computing requirements and other factors. Demand similarly may increase as a consequence of increased electrical device use, increased demand for cooling (such as at data centres) and increased electrification of transport but a net increase in demand due to these factors is not guaranteed. For example, with the advent of additional energy efficiency measures and changes in behaviours and/or patterns of consumption a reduction in demand (for electricity and heat) could offset increases.

In our scenarios we assume that, despite an increase in population, economic activity and demand for electrical device use, per capita energy (electricity and heat) consumptions falls by 19% (hybrid scenario) and 13% (centralised scenario). If we were to assume that per capita consumption remains the same as today, total demand for energy would increase by 25% by 2050 with a potential increase in infrastructure costs to meet such additional demand of 10% by 2050 in the hybrid scenario and 13% in the centralised scenario.

4.6.3 Impact of Smart Grid

A smart grid may enable more efficient load on the network system, which may reduce the amount of investment required in response to the increase in electricity demand and network capacity required.

4.6.4 Role of gas in the energy supply

In both demand scenarios considered by Arup, the demand for gas (particularly for residential heating) has been shown to decrease towards 2050. However, gas will remain part of the national generation and heating mix. It will be needed to supply industrial and large commercial developments. It also will be required to

serve as a fuel supply for highly efficient combined heat and power plant (CCGT with CHP), in conjunction with heat networks within city boundaries.

It is likely that the gas distribution network will need to be maintained. There is significant potential for a need to change the gas network's regulated framework. Two principal changes are considered likely to emerge over time. First, there may be a need to disconnect certain users, which will have to switch from, for example, gas heating to heat pumps or district heating – which would then lead to a need to reconfigure the local network. Second, there may be a need to change the regulated model to ensure gas network utilities remain viable and prices affordable.

Both these changes will need to be planned with significant lead time to ensure a smooth transition. Either change also would require close collaboration between the relevant stakeholders: national government, London government, the regulator Ofgem and the network companies. It is likely that planned changes would need to fall within and be part of future regulatory periods (RIIO GD2, GD3 or GD4).

4.7 Opportunities for consolidation

Collaborative working within the energy sector and across different sectors is achievable in principle – though currently limited by different regulations and regulatory bodies. Close working between energy companies, other utilities companies and the regulators would require a common understanding of the main drivers for the stakeholders, visibility and alignment between their plans (in terms of time and location). There are savings to be made, as demonstrated by Ofgem's insistence on suppliers' collaboration on the Eastern Link project, which led to cost savings on design. But drawing detailed conclusion from a limited number of examples is problematic. In the case of the Eastern Link, there was only one funding partner (Ofgem), enabling closer working. In order to encourage collaboration within and across sectors, a range of factors will need to be considered:

- How physically close projects would be;
- Who the ultimate client and the funding parties were, that need to ensure that costs efficiencies are achieved;
- How the different regulators would collaborate to ensure regulated companies were incentivised to seek costs efficiency;
- What rules would regulate the appointment and management of contractors;
- What systems would be in place to address the risks of underperformance, delay or damages; and
- Who would be responsible for overseeing programmes and coordination.

There are opportunities to link energy development to the waste and transport sectors. Waste-to-energy growth has been included in the cost scenarios presented in this chapter, shown as a type of district heating. We have not explicitly modelled the increase in demand that could be associated with the growth of electric vehicles. Should the capital become a world leader in the take-up of electric vehicles, there could be significant additional demand for electricity.

As we discuss in the transport section of this report, the effect of the roll-out of electric car infrastructure and the demand that it will place on the grid requires careful consideration.

4.8 Conclusions

National energy policy, which is driven by the interlinked objectives of decarbonisation, security of supply and affordability, is moving to a more complex interaction of fuel sources, leading to a more expensive energy system with significant investment required in infrastructure over the next 20 to 40 years. London's energy supply will still be dependent for at least half (and likely more) of its energy supply on national infrastructure. Costs are therefore likely to increase even as energy consumption on a per capita basis may remain stable or fall due to the impact of end-user energy efficiency measures.

However, there will be opportunities for London to shift from a more traditional centralised approach dependant on the national system to a 'hybrid' approach, which produces more energy locally through decentralised energy technology in combination with energy delivered via national infrastructure. The use of local energy and decentralised technologies will improve the overall efficiency of the energy system, in terms of primary energy consumption to deliver final energy to consumers. Although such an approach would require higher investment in the next 10 to 15 years, it should lead to overall lower energy costs in both system and consumption terms, after 2030 and an energy system which will likely be more resilient to system shocks both in terms of security of supply and price volatility.

This transition raises important questions about the timing and funding of decentralised energy infrastructure. In particular, there are important considerations around the distribution of costs and benefits. London government and other stakeholders will need to consider carefully whether who apart from users should bear the costs of future infrastructure development.

Across the different utilities, there could be a role for London government to potentially establish an entity that could oversee collaborative programmes and projects on a local basis. Such an organisation could be take the form of a structured entity with a regular remit and responsibility to promote the delivery and efficient integration of infrastructure investment across sectors and manage the relationships between different regulators, government bodies and stakeholders or it could be a board/committee which only focuses on limited opportunities for collaboration on specific projects and programmes. Therefore, the key issues to be considered would be around its scope, remit, powers, funding, governance and structure.

5 Water infrastructure

This section details our work with the GLA on its water infrastructure investment plan. Working closely with the GLA, we have considered potential future requirements in order to provide a preliminary estimate of the capital and operating costs associated with future growth. We attended a number of meetings with industry leaders, who have advised us as part of the GLA's Water Industry Advisory Group.

In broad terms, it is projected that water infrastructure expenditure will total some £94 billion between 2016 and 2050. In that period, it is projected that capital costs will comprise some two-thirds of the annual total, or £61 billion between 2016 and 2050. Thames Tideway Tunnel, smart metering investment and flood defence expenditure comprise the majority of enhancement expenditure, in addition to the level of expenditure on maintaining and operating the existing assets. It is projected that operational expenditure will steadily rise with the water sector's growing asset base, totalling £33 billion over the period.

5.1 The case for investment

In the Greater London area, privatised water services are provided by four companies:

- Thames Water – the biggest with approximately 4-5 million properties served in their London resource zone;
- Affinity Water (previously Veolia Water Central);
- Essex & Suffolk Water; and
- Sutton & East Surrey Water.

Thames Water is the sole company responsible for sewage disposal in London.

There are increasing pressures on the capital's water environment, which arise from the dense urban environment that has developed in close proximity to the River Thames and its many tributaries.

The forecast increase in population living in London means that there will be increased demand for drinking water in a region where there is already scarce water supply. Climate change could exacerbate the potential imbalance between supply in demand, as patterns of rainfall change in the future. Adaptation of the existing water infrastructure will be required in order to address population growth and to cope with these changes. Water sector infrastructure investments are intended to address needs around the areas of potable water supply, wastewater disposal and flood-risk management.

London benefits from water and sewerage infrastructure that remains largely unseen by the population. Some of the sewer network is more than 150 years old, beyond capacity and inevitably in need of on-going maintenance and repair. There are opportunities to ensure that more co-ordinated solutions to make use of existing green infrastructure are used so as to reduce the need for significant investment in replacing or upgrading the sewer network. This will rely on the support of all stakeholders across London.

London is exposed in the event of severe weather. This has been particularly evident recently, with historically unprecedented levels of rainfall over the winter of 2013 to 2014. These events serve as a reminder of the risks in some parts of London from flooding from a variety of sources, including rivers, sewers and groundwater. The Thames Barrier currently provides protection from tidal flooding in London but this important asset is also likely to require improvement during the next century, based on the Thames Estuary 2100 plan.

5.1.1 London policy imperatives

In October 2011, the Mayor published “Securing London’s water future”, which outlined the key policy objectives for London related to the water environment, covering areas such as water resources, flood risk management, wastewater disposal and paying for water services.

The strategy provides a vision for the management of the water-environment in a world-class city. The Mayor’s Water Strategy argues that there is a need to change how water is perceived as a resource and how it is used, so that there are sufficient water resources for the future and these resources are affordable for Londoners.

The Mayor’s Water Strategy complements the existing plans and strategies of other organisations in the water sector, such as the water companies and Environment Agency – presenting a London-specific view of water management in the city. The strategy also seeks to provide influence the development of other stakeholder’s plans for the use of water resources in London, through a number of actions, which will help to ensure that London has reliable and affordable water and wastewater services and resilient water infrastructure that can operate under more extreme weather scenarios.

5.2 Regulatory and policy drivers

The water industry has revenues fixed by Ofwat (the economic regulator) at five year planning intervals (AMP periods). The primary duties of Ofwat are to ensure customers continue to receive safe, reliable, efficient and affordable water and sewerage services that promote positive social, economic and environmental impacts today, tomorrow and over the long term. Its goals are: ensuring a fair deal for customers; keeping companies accountable; making monopolies improve; harnessing market forces; contributing to sustainable development; and delivering better regulation and ensuring that companies can finance their investment needs. Ofwat act as a proxy for competition in the water sector, which is currently limited for services and it has helped to ensure that customer bills are minimised as far as possible.

Defra and the Environment Agency have primary responsibility for tidal and fluvial flood risk management and they are also the regulator of the water environment. For example they set standards for discharges of wastewater to rivers and issuing licences for abstraction of water.

The Drinking Water Inspectorate is responsible for ensuring that the water companies maintain high water quality standards in the supply of water for public consumption - Water Supply (Water Quality) Regulations.

For long term planning, the water companies are required to develop Water Resource Management Plans (WRMPs) that set out how they will balance the supply and demand for their area over a 25-year period. There are currently no requirements to produce similar wastewater / drainage plans, although the five year Business Plans do cover wastewater and drainage.

In Arup's view, such a long-term plan is vitally important to ensure that long-term impacts and potential benefits are captured in this sub-sector. Water companies are actively being encouraged by the Mayor and the Environment Agency to develop 25-year drainage strategies.

In their WRMPs, the water companies have to demonstrate how they will meet the expected long-term demand for water in the region, taking into consideration factors such as expected population growth, changes in demand for water and climate change.

The Environment Agency has a well-developed tidal flood risk management plan for the Thames Estuary (the "TE2100" project), and the agency is confident in the costing and funding of this programme to 2035 (although this is still subject to Treasury approval on an on-going basis).

Fluvial, surface and groundwater flood risk management programmes are less well developed. Whilst the Environment Agency is updating its Long Term Investment Strategy (LTIS) in time for the Government Spending Review, there still appears to be a need for a long-term, strategic vision for flood-risk management, with supporting detailed five-year investment plans.

Many of the planned projects can only be delivered cost effectively through integrating them into wider regeneration projects and securing additional private-sector (partnership) funding or securing other public sector contributions (e.g. from a local flood defence levy). In the area of flood-risk management, the Environment Agency indicates that there is a deficit in the level of funding for capital projects to ensure that London is protected against fluvial, surface water and groundwater flooding in particular.

5.3 London's water infrastructure requirements

Major investment projects in the water sector are reasonably well defined and understood, even though there is some uncertainty over the scale and timing of investments towards 2040. There will need to be on-going investments to maintain existing water-related infrastructure such as the water and wastewater networks, treatment plants and existing flood-defence assets. This investment requirement will also present an opportunity to improve the capacity and performance of these assets and, importantly, to identify the synergies between sectors that will help to optimise the investment.

Arup has reviewed the projects defined in the WRMPs and other documents, in addition to modelling capital and operating requirements according to population growth. In broad terms, a significant portion of the capital expenditure required in the water sector - linked to major project investment - is required regardless of London's growth. We have concluded that one project, the new surface water storage reservoir, is unlikely to be required in the central population growth scenario, but could be required in the high population growth scenario.

Other investment is linked directly to the city's growth, including extensions of its sewers and connections and expansion of its treatment infrastructure. On-going renewals and maintenance is linked both to population growth and to growth of the asset base. We have modelled these requirements, and their associated costs, according to the different population scenarios. Unless otherwise stated, the costs presented in this chapter relate to the 'central' population scenario.

In the sub-sections below, we consider principal projects and/or areas of investment. We comment on the scale, likelihood and timing of these requirements, noting where they are linked to population growth.

5.3.1 Thames Tideway Tunnel

This £4.2 billion project (unindexed) is required to ensure that the UK complies with the legal obligations of the EU Urban Wastewater Treatment Directive (UWWTD) in relation to the discharge of untreated sewage into the Thames from the combined sewer network. This currently happens sometimes after even relatively little rainfall. Whilst the project continues to attract some criticism for not being the most cost-effective solution to dealing with the lack of capacity in the existing combined sewer, we believe there is no realistic alternative that will deliver the outcome required by the UWWTD, regardless of the level of population growth that occurs within the study period.

5.3.2 Environment Agency – Thames Estuary 2100 (TE2100) project

The TE2100 project is a long-term strategy for the tidal Thames to cope with rising sea levels, increased frequency of storm surges from the North Sea and the need to replace existing flood defences along the Thames. The project has been developed over the past 10 years and provides a framework of options in the short, medium and long-term for the estuary, including the need to consider the replacement of the Thames Barrier. Total capital investment costs are projected to be some £4.5 billion (un-indexed) before 2050.

Tidal defences in London protect around 350 square km of land, 1.25 million residents, over 500,000 homes and an estimated £200 billion of property value (2010) as well as other strategic assets such as power stations, water treatment facilities and transport assets.

5.3.3 New surface water storage reservoir (Upper Thames)

The need for a large, new storage reservoir to provide surface water storage in the Thames region is not currently included in the Water Resource Management Plan for the period 2015-40, although we understand that this major new storage resource is still being considered by Thames Water as a long-term option.

The proposals for a new reservoir in the Upper Thames region were previously challenged by regulators as not being the most cost effective solution for customers when balanced against other measures such as leakage reduction, demand management, metering etc. Other resource options such as groundwater abstraction are included in Thames current WRMP to manage the supply/ demand balance to 2040.

We project that in a central population growth scenario, capital expenditure on this new water storage reservoir would not be necessary. However, in a high-population growth scenario, it is possible that such a surface-water storage reservoir could be required within the study period. We have included this project in the costs projected for the high-growth scenario. We have assumed that this would cost in the region of £1 billion, in line with previously public reported costs.

5.3.4 Flood risk management

Flood risk management expenditure (with the exception of tidal defences, which are included in TE2100 project, above) includes risks from fluvial sources (rivers), surface water flooding and groundwater flooding. The responsibility for flood risk management in the UK is fragmented and relies on a number of agencies, including Environment Agency, water companies and local authorities. This issue was already recognised by the Mayor, who has convened the 'Drain London Forum' as a mean of ensuring a consistent and joined-up approach to the problem.

Under the terms of the Flood and Water Management Act, London boroughs are identified as "Lead Local Flood Authorities" with requirement to produce a local flood risk management strategy, which have now been delivered through the "Drain London" project.

Funding for fluvial defence projects is primarily provided through a grant from central government (FDGiA), although "partnership funding" is proposed to supplement a reduced contribution from central government. The reality is that private sector funding has not materialised on the scale required, largely because the private sector finds it difficult to immediately monetise the benefit from their investment and perceives that it has insurance in place to mitigate their risks of flooding impacting on their business. FDGiA investment is assumed to total some £65 million per annum from 2019, or some £2 billion over the study period.

5.3.5 Water-Sensitive Urban Design (WSUD)

Water-sensitive urban design (WSUD) is a land planning and engineering design approach which integrates the urban water cycle, including stormwater, groundwater and wastewater management and water supply, into urban design to minimise environmental degradation and improve aesthetic and recreational appeal. In our view, this has a broader perspective than Sustainable Urban Drainage Systems (SUDS), which is itself a component of WSUD.

To assess the investment need to consider integration of WSUD across London, we have considered current EU research (DG Environment) in this area, which provides an assessment of costs and benefits of climate proofing of natural water retention measures. The EU research provides costs estimates for measures including reducing infiltration, green roofs etc. We also have reviewed the forecast costs and benefits of the Thames Water pilot study for Counters Creek.

As the basis for an estimate of the land area requirement for the implementation of water sensitive urban design solutions, the Thames Water report on the Counters Creek catchment noted that around 17% of permeable areas such as gardens have been replaced by impermeable surfaces in London in the past 40 years, for

example from the conversion of gardens into hard-paved areas for vehicle parking.¹¹⁷ The Thames Tideway Tunnel, once implemented, will alleviate part of this problem in London, so we have conservatively assumed that 10% of the impervious surfaces will still need to be removed. Based on an EU estimate of €160,000 per hectare, this indicates a total of around £6.1 billion of investment is required.

For Counters Creek, we have looked at the estimated capital costs provided by Thames Water (£230m-£310m) in the period 2015-20, which is intended to protect 2,000 properties in the catchment.

We know from the report of the London Resilience Partnership, *London Strategic Flood Framework*, that there are around 680,000 properties in London at risk of surface water flooding. Applying an assumption that 30% of these will be at high risk (>1:100 frequency/ year) provides a forecast range of £1.4 to £2.1 billion of investment potential, assuming a scheme similar to Counters Creek is applied to the “at risk” properties in London. We note that the risk profile of properties in the Counters Creek catchment is particularly high because of the number of low-lying properties with basements.

As these two solutions will provide a different level of service (risk profile), we have assumed a range of £2-6 billion for implementation of WSUD across London, depending on the level of risk reduction required, the complexity of the implementation and the scope of work to be applied.

We have assumed that an investment at the lower-end of this range (£1.8bn) will commence in 2020, to be delivered over a 30 year period, at an average of £60m per annum.

5.3.6 Groundwater flood mitigation

The mitigation of groundwater flooding in London was previously considered in the so-called GARDIT (General Aquifer Research Development and Investigation Team) Strategy, which was defined by Thames Water, the Environment Agency and London Underground with the support of organisations such as the Corporation of London, Enviro-Logic, the Association of British Insurers (ABI) and British Telecom.

Originally, five phases were defined, most of which were to be delivered by Thames Water. The original programme aimed to complete delivery 70 Ml/d of abstraction in a five year period from 1998/99 to 2003/04, with 50 Ml/d of this abstraction licensed for public water supply.

The exceptional groundwater flooding events in London during the winter of 2013/14 were caused by high levels of rainfall across the region, at a time of already-high groundwater levels. To estimate the investment needed to mitigate future groundwater flooding, we have assumed that there is a need to reinstate up to 50 Ml/d of water abstraction, at a capex cost of £50 million and an on-going opex cost (pumping) of £5m per year from 2015 onwards.

¹¹⁷ Thames Water, *Sewer Flooding Alleviation in the Counters Creek Catchment*, Royal Borough of Kensington & Chelsea, 24 June 2010.

5.3.7 Maintenance of existing assets

The maintenance of existing assets in a stable (“serviceable”) condition is a key requirement of allowed water company revenues, which are subject to on-going review and challenge by Ofwat. This assessment is based on a review of long-term asset performance data, which seeks to ensure that there is no deterioration in asset condition in the long term. Where Ofwat has historically identified that assets have deteriorated, despite funding from customers, the water companies have been required to improve the condition of their assets and/ or return money to customers.

For flood-defence assets, the constraints on funding appear to have resulted in deterioration in the number of assets failing their target asset condition as of Q2 2013 (reported by Committee for Climate Change) although this target was expected to be met by year-end. However this output does also support a view that the maintenance of flood-defence assets might be suffering from a lack of maintenance investment.

5.3.8 Planning for growth

Despite the increasing focus on managing demand for water resources, improving management of wastewater and storm-water flows and taking an integrated approach to management of floods, it is evident that investment will be needed in new infrastructure across London to cope with the forecast increase in population. Such infrastructure will include additional capacity at water treatment works, sewage treatment plants, pumping stations, as well as the extension of existing water and wastewater networks to connect new customers.

Managing the water supply/ demand balance through leakage reduction programmes and water metering will also be needed. These assumptions are based around the current long-term water resource plans, supported by the Mayor’s Water Strategy.

As we have indicated earlier, future urban development could be managed to ensure that the level of impervious coverage is managed so that it does not increase significantly. This issue was already identified by the Mayor in the Strategy for Water.

5.4 Risks and uncertainties

Whilst a number of major projects in the water sector are well defined, there is increasing uncertainty regarding the long-term strategic direction for the sector, particularly around the integration of ‘green infrastructure’ with other water-infrastructure in London. For example, there are questions around how to ensure that the complete water cycle is considered in future planning for the city: making use of rainwater harvesting; grey water recycling; attenuation of surface water to prevent further overloading of the sewer network and so forth.

Policy decisions in these areas could help to ensure that the need for significant investment in future storm-water interceptor sewers (such as the current Thames Tideway Tunnel) could be deferred. Such interventions require a co-ordinated effort from many stakeholders with a responsibility in both the public and private sector.

For flood-risk management, there is a great deal of uncertainty regarding the impact of climate change on the frequency and severity of future storms or tidal flooding. Flooding mechanisms are also complex and can be quite localised, which makes investment decisions even more important within constrained public sector spending limits.

Investment decisions on potential projects such as a new surface-water reservoir to serve London will need to be taken in the next few years, as the relative cost and benefits of this project are considered by Thames Water alongside other measures to ensure that there are no supply-demand deficits (at the assumed standard of service) in the future.

5.5 Preliminary analysis of costs and benefits

5.5.1 Projected costs

The figure below sets out cost projections for the water sector based upon our work with the GLA and other stakeholders. Projected costs are split between enhancements and renewals (both capital expenditure items) and operations and maintenance (both operational expenditure items). These projections are shown in real terms, reflecting indexation as set out the annex to this report. These costs relate to the central population scenario and are presented in real (2014) prices. Note that each period represents not the single year but a five-year period. For example, '2015' includes 2011-2015, '2020' covers 2016-2020 and so forth.

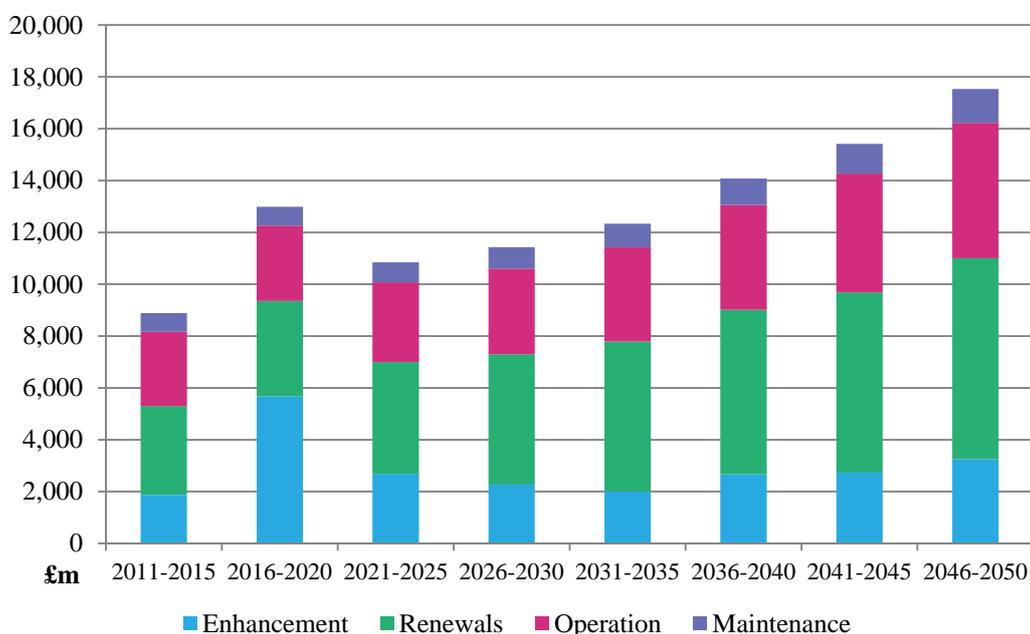


Figure 41: Water infrastructure expenditure 2011-2050 (£ million). 2014 prices, including 2% p.a. construction industry price inflation for enhancement and renewals costs. Source: Arup analysis

In broad terms, it is projected that water infrastructure expenditure will total some £95 billion between 2016 and 2050. In that period, it is projected that capital costs will comprise some two-thirds of the annual total, or £61 billion between 2016

and 2050. Capital expenditure is expected to increase from £7 billion in the five year period between 2020 and 2025 to £11 billion in the five years ending in 2050.

Expenditure in the five year period between 2016 and 2020 is projected to be exceptionally high, given the construction of the Thames Tideway Tunnel. The project represents planned enhancement capital expenditure of some £4.2 billion in total.¹¹⁸ It is assumed that £0.5 billion of that total will have been spent before 2015, with the remaining amount required between 2015 and 2020 based on our discussions with Thames Tideway team.

In later years, enhancements comprise measures to increase flood resilience and the continued introduction of smart metering. Flood defence-related expenditure is projected to total some £0.9bn of enhancement expenditure before 2050.¹¹⁹ Smart metering investment is projected to total some £1.3 billion before 2050.

We have estimated that both the need for additional fluvial, surface water and groundwater flood protection investment are delivered from 2020 onwards, in line with our analysis above.

Arup's view of capital renewals in this sector includes expenditure both on below ground infrastructure and above ground assets such as treatment works and pumping stations. It is projected that renewals expenditure will total some £40 billion in the years between 2016 and 2050, increasing at a rate of 2.5% per annum in the period.

The assumption of an increasing level of expenditure reflects the fact that the assets are ageing. It is likely that an increase will be required to maintain levels of service. However there is the opportunity that this cost could be mitigated if other policies such as the introduction of Water Sensitive Urban Design (WSUD) can be implemented successfully. This forecast level of capital expenditure also includes an assumption that the rate of replacement of the water and sewerage networks will need to increase from their current levels, to around 1% of the networks per annum.

It is projected that operational expenditure will steadily rise in real terms – with the water sector's growing asset base; influenced by an increase in energy-intensive treatment processes, pumping costs and reflecting the fact that there will be more assets to operate and maintain.

The water industry typically reports maintenance and operational expenditure together. Over the period from 2020 to 2050, it is projected that water infrastructure operational expenditure will total some £34 billion in the period in real terms, increasing 1% per annum, on average, in that period. Within this estimate, we have assumed that the industry continues to find operational efficiencies in the medium-term, which are broadly in line with those delivered historically. In the longer term, we believe that the scope for on-going savings in real-terms will reduce, as the industry has already delivered significant operational efficiencies since privatisation in 1989.

¹¹⁸ Individual project enhancement figures are not indexed according to inflation, as they are inputs to the cost model.

¹¹⁹ Individual project enhancement figures are not indexed according to inflation, as they are inputs to the cost model.

We have assumed that the level of operating and maintenance expenditure is split between operations and maintenance at a ratio of approximately 4:1 based on analysis of historical costs from the sector. This is reflective of the current split of activities between operations and routine maintenance activities in the sector.

5.5.2 Potential benefits

5.5.2.1 Water sensitive urban design

WSUD includes the design and planning of places to be more adaptable to flooding by designing buildings, infrastructure and public realm in flood risk areas with flooding in mind. There is considerable overlap between green infrastructure and WSUD in delivering the range of benefits that these interventions can bring.

WSUD may be associated with more intangible potential benefits around amenity, community and environment. We consider some of these benefits in the green infrastructure section of this report. Some of the qualitative benefits associated with WSUD include the creation of more green space, with a positive impact on land and property values.

In terms of water management, there are potential benefits associated with improved flood management and with the supply and treatment of water. More generally, WSUD can be used to improve the management of surface water, by reducing the impact on the natural hydrologic behaviour of catchments. This could primarily be delivered through retention and reducing downstream peak flood flows, volume of run-off and reduce the rate of run-off.

Information provided by Thames Water for its Counters Creek project indicates that the economic benefit of such investment could total £2 for each £1 of investment. The benefits of investment would include some implications of the 'cost avoided' of other sewerage enhancement schemes for example. Water sensitive design presents an opportunity to defer investment on wastewater treatment infrastructure, as it reduces load and shifts the water supply/demand balance, reducing capital and operating expense requirements.

5.5.2.2 Groundwater flood mitigation

The re-use of groundwater creates the opportunity for better utilisation of these resources as part of the public water supply. Improved re-use could help offset the costs of this abstraction. At present, some of the groundwater extraction is simply returned to rivers.

5.6 Opportunities for consolidation

The water sector has close interaction with a number of other infrastructure sectors, including:

- **Energy:** which is a major component of the current operating cost for the sector; and this is likely to increase as a result of more stringent wastewater treatment standards for example. There is potential for generating more energy from the water sector; including biogas generation.

- Green infrastructure: there is a potential to maximise benefit from existing and future investments in green spaces around London, in areas such as water re-use; providing water attenuation to reduce the impact of surface-water flooding. Retrofit of existing properties will be vital to ensuring that any objectives in this area are met. Relying only on new developments will slow the pace of change.
- Waste: the sector is already starting to explore the potential resources available in their own waste streams (for example, capturing chemicals arriving in the flows arriving at sewage treatment plants).

Collaborative working between the water sector and other utility sectors is achievable in principle. Close working between water companies, other utilities companies and the regulators would require a common understanding of the main drivers for the stakeholders, visibility and alignment between their plans (in terms of time and location). In order to encourage collaboration within and across sectors, a range of factors will need to be considered:

- The spatial proximity of projects;
- Who the ultimate client and the funding parties are that need to ensure that costs efficiencies are achieved;
- How the different regulators would collaborate to ensure regulated companies were incentivised to seek costs efficiency;
- What rules would regulate the appointment and management of contractors;
- What systems would be in place to address the risks of underperformance, delay or damages; and
- Who would be responsible for overseeing programmes and coordination.

There could be a role for the Mayor to establish an entity that could oversee such collaborative programmes and projects on a local basis. This could take the form of a structured entity with a regular remit and responsibility to promote the delivery and efficient integration of infrastructure investment across sectors and manage the relationships between different regulators, government bodies and stakeholders. Alternatively it could be a board/committee that focuses only on limited opportunities for collaboration on specific projects and programmes. Therefore, the key issues to be considered would be around its scope, remit, powers, funding, governance and structure.

5.7 Conclusions

It is clear that there are significant opportunities for the Mayor to influence the future direction of the water sector in London and to ensure that all stakeholders are aligned and working together to make the most cost-effective investment decisions for the long term. These build upon the objectives and policies already outlined in 'Securing London's Water Future', in areas such as ensuring that stakeholders work together to deal with surface water flooding or to seek specific incentives to promote the retrofit of existing properties in water efficiency measures.

In the area of integrated water management, related to the planning of new developments, there is certainly a role for the Mayor in setting the agenda and influencing stakeholder coordination to ensure that new developments take a holistic approach to water management during their planning.

As previously highlighted, future supply/ demand balance relies on customers reducing their use of water. This is likely to arise in part from the introduction of wide-scale water metering. We recommend that the Mayor should continue to promote water efficiency measures and work with Ofwat to secure a compulsory metering programme for London. In this area, the Mayor could provide additional support to ensure that water companies are focusing on installing water meters in all properties, which have previously been considered as uneconomic to meter (e.g. apartments).

If increasing water metering and other similar water efficiency measures are not possible or do not move forwards quickly enough, then a large, new reservoir could be required within the study period (i.e. before 2050). Such a reservoir would have significant cost implications for the sectors' suppliers and major stakeholders. We believe that it could, indicatively, cost around £1 billion. We have concluded that it is prudent not to include this cost in our model. This exclusion reflects not only supplier strategic planning, but also a likely scenario for future water use. Before investing in such a major project, stakeholders should ensure that other options, such as continued reduction in leakage and demand management, have been exhausted. Over time, it is possible that technology development could make such measures increasingly affordable and easy to implement.

There are a number of specific policy areas that could be considered by the Mayor in support of the existing strategy. Choices around governance in the sector are likely to relate to:

- Coordination of large scale stormwater attenuation in London, as seen for example in South Korea, including provision for combined stormwater and rainwater harvesting;
- Coordination of London Borough SuDs Approval Bodies (SABs) – including capacity building and direction;
- Direction and guidance of Section 106 and Community Infrastructure Levy for stormwater management (WSUD);
- Work with stakeholders across London to develop a better understanding of costs / benefits of 'soft' stormwater management; and
- Direction around targets and standards, e.g. to exceed minimum Building Regulation standards for demand management.

6 Education infrastructure

This section details our assessment of costs associated with London's education infrastructure requirements. London's school-aged population is projected to rise by around 20% over the study period. By 2050, the GLA has projected around 1.8 million individuals between the ages of four and 18 will live in London. The future capital cost of the city's education infrastructure has been arrived at by estimating the costs of additional infrastructure required serve this growing population as well as the cost of renewing London's existing stock of education infrastructure. We have also estimated costs relating to the operation of schools and education facilities.

6.1 London's education infrastructure requirements

In the sections below, we assemble GLA Intelligence demographic projections in order to establish a projection of the number of school children by age group in London until 2050. Assessing change in the number of school-aged children each five year period between 2016 and 2050, we allocate marginal growth of the youth population to new infrastructure, making assumptions about the number of children different school types could accommodate. These assumptions form the basis of our cost estimates, as presented in section 6.2 below.

6.1.1 School-aged population growth

GLA Intelligence has forecast London's population by year, providing a demographic breakdown of these figures.¹²⁰ As shown in Figure 42 overleaf, the school-aged population is projected to grow from some 1.5 million children in 2015 to some 1.8 million in 2050. These projections indicate that London's school-age population will represent some 17% of the total GLA population over the study period.

By 2020, GLA Intelligence projections show that the school-aged population will reach 1.6 million. This growth represents an increase of 107,000 relative to 2015. In the five years between 2021 and 2025, it is projected that London's youth population will increase by another 85,000 people, reaching 1.69 million in 2025. In absolute terms, London's population is projected to reach some 9.5 million by 2025. GLA Intelligence figures show that the rate of growth of the overall population will exceed four per cent during the 2020s.

¹²⁰ We have used the GLA's official, publicly available breakdown of the population by age group until 2040. In addition, the GLA has provided a projection of the total population in 2050 according to three scenarios. Arup has calculated the number of children by age group for the years between 2040 and 2050 according to the average implied by these two different estimates.

Greater London Authority, projected total youth population by age group and total population, 2015-2050 (single years)*								
	2015	2020	2025	2030	2035	2040	2045	2050
Age 4-10	768,587	822,708	824,207	809,586	798,808	802,781	842,185	881,667
Age 11-16	539,236	599,725	654,934	666,720	655,620	644,836	666,520	687,639
Age 17-18	189,909	182,431	210,586	223,315	224,289	220,722	224,491	227,913
Total youth	1,497,732	1,604,863	1,689,727	1,699,621	1,678,717	1,668,339	1,733,196	1,797,220
GLA Pop.	8,669,748	9,127,567	9,480,364	9,782,155	10,058,639	10,307,871	10,789,113	11,270,354
*Figures shown are a snapshot of the single year								

Figure 42: Projected total population by age group, 2015-2050. Each year above shows a single year, rather than a total of the previous five years (as in other tables presented in this report). Source: GLA Intelligence

GLA Intelligence projects a marginal decline in the school-aged population during the 2030s, even as London's total population is projected to continue to increase. By 2040, London's total population is projected to exceed 10.3 million people. In the same year, London's school-aged population is projected to be 1.67 million people. This figure represents a slight decline from the projected number of young people (1.7 million) in 2030.

In the 2040s, GLA Intelligence anticipates a reversal of this trend, with both the youth population and total population projected to increase. As the total population reaches some 11.3 million in 2050, it is projected that the youth population will comprise approximately 1.8 million of the total.

6.1.2 Additional school-aged children per five year period

We have considered growth of the capital's school-aged population within each five year period between 2016 and 2050, assessing the infrastructure required for new school-aged Londoners. The additional population projected for each age group, as projected by GLA Intelligence, is shown in Figure 43, overleaf. These figures represent the additional number of school-aged Londoners projected as compared to the previous five-year period. These figures represent the population of children that will be 'entering' a given school type in a given period.

As can be seen, London will add some 50,000 school-aged people to its population every five years. Growth will be highest in the period to 2020, when London will add more than 100,000 school-aged children to its population. After 2030, it is projected that the number of school-aged children added to London's population will level off, later growing at a faster rate.

Greater London Authority, projected additional number of children by age group within a given five-year period, 2011-2050*

	2011- 2015	2016- 2020	2021- 2025	2026- 2030	2031- 2035	2036- 2040	2041- 2045	2046- 2050
Age 4-10	49,780	54,121	1,500	(14,621)	(10,778)	3,973	39,404	39,483
Age 11-16	34,907	60,489	55,208	11,786	(11,100)	(10,784)	21,684	21,119
Age 17-18	12,294	(7,479)	28,155	12,730	974	(3,567)	3,769	3,422
Total additional population, ages 4-18	96,980	107,131	84,863	9,894	(20,904)	(10,378)	64,857	64,024

*Figures shown are the net number of school-aged people gained (or lost) within each five-year period relative to the previous five-year period.

Figure 43: Projected net additional youth population by age group, 2011-2050. Each column above shows a five-year total relative to the previous five-year period. Source: GLA Intelligence

Uncertainty around London's population growth is greater in later forecast periods. Additional analysis may be needed to refine school-aged population projections for later periods and reflect upon changes in the population projections made for the 2030s, 2040s and 2050s. At this stage, we have adopted these indicative population projections. Minor changes to the forecasts are unlikely to have a material effect on infrastructure requirement and cost projections. Inevitably, actual demographic change and population growth are likely to differ from the figures projected.

6.1.3 Education infrastructure requirements

6.1.3.1 New education infrastructure

To model additional capital and operating expenditure associated with pupil growth, we have allocated marginal growth of the youth population to new infrastructure, making assumptions about the number of children different school types could accommodate. We have focused on primary, secondary and sixth form schools, serving pupils aged four to 18, over the study period.¹²¹ Figure 44 overleaf shows the number of students we have assumed to be associated with each age category.

We have assumed that London government will reduce overcrowding in schools, reducing the number of pupils served by each school just as it increases the number of schools provided overall. Our assumptions therefore reduce the

¹²¹ For indicative purposes. School need has been determined according to demographic trend as shown on the previous page, with each school type representing one of three age groups. Specific school types, such as VA Schools, may differ from those shown. At this early stage of analysis, with costs provided for indicative purposes, we assume nurseries are included in primary schools and 'specials' into both primary and secondary. This may have the effect of under-estimating expenditure requirements. Small additional assumptions have been made around other school types in relation to renewals costs. These are outlined in the appendix to this report.

number of students per school relative to what has been seen in London over the past five years.¹²²

Assumed number of pupils per school by type	
Type	Number of pupils per school
Primary / Ages 4-10	420
Secondary / Ages 11-16	1,000
Sixth form college / Ages 17-18	250

Figure 44: Assumed number of pupils by school type. Source: ‘Low-end’ estimates based on long-term London and UK class sizes, as reported by the Department for Education, uplifted upon GLA guidance. See for example, Department for Education, *School Type and Size*, 2012, [.xls] document

It may be possible for school-related capital expenditure to be made more efficient. For example, converting schools or increasing class sizes rather than constructing additional facilities could reduce capital expenditure requirements.¹²³ It was beyond the scope of this study for us to incorporate assumptions around such potential savings in our cost assessment. Similarly, we do not take into account how new population growth might be allocated to ‘vacated’ school places in existing infrastructure. This means that there is a risk that we have over-estimated the number of new school facilities and associated costs. Further refinements to the model could help to deal with this uncertainty.

We provide assumptions around school sizes and unit costs in the appendix A9. Figure 45 overleaf shows our estimate of the number of schools required to serve London’s growing school-aged population.

¹²² See for example, Department for Education, *School Type and Size*, 2012, <https://www.gov.uk/government/publications/schools-pupils-and-their-characteristics-january-2012>.

¹²³ For recent record of the manner in which authorities have disposed of land, suggesting it could be used more efficiently, please see the Education Funding Agency’s listing of land disposals: <https://www.gov.uk/government/publications/school-land-decisions-about-disposals/decisions-on-the-disposal-of-school-land>.

Projected number of additional schools required by type, 2016-2050	
Type	Number of schools
Primary / Ages 4-10	330
Secondary / Ages 11-16	170
Sixth form college / Ages 17-18	196
Total	696

Figure 45: Project number of additional schools required by type, 2016 -2050. Source: Arup analysis.

As can be seen we estimate that London will require some 700 new schools over the period to 2050. The greatest share of need is projected to relate to school facilities serving children aged four to ten.

6.1.3.2 Renewal of new and existing education assets

Arup has included the cost of renewing existing schools in our cost estimates. As in other sectors, some of these costs are projected to relate to taking care of new infrastructure once it has been built. Other renewals costs relate to existing assets and include major refurbishment costs.

We have used a benchmark figure of three per cent of the value of enhancements to arrive at the cost of renewing education facilities that are yet to be built. The capital required for investment in the renewal of existing education facilities has been calculated as a percentage of the book value of London's current education assets, as provided by the GLA. The GLA has estimated that the book value of existing assets is some £16.5 billion. Arup has assumed lifecycle renewal costs of 3.5% of this existing asset base, reflecting conversations with relevant bodies and the GLA indicating a slightly greater need for investment in these assets.

6.2 Preliminary analysis of costs

The figures overleaf set out our results. These projections are shown in 2014 prices, including a 2% per annum uplift in construction costs. These costs relate to the central population forecast scenario detailed elsewhere in the report.

As can be seen, education capital expenditure requirements are projected to total £68 billion. Approximately half of all capital expenditure is projected to relate to the development of new school facilities, labelled 'enhancements' in the figure.¹²⁴ These costs are projected to total £32 billion between 2016 and 2050. Renewals

¹²⁴ We note that our projections include indicative estimates of the cost of land needed for development. We have assumed that building costs (including construction and 'fit out') comprise 40% of total costs, and that land costs comprise 60% of total costs. We also have assumed that 20% of total land requirements can be met through the use of land already owned by the relevant public authorities.

costs, including the capitalised maintenance of both newly built and existing (in 2014) education assets, are projected to total some £36 billion.

£bn 2014 prices, five year period ending	2011-2015	2016-2020	2021-2025	2026-2030	2031-2035	2036-2040	2041-2045	2046-2050	Total 2016-2050	CAGR 2016-2050
Capex	9	9	13	8	5	6	12	14	68	1.3%
Enhancements	6	6	9	4	0	0	6	7	32	0.4%
Renewals	3	3	4	5	5	5	6	7	36	2.4%
Opex¹²⁵	3	7	10	11	11	11	13	15	77	2.6%
Schools total	12	16	23	19	16	17	25	29	145	1.9%

Figure 46: Projected capital and operating cost requirements by five-year period, 2011-2050. 2014 prices, including c.2% p.a. construction industry price growth for capital expenditure requirements

Operating expenses, calculated as a fee per school place per annum, are projected to rise as over the period. In total, operating expenses are projected to total some £77 billion between 2016 and 2050.

Overall our analysis indicates that primary, secondary and sixth form colleges will require some £145 billion in the period between 2016 and 2050.

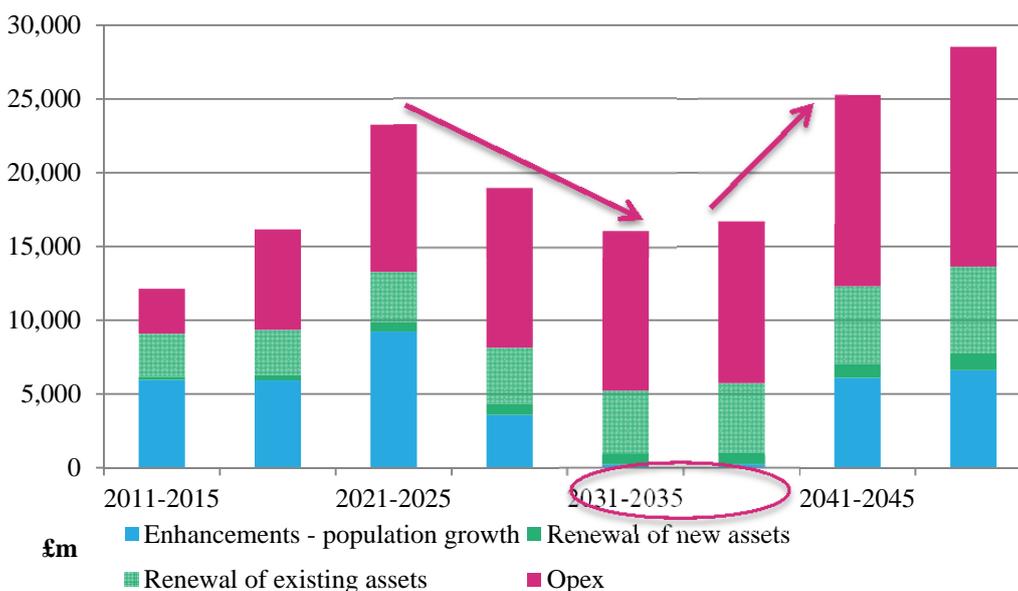


Figure 47: Schools expenditure 2015-2050 (2014 prices, including c.2% p.a. construction industry price growth). Source: Arup analysis

As shown in Figure 47, total costs are projected to decrease in the five year periods between 2026 and 2030; between 2031 and 2035 and - relative to the five years ending in 2025- between 2036 and 2040. In the 2030s, the decline in projected expenditure requirements relates to lack of growth (indeed there is a slight fall¹²⁶) in London's projected school-aged population. As a result, enhancement expenditure is not required. However, on-going renewal, operation and maintenance of London's education infrastructure are projected to bring total

¹²⁵ Opex costs include professional services such as teaching etc.

¹²⁶ Given the population projections discussed in the beginning of this chapter.

costs in line with previous periods, reaching some £17 billion between 2031 and 2035. With renewed population growth after 2041, expenditure is again forecast to increase.

6.3 Risks and uncertainties

There is inevitably considerable uncertainty around the assumptions used to determine the number of school places required and the number of schools these projections infer. In the first section of this chapter, we discussed some of the limitations of long-term population and demographic projections. Inevitably, actual population growth will differ from the levels projected, which could in turn have an effect on costs.

More efficient use of land, of existing assets and of new assets as they are built could mitigate the need for some additional development and/or construction. Conversely, more expenditure may be required, especially in relation to on-going capitalised maintenance of existing assets.

6.4 Conclusions

Demographic projections suggest that the capital's school-age population will increase in the coming decades. The school-aged population is projected to grow from some 1.5 million children in 2015 to some 1.8 million in 2050. On average, these projections indicate that London's school-age population will represent some 17% of the total GLA population over the study period.

Our analysis suggests that education facilities will require some £145 billion in the period between 2016 and 2050 for operations, renewals and enhancements. Education capital expenditure requirements are projected to total £68 billion over the plan period. Roughly half of all capital expenditure is projected to relate to the development of new schools facilities.

Given the high level of projected education expenditure requirements, a primary concern in the education sector is the relationship between central government and local authority funding. We attempt to address these considerations in the funding and financing section of this report.

7 Waste infrastructure

This section details our work related to the GLA's waste infrastructure investment plan. Working closely with the GLA, we have considered future requirements in order to provide a preliminary estimate of the capital and operating costs associated with future growth. Our work is based upon the GLA's own modelling of infrastructure requirements, along with our own analysis.

The demand for waste infrastructure is primarily driven by the permanent and transient population in London both of which generate solid waste.¹²⁷ As in other sectors, we have examined demand in relation to the GLA's central population scenario, which projects that the population will exceed 11 million in 2050.

The current waste management system is designed around the "take-make-use-dispose" linear economy. It is the responsibility of the 32 London boroughs and the City of London to collect, treat and ultimately dispose of household and some commercial waste. Waste produced by businesses is largely managed by the private sector.

The need for new waste infrastructure is expected to increase due to a rising population, waste volume growth and various policy imperatives which will shape how household and commercial waste are treated in the future. Household waste and commercial & industrial (C&I) waste together are forecast to increase from approximately 7.4 million tonnes per annum in 2010 to about 8.6 million tonnes in 2050 (see section 7.1).

Shifting government and corporate policy will frame London's infrastructure requirements over the study period. The Mayor has determined targets around the treatment of waste using recycling, reuse and landfill facilities which will need to be met before the early 2030s. These targets could support the transition to a "circular economy", as described in section 4. Over the medium-term, there will be a shift towards treating London's waste within London's boundaries, in order to meet "self-sufficiency" and "proximity" principles set out in government planning policy.¹²⁸

7.1 The case for investment

Waste disposal is a costly activity. The total cost to London of managing its municipal waste, including the collection, transport, treatment, and final disposal activities, was approximately £580 million in 2008/09. This figure represents about 20 per cent of London's total council tax bill of £2.98 billion. The average annual household council tax bill in London is £1,212 and therefore waste management represents £242 for the average council taxpayer¹²⁹.

Nearly half (42 per cent) of London's municipal waste was sent to landfill in 2010, costing about £265 million. It will become increasingly expensive to

¹²⁷ A number of waste streams have been excluded from the waste infrastructure cost review including construction, demolition and excavation waste (CDEW), healthcare waste and hazardous waste. These waste streams are beyond the scope of this study and/or are relatively small.

¹²⁸ Department for Communities and Local Government, *Planning for sustainable waste management: planning policy statement 10*, 20 March 2011, available: <https://www.gov.uk/government/publications/planning-for-sustainable-waste-management-planning-policy-statement-10>.

¹²⁹ Based on information provided by the Greater London Authority.

dispose of London's municipal waste in this way. Already, the GLA has identified that it is now cheaper to recycle household waste than to send it to landfill.¹³⁰

This is due to policy support favouring rises in landfill tax. The landfill tax has risen for active¹³¹ waste from £72 per tonne in 2013 to £80 per tonne in April 2014. Although step-changes in this tax have not materialised (i.e. beyond £80 per tonne), with-inflation increases mean a landfill mechanism for waste disposal is likely to remain more expensive than recycling or reuse in the future. Population growth will only exacerbate these pressures and could further increase the cost of traditional methods of disposal.

As London's population expands, increasing pressure will be placed upon its waste infrastructure. Arup has adopted the waste quantity forecast provided by the GLA for household waste and C&I waste.¹³² As shown in Figure 43, overleaf, it is projected that London could produce 8.6 million tonnes of household and C&I waste by 2050. In total, it is projected that the amount of waste the capital produces could increase by some 16 per cent between 2016 and 2050.

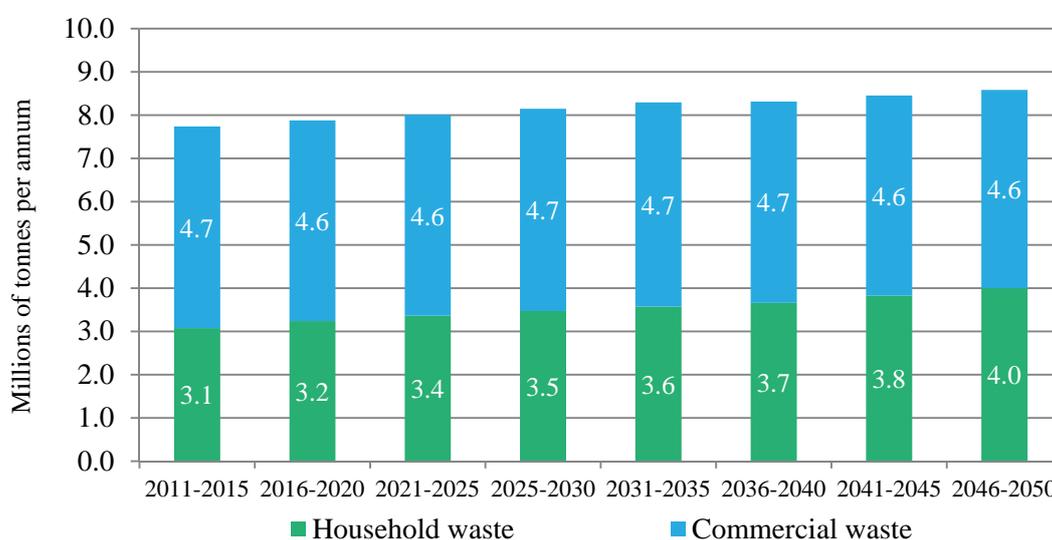


Figure 48: Historical and projected household and commercial waste (millions of tonnes), 2011-2050.

7.1.1 Policy context and statutory obligations

Investment is required to facilitate the development of new waste infrastructure in London to cope with the increasing waste quantities due to population growth and to replace some of the existing waste infrastructure, which will require gradual renewal. But London's future waste infrastructure requirements are unlikely to reflect historical patterns of treatment and disposal. Statutory obligations and targets for increased recycling and reducing land-fill are important drivers of

¹³⁰ Environment Agency, *London's Environmental Infrastructure Need: A Strategic Study*, June 2010, available: <https://www.gov.uk/government/publications/londons-environmental-infrastructure-needs-a-strategic-study>.

¹³¹ Active waste includes biodegradable matter such as wood and food as well as plastics and top-soil etc.

¹³² Greater London Authority/SLR Consulting Ltd (February 2014). *Waste Forecast Model for the Draft Further Alterations to the London Plan*.

investment which will shape the type and number of facilities required to handle London's growing volume of waste.

The Mayor has statutory powers with regard to London's municipal waste management. The GLA Act 2007 requires the London waste authorities to act in 'general conformity' with the Mayor's Municipal Waste Management Strategy. The Strategy sets the following key targets:

- Zero waste direct to landfill (by 2025 for Local Authority Collected Waste);
- 20 per cent reduction in household waste produced per household by 2031;
- Infrastructure to collect and refurbish 30,000 tonnes reusable items in 2013;
- Recycle or compost 50 per cent of Local Authority Collected Waste each year by 2020, 60 per cent by 2031 (currently 30 per cent);
- Recycle or compost 70 per cent of commercial waste by 2020 (currently 52 per cent);
- Local Authority Collected Waste management saving one million tonnes CO₂equivalent (eq) annually;
- Low carbon energy generation from non-recyclable waste; and
- London managing the equivalent of 100 per cent of its municipal and commercial waste by 2031.

7.1.2 A transition to a circular economy

In particular, central government and Mayoral policies will support a transition from a "linear" to a "circular" economy.¹³³ A circular economy ("take-make-use-remake") is an alternative to a traditional linear economy, in which we keep resources in use for as long as possible, extract the maximum value from them whilst in use, then recover and regenerate products and materials at the end of each service life.

A circular economy emphasises reuse and re-manufacture over landfill use. It is important to distinguish between reuse and recycling. Reuse relates to the recovery and regeneration of products or components. This differs from recycling, in which waste is converted into a reusable material.

This transition is considered often in terms of its environmental benefits. Reductions in the amount of resources sent to landfill can typically be expected to yield a range of these, including reduced greenhouse gas emissions and environmental degradation.¹³⁴ Business and industry also have been shown to benefit from this transition, such as through reduced input costs (see section 7.4.3 below), despite potential costs associated with changes to existing systems and practices.

¹³³ "Linear" industrial and consumption processes are characterised as "take-make-use-dispose" practices, which result in waste in landfills or incinerators.

¹³⁴ WRAP, *Contribution to economic growth*, undated, available: <http://www.wrap.org.uk/content/economic-and-environmental-benefits>.

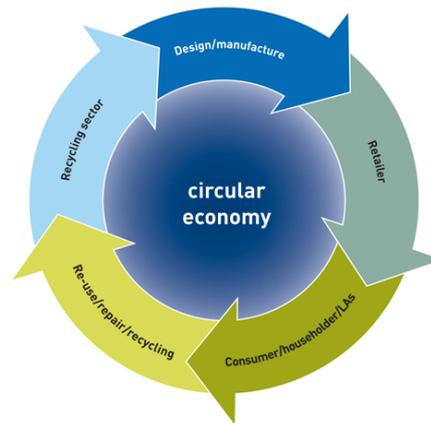


Figure 49: The circular economy moves away from traditional linear models, which result in the disposal of resources, towards a higher proportion of resources reclaimed through re-use or recycling¹³⁵ Source: Waste & Resources Action Programme

By moving to a circular economy model, there would be progressively less need for landfill disposal of waste, as more resources are reused, repaired or remanufactured. A transition to a circular economy necessitates investment in new and different types of infrastructure, even as traditional means of treatment and disposal are maintained, renewed or enhanced. Over the longer term, a transition could reduce the net costs to the public and businesses associated with waste management by maximising the economic value of waste.

7.1.2.1 Circular economy transition scenarios

Given the challenges associated with a transition to higher levels of waste reuse and remanufacture, there is some uncertainty around how waste will be treated in the future and if high levels of reuse can be achieved. To account for this uncertainty, Arup has modelled scenarios that account for different levels of reuse of waste and different levels of waste recycling. In the previous section, we noted broad differences between reuse and recycling.

Our scenarios relate primarily to differences in the proportion of waste that is reused and re-manufactured. We have modelled four such transition scenarios, as below:

- Base case – reuse/repair/remanufacture of **zero per cent** in 2050;¹³⁶
- Low – reuse/repair/remanufacture of **10 per cent** in 2050;
- Central – reuse/repair/remanufacture of **20 per cent** in 2050; and
- High – reuse/repair/remanufacture of **40 per cent** in 2050.

The high transition scenario was set out by the GLA. We find that the associated target of 40% is potentially achievable, but would require a strong public and corporate policy framework to succeed. We discuss this in the conclusion to this chapter.

¹³⁵ Waste & Resources Action Programme (WRAP) (2014), *The circular economy*, available: <http://www.wrap.org.uk/content/wrap-and-circular-economy>.

¹³⁶ Assumes a *de minimis* amount of reuse taking place, which is included in the recycling composting targets for the base case scenario.

The central and low transition scenarios have been developed to provide a sensitivity check and alternative. We have modelled the costs presented in this chapter according to our own central scenario for reuse, repair and remanufacture (20 per cent), which we believe more realistically reflects future potential. For the purpose of this study, Arup has assumed that the GLA recycling targets will be met by the dates targeted. The GLA has assumed that 45% of waste will be recycled in 2015; 50% will be recycled in 2020; and 60% will be recycled in 2031. The low, central and high scenarios inform the types of infrastructure required and, in turn, the costs associated with infrastructure development. The waste treatment method scenarios have been informed by GLA targets for recycling/ composting (including anaerobic digestion). Our combined re-use and recycling assumptions for each scenario are stated below.¹³⁷

Base case scenario

Household waste

The base case scenario for household waste is based on the waste forecast model included in the Further Alterations to the London Plan (FALP) and assumes zero per cent reuse/repair/ remanufacture, 60 per cent of recycling/composting (including reuse), 14 per cent intermediate waste processing, 40 per cent thermal treatment and zero landfill disposal by 2050.

C&I waste

The base case scenario for C&I waste assumes zero per cent reuse/repair/ remanufacture, 70 per cent of recycling/composting (including reuse), five per cent intermediate waste processing, 33 per cent thermal treatment and zero landfill disposal by 2050.

Low transition scenario

Household waste

The low transition scenario for household waste assumes 10 per cent reuse/repair/ remanufacture, 55 per cent of recycling/composting, 14 per cent intermediate waste processing, 36 per cent thermal treatment and zero landfill disposal by 2050.

C&I waste

The low transition scenario for C&I waste assumes 10 per cent reuse/repair/ remanufacture, 66 per cent of recycling/composting, five per cent intermediate waste processing, 27 per cent thermal treatment and zero landfill disposal by 2050.

¹³⁷ The waste infrastructure requirements sum to greater than 100 per cent of the total waste to account for waste that passes through an intermediate waste management facility such as a mechanical biological treatment (MBT) facility and is being processed into a solid recovered fuel before being transferred to an endpoint thermal treatment facility.

Central transition scenario

Household waste

The central transition scenario for household waste assumes 20 per cent reuse/repair/ remanufacture, 49 per cent of recycling/composting, 14 per cent intermediate waste processing, 31 per cent thermal treatment and zero landfill disposal by 2050.

C&I waste

The central transition scenario for C&I waste assumes 20 per cent reuse/repair/ remanufacture, 60 per cent of recycling/composting, 5 per cent intermediate waste processing, 23 per cent thermal treatment and zero landfill disposal by 2050

High transition scenario

Household waste

The high transition scenario for household waste assumes 40 per cent reuse/repair/ remanufacture, 50 per cent of recycling/composting, 14 per cent intermediate waste processing, 10 per cent thermal treatment and zero landfill disposal by 2050.

C&I waste

The high transition scenario for C&I waste assumes 40 per cent reuse/repair/ remanufacture, 49 per cent of recycling/composting, five per cent intermediate waste processing, 14 per cent thermal treatment and zero landfill disposal by 2050.

7.2 London's waste infrastructure requirements

As previously discussed, Household waste and commercial & industrial (C&I) waste is forecast to increase from approximately 7.4 million tonnes per annum in 2010 to about 8.6 million tonnes in 2050 (see section 7.1). Projected waste volumes have been attributed to six different treatment and disposal types. These different infrastructure types include:

- Reuse infrastructure
- Secondary material sorting and bulking
- Organic waste treatment
- Intermediate waste processing
- Thermal treatment
- Landfill

The net tonnage requirement allocated to each infrastructure type for the central treatment scenario is outlined in Figure 50 below. Over the study period, from 2016 to 2050, it is projected that the total volume of waste handled will increase from some 8.7 million tonnes per annum in the five years between 2016 and 2020 to some 9.5 million tonnes per annum in the five years between 2046 and 2050.

Secondary material bulking and sorting is projected to receive the most waste, whilst no landfill waste is projected after the 2030s.

Waste infrastructure type	2016-2020	2021-2025	2026-2030	2031-2035	2036-2040	2041-2045	2046-2050
Secondary material sorting and bulking	3.4	3.6	3.7	3.7	3.5	3.4	3.3
Thermal treatment	2.0	2.1	2.2	2.2	2.2	2.3	2.3
Organic waste treatment	1.5	1.5	1.6	1.5	1.5	1.5	1.4
Reuse infrastructure	0.4	0.6	0.8	1.0	1.2	1.5	1.7
Intermediate waste processing	0.7	0.7	0.7	0.7	0.7	0.8	0.8
Landfill	0.8	0.4	0.1	0.0	0.0	0.0	0.0
Total (millions of tonnes)	8.7	8.9	9.0	9.2	9.2	9.4	9.5

Figure 50: Projected waste by facility type per annum per five year period, 2016-2050. Millions of tonnes per annum. Source: Arup analysis

Approximately 40 new facilities are projected to be required over the study period, between 2016 and 2050. The majority of new facilities projected to be required will be either organic waste treatment facilities or secondary material sorting and bulking facilities. In addition to these new facilities, we have agreed to assume that existing and new waste facilities are replaced every 20 years, increasing the capital requirements in this sector.

7.3 Preliminary analysis of costs¹³⁸

Two separate approaches have been developed to estimate waste infrastructure costs. The first is based on a conventional estimate of capital and operational expenditure, and the second on using 'gate fees' reflecting the cost per tonne of waste treated. The figures presented relate to a 'conventional' approach.

The conventional approach of modelling waste infrastructure costs is based on using 'unit costs' for capital expenditure of providing the relevant waste infrastructure plus operational expenditure. Waste collection costs have been included as a separate expenditure to the waste infrastructure needs, but street cleansing costs are not included.

Figure 51 below sets out cost projections for the waste sector based upon our work with the GLA. These costs relate to the central population and central transition scenarios (as described above) and are presented in 2014 prices. Projected costs are split between capital and operating expenses, in addition to collection costs.¹³⁹ These projections are shown in real terms, including an underlying 2% annual uplift for construction industry price increases in capital costs.

¹³⁸ Costs have been included for street cleansing or the management of the excluded waste streams such as CDEW, healthcare and hazardous wastes. These lay beyond the scope of this study.

¹³⁹ Shown separately to differentiate from underlying operating costs

£bn 2014 prices, five year period ending	2011-2015	2016-2020	2021-2025	2026-2030	2031-2035	2036-2040	2041-2045	2046-2050	Total 2016-2050	CAGR 2016-2050
Capex	2	1	2	2	2	2	3	3	14	2.4%
Enhancements	2	1	1	1	2	2	2	2	12	1.9%
Renewals	0	0	0	0	0	0	1	1	3	5.2%
Opex (including collection costs)	4	26	0.1%							
Waste total	6	5	5	5	6	6	6	7	40	0.9%

Figure 51: Projected capital and operating cost requirements by five-year period, 2011-2050. 2014 prices, including c.2% p.a. construction industry inflation for capital expenditure requirements. Source: Arup analysis

It is projected that waste infrastructure expenditure requirements, including capital and operating expenses, will total £40 billion between 2016 and 2050. Operating expenses, shown above including collection costs, are projected to represent more than half of total projected expenditure. Capital investment requirements, including both enhancement (new facility) and renewals costs are projected to total some £14 billion.¹⁴⁰

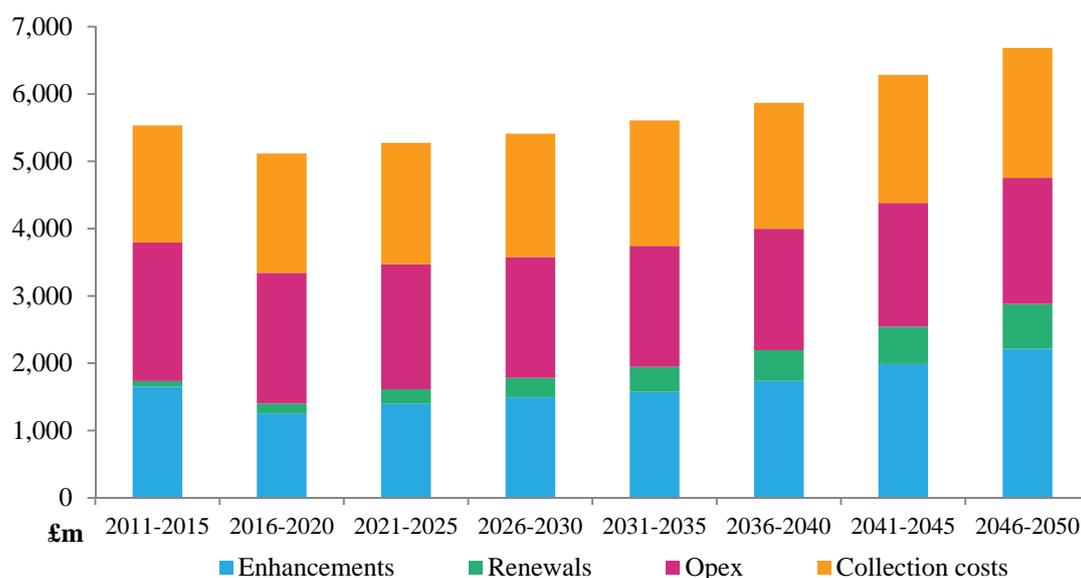


Figure 52: Waste infrastructure expenditure requirements, central transition and central population scenario. 2014 prices (£ million) including c.2% p.a. construction industry price inflation on enhancements and renewals. Source; Arup analysis

Figure 52 shows projected waste expenditure requirements by five-year period until 2050. As can be seen, waste infrastructure costs are projected to increase only slightly (less than 1% per annum) between 2016 and 2050, despite a significant forecasted increase in London's population. This is due to the shift in treatment of waste with the transition to a circular economy.

¹⁴⁰ Enhancement capital expenditure is projected to include land costs, calculated as 45% of total facility development costs.

As waste treatment moves progressively ‘up the waste hierarchy’ towards reuse, benefits are seen in capital and operating cost efficiency relative to population growth and waste growth respectively. Operating expenses, calculated on a per tonne basis, are projected to remain constant (some £4 billion per five-year period) despite waste volume growth. It is projected that the operating costs associated with reuse and secondary facilities are some 60% to 70% less expensive than traditional treatment methods.¹⁴¹

Renewals of the growing asset base, calculated as five per cent of enhancement costs, are projected to total some £3 billion over the study period. Waste collection costs make up a further third of the expenditure with also about £13 billion over the study period.

7.3.1 Benefits

Accelerating the transition to a circular economy and being more resource efficient has economic, environmental and social benefits for companies and society alike. With an increasing interdependence between resources (i.e. raw materials, energy, water, waste) compounded by increasing resource extraction costs and potential disruptions in material supply chains, a systematic approach to designing out material wastage and disposal has a number of economic benefits. For example, a study for the European Commission suggests that every percentage point reduction in resource use could be worth around €23 billion euros to EU businesses and lead to up to 100,000 to 200,000 new jobs in the EU.¹⁴²

Rising resource costs is one of the key business drivers for the transition to a circular economy. A report commissioned by the Ella MacArthur Foundation¹⁴³, found that, since 2000, the prices of natural resources have risen dramatically, erasing a century’s worth of real price declines.”¹⁴⁴ Rising commodity prices in the first decade of the twenty-first century reversed the long-term downward trend in food, non-food agricultural items, metal and energy experienced since 1990.

A systematic approach to designing out material wastage and disposal has been shown (at least in some cases) to benefit businesses by reducing input and materials costs. Recent research undertaken on behalf of the Ellen MacArthur Foundation suggests that the transition represents an “*annual net material cost savings opportunity of ... up to USD \$630 billion..., looking only at a subset of [European Union (EU)] manufacturing sectors.*”¹⁴⁵

Evidence of competitive advantage associated with greater control of material systems is evident in the automobile industry, where profit margins can be low and the impact of commodity price volatility can be high. At its dedicated remanufacturing plant near Paris, Renault re-engineers 17 different mechanical

¹⁴¹ It is assumed that the operating cost per tonne for reuse and secondary material sorting and bulking facilities is some £20 per tonne per annum. Intermediate, thermal and landfill facilities are projected to require operating expenses of some £70 to £90 per tonne per annum.

¹⁴² European Commission (September 2012). European Resource Efficiency Platform, Working Group I, Circular Economy / Greening the Economy First Report to Shapers.

¹⁴³ The foundation was established to promote the transition to a circular economy

¹⁴⁴ Ellen MacArthur Foundation, Towards the Circular Economy, undated, available: <http://www.ellenmacarthurfoundation.org/business/reports>.

¹⁴⁵ Ellen MacArthur Foundation, Towards the Circular Economy, undated, available: <http://www.ellenmacarthurfoundation.org/business/reports>.

“sub-assemblies” from water pumps to engines. Renault works with its distributor network to obtain used subassemblies, and supplements these with used parts purchased directly from end-of-life vehicle disassemblers, as well as with new parts where necessary. Renault’s ability to structure and run its reverse logistics supply chain and access a steady stream of core components, together with its deployment of highly skilled labour, has allowed the company to grow its remanufacturing operations into a €200 million business.¹⁴⁶

Overall, comparing the costs and benefits of moving from a linear economy to a circular economy suggests that there are significant economic, environmental and social benefits.

7.4 Opportunities for consolidation

Opportunities for consolidation exist with a number of sectors. In particular, there is an opportunity for energy generation from waste, having the potential to contribute to combined heat and power schemes in London. The treatment of organic waste via anaerobic digestion (AD) also provides an opportunity for generating energy in the form of electricity, heat or fuel (i.e. biogas-to-grid or biogas-to-transport-fuel). As the GLA progresses plans for the energy sector, agreeing a future development and demand ‘scenario’, it may wish to consider the benefits and costs associated with waste-to-energy developments.

Links with other sectors also could inform future cost-benefit analysis. Sustainable transport systems are an important aspect of providing an efficient, comprehensive and consumer friendly collection system for end-of-life products. The AD process also provides a beneficial fertiliser and soil improver, which links to the establishment of green infrastructure.

7.5 Risks and uncertainties

The rate of recycling may fail to achieve levels modelled and the transition to a circular economy may occur more slowly than has been projected. This delay could be in part due to a lack of a strong policy framework and understanding of the circular economy model resulting in uncertainties in the marketplace. The rate of recycling growth also slowed in recent years and this could continue.

Having said this, GLA recycling targets cited earlier in this chapter are in principle considered to be achievable given the significant improvement of Local Authority Collected Waste (LACW) recycling rates from nine per cent in 2000/01 to 34 per cent in 2012/13.¹⁴⁷ However, the incremental year-on-year increase in recycling rates has considerably slowed between 2009/10 to 2012/13 to an average of about 4 per cent, and almost no increase between 2011/12 and 2012/13. There is a risk that recycling rates of LACW may plateau or even decline.

¹⁴⁶ New business models or consumer incentives, in addition to new policies, could be required in order to support the re-use of household waste. We discuss such measures in the section below detailing evidence from other countries.

¹⁴⁷ Department for Environment, Food & Rural Affairs, *ENV18-Local authority collected waste: annual results* tables, 6 February 2014, available: <https://www.gov.uk/government/statistical-data-sets/env18-local-authority-collected-waste-annual-results-tables>.

It remains unclear how the majority of businesses and government will move from the existing linear model. The transition to a circular economy could require a range of policy measures, incentives and engagement. These are outlined in the conclusion to this chapter.

7.5.1 Evidence from other countries

Other industrialised nations have made the transition to a circular economy successfully. Evidence from Germany and Japan suggests the importance of public and corporate policy in fostering the transition. Both countries have developed government policies aimed at increasing resource efficiency (resource productivity), and have introduced laws to facilitate the establishment of closed loop material cycles.¹⁴⁸ As we discuss in the conclusion to this section, there is potential that some policy measures may be introduced at a local level, within London.

7.5.1.1 Germany

Whilst Germany's waste policy in the past focused on environmentally sound waste disposal, from the mid-1990s, the Closed Substance Cycle and Waste Management Act 1996 introduced a responsibility for manufacturers and distributors of products to design out waste and to initiate closed loop product collection systems.

This change in waste policy focus has resulted in very high global recovery rates. For example, 85 per cent of packaging, 88 per cent of paper products, almost 96 per cent of end-of-life vehicles, about 96 per cent waste electrical and electronic equipment and virtually 100 per cent of batteries collected are recovered.

Producer responsibility combined with a ban on landfilling of untreated municipal solid waste and the separate collection of recyclables / organic waste has helped to achieve a recycling rate (including composting and anaerobic digestion) of 63 per cent and almost zero municipal solid waste to landfill.¹⁴⁹

The resource and waste management sector has become an important economic and employment sector. The German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety states that: "Currently over 250,000 people are employed in waste management, an economic sector with revenues of around 50 billion Euros."¹⁵⁰

¹⁴⁸ United Nations Environment Programme (2011). Decoupling Natural Resource Use and Environmental Impacts from Economic Growth.

¹⁴⁹ Bundesministerium für Umwelt, Naturschutz Bau und Reaktorsicherheit [Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety], *Waste Management in Germany* 2013, December 2012 [published in German], available: <http://www.bmub.bund.de/service/publikationen/downloads/details/artikel/abfallwirtschaft-in-deutschland-2013/>. 2010 figures

¹⁵⁰ Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety, *Waste Policy Background: The development of waste policy in Germany*, December 2012, available: <http://www.bmub.bund.de/en/topics/water-waste-soil/waste-management/waste-policy/>.

7.5.1.2 Japan

In Japan, the term *Junkan-gata-shakai* (Sound Material Cycle Society) was first devised in 1991 by an expert committee of the Japan Environment Agency. A Fundamental Law for Establishing a Sound Material Cycle Society has been in place since 2000 with the first Fundamental Plan adopted in 2003. A revised version has since been adopted in 2008. The government recognised that in order to build a sound material cycle society, they would need to undertake a material flow analysis.

Understanding the flows of materials in terms of resources extracted, consumed and disposed of has been key in setting targets for material flow indicators that have enabled Japan to reduced waste generation and promote the efficient use of material inputs.

Sectorial and product specific recycling laws have supported the transition towards a sound material cycle. Japan's appliance recycling laws ensure the great majority of electrical and electronic products are recycled, compared with only 30-40 per cent in the UK.¹⁵¹ Of the appliances recycled in Japan, 74-89 per cent of the materials they contain are recovered. Perhaps more significantly, many of these materials go back into the manufacture of the same types of products from which they were reclaimed. High recycling rates are also connected to guidance systems and eco-efficiency evaluation indicators voluntarily developed by a consortium of leading Japanese electronics companies including Fujitsu, Hitachi and Panasonic.¹⁵²

In addition to the Fundamental Law for Establishing a Sound Material Cycle Society, a Law on Promoting Green Purchasing has been able to support the demand-side of recycled products.

7.5.2 Evidence from existing business practices

For London, collaboration between local government, business and industry will be an important to encouraging the transition from a linear economy. Adapting collection systems to incentivise consumer participation is critical to the transition to a circular economy. The system for collection of end-of- service life products must be comprehensive and most importantly, easy to use for consumers. Similarly, the resource and waste sector can help manufacturers 'design for recovery' by collaborating more closely with material scientists and designers to understand better the practical impacts of design choices on the recovery of materials. Designers could receive "hands-on" training in dismantling products, by visiting disassembly factories. The training could help designers to experience the difficulties of taking apart a poorly designed product.

An example of consumer-friendly collection is Apple's reuse and recycling programme.¹⁵³ Apple now offers a take-back system for iPhones, iPads, iPods and computers. At no cost, the consumer can either send their end-of- service life

¹⁵¹ Association for Electric Home Appliances, *Environmentally conscious design: the fourth edition of the Product Assessment Manual (Executive Summary)*, January 2007, available: http://www.aeha.or.jp/assessment/en/english_flame.html.

¹⁵² Panasonic Eco Technology Centre, *Home appliance recycling*, undated, available: <http://panasonic.net/eco/petec/material/>.

¹⁵³ Please see: <http://www.apple.com/uk/recycling/>.

product to Apple via their service provider¹⁵⁴ or bring it to an Apple retail store. If the device still has a monetary value this will be credited directly to the consumer's account.

7.6 Conclusions

The waste infrastructure cost model developed by Arup shows that the transition to a circular economy could help to reduce costs for waste infrastructure, limiting the need for the development of new landfill sites. However, there is a risk the transition to a circular economy will be slow, which means that the potential benefits are not being realised to the optimum extent.

Our review of the costs and benefits associated with moving to a circular economy suggests that the investment in new reuse, repair, remanufacture and recycling infrastructure, to facilitate the transition to a circular economy is outweighed by the economic, environmental and social benefits.

This transition could require public policy to incentivise reuse and remanufacturing. Many of these policy options may necessitate national (or even EU), rather than just GLA, interventions. However, the GLA could consider developing its own roadmap to a circular economy either as part of a national transition or, in as much as it could be possible, independently. London could adopt a range of policies to support this transition at a local level. Public and/or corporate policy could support this transition by:

- Implementing higher city-level recycling targets;
- Developing a national circular economy policy, ultimately aimed at eliminating the concept of waste;
- Making eco-design a responsibility for product manufacturers and distributors;¹⁵⁵
- Mapping the flow of materials through the UK economy and setting targets for material flow indicators;
- Providing some certainty around future policy action, developing a “circular economy road map” for London (potentially as part of a smart city concept);
- Continuing to promote a green procurement approach of goods and services;
- Maintaining the landfill tax and considering a ban on the disposal of untreated waste;
- Keeping ‘biological nutrients’ and ‘technical nutrients’ separate to avoid introducing ‘toxins’ into the biosphere;¹⁵⁶
- Considering incentives around the establishment of disassembly facilities and remanufacturing centres in London by, for example, providing business rate relief; and
- Considering the provision of training and education regarding the circular economy concept to raise awareness and change behaviours.

¹⁵⁴ Please see: www.dataserv-group.com.

¹⁵⁵ European Union, *Ecodesign Directive (Directive 2009/125/EC)*, available: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32009L0125:EN:NOT_

¹⁵⁶ Cradle to Cradle, *What is Cradle to Cradle*, available: <http://c2cislans.org/sjablonen/1/infotype/webpage/view.asp?objectID=1233>.

A range of these measures is likely to be required in the future. In particular, the GLA could consider developing measures to support recycling rates and creating a “road map” for the transition to a circular economy within the capital in the first instance.

Policy changes could yield real benefits. Arup’s analysis indicates that the infrastructure costs associated with a circular economy are an order-of-magnitude lower than they would be with the development of new thermal waste treatment infrastructure and disposal of waste to landfill associated with the continuation of a linear model. In total, we have projected that some £40 billion of expenditure could be required given a transition to a circular economy. Of this expenditure, it is projected that some £14 billion of capital (enhancements and renewals) expenditure will be required and some £26 billion of operating expenditure will be required.

8 Green infrastructure

This section details our work with the GLA reviewing London's long-term green infrastructure requirements. Working closely with the GLA, we have provided a preliminary estimate of the capital and operating costs associated with green infrastructure development. As with other sectors, we use population growth as the principal driver for assessing requirements to 2050.

Increased numbers of people living, working and visiting London could pose significant challenges to the quality of London's open spaces and other "soft" environmental assets. Competition for land and the need for greater housing and commercial development will place demands on the city's existing green spaces, and land within London's current boundaries that might be needed for new green space.

Green infrastructure is more than parks and public spaces; it is increasingly understood as a network of interventions aimed at solving urban environmental problems by "building with nature". These interventions can include efforts to increase biodiversity, enhance air quality, improve sustainable energy production, provide clean water and better manage storm water.

Arup has recommended a series of capital enhancements reflecting this understanding of green infrastructure, whilst also recommending the improvement of London's green spaces. The capital enhancements included in this sector comprise green roofs, green walls, rain gardens, sustainable drainage, green corridors, increased tree canopy cover and the enhancement of other natural areas.

The London Plan stipulates green space requirements for London residents. To accommodate population growth, Arup has calculated that, in accordance with current guidance, London would require 90 million square metres of additional green space to satisfy the demands of a growing population. Given spatial development limitations, a significant portion of this space is unlikely to be readily available. The implication of this is that London will need to use its existing green spaces more efficiently and invest in more innovative green assets (green roofs, rain gardens and 'pocket' parks for example) to protect and enhance the quality of life for its current and future inhabitants.¹⁵⁷

There are considerable opportunities to join investment in green infrastructure to investment in other sectors, including waste, transport and housing. Our focus in this particular section is narrow, including a select group of open space and other requirements identified by the GLA. In this chapter, we highlight some opportunities in the housing, transport and storm water management sectors. We make other recommendations related to 'blue-green' infrastructure in the water sector chapter of this report. We also discuss green infrastructure investment in relation to the Mayor's Roads Task Force and other 'World City' transport investment in that section of this report.

In the capital expenditure section of the executive summary, we have grouped green infrastructure capital costs projected in the transport and water sectors with the other green infrastructure costs. Such a re-grouping has the effect of increasing the capital expenditure estimated to be required. Re-allocating some transport and water-sector investment increases projected green capital expenditure to some £20

¹⁵⁷ Greater London Authority, *All London Green Grid SPG*, 2012.

billion over the study period. The figures presented below are as sub-set of those presented in the summary of this report.

As we discuss below, although investment in green infrastructure is shown to add to the cost of enhancements, renewals and on-going maintenance, these green infrastructure investments have been shown to have considerable environmental, social and economic benefits. Rethinking and restructuring the existing green space network to improve its performance and greening the built environment would enable the capital to address a number of environmental and social imperatives. These range from minimum green space requirements to a host of challenges potentially presented by a changing climate. They may include surface water management, urban cooling or ecological resilience. Investment could also yield a number of social benefits, linked to health improvements and community well-being.

8.1 The case for investment

The concept of green infrastructure is defined in the London Plan as:

“...the multifunctional, interdependent network of open and green spaces and green features (e.g. green roofs). It includes the Blue Ribbon Network but excludes the hard-surfaced public realm. It provides multiple benefits for people and wildlife including: flood management; urban cooling; improving physical and mental health; green transport links (walking and cycling routes); ecological connectivity; and food growing. Green and open spaces of all sizes can be part of green infrastructure provided they contribute to the functioning of the network as a whole.”¹⁵⁸

In an urban context, green infrastructure is noted as “one of the most effective tools available to us in managing environmental risks such as flooding and heat waves.”¹⁵⁹ Alongside a rising population, statutory requirements and policy imperatives are the foundation for the case for investment in green infrastructure. The London Plan is the primary driver for investment, specifying requirements for access to green space and objectives in relation to urban greening, canopy cover and habitat creation. The plan states that this approach is “to protect, promote, expand and manage the extent and quality of, and access to, London’s network of green infrastructure.”¹⁶⁰

In some other sectors, including transport, water and energy, green infrastructure investment is supported through particular policies and Mayoral priorities. For example, in the water sector, sustainable urban drainage systems and smart metring programmes included in water companies’ business plans reflect a growing emphasis on green-related infrastructure investment. In the transport sector, a significant portion of proposed expenditure related to the Mayor’s Roads Task Force relates to place-making initiatives and improved green spaces along the capital’s roads and highways.

¹⁵⁸ Greater London Authority, *The London Plan: draft further alterations*, January 2014, <http://www.london.gov.uk/priorities/planning/london-plan>.

¹⁵⁹ Department for Environment, Food & Rural Affairs *Natural Environment White Paper 2010*

¹⁶⁰ Policy 2.18 - Greater London Authority *The London Plan – Spatial Development Strategy for Greater London 2013* Greater London Authority

8.2 London's green infrastructure requirements

In establishing a baseline requirement for green infrastructure, our approach has been to:

- Establish open space (i.e. traditional recreational space) requirements on a per capita basis; and
- Assess other investment requirements in line with climate change, health, ecology and other policy drivers, as specified by the GLA.

We detail the types of capital (enhancement and renewals) investments included in our cost projections in the two sections below. Additional operating expenses, discussed in section 8.4.1 below, also are projected, relating to routine maintenance of London's recreation spaces as well as care and maintenance of London's expanding tree canopy.

8.2.1 Open space requirements

One component of the green infrastructure required over the study period will be continued improvement of recreational spaces. Current supply of this space is divided according to inner and outer London, as below.

- **Inner London:**¹⁶¹ green space supply stands at 17.81 square metres per capita.
- **Outer London:**¹⁶² green space supply stands at 45.68 square metres per capita.

Utilising the central scenario of population growth¹⁶³ for London by 2050, we have calculated that the ratio of supply to potential usage of open space by London's population will decrease by over a quarter relative to current availability, based upon current London Plan requirements. This decrease is primarily a result of the rising population in the city.

- **Inner London:** supply of green space will decline some 26% to 13.14 square metres per capita.
- **Outer London:** supply of green space will decline some 28% to 32.80 square metres per capita.

In all, we have concluded that London will require 90 million square metres¹⁶⁴ of additional green space up to 2050 in order to maintain the status quo in relation to

¹⁶¹ The statutory Inner London boroughs are: Camden, Greenwich, Hackney, Hammersmith and Fulham, Islington, Kensington and Chelsea, Lambeth, Lewisham, Southwark, Tower Hamlets, Wandsworth and Westminster and constitutes approx. 319km² = 319000000m² = 31,900ha. *Based on the Office of National statistics Census information 2011.*

¹⁶² The statutory Outer London boroughs are: Barking and Dagenham, Barnet, Bexley, Brent, Bromley, Croydon, Ealing, Enfield, Haringey, Harrow, Havering, Hillingdon, Hounslow, Kingston upon Thames, Merton, Newham, Redbridge, Richmond upon Thames, Sutton and Waltham Forest and constitutes approx. 1,253km² = 1253000000m² = 123,300ha. *Based on the Office of National statistics Census information 2011.*

¹⁶³ Growth of population provided by the GLA

¹⁶⁴ To ensure the status quo, London would require approximately 108 million square metres of green space before 2050. Arup does not conclude that this amount of land is likely to be required.

access to green space. We have used this amount as the basis for determining cost requirements.

8.2.2 Other green infrastructure enhancement requirements

The London Plan sets out a number of policies to promote the delivery of additional space to deliver a range of other functions and benefits. For example, policy 5.10, “Urban Greening”, identifies the increment of ‘green’ surface area in the Central Activities Zone (CAZ) by at least 5% by 2030 and a further 5% by 2050, primarily to alleviate predicted impacts of climate change.

In addition to the renewal of existing parks and gardens, other enhancements and investments have been proposed as part of London’s infrastructure investment plan. These enhancements include:

- The adaptation of the green space network utilising green infrastructure (enhancement);
- The introduction of greener versions of Quietways cycling infrastructure (enhancement);¹⁶⁵
- Review of the current level of funding for urban tree planting and establishment of future funding requirements to 2050 (enhancement);
- Establishment of associated funding requirements for elements of green infrastructure, such as tree planting, sustainable drainage and green spaces, specific to future housing developments (enhancement);

We detail our approach to costing these investments in appendix A8 to this report. In the sections below, we provide an indicative overview of the potential costs and benefits associated with investment.

8.3 Risks and uncertainties

The delivery of green infrastructure takes place in an uncertain environment. Funding and resourcing of green infrastructure is shared by a wide number of public and private beneficiaries, including those with a stake in housing, public health, transport and environmental protection, as well as those concerned with amenity, sport and recreation. Because green infrastructure investment occurs in a wide range of infrastructure sectors, the scope of investment in ‘green’ infrastructure is blurred. Our approach has been to show costs associated with different green investments according to the sector with responsibility for their development. Costs associated with investment could be higher or lower, depending on how green infrastructure is defined and structured.

We believe that residential development will continue to support the provision of green space, reducing the need to develop recreation space. We have assumed that, through the provision of new housing, up to 18 million square metres of green space could be provided.

¹⁶⁵ Greater London Authority *The Mayor’s Vision of Cycling in London – An Olympic Legacy for all Londoners*. Greater London Authority, 2013.

8.4 Preliminary analysis of costs and benefits

8.4.1 Capital and operating costs

Projected costs are split between capital and operating expenses. Enhancements include investment in 'greener' cycling Quietways¹⁶⁶ and investment in the provision of public spaces across London's new housing estates. Renewal expenditure represents the effort to improve the quality of existing green space and infrastructure. These projections are shown in 2014 prices.¹⁶⁷ These costs relate to the central population growth scenario.

The figures presented below are as sub-set of those presented in the summary of this report. As discussed, this chapter adopts a more narrow view of green infrastructure, excluding the infrastructure requirements and associated costs specified in the plans for other sectors.

Figure 53 below shows our estimate of costs for the open space and other new development requirements outlined in sections 8.2.1 and 8.2.2 above. In the period between 2016 and 2050, it is estimated that some £2 billion of capital expenditure will be required. Of this, £1.6 billion is projected to be required for renewal of the capital's existing green spaces. Capital enhancements, including green Quietway enhancements and accessible green space within future housing developments, are projected to require some £500 million of expenditure between 2016 and 2050.

£bn 2014 prices, five year period ending	2011-2015	2016-2020	2021-2025	2026-2030	2031-2035	2036-2040	2041-2045	2046-2050	Total 2016-2050	CAGR 2016-2050
Capex	0.34	0.29	0.28	0.25	0.25	0.24	0.35	0.39	2.1	1.0%
Enhancements	0.02	0.04	0.07	0.07	0.08	0.08	0.08	0.08	0.5	2.0%
Renewals	0.32	0.24	0.20	0.18	0.18	0.17	0.27	0.31	1.6	0.7%
Opex	0.02	0.03	0.04	0.05	0.05	0.06	0.07	0.08	0.4	3.2%
Green total	0.35	0.32	0.32	0.30	0.30	0.30	0.42	0.46	2.4	1.3%

Figure 53: Green open space and other new development requirements - projected capital and operating cost requirements by five-year period, 2011-2050 (2014 prices, including c.2% p.a. construction industry uplift for capital expenditure requirements).

In addition, some £400 million of operating expenses are projected to be required over the plan period. Operating expenses are projected to relate to routine maintenance of London's recreation spaces as well as care and maintenance of London's expanding tree canopy.¹⁶⁸ In total, some £2.4 billion will be required over the study period, between 2016 and 2050.

¹⁶⁶ See for example <http://www.tfl.gov.uk/corporate/about-tfl/how-we-work/planning-for-the-future/vision-for-cycling/central-london-cycling-grid>

¹⁶⁷ But including a 2% pa underlying increase in capital expenditure costs.

¹⁶⁸ The operating expenses associated with tree canopy maintenance are calculated as an additional 5% of all other green infrastructure operating expenses.

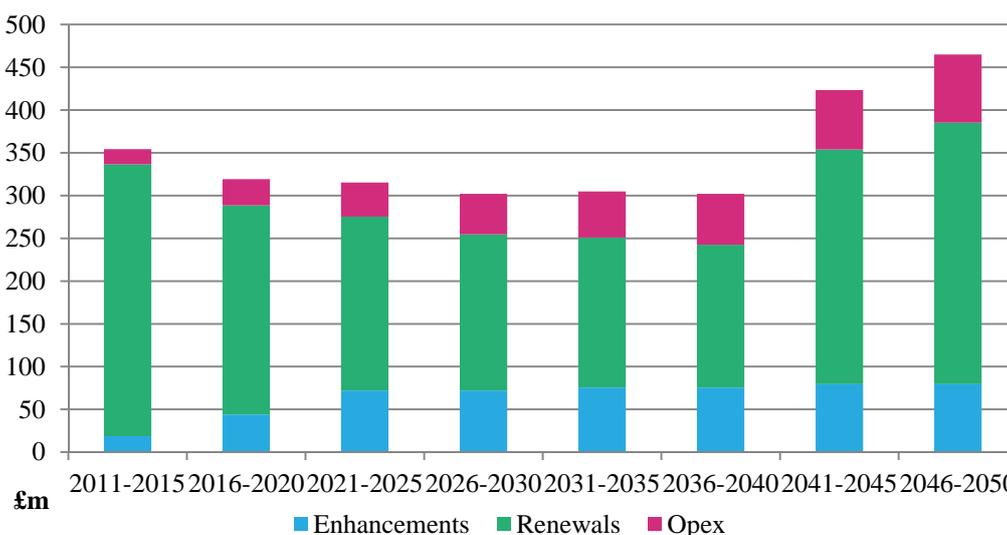


Figure 54: Green infrastructure expenditure 2015-2050 (£ million, 2014 prices including a 2% pa underlying increase in capital costs)

Figure 54 above shows projected capital and operating cost requirements from the previous figure in a graphical format.¹⁶⁹

8.4.2 Quantifying benefits

There is evidence that investment in green infrastructure yields environmental, economic and social benefits, which in some cases can be quantified in financial terms. Reports by central government acknowledge that, although “in most cases there is little doubt that returns on green infrastructure investment are high,” a difficulty remains around convincing budget holders of the value associated with ‘indirect’ impacts.¹⁷⁰

As economic and financial analysis of green infrastructure investment is less established than that of other infrastructure sectors, the GLA requested that Arup consider in particular the evidence of benefits of investments, in order to inform future work and on-going analysis.

8.4.2.1 Economic benefits

One literature review concluded that, whilst it could be asserted that there is little “direct, strong and reliable evidence of impacts of green space on economic growth,” some evidence supports claims of green infrastructure’s positive effects

¹⁶⁹ The GLA has provided a breakdown of London’s forecast population through the 2030s and an endpoint total estimate in 2050. As discussed in the education infrastructure section of this report, these end-point estimates produce a sudden ‘uptick’ in the population in 2045 when averaging estimates of 2040 and 2050. Estimates of the population in the 2040s and 2050 are likely to change over the short and medium-term. Minor changes would not have a material effect on costs as they currently have been estimated.

¹⁷⁰ Land Regeneration and Urban Greenspace, Centre for Forestry and Climate Change, *Benefits of Green Infrastructure: Report to Defra and DCLG*, October 2010, p. 2, available: [http://www.forestry.gov.uk/pdf/ur_gp_benefits_of_green_infrastructure_main_report.pdf/\\$FILE/ur_gp_benefits_of_green_infrastructure_main_report.pdf](http://www.forestry.gov.uk/pdf/ur_gp_benefits_of_green_infrastructure_main_report.pdf/$FILE/ur_gp_benefits_of_green_infrastructure_main_report.pdf).

on GVA.¹⁷¹ Some case evidence has shown positive additionally related to job creation, business start-up and levered private investment, consequently increasing GVA. One study found that tree replanting, woodland management and recreational area access in the Mersey Forest, Merseyside, generated £2.30 for every £1 invested.¹⁷²

Green infrastructure may play an indirect but important role in business and residential investment decisions. One academic centre's review of evidence in the UK and USA concluded that "the importance of green infrastructure to the attractiveness of cities and neighbourhoods to people and investors is relatively well understood by city planners and developers."¹⁷³ The study concluded that this effect on neighbourhoods' attractiveness is the largest short-term, local effect of green infrastructure investment. The study considered New York City's High Line as an example relevant to London, but did not quantify the monetary impact of investment in new public spaces or other green infrastructure enhancements, including those targeting the potential effects of climate change.

8.4.2.2 Environmental and social benefits

UK government-funded research has supported the conclusion that urban green infrastructure "can deliver a wide range of environmental benefits."¹⁷⁴ The study identifies benefits including reductions in air pollution, reductions in flood risk and amelioration of high summer temperatures caused by the urban heat island effect and climate change. The report to Defra and DCLG on the environmental benefits of investment contains a detailed review of the literature considering these environmental benefits.

Evidence supporting these claims is scattered, the product of a wide range of studies applicable to many different cities and geographies. In general, these studies support the enhancements included in Arup's cost analysis and supported by the GLA, demonstrating that the environmental benefits of green infrastructure investment beyond amplifying open space availability and making neighbourhoods more attractive.

Examining those studies applicable to London, it has been found that green space investment benefits the capital's environment. In London, a case study "covering a 10 km x 10 km area of the East London Green Grid (ELGG) showed the potential for green space to reduce particulate (PM10) pollution. PM10 is an issue

¹⁷¹ *Ibid.*

¹⁷² Regeneris Consulting, *The economic contribution of the Mersey Forest's objective one-funded investments*, October 2009, available: <http://www.merseyforest.org.uk/pages/displayDocuments.asp?iDocumentID=246>. Note: it was concluded that this analysis accounted for additionally factors but that its NPV calculations were not consistent with government guidance.

¹⁷³ Sheffield Hallam University: Centre for Regional Economic and Social Research, *Green Infrastructure's contribution to economic growth: a review*, July 2013, p. 73, available: http://randd.defra.gov.uk/Document.aspx?Document=11406_GI_Economic_Catalyst_Final_Report_July2013.pdf.

¹⁷⁴ Land Regeneration and Urban Greenspace, Centre for Forestry and Climate Change, *Benefits of Green Infrastructure: Report to Defra and DCLG*, October 2010, p. 70.

in urban areas due to links between human exposure and adverse health impacts.”¹⁷⁵

Evidence of green infrastructure’s beneficial effects on air quality has been shown in other cities. The city of Chicago has estimated that investment in “greening” only a small percentage of the city’s rooftops has significantly reduced air pollution. Converting 10% of Chicago’s rooftops has been shown to remove 17,400 Mg of nitrogen dioxide each year. In turn, Chicago estimates that this investment could result in avoided public health costs of \$29.2 million to \$111million annually.¹⁷⁶

A review of investment in Manchester concluded that green infrastructure investment can reduce water runoff by nearly one fifth. Research has found that adding green roofs to all buildings, retail spaces and high-density residential units in its centre has reduced run off by 17% - a figure which could be replicated for London.¹⁷⁷ The costs associated with sustainable urban drainage systems (SUDS) investment have been found to be significantly lower than traditional mechanisms.

In Scotland, research found that the capital costs of traditional drainage systems can be double the cost of SUDS, and that annual maintenance of traditional systems can be 20-25% higher than that of SUDS.¹⁷⁸

8.5 Opportunities for consolidation

There is a significant opportunity to encourage efficiency through more strategic oversight of the city’s green infrastructure. The components of the existing green infrastructure network are owned and managed by a number of public and private sector organisations delivered through a range of funding entities. This risks an un-coordinated approach to implementation, funding and delivery.

The enhancements that Arup and the GLA have recommended as part of this engagement involve close links to other infrastructure sectors. There may be an opportunity to group projects and encourage efficient delivery through more coherent oversight and governance.

8.6 Conclusions

As London continues to grow, the pressure placed upon both brownfield and greenfield land will increase. Existing parks and open spaces will need to be used more efficiently as the population increases. But other investment could be required in order to help to mitigate the negative effects of population growth whilst making the capital a more attractive and liveable city.

Other interventions, including tree planting, improved storm water management, and green adaptations of the transport network could prove beneficial. Investment

¹⁷⁵ Tiwary, A, et al., *An integrated tool to assess the role of new planting in PM10 capture and the human health benefits: A case study in London. Environmental Pollution*, 157, 2645-2653.2009.

¹⁷⁶ Clark, C et al., *Green Roof Valuation: A Probabilistic Economic Analysis of Environmental Benefits January*, 2012.

¹⁷⁷ Gill, SE, et al. Adapting cities for climate change: the role of the green infrastructure. *Built Environment*, 33, 115-133. 2007

¹⁷⁸ Duffy, A, ‘A cost comparison of traditional drainage and SUDS in Scotland. *Water Science & Technology*, 57, 1451-1459. 2009. See also the Water chapter in this report.

in the proposals discussed in this report provide a pathway to shape and deliver the city's green infrastructure requirements over the longer term.

In total, we have projected some £2.4 billion of green infrastructure costs over the study period, between 2016 and 2050. However, this figure represents a narrow view of green infrastructure, not accounting for the cost requirements associated with public and private sector proposals across a range of other infrastructure sectors. As discussed in this section and in the executive summary of this report, re-grouping projected to costs to demonstrate green investment requirements across a range of sectors produces a much higher estimate of investment needs for green related infrastructure over the plan's period of 2016 to 2050.

The green infrastructure cost model developed by Arup shows levels of investment required is comparable to other global cities, including New York. A growing body of research provides evidence that investment in this infrastructure yields not only environmental but also social and economic benefits.

It is our view that the planning and development process provides one of the best opportunities to encourage the delivery of green infrastructure. Additions to the London-wide strategy could further encourage implementation of green infrastructure in new developments. For example, developers could be encouraged to develop green roofing through a tax relief or incentive scheme.

London government could consider the establishment of a strategic body in order to co-ordinate long-term investment in this sector and ensure the delivery of green infrastructure. This may prove to be cost effective, and the body could make it more likely that London realises the significant potential benefits of green infrastructure for an urban population.

9 Digital connectivity infrastructure

This section details our work with the GLA reviewing London's long-term digital connectivity infrastructure needs. The UK is in a phase of significant investment in new networks and technologies, and London has benefitted from this investment. Future digital connectivity infrastructure investment will need to continue to address increasing demand, both from demographic growth and continued societal change.

The advent of the internet has heralded lifestyle and business change.¹⁷⁹ The number of devices connected to the network continues to increase. More and more consumers are 'multi-tasking', using multiple devices, and numerous services, at the same time. Tastes and markets are changing. The rise of video on demand, and virtual shopping, for example, are encouraging even greater use of telecommunications infrastructure. It is expected that the demand for data and faster broadband speeds will continue to rise. Future broadband infrastructure will be required to meet this increasing demand whilst maintaining adaptability to meet as yet unknown future uses.

The potential for innovation, coupled with limited existing knowledge of London's digital connectivity infrastructure by London government, makes projecting future requirements difficult particularly when compared to other infrastructure sectors.

London's telecommunications infrastructure is provided privately and regulated by the Office of Communications (Ofcom). A large portion of the capital's existing broadband infrastructure is owned and/or controlled by BT Group (BT). Operators, including BT, have not been required by the regulator to provide comprehensive, granular geographic information on the availability of their networks.

Our approach has been to project possible costs associated with the development of London's 'dark fibre'¹⁸⁰ network and other digital connectivity infrastructure, enhancing digital access and extending it to areas that are currently underserved and/or projected to be underserved. In particular, this work has focused on the infrastructure required to provide:

- Access to Next Generation Access (NGA)¹⁸¹ fibre broadband to every home by 2020 (i.e., an additional 150,000 underserved properties) – plus renewals thereafter;
- Public access Wi-Fi across London;
- 4G mobile access to the internet from nearly every part¹⁸² of London (indoor and outdoor);

¹⁷⁹ Ofcom, *Infrastructure Report*, 2013, available:

http://stakeholders.ofcom.gov.uk/binaries/research/telecoms-research/infrastructure-report/IRU_2013.pdf.

¹⁸⁰ A dark fibre or unlit fibre is an unused optical fibre, available for use in fibre-optic communication.

¹⁸¹ 'Next Generation Access' (NGA) infrastructure networks make use of technologies such as fibre-to-the-cabinet (FTTC) and fibre-to-the-premises (FTTP) network architectures in order to increase average connection speeds.

- Next generation ('5G') mobile access to the internet from nearly every part of London (indoor and outdoor) from 2020; and
- Related cyber security costs.

We have modelled the cost of providing digital connectivity infrastructure making a series of assumptions around the potential demand for the infrastructure and the costs associated with its development. These assumptions have been based on Arup's professional experience rather than detailed information provided by the regulator, private firms or other government agencies or bodies.

As we later detail, the capital and operating expenses associated with delivering these outcomes are projected to total some £10 billion over the period between 2016 and 2050. The majority of these costs are projected to be associated with capital enhancements, totalling some £8 billion between 2016 and 2050.

9.1 The case for investment

9.1.1 London's "not spots": the need for greater connectivity

Given rising business and consumer requirements, the availability and take up of super-fast broadband is of particular interest. Super-fast broadband, delivered via more sophisticated fibre-optic broadband networks, provides speeds in excess of 30 megabits per second (Mbits/s).¹⁸³ In London and other urban centres average speeds are considerably higher than Britain as a whole, but not defined as 'super-fast'. Ofcom reports that the average speed in urban areas is some 23 Mbits/s in urban areas. The average UK residential broadband connection was some 14.7 Mbits/s in 2013.¹⁸⁴

There are gaps in London's broadband network. Five percent of London's premises have a broadband speed of less than 2 Mbp/s, below the basic requirement for a broadband service. Many other premises rely on slow connections. There is limited company or government data maintained on connection availability or speed. Self-reporting by users provides some indication of slow broadband speeds.¹⁸⁵ As shown in Figure 55 overleaf, slow and no service areas are distributed throughout the capital. The red circles indicate areas where services are less than 1 Mbit/s.

Whilst service providers understandably argue that investment in internet access is commercially driven and demand led, from a public policy perspective, in the coming decades, it is arguable that internet access may come to be defined as a necessity good.¹⁸⁶

As we have discussed, increasing demand for internet access will relate in part to growing leisure use. Growing demand will also relate to increasing traffic to

¹⁸² For practical and technical reasons, it is virtually impossible and certainly not cost effective to provide coverage for every single part of London.

¹⁸³ Ofcom, *Infrastructure Report*, 2013, p. 2 (1.9).

¹⁸⁴ Ofcom, *Infrastructure Report*, 2013.

¹⁸⁵ Self-reporting by users could provide a poor estimate of the infrastructure gap. For example, internet users with severely limited access may be less likely (or able) to report the lack of a connection.

¹⁸⁶ In economic terms, there is reason to believe the demand for super high speed internet access will have a low level of elasticity relative to price.

complete routine tasks and business functions. This shift, already underway, will transform requirements around super high speed internet access, turning this fast connectivity from a “luxury” to a basic need, vital to individuals’ participation in the economy and society.

This requirement will raise important social equity considerations. Already, many countries’ governments have adopted laws aimed at ensuring access is broadly available and/or preventing unreasonable restrictions on such access.¹⁸⁷

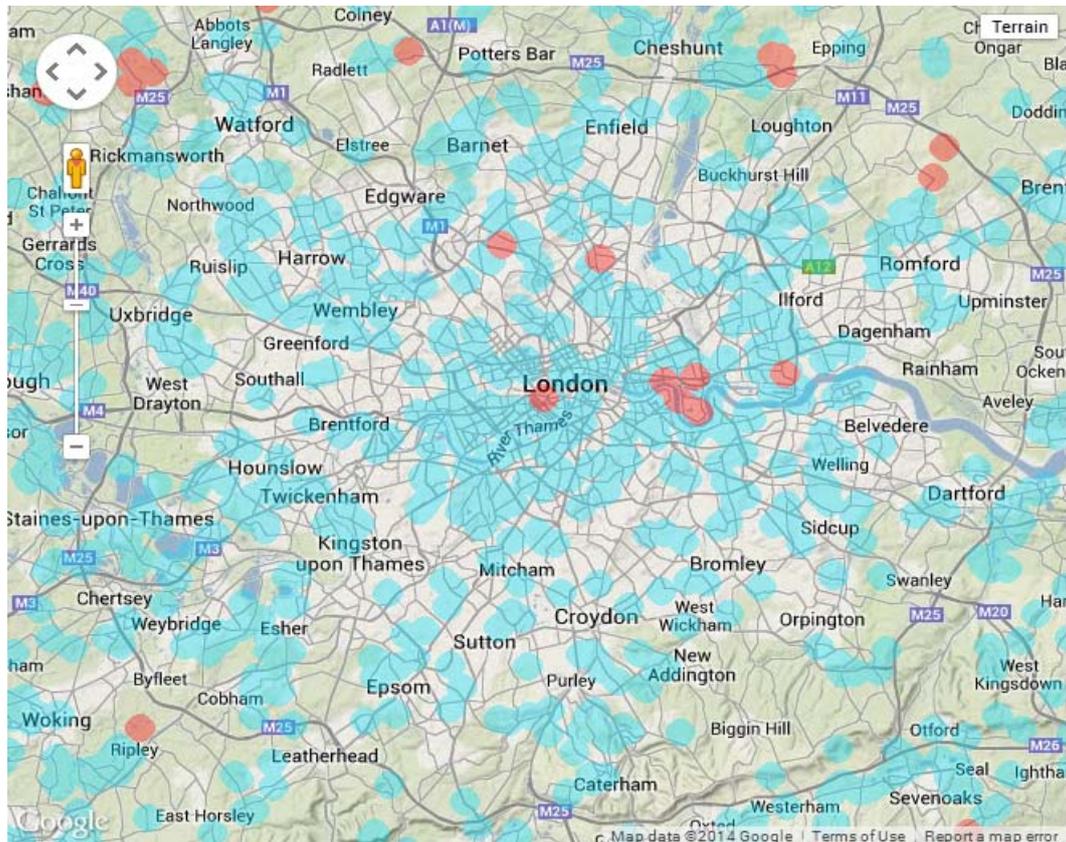


Figure 55: Self-reported distribution of slow broadband connections. Blue areas indicate a connection of less than 2 Mbps/s; red dots indicate no connection. Because this map is based upon self-reported incidence of low broadband speed, it should be regarded as only a potential indication of London’s shortfall. Actual incidence of slow or no connection is likely to differ significantly from the volume presented in this map. Source: broadband-notspot.org.uk.

Investment in broadband alone will not support London’s evolving digital connectivity requirements. Whilst it is not possible to anticipate dramatic changes in this sector, it is widely acknowledged that investment in other technologies - particularly public Wi-Fi access and 4G and 5G enhancements - could support demand for connectivity over the short and medium-term.

¹⁸⁷ See, for example, Wunsch, Silke, *Deutsche Welle*: “Internet access declared a basic right in Germany,” 27 January 2013, available: <http://www.dw.de/internet-access-declared-a-basic-right-in-germany/a-16553916>.

9.2 London's digital connectivity infrastructure requirements

We discuss these different infrastructure types in the sections below, noting primary assumptions important to determining the capital's digital connectivity infrastructure requirements.

The different types of digital connectivity infrastructure discussed in this chapter are not mutually exclusive. No system will be robust or mature enough to operate independently or meet all market requirements. Some form of investment in each type of infrastructure is likely to be required in the coming decades.

Decisions around future action will require a much improved understanding of the capital's existing digital connectivity infrastructure. As we have noted at present, no regulator or business-provided information appears to be able to identify reliably, areas of poor or more limited broadband coverage. More accurate information will be required prior to developing future investment options and appraising them.

A large portion of future investment in this infrastructure is likely to originate in the private sector. For example, nearly 80% of NGA infrastructure is owned by BT.¹⁸⁸ In 2013, the company upgraded¹⁷⁶ service exchanges to FTTC. Should BT continue to upgrade its NGA infrastructure as planned, the availability of NGA infrastructure across London will increase to 91% by 2015.

9.2.1 Expanding the capital's Next Generation Access (NGA) infrastructure

In order to achieve superfast broadband speeds, new infrastructure is required. NGA infrastructure networks make use of technologies such as fibre-to-the-cabinet (FTTC) and fibre-to-the-premises (FTTP) network architectures in order to increase average connection speeds. FTTC and FTTP architectures increase speeds by increasing the proximity of the fibre optic connection to business and residential customers, reducing the need for connections via older technologies and copper wire.¹⁸⁹ The availability of these NGA networks is increasing. By 2013, 73% of all UK premises were served by at least one NGA network, representing an increase in of more than two-thirds in a single year.¹⁹⁰

¹⁸⁸ Virgin Media is the second most active firm in the market. Other operators that own their fibre network infrastructure and provide services primarily to the business customers are: Colt, EasyNet, Exponential-e, Geo Networks, KCOM, Level3, SSE, Surf Telecom, Talk Talk, Virgin Media Business, Vodafone and Vtesse.

¹⁸⁹ Older mechanisms, such as the fibre-to-the-node (FTTN) architecture, supply fibre only to the street cabinet, often a considerable distance from customers. Because the fibre optic cable is a further distance from the user's connection, speeds are reduced.

¹⁹⁰ Ofcom, *Infrastructure Report*, 2013.

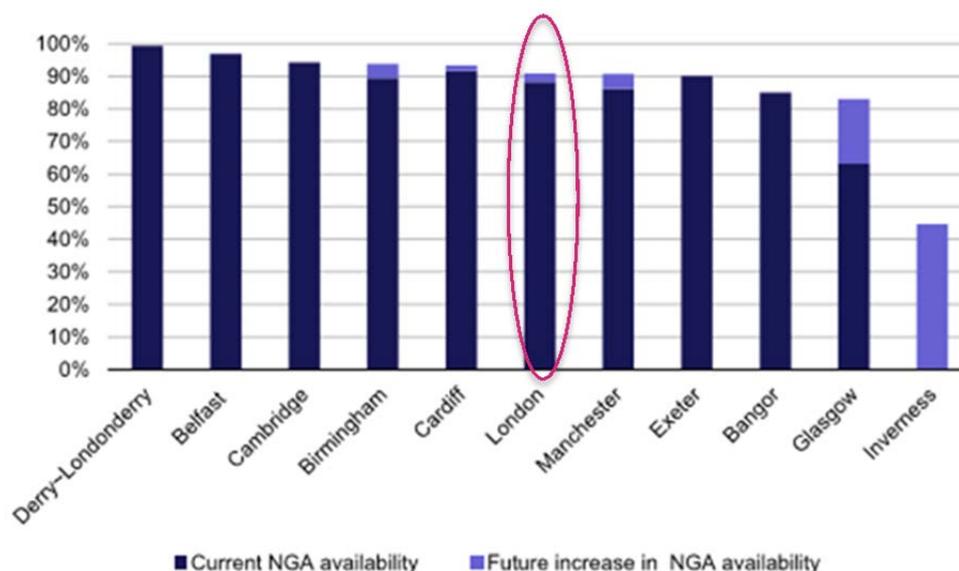


Figure 56: Estimated current and future availability of NGA infrastructure from BT and/or Virgin Media. Source: Analysis Mason for Ofcom, *Cities Project* (2013).

As can be seen from Figure 56, London's next generation connectivity outpaces the country's less urbanised areas but remains lower than for some other UK cities. Analysis prepared for the Ofcom *Cities Project* concluded that 88% of all premises in the capital are served by at least one NGA network.¹⁹¹ Cambridge's current NGA availability is some 5% higher, and Birmingham similarly is projected to see its NGA availability outpace London's by 2015.

9.2.1.1 Next Generation Access (NGA): Residential infrastructure assumptions

Ofcom has estimated that under the current plans of BT's Openreach, around 5% of residents will remain without access to superfast broadband. This number is likely to diminish (as a proportion of the total) as new homes are built; it is virtually certain that all new homes in London will be provided with Fibre to the Home (FTTH) over time. Accelerating FTTH provision may require additional policy support in the short to medium term. We discuss this later in this section. Over the period to 2050, the number of homes without access to superfast broadband is likely to fall to about 3%, taking into account the development of newly constructed homes in the study period. That means an estimated 150,000 homes in all will require supplementary infrastructure.¹⁹²

Homes in London are currently distributed at an average density of approximately 350 residences per kilometre of street.¹⁹³ Unserved homes are likely to be less spatially concentrated (i.e. located in less densely built up areas). To estimate the cost of provision of FTTH to unserved properties, we assumed a "density" of 300

¹⁹¹ Analysis Mason, *Cities Project*, 8 July 2013: Final Report for Ofcom.

¹⁹² There are about 5.2m households in the GLA area.

¹⁹³ Arup calculation of *street* rather than per kilometre density.

residences per kilometre of road. The average cost per residence is the cost of one kilometre of network extension divided by the number of homes per kilometre.¹⁹⁴

Adjusting for construction industry price growth, we have included capital expenses of some £220 million in our projections between 2016 and 2050.

9.2.1.2 Next Generation Access (NGA): Commercial infrastructure assumptions

Several small business users in the same geographical area may represent sufficient demand to encourage a communications provider to extend its optical fibre network. Accordingly, Arup has assumed that, on average, each unserved business premises is 800 metres from the nearest point of connection to a public network.¹⁹⁵ Arup's capital expenditure estimation is therefore based upon the trench and duct installation from points of connection to premises of each of these notional businesses.

Arup estimates that a network extension of 800 metres would on average enable 20 additional businesses to be connected, with each requiring on average a further 10 metres of trench and duct installation. This implies 50 metres of network extension per connectable business.

9.2.2 Public access Wi-Fi

Wi-Fi is widely used in businesses and in homes, and in "hot-spots" such as coffee shops and railway stations. BT Wi-Fi claims to offer access to subscribers at over five million hot-spots in the UK and free public access at several thousand locations. A small number of councils also provide Wi-Fi networks.

9.2.2.1 'Blanket' public access Wi-Fi

The GLA requested that Arup include in its infrastructure cost assessment an estimation of the costs associated with providing blanket Wi-Fi coverage. We estimate the capital enhancement cost of Wi-Fi infrastructure to be £2,000 per site.¹⁹⁶ We estimate that to cover the built-up parts of London (i.e. excluding parks and other open land) would cost some £2 billion.¹⁹⁷ It may be technically feasible for existing Wi-Fi installations to be integrated, reducing the need for new expansion of the Wi-Fi network. If existing hot-spots could form part of the

¹⁹⁴ BT's Openreach uses the same network to serve residential customers as business customers. However, in large parts of London's suburbs, businesses tend to be located in places that are physically separate from residential development. It is therefore assumed that the same network infrastructure costs as have been developed for business premises apply to residential premises, but that as a rule, separate network extensions are necessary for connecting residential premises. Note that as in the City of London, businesses at times have custom secure networks from which residents sometimes benefit.

¹⁹⁵ Arup assumption based upon the average distance of a commercial premise to the point of connection, including properties in dense, central areas and those in less dense areas, including business parks.

¹⁹⁶ Assuming no 'civils' works are required and 'backhaul' of the system would be possible via BT's Openreach.

¹⁹⁷ Note that this value is not indexed to account for the time value of money, including the cost of construction industry inflation

universal access network, then the capital cost of achieving blanket coverage might be half this amount, some £1 billion.¹⁹⁸

Adjusting for construction industry price growth, we have included capital expenses of some £1,580 million in our projections between 2016 and 2050. The actual cost will depend critically on the data speed required. The implication is that Wi-Fi and 4G would still have to operate in tandem to provide high speed connectivity.

9.2.2.2 Targeted public access Wi-Fi

For the purpose of this study, Arup has included the costs of blanket public access Wi-Fi in our cost projections. We find that Wi-Fi technology may not be well-suited to providing blanket coverage. Despite its low cost relative to other infrastructure types, Wi-Fi provides limited range and capacity. Rather than provide such blanket coverage, the GLA could consider advocating investment in more limited, targeted Wi-Fi investment. These investments could target high streets and cultural institutions, as outlined below.

If (as with other cities in the UK), London were to provide coverage only along its approximately 200 high streets,¹⁹⁹ its Wi-Fi infrastructure costs could be far lower than the cost of providing blanket coverage. It is estimated that about 40 hot-spots would be required to provide coverage of the average high street,²⁰⁰ implying an overall capital cost of £16 million.²⁰¹

The provision of indoor Wi-Fi access in public spaces is already extensive, although provision varies considerably. Should existing Wi-Fi facilities be modified and reinforced as required to provide free public access, the incremental cost could be relatively modest. Each location would be likely to present specific issues, requiring an initial assessment. Assuming that free public access will be provided at 100 museums, art galleries, leisure centres and other similar institutions, we estimate the cost could be some £4 million.²⁰²

We estimate that the total cost associated with investment in a more limited public access Wi-Fi network for London's public spaces, focused on high streets and indoor coverage at cultural and sporting venues, could be some £20 million.²⁰³

9.2.3 Expanding 4G infrastructure

Having a higher bandwidth and lower cost than cellular transmission, Wi-Fi already is used extensively to supplement the capacity of mobile networks for data transmission where it is available. Cellular handsets generally have the capability to detect and connect automatically via Wi-Fi. To the extent that Wi-Fi coverage is enhanced, its role in supporting mobile networks would increase in significance - arguably to the ultimate benefit of users.

¹⁹⁸ Note that this value is not indexed to account for underlying industry price growth.

¹⁹⁹ This is the number of 'town centres' (a term used synonymously with 'high streets') identified in the Mayor's London Plan.

²⁰⁰ Assuming the average high street is 2 kilometres in length, including side streets with shops.

²⁰¹ Note that this value is not indexed to account for underlying industry price growth.

²⁰² Note that this value is not indexed to account for underlying industry price growth.

²⁰³ Note that this value is not indexed to account for underlying industry price growth.

UK mobile operators already are upgrading to 4G in areas of high demand for data communications. The transition of public mobile networks to 4G in the Long-Term Evolution (LTE) form²⁰⁴ is likely to be substantially completed by around 2020, in line with regulatory requirements. At least one public 4G network would be required to provide indoor coverage for at least 98% of the population.

The cost of upgrading a public mobile network to 4G in London would relate to the number of sites covered and the number of switches required per site. We estimate some 1,500 sites would require coverage, at a cost of some £17,111 per switch. In total, we estimate the cost of upgrading one public 4G network, deployed at 2600 MHz²⁰⁵, to be some £385 million (unindexed).²⁰⁶

Adjusting for construction industry price growth, we have included capital expenses of some £245 million in our projections between 2016 and 2050. The actual cost will depend critically on the data speed required. The implication is that Wi-Fi and 4G would still have to operate in tandem to provide high speed connectivity.

9.2.4 Roll out of 5G

The capacity and coverage characteristics of 5G have yet to be defined. Similarly there is uncertainty around the timescale for deployment of 5G connectivity. Based on past experience, it can be said with some level of certainty that 5G will enable higher speeds for data communications and utilise higher radio frequencies. This implies the need for more base stations. In consequence, the overall cost of deployment of 5G is likely to be slightly higher than predicted for 4G. As a very rough first estimate, we conclude this cost could total some £500 million for the GLA area (unindexed).²⁰⁷ Adjusting for construction industry price growth, we have included capital expenses of some £619 million in our projections between 2016 and 2050.

9.2.5 Protection of systems and data

Expansion of the digital infrastructure network, along with increasing reliance upon it, will necessitate investment in cyber security. Cyber security entails the protection of information technology systems and data from cyber-attacks. Different forms of cyber security include firewalls, anti-virus software, intrusion detection and prevention systems, encryption and login passwords. The protection of critical infrastructure from cyber-attacks normally is the responsibility of the asset owner or operator.²⁰⁸ Typically, the planned response to—or potential mitigation of—cyber-attacks on critical infrastructure would include the provision of redundant data centre capacity.

²⁰⁴ LTE is a standard for wireless communication of high-speed data for mobile phones and data terminals based on the GSM/EDGE and UMTS/HSPA network technologies, increasing the capacity and speed using a different radio interface together with core network improvements (Source: Wikipedia).

²⁰⁵ Assumes 1,500 sites required with backhaul and 15 switches; other infrastructure shared with 3G networks.

²⁰⁶ Note that this value is not indexed to account for underlying industry price growth.

²⁰⁷ Note that this value is not indexed to account for underlying industry price growth.

²⁰⁸ See Cyber Security in the UK, Parliamentary Office of Science and Technology, September 2011. If the scope of the requirement were broadened to include a large slice of economic activity, the quantity of data centres required would increase many-fold. Support

Our cost projections include the provision of 50 data centres over the study period, between 2016 and 2050, in order to support back-up and business continuity and to provide some additional support for business in general.²⁰⁹ It is difficult to assess the scale of provision that would be required. As an indication, a data centre in London specialised in the provision of cyber security would have a construction cost of about £5 million (unindexed) for a capacity of 500 'racks'.²¹⁰

In total, we have projected capital expenditure of some £394 million for these data centres between 2016 and 2050. Related to particular infrastructure aimed at mitigating the risks associated with attacks, this figure represents only a portion of the business and wider costs that will be associated with cyber security. A recent report by the Department for Business, Innovation and Skills (BIS) found that the cost of a cyber-security breach for a large business can be as high as £1.15 million.²¹¹ One government report found that the overall cost of cyber-crime to the UK economy is some £27 billion per year.²¹²

9.2.6 Other capital costs

Given uncertainty after the 2030s, with the significant potential for future innovation and development in the sector, it is likely that further expenditure will be required. In discussion with the GLA, we have found it reasonable to 'roll forward' projected capital expenditure requirements such that, on average, projected capital expenditure does not decline in real terms over the study period, from 2016 to 2050. On average, we have projected additional investment requirements of some £600 million (unindexed) each five-year period. Adjusting for construction industry price growth, we have included capital expenses of some £5,065 million in our projections between 2016 and 2050.

²⁰⁹ Data centres, once established, are long lasting. For example, Telecity, a data centre on the Isle of Dogs, is over 25 years old. We acknowledge that a smaller number of data centres could be included if intended to support only business continuity requirements.

²¹⁰ Arup internal benchmarking. Excluding land costs. Does not account for underlying industry price growth.

²¹¹ Department for Business, Innovation and Skills, Cost of business cyber security breaches almost double, 29 April 2014, available: <https://www.gov.uk/government/news/cost-of-business-cyber-security-breaches-almost-double>.

²¹² Cabinet Office, Report released into the cost of cybercrime, 17 February 2011, available: <https://www.gov.uk/government/news/report-released-into-the-cost-of-cyber-crime>.

9.3 Preliminary analysis of costs and benefits

The figures below sets out Arup's cost projections for digital connectivity infrastructure. Projected costs are split between capital and operating expenses. These costs relate to the central population scenario. These projections are shown 2014 prices, including a 2% per annum construction industry uplift for capital expenditure.

£bn 2014 prices, five year period ending	2011-2015	2016-2020	2021-2025	2026-2030	2031-2035	2036-2040	2041-2045	2046-2050	Total 2016-2050	CAGR (2016-2050)
Capex	.8	1.9	.5	.8	1.0	1.1	1.3	1.4	8.1	-1.0%
Opex	.0	.1	.2	.2	.2	.3	.4	.4	1.8	4.1%
Digital connectivity total	.8	2.0	.7	1.0	1.3	1.4	1.6	1.8	9.9	-0.3%

Figure 57: Projected capital and operating cost requirements by five-year period, 2011-2050. 2014 prices, including c.2% p.a. construction industry uplift for capital expenditure requirements. Source: Arup analysis

As shown in the figure above, digital connectivity expenditure requirements, including both capital and operating expenses, are projected to total some £10 billion between 2016 and 2050.

Some 80% of this investment is projected to relate to capital expenditure requirements, totalling £8.1 billion between 2016 and 2050. Capital expenses are projected for each of the areas identified in section 9.2 in the table below.

Enhancement	Cost (£million), 2016-2050 (includes 2% p.a. construction industry price inflation)
Broadband connectivity	£220m
Wi-Fi	£1,580m
4G	£245m
5G	£619m
Cyber security (data centres)	£394m
Other capex requirements	£5,065m
Total	£8,123m

Figure 58: Projected capital enhancement expenditure by area of investment, 2016-2050. 2014 prices, including 2% p.a. construction industry price inflation. Note: investment in Wi-Fi and 4G infrastructure is projected to occur in the 'baseline' period, before the end

of 2015. £650 million of Wi-Fi investment is projected before the end of 2015; and an additional £157 million of 4G investment is projected before the end of 2015.²¹³ Source: Arup analysis

Projected capital expenditure includes only enhancements to digital connectivity infrastructure and not for renewal of these assets. We have assumed that renewal of broadband assets is unlikely to occur within the study period and that other assets are likely to be replaced via investment in further enhancement capex.

Operating expenses, projected to total approximately £2 billion between 2016 and 2050, have been calculated as a percentage of capital expenditure per five-year period. Wi-Fi, 4G and 5G infrastructure operating expenses are anticipated to be higher than the operating costs associated with broadband infrastructure. Wi-Fi, 4G and 5G operating costs have been projected as 5% of capital expenditure per period, whilst broadband operating costs have been projected as 0.5% of capital expenditure per period.

Currently projected investment is concentrated over the short and medium-term, to 2030. Roll-out of super high-speed broadband, 4G and Wi-Fi connectivity are underway. Given uncertainty after the 2030s, with the significant potential for future innovation and development in the sector, it is likely that further expenditure will be required.

In discussion with the GLA, we have found it reasonable to ‘roll forward’ projected capital expenditure requirements such that, on average, projected capital expenditure does not decline in real terms over the study period, from 2016 to 2050. On average, we have projected additional investment requirements of some £600 million (unindexed) each five-year period. Adjusting for construction industry price growth, we have included capital expenses of some £5,065 million in our projections between 2016 and 2050.

9.3.1 Potential benefits

A recent report commissioned by the Department for Culture, Media and Sport (DCMS) found that the availability and take-up of faster broadband speeds will add about £17 billion to the UK’s annual Gross Value Added (GVA) by 2024.²¹⁴ These economic impacts are additional to the social benefits derived from bridging the “digital divide” and the environmental benefits associated with reduced commuter journeys and other lifestyle adjustments made as a result of broadband use. Although applicable to the UK as a whole, the findings of this analysis, adjusted for a London context, could be used to analyse more specific broadband projects in cost-benefit terms. Broadband investment has been shown to provide:

²¹³ No other ‘historical’ expenditure is reported; to date, private operators have borne the cost of installation. As previously discussed, operators are not required to disclose these costs within the current regulatory regime. Government has not yet supplemented these expenses in committed costs, although the government’s Super Connected Cities voucher scheme sets aside some £100 million for an Urban Broadband Fund. Arup understands some £10 million will be provided to a selection of London’s boroughs. Source: SuperConnected Cities, Connection Vouchers: About the SuperConnected Cities programme, undated, available:

<https://www.connectionvouchers.co.uk/superconnected-cities/>

²¹⁴ DCMS, *The Benefits of Broadband*, 14 November 2013, available: <https://www.gov.uk/government/news/the-benefits-of-broadband>.

- Excellent value for taxpayer money with a net return of £20 for every £1 spent by 2024;²¹⁵
- A significant short-term boost to the UK economy, as network construction adds around £1.5 billion to the economy, including £0.5 billion and about 11,000 jobs in 2014 alone;
- Long-term economic growth, with public investment increasing annual GVA by £6.3 billion; and a net increase of 20,000 jobs in the UK by 2024;
- Carbon savings, totalling around 0.4 million tonnes a year of carbon emissions savings nationally, through reduced commuting, business travel and firms shifting to more energy-efficient cloud computing.

Analysis of the economic benefits of broadband investment is still emerging. DCLG analysis has not been completed specifically for London. Nonetheless, a “body of research” is beginning to support the DCMS hypothesis that broadband has an important economic impact. One study, commissioned by the International Telecommunication Union (ITU), found that broadband has a stronger “productivity impact in sectors with high transaction costs, such as financial services, or high labour intensity, such as tourism and lodging.”²¹⁶ Emerging research could suggest that London is uniquely positioned to benefit from increased investment in super high speed connectivity, and that these benefits could significantly outweigh the costs (whether to the private sector, public sector or both).

9.4 Risks and uncertainties

Investment in digital connectivity infrastructure could face a higher degree of uncertainty not seen in other sectors. Given the rate of change seen in the sector, there is very considerable potential for new technological development to occur within the study period. A complete transition from broadband to improved wireless connections could in theory occur, although these have not been projected by Ofcom, providers, or experts. Needless to say, no one can predict the future of digital connectivity with much certainty.

There is therefore considerable uncertainty associated with our cost estimation in this sector. Only limited information about current costs is publicly available. There is limited knowledge of existing coverage and future rollout plans, but also how commercial providers make specific development decisions. There is a risk that costs will vary considerably over the long-term, with market changes and technological development.

Uncertainty around potential developments in the sector mean there is considerable risk around ‘picking winners’ in an evolving marketplace and an opportunity remains that alternative (and possibly unknown) technologies are adopted over the long-term.

²¹⁵ Although the benefits associated with investment may be significant, current market regulations could prohibit direct intervention to support London’s digital connectivity infrastructure.

²¹⁶ International Telecommunication Union, *The impact of broadband on the economy: Research to date and policy issues*, April 2012, p. 2, available: https://www.itu.int/ITU-D/treg/broadband/ITU-BB-Reports_Impact-of-Broadband-on-the-Economy.pdf.

9.5 Opportunities for consolidation

There are opportunities to consolidate current and future activities around providing digital connectivity infrastructure. Prior to establishing the potential benefits associated with consolidation, it will be important to assess whether existing infrastructure could be used for the roll out of digital connectivity infrastructure, e.g. TfL or borough installations for fixed broadband (fibre installation).

A minimum of 42,000 additional housing units need to be added to London annually by 2050. There is an opportunity to ensure that these new homes – in addition to new commercial properties -- are made Fibre to the Premises (FTTP) ready. FTTP is not yet provided as standard in many developments in London, but new developments offer an opportunity to upgrade London's broadband provision during construction.

The Olympic Park is a good example of how the Olympic Development Authority and developers worked with BT Openreach from the beginning to ensure that buildings feature FTTP. Developing buildings with FTTP access could help to reduce the cost of provision of fibre connectivity. More widely, there may be an opportunity to introduce a wider “dig once” policy across this and other sectors, linking investment in digital connectivity to the development and renewal of other utility and transport assets.

With regards to 4G and 5G, operators may be able to reduce the cost by using existing sites and equipment, or by increased infrastructure sharing; on the other hand, if data volumes continue to increase, many more sites may be required to provide adequate capacity. A key issue is that capacity (“speed”) and coverage are intimately linked; to increase data speeds more base stations would be needed. If the locations of high data demand are predictable then provision through Wi-Fi would be cheaper. Augmenting the number of 4G/5G base stations would be appropriate only if increase data demand was widespread.

9.6 Conclusions

Our projections indicate that the costs associated with London's digital connectivity infrastructure could total some £10 billion over the study period, including both capital and operating expenses. Capital costs are projected to total some £8 billion, with operating expenses projected as a percentage of this figure. These projections are indicative, relating to the expansion of London's Wi-Fi, 4G and 5G networks, as well as investment in cyber security. Given significant uncertainty after 2030, we have include projections related to yet-unknown enhancements, ‘rolling forward’ expenditure to account for likely future investment.

As we have discussed, there is little information about coverage and availability of digital connectivity infrastructure in London. This is a reflection of market conditions and the regulatory regime. This is different compared to other utilities such as energy and water. There is an evident need to work with telecoms providers and Ofcom to understand areas which are currently underserved and may merit future coverage.

The GLA may need to commission a survey to establish which areas are underserved in the short term, in order to guide investment and policy decisions.

In order to address the need for infrastructure in existing areas, there are some actions the GLA could take:

- Targeted rollout of a 'dark fibre' installation. This would be in areas that are not commercially viable for service providers. However, the management and operational aspects of the dark fibre installation need to be considered, as well as any "exit strategy";
- Investigate whether public sector demand could be consolidated to provide demand for broadband in underserved areas;
- Assess whether existing infrastructure (i.e. TfL or borough installations) could be used for the rollout of digital connectivity infrastructure.

Looking to the future, London government as a whole could consider several policy initiatives to stimulate digital connectivity beyond the level supported by the commercial market. These initiatives could include:

- Amendment of the planning policy framework to encourage developers to make new developments 'broadband-ready', similar to agreements for other infrastructure. This could include a reduction in the cost of provision of fibre connectivity as the cost of way leaves and infrastructure usually represent the biggest cost to broadband providers; and
- Review of the broadband installations permit scheme requirements in situations where significant work is not required in order to prevent delays in broadband installation.

As we have reviewed, existing UK government studies suggest that the costs of investment in this infrastructure are outweighed by the benefits. There is reason to believe that, at least in part, the beneficial impacts modelled nationally (some £20 for each £1 of investment) would apply to at least some expenditure occurring in London.

10 Establishing London's infrastructure funding gap to 2050

The total cost associated with London's infrastructure operation, maintenance, renewal and enhancement are considerable. Our estimates show they could exceed £2,000 billion by 2050. Much of the burden to fund infrastructure development and pay for its operation will fall on the private sector and/or central government. User charges, particularly in the utilities sectors, are likely to fund a significant portion of both operating and capital expenses. Central government grant will most likely fund a portion of transport enhancements via, for example, Network Rail. A considerable share of projected costs is likely also to fall on businesses and citizens (as taxpayers as well as service users) and London government.

In order to inform an understanding of future funding requirements, the GLA requested that Arup provide a preliminary indication of the "gap" between projected costs and revenues. Arup has considered the gap across a range of sectors, focusing in particular on housing and transport infrastructure, which contribute the largest share of projected costs during the study period. For the remaining six sectors, costs are "unfunded" at present. In other words, the 'gap' identified will need to be funded by a combination of (re-allocating) existing resources, identifying new sources of revenue, accessing new capital receipts or through user charges. In the utilities sectors, we have conducted a preliminary analysis of the potential impact of infrastructure development on user charges, including energy, waste and water bills.

Our preliminary assessment indicates that the "gap" in housing and transport between projected future costs and income sources could be approximately £135 billion in the study period. We detail our housing and transport sector analysis below and discuss the potential funding mechanisms available in different infrastructure sectors. In the next chapter of this report, we consider ways of closing the gap, focusing on opportunities to consolidate projects and achieve efficiency savings. The report concludes with a discussion of potential additional revenue sources.

10.1 Housing funding gap

The Mayor has overall strategic responsibility for planning in London, both in terms of plan making and development control. The Mayor is also responsible for the delivery activities previously provided by the Homes Communities Agency (HCA) in London as well as the activities previously provided by the London Development Agency (LDA). These include delivering more new affordable homes in London, improving the quality of existing housing, meeting Londoners' housing needs and promoting opportunities for mobility across the capital. The Mayor receives a capital investment budget from central government over a defined spending review period. This pot is offered to private registered providers (PRPs) in competition with each other to deliver housing at best value. The balance of the upfront capital requirement is provided by PRPs. This subsidised investment is funded through future house sales and affordable rental income

(increasingly cross-subsidised by a wider portfolio of housing offered at market rents).

Boroughs play a significant role in addressing housing needs. This includes judging the mix of homes needed to meet local needs and aspirations within the context of their community plans and place-making activities as well as general conformity with the London Plan. Boroughs must refer these local development plans and any major planning applications to the Mayor. Through engagement with housing developers and PRPs, public sector subsidy is used to develop properties for both affordable home ownership and affordable rent, at a range of discounts to the market rate. Where the boroughs retain ownership of their own housing stock, their key responsibility is its maintenance. Maintenance of these properties (and servicing of any related housing debt) must be 'self-financed' through the Housing Revenue Account (HRA) using the rental income generated. Efficient operation of the HRA to generate surpluses can create additional capacity for investment in new housing stock (subject to central government imposed borrowing caps), although this is rare given the financial pressures created by existing housing stock in many boroughs.

10.1.1 London government costs and funding

It is estimated that London government faces a funding gap of some £154 billion in the housing sector, including renewals and new build costs (before debt service costs). This gap consists of £11 billion in relation to renewals for estimated 'Decent Homes' type obligations (energy efficiency, estates regeneration, etc.) with the balance of £143 billion related to delivering new units required. Based on historical analysis, if £34 billion of capital funding were secured by London government this could be used to leverage in the order of £109 billion of private capital, reducing the total funding gap to the public sector to £45 billion. This is shown in Figure 59 overleaf.

Some £363 billion of expenditure is projected to relate to market rate housing delivered by private developers.²¹⁷ Affordable housing costs, including land costs, land remediation costs and housing unit construction, renewals and operations costs, are projected to total some £437 billion. Over the appraisal period we have assumed that 40% of affordable housing capital costs will relate to affordable ownership and 60% to affordable rental units. It is assumed that London government will be responsible for a portion of these costs, with 15% and 30% upfront capital subsidy provided by government, to deliver units below the market rate. Beyond this capital subsidy, it is assumed that remaining costs are addressed by PRPs and boroughs (through their own housing stock), through future sales and rentals.

²¹⁷ The costs for all market rate housing projects are assumed to be fully met by the private sector.

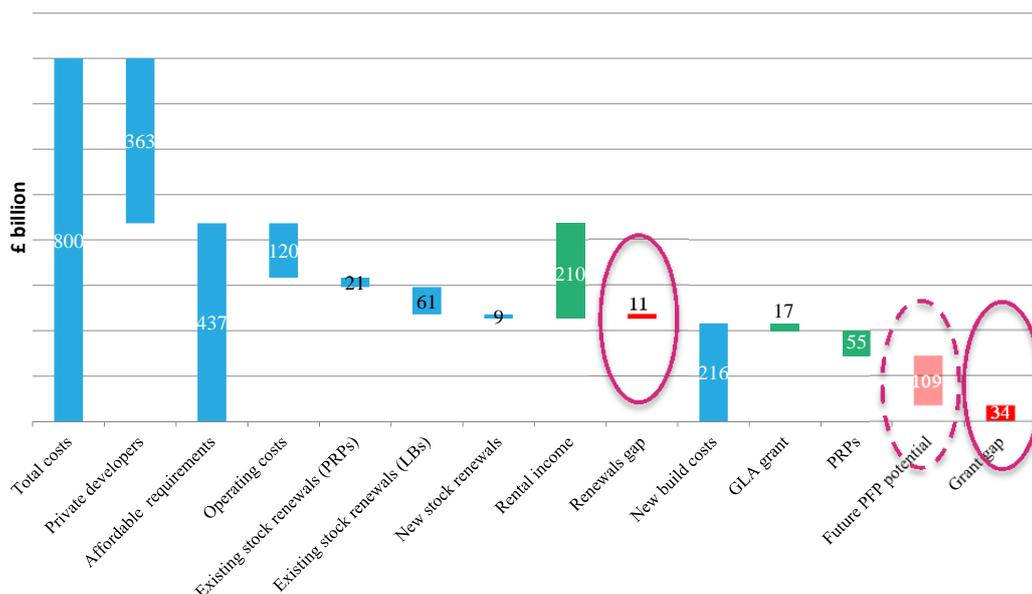


Figure 59: Chart showing projected costs, revenues and funding gaps for the housing sector, 2016-2050 (£bn, 2014 prices, including 2% pa underlying uplift in construction costs). Costs are shown in blue, revenues in green and the gap in red, including leveraged potential.²¹⁸ Source: Arup analysis

10.1.2 Operating and capitalised maintenance (renewals) costs and funding

Operating costs related to affordable units are projected to total some £120 billion to 2050. On-going capitalised maintenance of the affordable housing stock, comprising PRPs' existing stock renewals, London boroughs' existing stock renewals, and the renewal new affordable housing units, is projected to total some £90 billion (£21 billion, £61 billion and £9 billion, respectively).²¹⁹ Rental income is assumed to cover these costs entirely.²²⁰ However, a shortfall in funding related to other capital renewals (the 'renewals gap'), for investment in energy efficiency, achieving and maintaining 'Decent Homes' standards and estate regeneration, is evident. It is assumed that funding comparable to previous 'Decent Homes' allocation does not exist to support these costs, leaving a renewals-related funding gap of some £11 billion over the study period.

10.1.3 New construction costs and funding

New construction costs related to affordable units are projected to total some £216 billion over the study period. An estimate of the future capital grant available was made based on the GLA's historical expenditure, as shown in the National

²¹⁸ Registered providers' potential funding of £109bn is leveraged private sector income contingent on the £34bn of public sector capital shown.

²¹⁹ Please refer to the housing chapter of this report for a complete discussion of projected housing costs.

²²⁰ This simplifying assumption does not account for the potential for rental income requirements to outpace inflation or income growth or other market changes over the study period. For boroughs, rental income is represented by Housing Revenue Account (HRA) revenues, which include rental income and government support to cover operating costs.

Affordable Housing Programme, equating to £500 million per annum. A gap in London government housing grant/capital funding – additional to renewals identified above - of £34 billion - will need to be funded from newly committed central government grant, access to new funding streams or access to new capital receipts, e.g. developer contributions or housing sales. This £34 billion would be used to leverage in the order of £109 billion of private capital. In this context, London could benefit from central government agreeing a more long-term and reliable funding stream for housing, similar to that secured by TfL, enabling the Mayor to get a better deal for Londoners and negotiate longer-term agreements with PRPs and boroughs to secure housing needed. Until then, PRPs and boroughs will continue to bid for the short-term pots available and leverage borrowing headroom in the HRA to deliver new affordable homes and to balance this spend between new build and renewals of existing stock.

10.2 Transport funding gap

Across London, a number of agencies, operators and authorities pay for and deliver transport infrastructure and services. These include the DfT, TfL and the boroughs, the Highways Agency, Network Rail, train and bus operators and airport operators.

TfL is responsible for the planning, delivery and day-to-day operation of large parts of London's public transport system. Its role is to implement the Mayor's Transport Strategy and manage services across London, for which the Mayor has ultimate responsibility. TfL manages or operates London's buses, the London Underground, the Docklands Light Railway, London Overground, Croydon Tramlink, London River Services, Victoria Coach Station, the Emirates Air Line, Cycle Hire and the London Transport Museum. As well as running London's Congestion Charging scheme, it manages a 580km network of main roads (Transport for London Road Network or 'red routes'), all of the city's 6,000 traffic lights, and regulates taxis and the private hire trade. TfL funds borough transport plans, with support from GLA. London Boroughs retain a key statutory role in relation to highways.

10.2.1 London government costs and funding

It is estimated that London government, including TfL and the boroughs, face a gap of some £89 billion (before debt service costs and other central overheads). As in the housing sector, this gap relates to capital expenses, including renewals, after eliminating the share of costs likely to be met by the private sector and other public bodies. We also have made assumptions around possible future fares income and the capacity of future central government grant. These are outlined below.

We have assumed that all aviation costs, projected to total some £268 billion, will be covered by the private sector. It is likely that the Thames Estuary Airport could require at least some subsidy, but eliminating aviation costs allows our analysis to focus on more certain future costs as the Davies Commission continues to address questions around the region's aviation capacity. The funding gap therefore could be considered a "lower bound" in relation to the Estuary airport's development.

We have also assumed that central government, its agencies and other bodies will continue to provide for the transport infrastructure costs that they have funded up to now. This 'central government share', projected to total some £174 billion, includes national rail projects, High Speed 2 and Highways Agency projects. It is assumed that all remaining costs, including TfL project costs and other roads costs, will be addressed by London government.

London government's share of transport costs in the study period is projected to total some £542 billion. Nearly all of these costs relate to TfL investments with a relatively modest portion going to London borough roads projects.

A core revenue funding stream for TfL is the fare and congestion charging base from both existing and new infrastructure. Using the TfL business plan as a base, we projected existing fares out to 2050 using conservative assumptions. We have assumed that fare growth does not outpace inflation in real terms over the study period. In a later section of this report, we consider possible mechanisms for reducing the gap between current revenues and projected costs, including above-inflation fare growth. We also have made an assessment of the possible fares from new schemes by reference to existing modes.

10.2.2 Operating costs and funding

As shown in Figure 60 below some £273 billion of the £542 billion of London government costs is projected to relate to operating costs. Our analysis of the TfL business plan and of future revenue potential shows that fares could meet operating expenses and provide a significant contribution to capital investment requirements. Projected costs related to borough road maintenance (excluding those which form part of the TfL Road Network or Borough Principal Road Network, both of which are managed by TfL) are assumed to be 'unfunded'. In other words, the 'gap' identified will need to be funded by re-allocating existing resources, identifying new sources of revenue or accessing new capital receipts. These costs are projected to total some £12 billion over the study period.

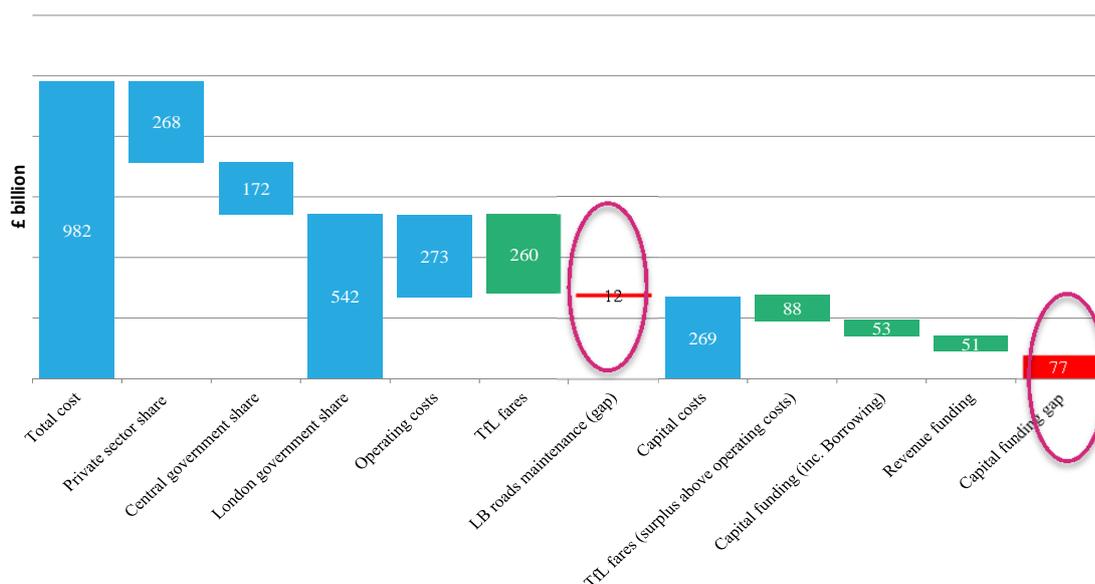


Figure 60: Chart showing projected costs, revenues and funding gaps for the transport sector, 2016-2050 (£bn, 2014 prices including 2% pa underlying uplift in construction)

costs). Costs are shown in blue, revenues in green and the gap in red. Source: Arup analysis

10.2.3 Capital costs and funding

Capital costs (enhancements and renewals) for TfL projects in the period 2016 – 2050 are projected to total some £269 billion over the study period. Our analysis of the TfL business plan and of future revenue potential shows that fares will more than meet operating expenses. Therefore, we estimate a portion of these costs - some £88 billion - could be met by surplus fare revenue.

Other core sources of revenue funding (£51 billion illustrated above) include the General Grant from central government and TfL's Business Rates Retention (capturing a proportion of the growth in London's business rates), both of which we assume remain flat in real terms beyond the business plan period. Both of these revenue streams could vary substantially over the period. In particular, the General Grant, negotiated directly with central government, could be subject to periodic/on-going reductions and uncertainty. The core capital funding stream (£53 billion illustrated above) is the Investment Grant from central government. It is also negotiated directly with central government and could be subject to periodic/on-going reductions and uncertainty. We have accounted for a period of on-going borrowing as per TfL's current borrowing levels, although we have not attempted to estimate debt service costs.

The remaining gap identified will most likely need to be funded through structuring of fares and charges, agreement of additional central government grant, new sources of revenue or access to new capital receipts. Transport projects in particular often lead to consequential retail, commercial, and/or housing developments. There is a growing focus on capturing a share of the value from these developments to provide additional funding for new transport connections. Such developer and third party contributions are already being considered in detail for Crossrail 2 with nearly 45% of funding estimated to be raised in this way.

10.3 The impact of expenditure on utility bills

10.3.1 The energy sector

London's energy infrastructure forms part of the national system of generation, supply and network provision (including transmission and distribution). The electricity generation and gas supply markets are largely unregulated and firms are largely free to make their own capital and operating investment decisions. Prices are generally determined through competitive forces and where present, government direction of price is indirect, through targets and obligations on firms to purchase or supply particular forms of energy, including renewables.

Transmission and distribution companies, on the other hand, operate in regulated markets as they operate effectively as national or regional monopolies. The regulator, the Office of Gas and Electricity Markets (Ofgem), is tasked with protecting consumer interests, promoting competition where appropriate. Ofgem issues companies with licences to carry out activities in the electricity and gas

sectors, sets the levels of return which the network companies can make and decides on changes to market rules. Financing for generation and network infrastructure is put in place by the generation and network companies - primarily in the form of equity, bonds and bank loans – secured against the revenue generated through consumer bills.

Direct investment in London's energy infrastructure falls into one of three different categories:

- Non-regulated infrastructure investment (mainly generation), including decentralised heating networks;
- Regulated distribution infrastructure investment; and
- Domestic and small-scale commercial energy efficiency and low-carbon technology investment.

Non-regulated infrastructure investment is funded by consumers, through energy bills. Regulated distribution investment similarly is funded by consumers, through energy bills.

Domestic and small-scale commercial energy efficiency and low carbon technology investment is funded by consumers, including individual households and building owners. These investments often receive a public subsidy, via central and local government support schemes. Examples of these programmes include the Renewable Heat Incentive, the Feed in Tariff, the Green Deal and the Energy Company Obligation.

We have estimated that approximately 90% of all (direct and indirect) costs over the period are funded directly by the private sector (around 60% by revenues in unregulated sectors and 30% in regulated sectors). Only about 10% would be funded via public sector sources or through direct subsidies (such as the Renewable Heat Incentive or Small Scale Feed in Tariff).

London government has little or no influence over indirect investment, which is left to the functioning of the market and national policy. The Mayor may have some influence over national policy, although we assume it is perhaps inevitably, somewhat limited. London government may have a different degree of influence over direct investment and may be in a position to influence distribution network companies in the energy market - via the statutory consultation process during the periodic reviews of their business plans - although final regulated revenue decisions remain in the hands of Ofgem. Perhaps the area of most potential influence is over investment in decentralised energy. For example, district heating where London government could target investment according to need.

10.3.2 Energy bills

Current projections from central government show prices for electricity and gas increasing over the next decade and beyond to 2030. The increase in unit costs is mitigated by an assumed improvement in energy efficiency and lower

consumption per households, which leads to a final energy bill unchanged or only marginally higher.²²¹

As can be seen in Figure 61 below, in our analysis we have similarly assumed an improvement in energy efficiency and an overall reduction in energy consumption per capita, concentrated primarily in heating (heating per household falls from 12.8MWh per annum in 2015 to 8.3MWh per annum in 2050). On the other hand we expect consumption of electricity to increase (from 3.9MWh to 5.6MWh in 2050).

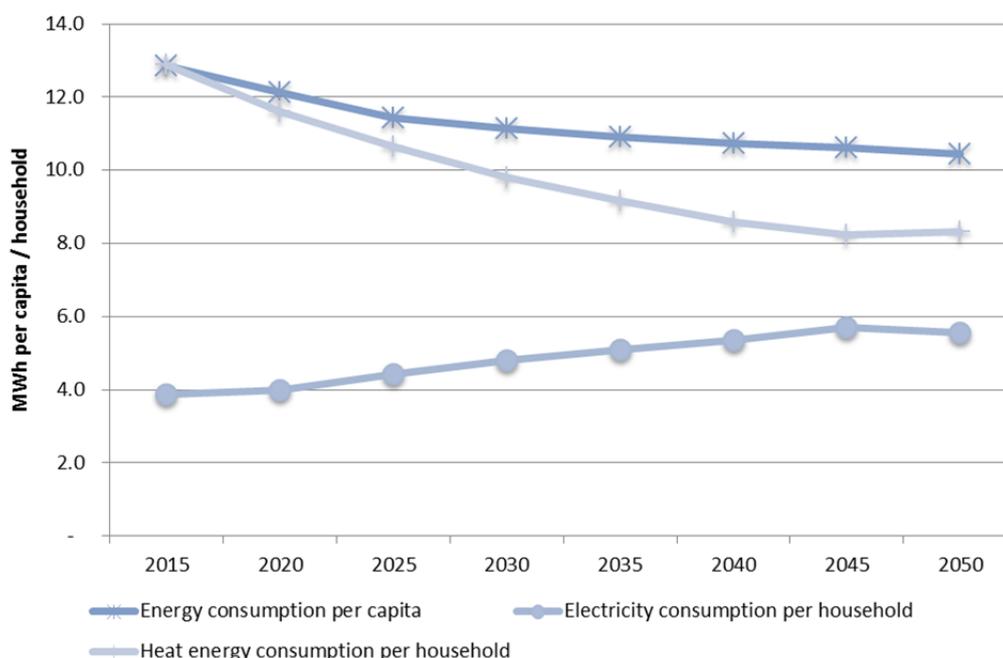


Figure 61: Energy consumption per capita (estimate 2015-2050). Source: Arup analysis

In line with current Government policies, in our scenarios we have projected a significant programme of investment to decarbonise energy supply. Such investments do imply that real costs per capita (and per households) increase compared to today.

In the ‘hybrid’ scenario the average cost per capita (including all capital investment, opex and supply costs) would rise from £344 per annum in 2015 to around £909 (real 2013 prices) in 2050. This figure include the costs of supplying energy to both domestic and non-domestic consumers (whilst final consumers pay directly only the domestic energy bills, they do pay the increase in non-domestic energy through the potential increase in products and services costs). In the centralised scenario by 2050 the costs per capita reach £1,076 per annum or about 20% higher than in the hybrid scenario. Figure 62 overleaf shows costs for both the hybrid and centralised scenarios as a proportion of London GVA.

²²¹ See “Estimated impacts of energy and climate change policies on energy prices and bills”, <https://www.gov.uk/government/publications/estimated-impacts-of-energy-and-climate-change-policies-on-energy-prices-and-bills>

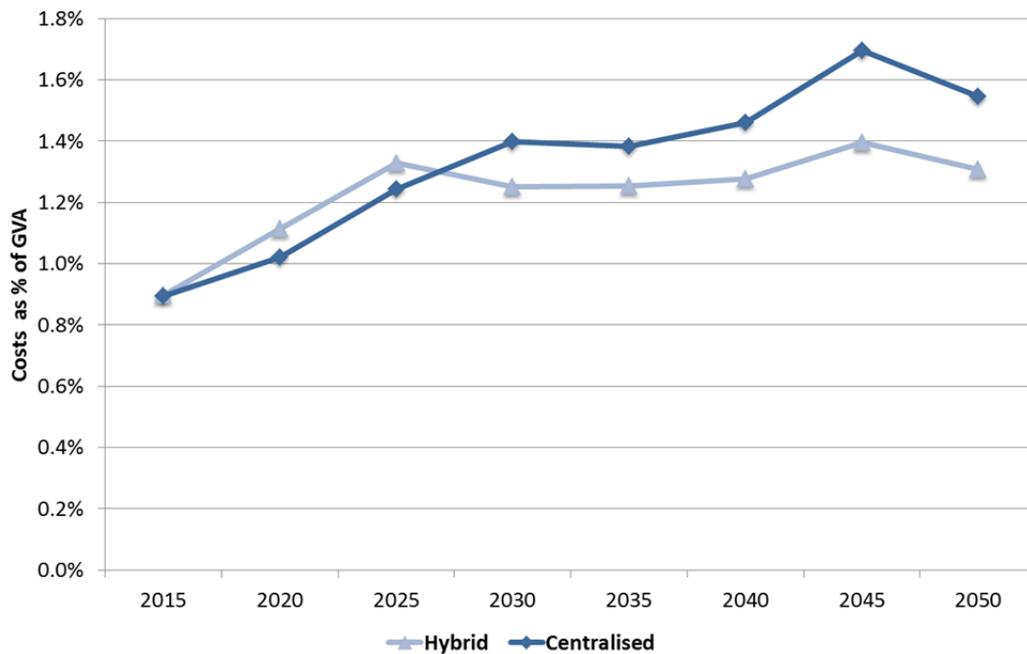


Figure 62: Energy costs as percentage of London GVA. Source: Arup analysis

Focusing on the domestic sector and particularly on residential consumer energy bills, we have estimated an increase of around 4.6% growth per annum in real terms until 2025 and 1.5% per annum thereafter to 2050. In the centralised scenario the increase in bills would be about 4.0% and 2.2% per annum growth to 2025 and 2050 respectively.

There will be differences in the energy bills paid by customers depending on the type of energy sources deployed, particularly for heating; the type of levies charged through regulatory framework, government policy and the level of taxation at any time. As the traditional model of electricity and gas bill changes with the deployment of heat pumps, solar PV, district heating, new models may emerge that will have an impact on final charges for consumers.²²²

The figure below shows our projections for household bills on an indexed basis. The majority of the increase in costs (and therefore bills) over time is due to the increase in electricity prices and the deployment of measures and policies to address climate change. In particular the increases are reflective of costs associated with an electricity mix primarily composed by renewable and nuclear energy and, in the longer term, Carbon Capture and Storage. The costs of electrifying both heat and transport will also put pressure on prices and bills.

²²² The analysis made no assumption with regard to the type of utility business model and therefore the type of financing required and its impact on bills and affordability. At the same time we have assumed that capital expenditures costs are directly and immediately passed on to final consumers, even though we acknowledge that different tariff structures will be applied in reality.

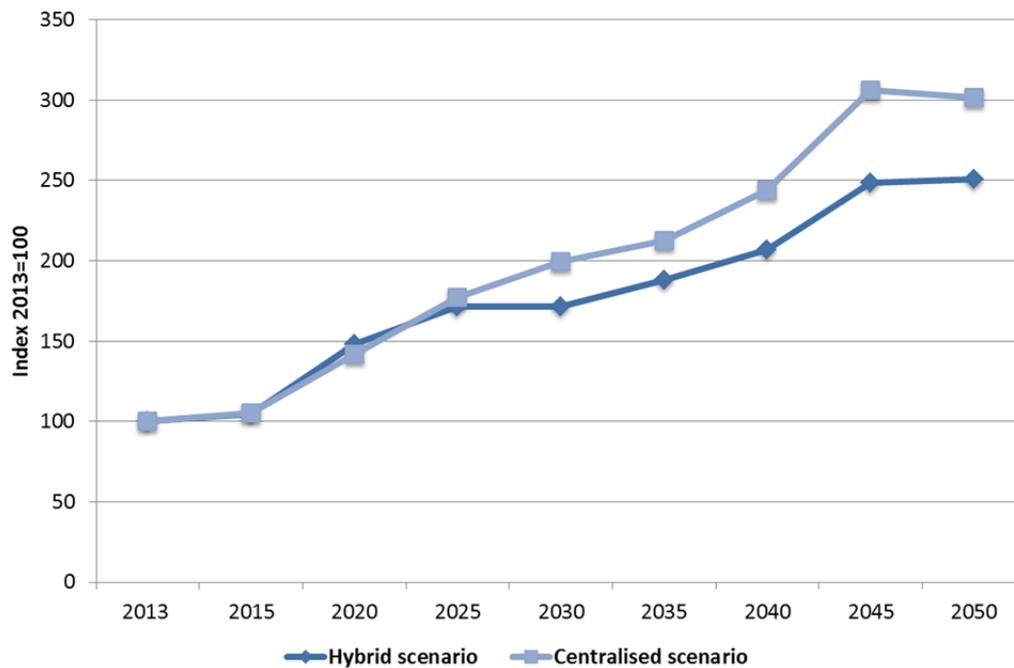


Figure 63: Index household energy bill (estimate 2013-2050). Source Arup analysis

In light of this analysis, a shift to decentralised (hybrid) energy may provide some relief for consumers in the long term.²²³ Over the short term, however, consideration must be given to how to finance the still significant capital expenditure required to develop decentralised energy solutions. Most investment will still be the responsibility of private sector investors, although some contributions could be made by local authority or other organisations.

As noted earlier, we have estimated that approximately 90% of all (direct and indirect) costs over the period are funded directly by the private sector (around 60% (by revenues) in unregulated sectors and 30% in regulated sectors). Only about 10% would be funded via public sector sources or through direct subsidies (such as the Renewable Heat Incentive or small scale Feed in Tariff). However, the majority of such investment - not coming via unregulated sectors - will be related to investment to be made in London. Approximately 50% of the direct (London) costs are expected to be financed in regulated sectors, 20% in unregulated sectors and about 30% via public sector or direct subsidies. As can be seen in Figure 64 overleaf, investment in the regulated and public sector supported sectors will be concentrated in the earlier period accounting for about half of all investment. After 2025 only 35% will be financed via regulated charges or subsidy.

²²³ Overall, it is likely that households supplied by decentralised heat energy solutions will by 2050 pay a lower energy bill than other households whose heat energy is supplied by heat pumps or gas.

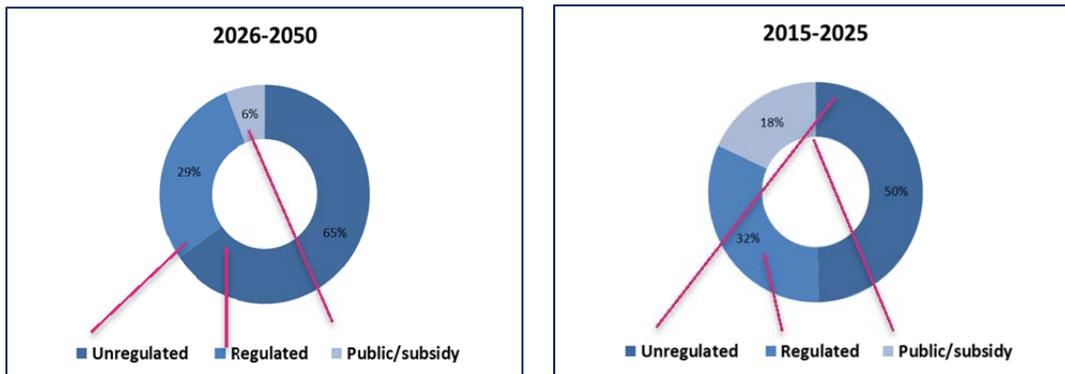


Figure 64: Sources of funding (estimate): Source: Arup analysis

Overall, there is an expectation of costs for consumers and therefore energy bills to increase both in the short and long term, primarily due to the decarbonisation of the UK energy system. London consumers may also face rise in energy bills in the period to 2025 to develop decentralised energy solutions. The magnitude of such increases will be dependent on the speed of the programme to roll out decentralised installation and networks, the technologies adopted and most importantly the policy, market design and commercial arrangements adopted over the period.

Similarly, the final impact on consumers' bills will be very much dependent on changes in consumer behaviour that will occur over the period in response to technological changes (such as energy storage, smart meters or a smart grid), or policy developments (for example to stimulate energy efficiency). In fact, the choice of type of energy supply (in heat as well as electricity) will be affected by many factors, including costs, commercial and policy incentives. The total amount of energy and when and how it is consumed will also be dependent on the costs and benefits of the technologies available but also on behaviours that can be, to a certain extent, influenced through policy and commercial incentives (such as time of use tariffs).

It is highly likely that as the digital / smart revolution begins to shape ways in which energy is used, and products are developed to facilitate this, consumers will gain more ability to manage their consumption, their costs (choosing when to consume in order to avoid most punitive pricing) and therefore their bills.²²⁴

10.3.3 The water sector

Consumer bills cover the water companies' (supply and sewerage) operating expenses, their investment in new infrastructure and their replacement of existing infrastructure. Consumer bills also support entirely the cost of the financing up-front investment. Financing for water infrastructure is put in place by the water companies - primarily in the form of equity, bonds and bank loans – secured against the revenue generated through consumer bills.

The Environment Agency provides flood risk management services and management of assets as well as regulating the abstraction of water for supply and the release of treated effluent back into the environment (the Drinking Water

²²⁴ It was beyond the scope of our analysis to take into account such potential changes. These may ultimately help consumers manage the expected increase in energy costs.

Inspectorate regulates water quality). Funding for fluvial defence projects is primarily provided through a grant from central government (FDGiA). In London the operational activities of the Environment Agency are undertaken by the South East region through the North East Thames area, the West Thames area and the Kent and South London area.

As with the centralised energy market, London and the GLA have little or no influence over the water companies or sewer undertakings, except through the statutory consultation process during the periodic reviews of the water companies' business plans. This means that the investment required to both reinforce the network for continuity of supply and satisfy future demand in London, is not currently in the Mayor's control, rather is left to the functioning of the (regulated) market.

10.3.3.1 Water bills

In the future, the water sector is expected to remain private-sector led with the Mayor championing the needs of London for greater levels of investment. The water supply and sewerage investment identified in this study will have an impact on consumer bills. The major impact is expected to be the Thames Tideway Tunnel. Of the capital expenditure projected to be required in the water sector, the Thames Tideway Tunnel represents the largest single proposed investment, its costs projected to total some £4 billion over the next five years.²²⁵

In advance of the tunnel's construction, one of the region's water companies has estimated the impact of its development on customer bills. Thames Water reports that "it is...undeniable that our...wastewater customers will face higher bills to pay for the proposed Thames Tideway Tunnel, in the same way that people in South West England have paid for improvements to sewage treatment works in the interests of cleaner beaches, at a much higher cost per head."²²⁶ Based on the Thames Water business plan for AMP6 (2015-20), the impact of the Thames Tideway project on average customer bills is £40 per year (2013/14 prices) compared to the remainder of their capex programme in AMP6, which has an impact of £21 per year (before efficiencies). The company's average combined water and sewerage bill for 2014 is around £350 per property per year (2014 prices).

In average terms, these estimates show that the Thames Tideway Tunnel alone will increase bills by some 18% (in 2014 prices). Thames Water has noted "this means that the average wastewater bill of Thames Water customers, which have for many years been among the lowest in the country, would rise to around the national average."

In addition, Defra now expects a more significant level of third party contributions ("partnership funding") to supplement its funding sources in order to deliver local flood defence schemes, e.g. from local authorities, at risk

²²⁵ Representative value cited in public documents, excluding the potential effects of inflation. Arup's cost estimates, shown previously in this report, include construction industry inflation when reported in real terms. Arup has not included the costs associated with a new reservoir in its projections.

²²⁶ Thames Water, *London Tideway Improvements; Frequently asked questions*, 27 August 2012, available: <http://www.thameswater.co.uk/about-us/8877.htm>.

businesses, housing developers and statutory undertakers (either through in kind contributions building defences or in cash) . In reality private sector contributions have not materialised on the scale required, largely because the private sector finds it difficult to immediately monetise the benefit from their investment or perceives that it has insurance in place to mitigate the risks of flooding impacting on its businesses. This has resulted in local authorities putting up significant portions of the partnership funding required.

The Mayor could elect to divert greater levels of funding to strategic water or flood defence projects where these are strategically important for London, to ensure that London is protected against fluvial, surface water and groundwater flooding in particular and to ensure that the City is resilient from other future risks such as drought.

10.3.4 The waste sector

Household waste collection and disposal is the statutory responsibility of individual London boroughs. Commercial waste disposal is not a statutory function, but some commercial businesses pay the local authority to provide it.

As a statutory function, London boroughs procure the capacity to process waste either through recycling facilities or incineration/landfill. The household waste sector is funded through council tax (socialising the cost such that those with higher Band properties pay relatively more) and the commercial waste sector is paid for directly by users. Private providers are encouraged to invest in new capacity through the guarantee of a 'gate fee' underpinned by the council tax. As we noted earlier in the report, the impact on council taxpayers may be offset by secondary revenues generated from turning waste into energy and supplying this to consumers as well as revenues from selling recycled materials to manufacturers.

As raw materials for manufacturing may become scarcer and more expensive, the expected future trend is that more waste will actually be reclaimed and re-used by the private sector in a move to a circular economy and away from the linear approach to disposal. This is likely to be driven by the private sector in a bid to improve cost efficiency.

The public sector will still be required to maintain capacity to dispose of residual waste. Capacity will need to be funded by taxation or user charges with the impact minimised to the extent possible through secondary revenue generation and efficiencies in delivery.

10.3.5 Waste bills

Information provided by the GLA indicates that local authority waste bills for waste collection and treatment/disposal amounted to about £500 million in 2011/12. This equates to some £61 per person (based on a population of 8.2 million) or about £2.91 per household per week.

Over the long term, achieving the projected targets in the waste sector's transition to a circular economy is likely to lower local authority waste bills. Our projections show that the waste bills could fall to some £39 to £49 per person in 2050 (2014 prices) based on the high transition scenario and the base case scenario, a decrease of nearly 25% on 2011/12 costs.

10.4 Other infrastructure funding requirements

10.4.1 Schools infrastructure

It is the statutory responsibility of individual London boroughs to identify the need for future schools places and to make sure there is suitable provision in place to satisfy growth. Central government then provides the majority of the capital funding to create the school places and to carry out capital maintenance and repair work to existing school buildings (Basic Need / Devolved Formula Capital), supplemented by capital contributions from London boroughs. An indicative survey by the GLA across the academic years 2011/12 and 2012/13 suggests that central government capital funding represents around one third of the funding required. Our analysis, therefore, suggests that London government – predominantly London boroughs - will need to identify in the region of £11 billion over the period to 2050 to fund new school places and an additional £12 billion to undertake renewals on both new and existing schools facilities. A 'Dedicated Schools Grant' is provided by central government to cover all schools operating costs.

The significant increase in projected population creates the need for major increases in the number of school places and will place additional pressure on London boroughs to make necessary contributions. This investment will need to be made by increasing central government contributions or from additional sources raised locally. A wide range of new sources is likely to be difficult to access without providing London government with greater control and freedom over its local tax base. Further innovation and efficiencies will also be required to bring down costs.

10.4.2 Green infrastructure

Green infrastructure is a network of open and green spaces and green features (e.g. green roofs) and also includes the 'Blue Ribbon Network'. It provides multiple benefits for people and wildlife including: flood management; urban cooling; improving physical and mental health; green transport links (walking and cycling routes); ecological connectivity; and food growing.

The components of the existing green infrastructure network are owned and managed by a number of public and private sector organisations delivered through a range of funding entities. This risks a sub-optimal approach to implementation, funding and delivery. London boroughs receive a general allowance from central government for the upkeep of parks and green spaces. This is unlikely to be sufficient to fund the £1.6 billion of identified capital renewals and operating costs over the study period. As a "soft infrastructure" sector, it is often not properly understood in terms of impact. It is often first in line for government

economies in a fiscal downturn. Other government agencies and public trusts such as the Environment Agency or the Port of London Authority also have limited amounts of funding to regenerate spaces for green infrastructure, e.g. river routes, pathways and waterways.

New green infrastructure is often delivered in tandem with other projects. Housing developers have targets per unit of new housing delivered and new transport projects also often invest in green infrastructure to make it more accessible. Private companies investing in new properties often have a greater focus on the green credentials of buildings whether because of civic/green planning policies such as BREEAM (Building Research Establishment Environmental Assessment Methodology) or the perception it gives to customers and clients. Nearly 50% of the new green infrastructure capital costs identified in this study relate to that provided by housing developers as a planning condition.

Other 'one-off' developments may be delivered through capital sums granted through Lottery Funds, major events such as the Olympics or linked to wider regeneration masterplans or projects attracting charitable donations such as the proposed Thames Garden Bridge.

Investment is also needed in utilitarian schemes such as CO₂ 'sinks', walkways, flood enhancement as well as community and wellbeing driven schemes such as cycle Quietways. A significant portion of new green infrastructure capital costs identified in this study relate to an allowance for developing Quietways.

New York City has initiated a "Green Infrastructure Program" specifically targeted at reducing combined sewer overflow discharges into New York City's water bodies, whilst also improving the appeal of city streets and neighbourhoods and improving air and water quality. It is a multiagency initiative led by the Department of Environmental Protection to design, construct and maintain a variety of sustainable green infrastructure practices on City owned property. Capital as well as revenue funding is largely committed from the public sector agencies but the cross agency approach is intended to identify opportunities for green infrastructure implementation through existing and planned capital projects across the City's combined sewer area.

Without structural changes, green infrastructure will continue to be delivered along traditional means, principally through government grants and developer contributions. The Mayor could elect to divert a greater share of available funding to green infrastructure or with broader tax setting powers, properties or businesses could be directly levied a tax for the benefit they get from the green infrastructure around them. A key challenge would be developing a mechanism to identify all beneficiaries, measuring the benefits accruing and then to capture a share of these equitably.

10.4.3 Digital connectivity infrastructure

Principal components of digital infrastructure include trunk and transmission assets, fixed phone lines (including broadband) and mobile phone networks. The

telecoms industry in the UK is deregulated and operates as a competitive market. BT is the main provider of fixed telephones and broadband lines. Ofcom is the competition authority for telecoms, enforcing remedies in markets where it believes dominant operators may have a potentially harmful influence on competition or consumers.

Through their telephone, broadband and mobile phone bills, customers pay entirely for telecoms companies' operating costs, their investment in new and replacement infrastructure and the cost of the financing taken on to pay for this. Both the capital and operating digital connectivity costs identified in this study – estimated at around £10 billion over the study period - are expected to be funded predominantly by the private sector, with some public funding to deliver or accelerate socially important projects or projects identified as critical to increasing London's competitiveness (e.g. this was an objective of the broadband voucher scheme for SMEs).

As with other regulated or commercially competitive markets, London and the GLA have limited influence over service providers. This means that the investment required to extend services into areas not currently serviced or to invest in resilience/expansion measures, e.g. 'dark' fibre, is not directly in the Mayor's control. With greater powers, there may be an opportunity for the Mayor and boroughs to divert more funding to supporting digital connectivity investment. However recent efforts by government to spend on broadband infrastructure have been watered down after legal challenges over issues related to state aid, leading to a lack of clarity in the role of the public sector in this sector.

10.5 Conclusions

In overall terms, our analysis suggests costs of some £2,000 billion in real terms are required to pay for the expansion, renewal and operation of London's infrastructure. Whilst much of the infrastructure investment required in London is likely to be delivered and funded through the private and regulated sector, as well as central government, a significant element will fall to London government to find. It is clear that the funding gap between projected future costs and income sources in housing and transport of approximately £135 billion in the study period represents a significant challenge, in addition to the remaining sectors of the study where it assumed that costs are "unfunded" at present.

In order to deliver the identified infrastructure requirements, additional sources of funding will need to be identified, be it through newly committed central government grant, access to new funding streams or access to new capital receipts. Unpredictable central government grant streams do not provide the certainty or promote the longer-term planning that major infrastructure requires, both in delivery or long-term maintenance. In 2007 a ten year funding settlement for TfL was established, however in 2010 this was reduced to 5 years. This is anomalous with the delivery of transport projects which can be 5 years in the planning phase. TfL itself maintains a 10 year planning horizon in its business plan.

A return to a ten year funding settlement for TfL, extended to housing, with political commitment to restrict subsequent amendment, is likely to create greater stability over cashflows and delivery of investment plans. Broadening the range of funding sources for London government to include a number of different tax sources would create a more diversified revenue stream. A lack of certainty over funding in the medium term makes it harder to create the conditions to leverage private sector investment and secure investor confidence.

The London Finance Commission concluded that “London government needs fewer borrowing constraints and greater devolved tax powers to enable it to invest more comprehensively without the need for ad hoc, project-by-project financing arrangements.” As would be the case for Britain’s other major cities, London is likely to benefit from fiscal autonomy that matches continuous, stable funding streams with the ability to determine local need. Greater local control similarly should enhance political accountability, fiscal discipline and responsibility.

Should London government be permitted to retain a greater share of the tax revenues it generates, there is good reason to believe that central government funding could be reduced over time. One recommendation of the Finance Commission was that yields of newly devolved taxes should be offset through corresponding reductions in grant, ensuring a fiscally neutral position for the exchequer. London would, however, be in control of this part of the tax base and it would have an incentive to grow it as it would receive the benefit of upside in the long-term.

With fiscal devolution there is the opportunity, subject to policy objectives, of recalibrating where funding is spent, using some of the devolved tax based funding streams or powers to subsidise bills or to accelerate delivery of schemes deemed critical to London. There may also be the freedom to move away from tax based funding sources to targeted user pay models where appropriate, or to optimise how taxes are structured; for example, revisions to council tax bandings. In sectors which are not inherently revenue generating, such as green infrastructure, London could seek to identify more effectively the beneficiaries of such investment so as to capture a contribution to the investment and upkeep of the assets; for example business rate supplements for local businesses which benefit from improvements in the surrounding public areas.

In the short term, limited and modest proposals for fiscal devolution will not in themselves generate the financial resources to make a significant dent in the additional public capital investment requirements facing London. For example, the London Finance Commission proposed devolving London’s five core property taxes but with a corresponding reduction in central government grant. This would provide for a fiscally neutral position for the Treasury at the outset. Only the growth in the property taxes would be additional for London government finances. However, with regular revaluations and year on year increases, the property tax base may yield more significant sums. As a point of illustration only, over twenty years, a 2.5% per annum real increase in revenue would equate approximately to an extra £78 billion of income (on an undiscounted basis), which

shows the impact of such an assumption.²²⁷ Given the many competing demands for public resources, not all of this would necessarily be available for spending on infrastructure.

Irrespective of fiscal devolution, additional powers to implement new revenue making schemes will need to be granted in order to close the funding gap. Some initial concepts are discussed in chapter 12.

²²⁷ Inevitably, revenue growth tends to be “back-ended”. In the example cited, the last five years raises nearly twice as much as the revenue generated in the first ten year period (on an undiscounted basis).

11 Closing the funding gap: potential cost savings and efficiencies

To arrive at an indicative estimate of the opportunity that exists to deliver London's infrastructure needs more efficiently, we have focused on some of the key policies and strategies currently targeting greater efficiency in the built environment.

Over the last five years there has been increased recognition of the importance of efficiency in delivering the UK's infrastructure. This perhaps commenced with the Infrastructure UK Cost Review of 2010 (HM Treasury) and more recently Construction 2025 published in 2013. These identified significant opportunities to achieve efficiency through improved understanding of assets in the built environment, efficiency in design, procurement and engineering and in carbon reduction.

Based on this analysis we believe that it is reasonable to anticipate that the cost of the infrastructure plan to 2050 could be reduced by between 10-15%. As we try to demonstrate below, the initiatives described represent an on-going theme of improvement and efficiency for investment in the built environment. It is reasonable to anticipate that this will continue into the future as our infrastructure needs change and advances in technology and our environment demand alternative solutions to be developed.

The following section details the potential for future cost efficiency that exists in delivering London's infrastructure needs to 2050. Given the range of sectors (such as rail, highways, energy, waste and green infrastructure), the nature of client organisations (public, private, regulated) and the level of maturity and delivery capability in each, there is a wide spectrum of initiatives and improvements that have the potential to deliver cost efficiency. The primary drivers or motivating factors for efficiency are detailed in Figure 65 below and overleaf.

Sector	Strategic model
Transport (TfL)	Delivery of the Mayoral Transport Strategy; demonstrating value for money to voters, making resources go further, maximising third party contributions
Rail (Network Rail)	Economic regulation - delivery of Control Period targets and ensuring value for money.
Aviation	Regulation – improved service offering to airlines and passengers in line with Control Period targets (for 'designated' airports) plus normal commercial competitive pressures.
Highways (National)	Roads Reform – transforming HA into a Government owned company. Quasi-regulated. Value for money for taxpayers.

Highways (Local)	Maximising value from central government funding, ensuring value for money for taxpayers.
Housing (Private sector)	Developer led – value enhancement
Energy (Private sector)	Regulation – RII model and outperformance; normal commercial incentives.
Energy (Public sector)	Achieving a low carbon economy for wider public policy objectives; value for money for taxpayers
Water	Regulation – delivery of outputs in regulatory settlement and achieving outperformance
Education	Delivery of government objectives around a range of social and some economic objectives
Waste	Delivery of European and UK carbon and solid waste reduction targets; value money for taxpayer; commercial incentives
Green	Broad range of strategies both public and private sector led to deliver national and local improvements
Digital connectivity/broadband	Private sector led – market driven but with government interest in trying to secure near universal levels of coverage

Figure 65: Principal factors in driving efficiency by selected sectors. Source: Arup analysis

Construction contributes approximately £90-£100 billion per annum to the national economy of which the private and private regulated sector contributes approximately 60%.²²⁸ Delivery of regulatory targets to (or in excess of) defined levels of efficiency is therefore the most common motivating factor.

Several established initiatives exist for cost efficiency in the built environment promoted by central government, client organisations and professional bodies and institutes. These initiatives represent an on-going theme of improvement in the construction industry that began in 1994 with the production of the Latham Report²²⁹ to the 2010 Infrastructure UK Cost Review that will continue as the industry, market and economy evolves.

The following sections are a snapshot of industry initiatives and strategy that have the potential deliver future cost efficiency. These are likely to be conservative based on our current understanding and ability to predict the impact of technological innovation and advancement.

²²⁸ *Government Construction Strategy*, [2011], Cabinet Office

²²⁹ *Constructing the Team*, Latham [1994], London: HMSO

11.1 Public sector cost efficiency initiatives

In the public sector there exists a wide range of initiatives at both central and local government level that seek to deliver more efficient social and economic infrastructure. These initiatives have wider influence on industry practice including the private sector. The key strategy documents in central government over the last three years include:

- The Infrastructure UK (IUK) Cost Review;
- The Government Construction Strategy;
- HM Government Industrial Strategy: Building Information Modelling;
- Infrastructure Carbon Review; and
- Construction 2025.

The IUK Cost Review was published in 2010 with the objective of understanding the causes of the perceived high cost of infrastructure in the UK versus European comparators. The report benchmarked projects across both the public and private sectors and identified a range of improvement measures with the potential to reduce costs by up to 15%.

The Government Construction Strategy of 2011 set out the framework for a number of workstreams with the objective of reducing the cost of government only projects by 15-20% by the end of the current Parliament.

Under the government's industrial strategy "Building Information Modelling" (BIM) was published in 2012. This document identifies the measures required to leverage the full scope of opportunity by developing market leading capability in BIM.

Linked to the IUK Cost Review, the Green Construction Board commissioned a study to review carbon emissions in UK infrastructure. The Infrastructure Carbon Review²³⁰ highlights barriers and enabling measures to reducing carbon emissions across all industry sectors. As detailed in the report, carbon reduction enables cost and resource efficiency, reductions in capex and opex and mitigates the impact of climate change.

Finally, Construction 2025²³¹ outlines the government's long term strategy setting out how industry and government will work together to place the UK at the forefront of the global construction industry detailing key themes and commitments. These include maximising the UK's competitive advantage in digital design and developing market and technology based plans to secure employment and growth opportunities from reducing carbon in the built environment.

Each of these strategy documents are entwined and represent an on-going central government commitment to improving infrastructure efficiency. Delivering London's infrastructure requires consideration of these strategy documents and their key themes and improvement measures.

²³⁰ *Infrastructure Carbon Review*, [2013], HM Treasury

²³¹ *Construction 2025: Industrial strategy for construction*, [2013], BIS

11.2 Infrastructure UK (IUK) Cost Review

The IUK Cost Review of 2010 identified the following improvement measures to deliver £2-3bn annually across the industry and all infrastructure sectors:

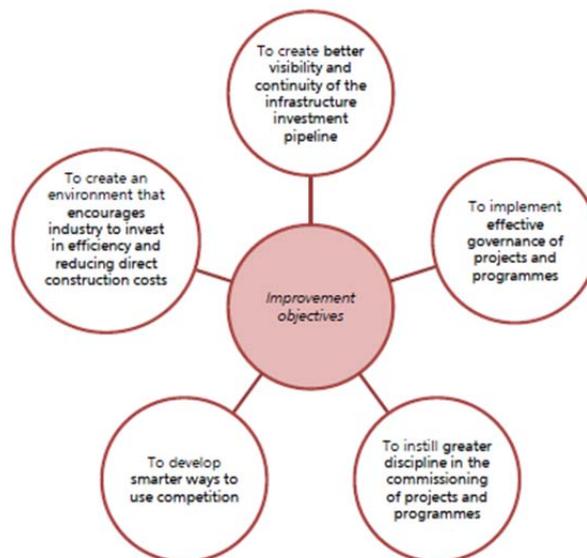


Figure 66: IUK Improvement objectives. Source IUK Cost Review, HM Treasury, 2010

Based on the above improvement objectives, IUK initiated a three year improvement plan to improve or enable the following initiatives:

11.2.1 Pipeline visibility and certainty

Research from the Infrastructure Cost Review²³² demonstrated that a stop-start infrastructure pipeline has the effect of stifling investment, supply chain growth and adding to the overall costs of programmes. Pursuing greater visibility of the infrastructure pipeline supports longer-term investment planning and drives the use of a more effective programme driven approach.

The government is also using improved pipeline visibility in the infrastructure sector to identify capability gaps in the supply chain that need to be addressed²³³ to meet future demand and enable further growth. As a result it is apparent that pipeline visibility and certainty is inherently intertwined with other cost saving mechanisms. Rather than operating individually; these need to complement and facilitate more effective overall practices.

11.2.2 Effective governance

In order to drive the efficient delivery of infrastructure projects, leadership capability and effective governance must be established. The application of the Infrastructure Procurement Roadmap - whilst procurement related - requires

²³² *Infrastructure Cost Review*, [2010], HM Treasury

²³³ *Infrastructure Cost Review*, [2010], HM Treasury, p. 26.

strong leadership alongside clear governance structures in order to deliver large scale projects effectively²³⁴.

Leadership and governance can be further strengthened through addressing a client's skills base deficiencies and the overall ability of the public sector to deliver projects effectively.

According to HMT in their 2012-2013 Infrastructure Cost Review²³⁵ the highways and rail sectors have experienced improved governance through the grouping of long term programmes to improve overall efficiency. This practice could be explored on a much wider scale across the infrastructure sector in order to drive efficiencies through governance.

11.2.3 Behavioural change

Studies have shown that procurement behaviours in the infrastructure sector are too often lengthy, expensive, adversarial, and risk averse. In order to ensure the delivery of infrastructure more effectively, infrastructure projects and programmes must move to address these negative behaviours and the long standing issues of inefficiency in the approach to procurement, project delivery and supply chain engagement.

Delivery of cost savings requires a collaborative approach between clients and contracting bodies. A study by IUK²³⁶ demonstrated that there is considerable progress in supply chain companies achieving BS 11000 (Collaborative Business Relationships), with 40% certified and 40% currently working towards certification. This is a useful starting point in improving procurement behaviours between clients and supply chains, particularly for more complex major projects and long term programmes of work.

There is also much to be learned from discussing and sharing best practice. One of the most significant benefits of the IUK programme has been the establishment of a Client Working Group bringing together leaders from across the industry to discuss and explore alternative ways of working.

11.2.4 Effective programme management

Effective programme management is a critical factor in delivering infrastructure projects effectively and achieving cost reductions. Currently, London lacks an overarching programme management office which could oversee such practices and drive best practices in project delivery. Establishing effective programme management process would result in:

- Enhancing the GLA's capability to oversee project packaging, sequencing, project momentum monitoring, stakeholder engagement and delivery strategy coordination;
- Building the GLA's capability to meet programme and project management challenges effectively;

²³⁴ *Infrastructure Cost Review*, [2010], HM Treasury, p. 29.

²³⁵ *Infrastructure Cost Review*, [2010], HM Treasury, p. 22.

²³⁶ *Infrastructure Cost Review*, [2010], HM Treasury, p. 20.

- Delivering industry strategies to ensure readiness for the project, including a certainty of investment to support up-skilling and up-resourcing and innovative procurement processes;
- Efficient delivery monitoring, identifying systematic trends, issues and problems, and developing solutions to address issues and problems during the delivery process;
- Stable and sustainable expenditure patterns due to appropriately scoped, costed and designed programmes;
- Resolving programme issues and impediments with less complexity; and
- Drawing on industry knowledge and experience to identify common issues, develop responses and share best practices to ensure preventative management.

An example of such a management model can be seen in Queensland, a region of Australia growing by up to 1,000 people per week (about half the rate of population growth in London). The strains on the state's infrastructure created by this growing population led to the development of the '*South East Queensland Regional Plan 2005 – 2026*',²³⁷. This included more than 445 projects across all infrastructure sectors, with 94 projects valued at over AUS\$100 million (£185m) and 12 over AUS\$1 billion (£1.85bn). The government anticipated the challenges that were likely to be met in attempting to deliver such a complex programme of works. A Programme Management Office (PMO) was established by the Queensland Government to address these and facilitate successful project delivery. This office comprised representatives from the Coordinator General (Department of Infrastructure), Arup and the Peron Group, and was supported by the Queensland Treasury.

11.2.5 Driving supply chain efficiencies

As discussed in the HMT Infrastructure cost review 2012-2013²³⁸, while clients have been utilising their industry expertise to set cost targets, only 33% of their supply chain providers felt that they were being selected in accordance with transparent costs targets and long term outcomes.

In the public, private and regulated sectors, client organisations are faced with the demand for greater efficiency and effectiveness, which makes investments and real change in their own organisations even more difficult.

Working with the Institution of Civil Engineers the government has considered the case for developing greater collaboration and supply chain integration²³⁹. However, following on from this the government recognised that contracts alone will not support the delivery of improved performance or greater efficiency. In order to support growth in efficiency behaviours will need to align and commercial arrangements formed throughout the supply chain. Frequently collaboration agreements can stall at the first tier level. For this reason; the government is exploring improved guidance for the NEC suite of contracts that achieves greater alignment and consistency.²⁴⁰ The NEC contracts reinforce

²³⁷ *South East Queensland Infrastructure Program Management Office*, [2007], Arup

²³⁸ *Infrastructure Cost Review*, [2010], HM Treasury, p37.

²³⁹ *Infrastructure Cost Review*, [2010], HM Treasury, p41.

²⁴⁰ NEC Contracts, [Online], Available: <http://www.neccontract.com/>, [31st May 2014].

greater collaboration and supply chain integration overall; the resulting work should provide benefits to both the public and private sectors.

11.2.6 Effective risk management

As highlighted by the Infrastructure Risk Group in their report, *Managing Cost Risk & Uncertainty In Infrastructure Projects*, there is a considerable number of programme management factors which drive up the costs of infrastructure delivery related to project risk²⁴¹. These include practices such as:

- Project teams and supply chains underestimating their risk estimates in order to secure work, without considering the longer term impacts this could have on project delivery;
- Complex risk fund release processes influencing projects to hold excessive local contingencies; and
- Organisational requirements for projects to return unused risk funds before project completion, has the effect of discouraging project teams from risk mitigation²⁴².

Increased risk mitigation could deal effectively with these issues, where risk is managed along with other behavioural influences, such as the London Underground's Ring-Fenced Risk Model²⁴³. This model is attractive as it incentivises projects to deliver risk mitigation targets, rather than penalising them by withdrawing reductions from the contingency funding. Case studies exist for both Network Rail and the Highways Agency to demonstrate this approach.

11.2.7 Efficient procurement

Recognising that the issue of procurement is more complex than the selection of a contract form and lowest cost tendering, IUK published a consultation report entitled '*Infrastructure Procurement Routemap: a guide to improving delivery capability*' in 2013 which examines the issues around procurement in more detail. It provides a coherent approach to assessing client, sponsor and supply chain capability and improving the quality of procurement decision making.

This routemap includes:²⁴⁴

- A suite of assessment tools developed as part of the Routemap to enable sponsors, clients and the supply chain to align behaviours and identify capability gaps;
- The use of complexity assessment tools for establishing the nature of the delivery environment;
- Enabling the adoption of the common characteristics and behaviours associated with successful infrastructure project and programme delivery;
- Pragmatic approaches to compliance with EU procurement legislation; and

²⁴¹ Infrastructure Risk Group, 2013, p8.

²⁴² Infrastructure Risk Group, 2013, p12-14.

²⁴³ Infrastructure Risk Group, 2013, p17.

²⁴⁴ *Infrastructure Cost Review*, [2010], HM Treasury, p. 3.

- An on-going role for industry leaders and experts in the infrastructure sector to identify, develop and disseminate best practice.

The recent London Underground works at Bank Station are a good example of providing a more effective procurement process through early supplier engagement²⁴⁵. In this case LU were concerned that the traditional approach to early contractor involvement did not adequately incentivise or reward contractors to achieve innovation early in the stages of design and development. As a response to this, LU developed a new approach when tendering the upgrade works to Bank Station rewarding contractors Intellectual Property.

11.2.8 Standards and specifications

Increasing number of standards in recent years has added further complexity to the delivery of infrastructure projects. This can lead to problematic client interpretations causing quality control issues, excessive works outside of scope and duplication.

A report by the Industry Standards Group, entitled 'Specifying Successful Standards', is aimed at reducing the number of bespoke in-house standards that apply to infrastructure projects and promote consistency between client groups²⁴⁶.

As a result of this report, the industry is challenged with simplifying procurement specifications and the removal of unnecessary technical standards which are complicating delivery and increasing costs. In order to pursue this there is a need to change how clients and companies work with these standards and alter their recognition of the adverse impacts the 'traditional' approach to standards have, in particular their influence on client requirements.²⁴⁷

11.2.9 Infrastructure data

The HMT Infrastructure Cost Review 2012 -2013 identified opportunities which could be captured from a consistent approach to managing and sharing infrastructure related data. The government is supporting cost sharing initiatives between infrastructure clients and also promoting more a consistent reporting of project outcomes to increase efficiency for future projects.

The current accuracy of data is heavily sector dependent, with sectors such as water and energy having much more accurate data collection techniques than examples in the public sector.

11.3 Government Construction Strategy

In 2011, the government's Plan for Growth highlighted the importance of the construction industry to the UK economy with central government identified as the industry's biggest customer.

The ability of the public sector to realise full value from public sector construction has been widely documented. The 2011 Government Construction Strategy set out

²⁴⁵ *Infrastructure Cost Review*, [2010], HM Treasury, p. 18.

²⁴⁶ Industry Standards Group, *Specifying Successful Standards*, 2012, [Online], Available: <http://www.ice.org.uk/Information-resources/Document-Library/Specifying-Successful-Standards>

²⁴⁷ Industry Standards Group, 2012, p. 8.

a range of measures to reduce costs by up to 20% by the end of the current parliament. These included:

- Improving co-ordination and leadership;
- Establishing a forward programme of projects and programmes;
- Improving governance and client skills;
- Greater challenge through HM Treasury, Cabinet Office, the Major Projects Authority and the Integrated Assurance and Starting Gate Review processes;
- Improving value for money, standards and greater and more visible cost benchmarking;
- Efficiency and elimination of waste;
- Introduction of Building Information Modelling across all public sector projects;
- Aligning design and construction with operation and asset management;
- Reforming Supplier Relationship Management;
- Improving competitiveness and reducing duplication for instance in the use of frameworks;
- Introduction of new procurement models;
- Client Relationship Management; and
- Implementation of existing and emerging Government policy in relation to sustainability and carbon.

Following publication of the strategy and the initial development of the workstreams, much of the strategy is now focused on implementation in industry through pilots of new procurement models.

As the end of the current parliament approaches, the government's strategy is now focused on the longer term objectives for industry efficiency detailed in Construction 2025.

11.4 Building Information Modelling (BIM)

Building Information Modelling (BIM) describes a collaborative approach taken through the life of an asset to deliver greater value. It is founded upon the creation, collation and exchange of 3D models and the attachment of structured intelligent data. Many aspects of BIM have existed in the industry for many years but have been used in isolation or to deliver short term requirements.

Under the Government Construction Strategy of 2011 the Government stated its intention for collaborative 3D BIM to be required on all projects by 2016. This effectively initiated a four year change programme in industry to implement BIM.

BIM is transforming the way that assets are designed and constructed across all industrial sectors. The implications are wide ranging with BIM initiating changing

relationships between clients and their supply chains and in client business models.

At a city level, the use of more technology and improved asset data can unlock opportunities including carbon reduction, improved asset data and cost efficiency in terms of capital, operating and maintenance expenditure.

A wide range of resources are already shared publicly via the Construction Industry Council (CIC) and BIM Task Group. At a strategic level the HM Government Industrial Strategy: Building Information Modelling sets out the barriers and measures required to maximise the benefits of BIM collaborative tools and capability.

11.5 Infrastructure Carbon Review (ICR)

The ICR published in 2013 set out the benefits of capital and operational carbon reduction. These include:

- Cost reduction;
- Unlocking innovation and delivering more effective solutions;
- Driving resource efficiency;
- Raises the UK's competitive advantage and export potential; and
- The measures contribute to climate change mitigation.

The rationale for cost efficiency by reducing capital and operational carbon is very clear. The sourcing and processing of resources and their subsequent use in the built environment consumes large amounts of energy. The use of energy is in turn strongly linked to carbon. Using fewer resources will reduce carbon consumption; reduce the energy used in processing and assembly and lower costs.

Carbon emissions associated with infrastructure are shown in the following graphic detailing the proportion of directly controlled carbon emissions and those where the sector influences end user emissions.

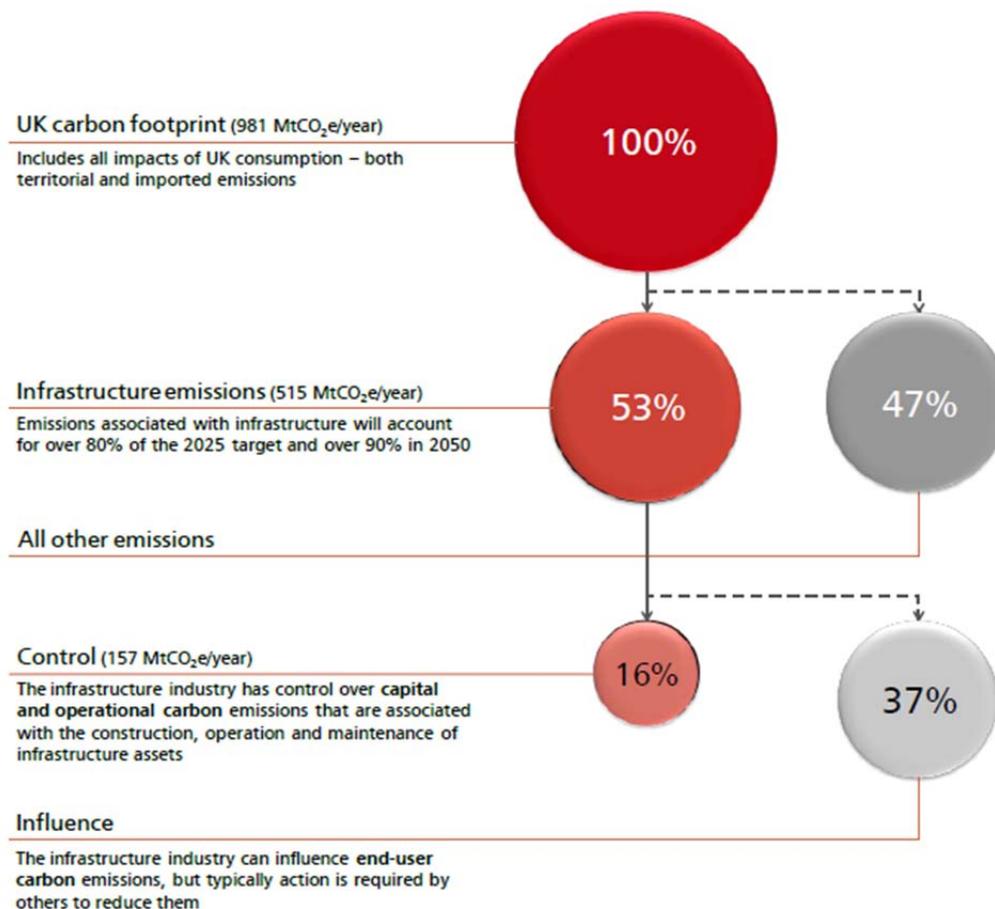


Figure 67: carbon emissions associated with infrastructure. Source: Green Construction Board

The ICR highlights the scale of carbon reduction required in UK infrastructure relative to its legal European objectives and the additional targets set by government. It also highlights the scale of the challenge to achieve these targets particularly in infrastructure where the associated carbon emissions are anticipated to rise relative to the total UK carbon footprint by 2025.

The challenge to meet EU and UK carbon reduction targets by 2025 demonstrates that significant efficiencies have yet to be made and could play a key factor in delivering the GLA infrastructure plan more efficiently.

11.6 Construction 2025

Construction 2025 is a joint government and industry strategy to place the UK at the forefront of the global construction market by 2025, building on the UK's world class expertise in architecture, design and engineering.

By theme, the vision for Construction 2025 is to enable the following²⁴⁸:

- People – an industry that is known for its talented and diverse workforce;

²⁴⁸ *Construction 2025*, BIS, July 2013

- Smart - an industry that is efficient and technologically advanced;
- Sustainable - an industry that leads the world in low-carbon and green construction exports;
- Growth - an industry that drives growth across the entire economy; and
- Leadership - an industry with clear leadership from a Construction Leadership Council.

By achieving this vision the strategy aims to reduce whole life costs, deliver projects and programmes faster, reduce emissions and improve exports for construction products and materials.

The action plan included in the strategy document is in the early stages of development. However, the strategic priorities are identified as follows:

Smart construction and digital design: industry and government will fully commit to the 'Digital Built Britain' agenda with the aim of building on the UK's current market advantage.

Low carbon and sustainable construction: industry and government will develop market and technology based plans to secure jobs and growth by reducing carbon in the built environment. This will be led by the Green Construction Board.

Global trade: industry and government will work together to identify global trade opportunities for UK professional services, contracting and product manufacturing.

11.7 Industry initiatives

A wide range of industry initiatives exist to deliver assets in the built environment more efficiently. These include the use of improved procurement practices, investment in key skills and workers and the use of innovative materials and manufacturing techniques. The following are a small sample of the range of efficiencies that can be realised in London's Infrastructure Plan.

11.7.1 Pipeline

Establishing a long term pipeline of work is fundamental to the efficient delivery of long term projects and programmes. With greater knowledge and certainty of the pipeline clients can engage in more collaborative relationships with the supply chain to achieve mutual benefit. Best practice examples exist in the regulated utilities (Reference @One Alliance case study) and in the rail sector.

Case study: @One Alliance²⁴⁹

Anglian Water provides water and wastewater services to 4.3million customers over a region of approximately 27,500 square km. The organisation is in the fifth generation of its asset management strategy regulated by OFWAT. Anglian Water has adopted a long term collaborative relationship with its supply chain, known as the @One Alliance, to

²⁴⁹ *Infrastructure Cost Review*, [2010], HM Treasury

deliver the challenging efficiency targets demanded by the regulator. This involves developing the supply chain to not only drive procurement savings but to identify new and innovative approaches to product development and efficiency. This strategy contrasts with other approaches in the sector based on risk transferral and a desire to manage contractual risk over a delivery period.

The @One Alliance is targeting 20% in cost efficiencies from its programme during AMP5, reducing embodied carbon by 50% and operational carbon by 20%.

11.7.2 Procurement practice

Early Contractor Involvement (ECI) is a service procured by construction clients to bring expert knowledge of the construction process to their projects or programmes of work. Approaches to ECI vary across clients and industry sectors but all have a common objective to deliver a better value solution to the client. In most cases a first tier contractor provides the ECI service.

Case study: Bank Station Capacity Upgrade

London Underground has developed a new approach to obtain greater value from its supply chain. Innovative Contractor Engagement (ICE) is a new procurement process that aims to obtain greater benefit from main contractors on major design and build projects.

The process is being adopted for the first time on the Bank Station Capacity Upgrade, one of London Underground's largest and most complex projects. Pre-qualified bidders were given LU's project design. Next the bidders went through a confidential review phase to develop new innovative ideas and designs. The goal of this phase was to improve the project's business case, reduce the amount of time taken to deliver the project and the construction's impact, while meeting the project's requirements.

Savings of £61m have already been claimed on the £500m project.

11.7.3 People

The risks associated with skills shortages include higher labour costs above inflation, shortages impacting construction timescales, delay to major projects and unproductive competition between delivery organisations. Focusing on common skill requirements across London's infrastructure needs and providing training and development opportunities and employment will reduce risk and cost during construction, operation and maintenance.

Case study: Crossrail investment in training and development

The Tunnelling and Underground Construction Academy (TUCA) was established in 2011 by Crossrail. The academy was developed and funded by Crossrail to address the shortages of key skills anticipated during the course of the works' programme. The skills developed are also transferrable to other major projects in London including

National Grid's London Cable Power (LCP) project, Thames Tideway and if approved, HS2.

The investment of £13m will be offset by the increased availability of skilled workers to the Crossrail programme.

11.7.4 Manufacturing

Historically there has been scepticism as to the suitability of additive manufacturing for the purpose of construction and engineering, but research in this area is increasingly challenging those boundaries, such as developing applications using concrete as the material.

Case study: Manufacturing and materials innovation

“Additive Manufacturing” refers to a process by which digital 3D design data is used to build up components layer by layer using materials which are available in fine powder form. A range of different metals, plastics and composite materials may be used.

If proven successful, this process has the potential to reduce costs, cut waste and reduce the carbon footprint of the construction sector. Even more importantly, from a design perspective, this approach potentially enables very sophisticated designs to be developed at a much more affordable cost as complex individually designed pieces can be produced more efficiently than traditional methods.

11.8 Conclusions

The programme of investment proposed to cater to London's growing population and to ensure future economic growth is associated with high levels of capital expenditure. The levels of capital expenditure projected for the 2020s represent a step change in investment from current levels. It will be important that infrastructure sector look to achieve cost savings and efficiency in the design, procurement and delivery of London's proposed infrastructure development.

In the public sector, there exists a wide range of initiatives at both central and local government level that seek to deliver more efficient social and economic infrastructure.²⁵⁰ These identified significant opportunities to achieve efficiency through improved understanding of assets in the built environment, efficiency in design, procurement and engineering and in carbon reduction.

A wide range of industry initiatives are also in place to deliver assets in the built environment more efficiently. Technology development and manufacturing improvements will in part be critical. For example, “Additive Manufacturing”, a process by which digital 3D design data is used to build up components layer by

²⁵⁰ The key strategy documents in central government over the last three years include The Infrastructure UK (IUK) Cost Review; The Government Construction Strategy; HM Government Industrial Strategy: Building Information Modelling; the Infrastructure Carbon Review; and Construction 2025. Citations for each of the above-named documents can be found in SECTION of this report.

layer using materials which are available in fine powder form, has the potential to reduce costs, cut waste and reduce the carbon footprint of the construction sector. Perhaps more importantly, this approach potentially enables very sophisticated designs to be developed at a much more affordable cost as complex individually designed pieces can be produced more efficiently than traditional methods.

Encouraging skills development and labour supply also will be critical. The risks associated with skills shortages include higher labour costs above inflation, shortages impacting construction timescales, delay to major projects and unproductive competition between delivery organisations. Focusing on common skill requirements across London's infrastructure needs and providing training and development opportunities and employment will reduce risk and cost during construction, operation and maintenance. For example, the Tunnelling and Underground Construction Academy (TUCA) was established in 2011 by Crossrail to address the shortages of key skills anticipated during the course of the works' programme. The skills developed are also transferrable to other major projects in London including National Grid's London Cable Power (LCP) project, Thames Tideway and if approved, HS2.

Based on this analysis we believe that it is reasonable to anticipate that the cost of the infrastructure plan to 2050 could be reduced by between 10-15% through:

- Improved strategic planning and decision making focused on London's needs;
- Improved knowledge and understanding of London's assets and the creation of longer term, sustainable pipelines of work for new build, renewals, operation and maintenance activities;
- Efficiency in the design, procurement and delivery of projects and programmes of work;
- Strategic planning for future skill and employment opportunities;
- Advances in digital technology;
- Advances in manufacturing and sustainable materials; and
- Reducing the quantity and cost of carbon in the built environment

12 Closing the funding gap: potential additional sources of revenue

In chapter 10, we highlighted the fact that limited fiscal devolution of property taxes²⁵¹ may provide one means by which to help pay for infrastructure investment in addition to the efficiencies discussed in chapter 11. In this section we consider a slightly broader range of sources that could in theory be used. These are shown in Figure 68.

The table provides an illustrative estimate of the level of income each source could theoretically generate during the period of the plan.²⁵² It does not consider financial structuring implications, the potential impact on London's competitiveness or willingness/capacity to pay. We discuss each option in more detail below.

Potential additional source	Amount (£bn, 2014 prices, undiscounted)
Business Rate Supplement	3
Council Tax Supplement	2
London income tax share	33
South East income tax share (excluding London)	23
Motoring duty	48
Hotel tax	6
TfL fares increase	79
User charging (new roads)	Project specific
Property development	Project specific
Sponsorship and third party contributions	Project specific

Figure 68: Potential sources of revenue indicative amounts (£ billion). Source: Arup analysis

²⁵¹ Council tax, business rates, stamp duty land tax, annual tax on enveloped dwellings and capital gains property disposal tax.

²⁵² Note as we discuss, in a number of cases this is not for the full thirty five year period 2016-2050.

12.1 Business Rate Supplement

In April 2010, the Mayor introduced a Business Rate Supplement (BRS) of two pence in the rateable pound on non-domestic properties with a rateable value (broadly the open market rental value at the valuation date) of over £55,000. This is for properties on the rating lists of London's 33 billing authorities. This is to pay for a proportion of the costs of Crossrail 1. The GLA expects the Crossrail BRS will run for a period of between 24 and 31 years until its £3.5 billion of borrowing is repaid, with a latest target end date of 2037-38.

Under the current regulations a BRS supplement additional to the Crossrail BRS could not be levied as this would exceed the maximum permitted 'multiplier' of two pence. However, after the Crossrail 1 BRS end date, the BRS scheme could be extended (subject to fulfilling the requirements of the 2009 Business Rate Supplements Act) to invest in additional projects aimed at promoting economic development.

As has been achieved with the Crossrail BRS, this BRS would provide a predictable revenue stream to borrow against and deliver the required investment. In 2012-13 the net income from the Crossrail BRS after collection costs, was £225 million (2011-12: £232 million). This is forecast to rise to £413 million in 2037 (nominal terms) driven in part through volume growth and expected increases in commercial property rents. Carrying forward the Crossrail BRS assumptions for a further thirteen years could raise approximately £3 billion (2014 prices) by 2050.

12.2 Council Tax Supplement

In 2003, the Mayor committed to raise up to £625 million from London council taxpayers as a contribution to the public sector funding package for the 2012 Olympic Games and Paralympic Games over the eleven year period 2006-07 to 2016-17. The £625 million is raised by a nominal Band D precept amount of £20 (38p a week) for 10 years and approximately £9 in 2016-17 which results in income of around £61 million per annum.

If such a precept was continued in order to pay for necessary infrastructure requirements, assuming the precept rises with inflation, this could raise approximately £2 billion (2014 prices) over the study period from 2017 onwards.

12.3 Payroll tax

12.3.1 London income tax share

A cost neutral measure for London employees would be to devolve a portion of the income tax collected nationally, based on the number of employees working within London. Using data from government "Income Tax statistics and distributions" (GLA Economics) we used simplifying assumptions²⁵³ to assess a level of income tax London currently contributes. This results in approximately £40 billion of income tax per annum and is broadly in line with recent work carried out by Oxford Economics for the City of London (£33 billion on a

²⁵³ Including projected employment growth and average income by tax band and current income tax arrangements.

workplace basis in 2009/10)²⁵⁴. A share set at 2% of the current marginal band (i.e. 0.4% out of the 20% basic rate, 0.8% out of the 40% higher rate and 0.9% out of the 45% higher rate) could raise approximately £33 billion (2014 prices) over the study period.

12.3.2 Regional income tax share

Devolution of a portion from the wider south east region to pay for required infrastructure where the benefits extend beyond the boundaries of London could also be explored. Using the same approach to above, the South East contributes a marginally lower level of income tax than London of approximately £25 billion per annum and could raise approximately £23 billion in real terms (2014 prices) over the study period.

12.4 Motoring taxes

Taxes on motoring are broadly made up of two elements: vehicle excise duty (VED) – a tax on ownership (linked either to engine size or CO₂ emissions); and fuel duty – a tax on use. For motor vehicles registered since 2001 the VED system has become increasingly geared towards the carbon dioxide emission rating of the vehicle whereas previously it was linked to engine size. Since 1937 these motoring taxes have been a general revenue raising mechanism with proceeds not hypothecated to road construction or maintenance. In nominal terms, receipts from both VED and fuel duty have been rising since 1987. However, in real terms, VED and fuel duty receipts have been steadily falling since the late nineties²⁵⁵ although they have plateaued in the last few years.²⁵⁶ In 2012 for the UK as a whole, they brought in to the Treasury a total of £5.9bn and £26.7bn respectively.²⁵⁷

One option for funding Roads Task Force investment of close to £1.5bn per annum would be to devolve setting and collection of VED in London, which could be replaced with a duty based on motorised vehicle kilometres. TfL reported that in 2012 there were approximately 29bn motorised vehicle kilometres travelled in London. London represents around 8% of licensed vehicles in Great Britain and a levy of close to two pence per motorised vehicle kilometre would result in income to London that is revenue neutral with the current contribution to VED at close to £0.5bn per annum.

Taking a share of fuel duty raised in London could also be a consideration. The current duty rate for unleaded petrol, diesel, biodiesel and bioethanol is £0.5795 per litre. In 2012, according to figures from DECC, Greater London road transport consumed 2,126 kt of fuel out of 33,339 kt nationally. Using high level assumptions that equate consumption with share, London could have earned a contribution in 2012 of around £1.7bn (2014 prices).

²⁵⁴ *London's Competitive Place in the UK and Global Economies*, Oxford Economics, page 86

²⁵⁵ RAC Foundation *Fuel for Thought: the what why and how of motoring taxation*, page 46

²⁵⁶ Transport expenditure statistics, produced by the Department for Transport (Table TSG1310)

²⁵⁷ *ibid*

Assuming that such contributions remain flat in nominal terms (as a function of falling consumption and increasing charges), control of these revenue streams could raise approximately £11 billion and £37 billion in real terms (2014 prices) over the study period. Higher rates have the potential to generate more revenue. A distance based charge could help to achieve broader policy objectives associated with the environment and congestion reduction. However, there are clearly challenges in identifying a 'fair' share in relation to these duties and dealing with the fact that both vehicle mileage and hydrocarbon fuel consumption have been falling in London.

12.5 Hotel tax

A number of major international cities have supported the proposal for some form of tax on tourists. Often referred to as a hotel tax, bed tax or tourism tax, schemes are already in place in a number of cities such as Rome, Milan, Venice, Hamburg, Zurich, Barcelona, New York and Vancouver. Other cities are actively promoting schemes, such as Dubai which is looking to use it to fund projects for the 2020 World Expo convention.

No schemes are currently in place in the UK although a number of cities have considered their implementation. The most notable example is Edinburgh where councillors initially voted in favour of its introduction only for it to be scrapped due to a lack of support from the Scottish government and local stakeholders.

Hotel taxes can be structured in different ways. These include the method of charging (e.g. sliding scale by accommodation type, sliding scale by room charge or percentage of room charge), exemption schemes and how the tax is collected.

If such a scheme were created in London, we estimate it could raise approximately £6 billion (2014 prices) over the study period.

If it was decided to take such a scheme forward, a full appraisal would need to be conducted. A conclusion by Sir Michael Lyons in his 2007 report was that "accommodation taxes have been deployed in a number of places around the world, with varying degrees of success. It is clearly important to weigh the contribution that tourists make to the local economy against the costs they impose and the likely impact on the tourist industry of any taxation proposal".²⁵⁸

12.6 TfL fares

The TfL farebox represents a significant source of revenue. At around £22bn for each five year period, it currently offsets around half of TfL's total transport costs (capex and opex). If we exclude certain capital investment schemes such as Crossrail, this figure would be higher. TfL is due to make an operating surplus by 2020. Our funding analysis, presented earlier and developed with the GLA, is based on a growing farebox revenue – caused by increased ridership on the

²⁵⁸ Sir Michael Lyons, *Place-shaping: a shared ambition for the future of local government*, March 2007

existing system, and new farepayers on new services, calculated on a mode-by-mode basis, and projected forwards at historical growth rates.²⁵⁹

Notwithstanding the broader policy considerations of fares rises, in principle, real term increases could make a significant contribution towards the additional costs of infrastructure. We have modelled a scenario with a hypothetical fare rise across London's transport system (Underground, rail, DLR, Tramlink, buses and other systems) of a further 1% above the scenario adopted in our underlying analysis.²⁶⁰

Using an elasticity of -0.1,²⁶¹ we have included this for every year of the study period beyond 2015. As can be seen from Figure 69, by the end of the study period in 2050, London's annual farebox would be around 37% higher (£4.7 billion per annum) in real terms compared to our base case. Taken over the entire period, this constitutes a significant increase in revenue of some £79 billion (2014 prices).

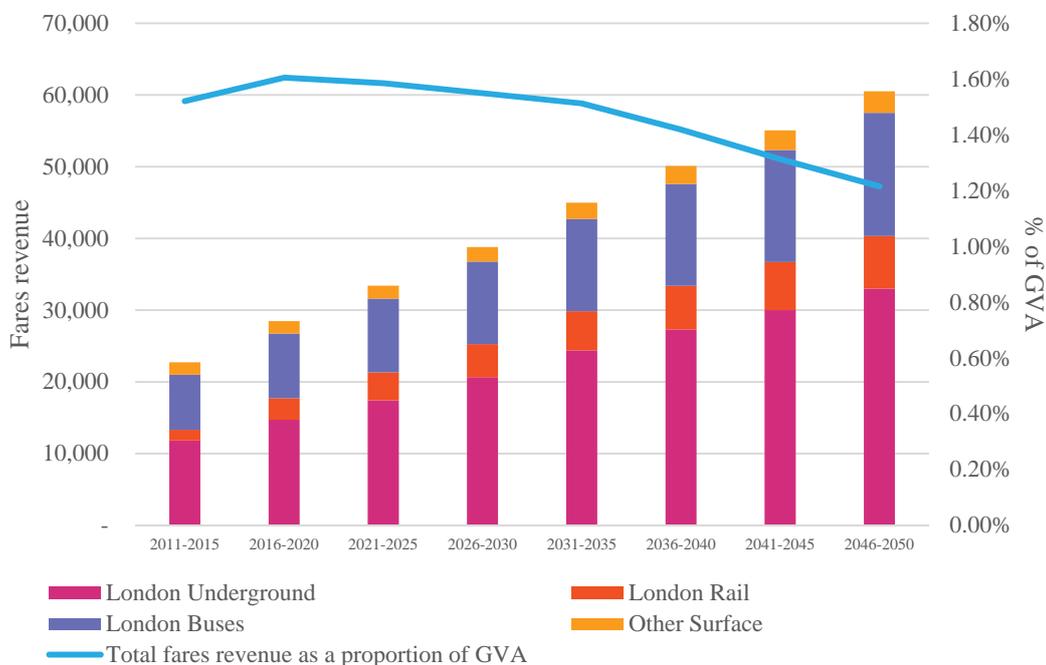


Figure 69: Projected TfL fare revenue by service assuming 1% real increase in tariffs per annum (2014 prices) and fare revenue as a proportion of London GVA (growth of 3.5% p.a.). Source: Arup analysis.

It is important to note that public transport fares rises may also have undesirable consequences. They are likely – at the margin – to increase the use of some other modes. Public transport fares rises may also have to be carefully thought through so as not to create unacceptable social equity issues.

²⁵⁹ For more details see appendix A4

²⁶⁰ In our central scenario, fares remain constant in real terms from 2015 to 2033. From 2034, total fares revenue is dampened' by 1% per annum (before any notional adjustment for RPI).

²⁶¹ This means that for every one-percent increase in fares, there would be a 0.1% decrease in ridership. The farebox would therefore grow by 0.9% per annum. This is no more than an indicative estimate used for illustrative purposes. In reality elasticities will vary significantly from one mode to the next.

12.7 User charging on new road schemes

The Roads Task Force and a Department for Transport consultation in 2013 suggested building a new lower Thames Crossing. Whilst the options for these are still being determined, the scheme with the highest benefit to cost ratio has a cost of between £1.2bn and £1.6bn. Proposals have been put forward for both the new crossing and the existing Blackwall tunnel to be tolled.²⁶² Whilst user charging of river crossings is a tested means by which to raise revenue to pay for infrastructure, they have sometimes proven unpopular with motorists unless they can see real benefits associated with their introduction.

12.8 Property development

12.8.1 Land and assets owned by public sector

Substantial amounts of land and buildings are owned by the public sector in London. By efficiently managing these assets, the public sector can contribute to reducing the funding gap or delivering infrastructure in a number of ways. These include:

- maximising the use of existing assets;
- increasing commercial opportunities; and
- selling vacant land parcels and surplus assets.

To get the most from these high-value assets, they would arguably need to be put to use with a view to maximising the contribution they could generate towards paying for infrastructure associated with their development or closing the wider funding gap.

The Mayor is currently one of the largest owners of public land in London having assumed responsibility for 670 hectares of land in 2012 as a result of the Localism Act. The Mayor is committed to having a plan for all surplus land by end of his term. For example, the Mayor, with commercial partners, is developing GLA owned land at Royal Docks in Newham into housing and mixed-use commercial and retail developments.

In relation to operational assets (e.g. transport infrastructure and London borough owned housing stock), a balance is required between maintenance, upgrade/renewal and operational activity so as to enhance performance whilst at the same time minimising unnecessary investment. In housing, for example, there may be opportunities to reclaim, renew and renovate existing vacant properties at better value building properties.

A co-ordinated approach to asset management (existing and new) and land use across London public sector organisations is seen as a key requirement in developing proposals for the delivery of infrastructure in the long-term.

²⁶² <https://consultations.tfl.gov.uk/rivercrossings/30f81277>.

12.8.2 Land owned by private sector

12.8.2.1 Developers

Beneficiaries from investment in infrastructure can include property owners and developers who see land and property values rise as a result of investment in infrastructure.

London First noted that developer contributions under the Community Infrastructure Levy (CIL) and Section 106 are currently generating around £40 million annually towards Crossrail 1 and are expected to be contributing around £100 million a year by 2020.²⁶³ Development resulting from infrastructure investment is also likely to lead to increases in the council tax and business rates tax base, although stamp duty when property changes hands is currently recouped by Treasury.

CIL is less predictable than, say, a Business Rate Supplement as it is predicated on levels and types of development taking place at any time, but could still provide an important source of infrastructure funding. Developer contributions are also a key source of funding for the Northern Line Extension on the Battersea Power Station site and the wider Vauxhall Nine Elms Battersea Opportunity Area.

In addition, London First's report noted that intensification of development could lead to an increase in CIL receipts as well as council taxes and business rates where significant development is permitted, for example, near and above new stations.

12.8.2.2 Businesses / homeowners

London would clearly also benefit from devolution of the suite of property taxes. With access to its own tax base, the income generated from rising London property prices, including resulting from investment in infrastructure, could be used to address the shortage of both affordable and market housing homes. In addition, it could have the freedom to restructure council tax and stamp duty to increase efficiency and transparency in its implementation. Even if full devolution was not considered, there is scope for restructuring these taxes to allow for a proportion to be retained locally. For example, one option could be an 'earmarked sellers' stamp duty whereby a portion of income is captured locally from the uplift in value of properties resulting from investment in new railway stations.

It will be important, on a project by project basis, to identify opportunities to capture appropriately value uplift from public investment and to maximise consequential development to reduce the impact on the public purse. Key challenges to be addressed, however, will include the extent to which the impact of interventions could have on future developments.

12.9 Third party contributions and sponsorship

Third party contributions towards infrastructure schemes – both public and private sector - are increasingly being explored, in particular where clear benefits to the contributor have been identified and articulated (additional to developer

²⁶³ *Funding Crossrail 2*, London First Crossrail 2 Task Force, February 2014

contributions). A recent report by London First exploring options for funding Crossrail 2 suggested a major source of funding (£2 billion or 11% of scheme costs) could come from Network Rail because of the additional capacity Crossrail 2 will provide, reducing the requirement for increasing capacity on existing lines into Waterloo. This principle could be extended to a range of new schemes.

Co-ordinating investment and ensuring that all beneficiaries make a fair contribution (reflective in part of their avoided costs) is one way to make investment happen. In addition, the Crossrail 1 funding package contained contributions from a number of direct beneficiaries of the new line including the City of London Corporation (£250 million) and BAA/Heathrow (£230 million), representing 3% of the £14.8 billion cost estimates in 2010 (4% when factoring in voluntary funding from other London businesses).²⁶⁴ Canary Wharf Group contributed £150 million towards the construction of the Crossrail station at Canary Wharf (c. 30%) and Berkeley Homes contributed towards the construction of the Crossrail station at Woolwich.

A less commonplace route to securing perhaps more modest third party funding is the use of sponsorship deals. TfL has some experience of this for new infrastructure investment. In 2010 Barclays Bank signed up to a £50 million five year deal for naming rights to the Mayor's bicycle hire scheme and in 2011 Emirates signed up to a £36 million ten year deal for naming rights to the Thames cable car (Emirates Airline) as well as termini at Greenwich Peninsula and Royal Docks.²⁶⁵

There may, therefore, be opportunities to take advantage of sponsorship of both new and existing infrastructure (stations, signs, vehicles, lines, supporting infrastructure, etc.) where it is highly visible to a wide range of consumers and uniquely attractive to particular parties. TfL is exploring a broad range of commercial opportunities and the Business Plan does include large increases in assumed commercial income.

Any project taken into development should consider how best to maximise income from third party contributions by identifying, articulating and valuing the benefits and then putting in place a mechanism to capture the contribution and to ensure a good deal is struck for the public sector. Any sponsorship plans should not be undertaken without detailed consultation of such a strategy objectively setting out the benefits (e.g. keeping fares down or providing new infrastructure) and the costs (e.g. direct costs such as printing maps and recording station announcements as well as indirect costs such as public acceptability, branding and reputational risk).

²⁶⁴ <http://www.crossrail.co.uk/about-us/funding>

²⁶⁵ There are further examples in the UK where smaller stations on Network Rail infrastructure have been sponsored by local universities and businesses, in particular where large businesses are headquartered. Generally this relates to station sign sponsorship rather than whole station branding, e.g. Vodafone at Newbury, Capital One and the University of Nottingham at Nottingham, AXA Winterthur at Basingstoke and Aviva at Norwich.

12.10 Conclusions

There is considerable potential for London to raise the capital required to support infrastructure development. We have considered a range of new funding sources, ranging from the traditional to the more radical. Of the seven sources considered that are not project specific, we have identified potential revenues ranging from £3 billion to some £80 billion over the study period. For example, a cost neutral measure for employees would be to devolve a portion of the income tax collected nationally, based on the number of employees working within London. It is estimated that such devolution could generate £33 billion of revenues during the study period.²⁶⁶

These projections have not included potential additional revenue from devolved property taxes. As noted in chapter 10, a 2.5% per annum real increase in property tax revenue would equate approximately to an extra £78 billion of income (on an undiscounted basis).

The potential revenues identified should be considered separately and on an indicative basis. Competing demands for scarce resources would dictate that only some portion of future revenues, whether from property taxes or other sources, be available for infrastructure development. Moreover, changing London government's fiscal powers would be likely to have dynamic effects on the revenues generated by individual mechanisms, and there is uncertainty around the projections made. There is similar uncertainty around the composition of London government's overall income, which could change with the introduction of new taxes and other sources of revenue.

This discussion of revenue potential has not accounted for the profile of investment across the different infrastructure sectors the GLA is considering. Additional analysis would be required in order to understand the relationship between the investment programme and potential funding sources. In addition, future analysis would need to address the debt profile and financing costs associated with different investment proposals.²⁶⁷ It is likely that such considerations would need to be addressed to achieve support for new revenue mechanisms. Most of the fiscal powers discussed in this chapter would require some form of central government support.

There is considerable potential in devolved revenue sources. A more local approach to funding infrastructure development could help to foster a virtuous cycle of efficient investment, growth and accountability, more effectively structuring incentives and decision-making. As the London Finance Commission (LFC) has identified, localised fiscal powers could level the playing field with other international cities that have greater control of local revenues and spending. There is no reason these funding mechanisms could not be used by other British cities, supporting existing initiatives such as City Deals, Community Budgets and efforts to increase the involvement of Local Enterprise Partnerships (LEPs) in spending decisions.

²⁶⁶ 2014 prices.

²⁶⁷ As we have discussed, debt costs have not been included in our funding gap projections.

A1 Introduction to Arup's approach

A1.1 Cost projections

For the purpose of assessing the cost of London's infrastructure requirements to 2050, Arup has established a cost model (the Model) which compiles inputs and calculations for each of seven infrastructure sectors:

- Housing infrastructure;
- Transport infrastructure;
- Energy infrastructure;
- Schools infrastructure; Water infrastructure;
- Waste infrastructure;
- Green infrastructure; and
- Digital connectivity infrastructure.

This work has been conducted working with members of the GLA infrastructure investment plan team and sector-specific specialists working for the GLA and other parts of London government. Our work is intended to provide an early indication of possible costs associated with the potential investments in different infrastructure. Our projections, unless otherwise stated, relate to the costs associated with investment occurring within both the public and private sectors.

High-level parameters, including the Mayor's own policy objectives, have framed the type and quantum of infrastructure required for each sector. Our approach to modelling has varied for each sector, reflecting differences in regulation, ownership and control and GLA requirement (in order to inform the investment plan), as well as information available.

Infrastructure typically is considered as an enabler of growth. Its development is correlated strongly with population growth and economic expansion. Working with the GLA, it has been assumed that projected population growth is the primary driver of infrastructure requirements across the majority of sectors. As we discuss below, it has been assumed that, with such long-term investment, London's economy will grow at a rate outpacing historical levels.

As the GLA refines its understanding of different policy objectives and investment requirements, these indicative costs will change. Our projections are reported on an 'order of magnitude' basis and are not presented for reliance by the GLA, funders or potential investors.

A1.2 Funding 'gap' and revenue projections

In order to inform an understanding of future funding requirements, the GLA requested that Arup provide a preliminary indication of the "gap" between projected costs and revenues. Informed by on-going discussion with the GLA, its advisory group and other stakeholders, our analysis has varied across the different sectors considered. Given variation in our approach and some of the assumptions

made, the gap estimated is intended for indicative purposes and should not be considered complete, as we discuss below.

We have focused upon the transport and housing sectors in particular detail, as these two sectors represent the large majority of projected capital expenditure over the study period and are likely to be funded in part by local government. Our approach has been to provide an indicative estimate of the gap between projected expenditure requirements and projected revenues from taxes, grants, borrowing²⁶⁸ and other such sources. User charges, particularly in the utilities sectors, are likely to fund a significant portion of both operating and capital expenses. Because of this, we have agreed with the GLA to focus on the potential impact of projected expenditure on bills for those sectors. For the remaining sectors, we have assumed that projected costs at present are 'unfunded', as we discuss in chapter 10 of this report.

A1.3 Cost model

The Model consolidates different modelling approaches, which have been built in conjunction with each individual sector work stream. Sector-specific modelling sits 'behind' the cost model for those sectors where additional supply and demand considerations have been reviewed and projected. The transport, energy and water sectors each relate to independent sub-models that are active in the assumptions section of the associated Microsoft Excel file.

The Model includes four sections:

- **Inputs (In_)**, which consolidates hard-coded and variable inputs to the model as a whole and each infrastructure sector. Variable inputs are intended to enable the GLA leads to address questions around supply and demand factors raised in the course of this engagement. Inputs that are variable have been colour-coded [Blue on Light Yellow](#) ;
- **Calcs (C_)**, where calculations take place for each sector, broken down as one sector per sheet;
- **Results (R_)**, which consolidates and summarizes outputs from the calculation sheets; and
- **Assumptions**, which contains any 'sub-models' of supply and demand factors or further calculation steps that are particularly complex or relate to a time basis inconsistent with the cost model; and which references documents and analysis used as source to certain inputs.

The model incorporates flexibility around different scenarios. As stated in section 1 of this annex, we have included population growth as the basis for three scenarios (central; high; low) informing each of the infrastructure sectors.

²⁶⁸ Please note that it was agreed with the GLA that borrowing potential should be carried forward as a source of revenue but that debt servicing costs should not be included in our projections. This makes it likely that our estimate of the gap between costs and revenues is conservative, below the amount likely to be required in order to meet expenditure requirements and debt servicing costs.

Further to this, certain sectors also rely upon a number of sub-scenarios which can be chosen in a similar manner; these represent a variety of situations and are explained in each sector section. The outputs sheet (R_Summary) includes a summary of all selected scenarios (and selection drop-downs) so as to provide a reminder of what scenarios are being modelled and have consequently provided the outputs shown.

A1.4 Five-year reporting periods

In order to avoid spurious accuracy we have considered project delivery in five-year periods for each of the sectors. This approach is intended to reflect the fact that projects often 'slip' (forward or backward). Each period in the model refers to the five years *prior to and including* that year. For example, the period '2015' refers to the years 2011-2015 (inclusive), and the period '2050' refers to the years 2046 to 2050 (inclusive).

It is therefore important to distinguish figures stated as *per annum (pa)* and *per (five-year) period (pp)*. Each sector calculation sheet contains a summary per annum and per period.

A1.5 Baseline costs

Arup has set the period 2015 (2011-2015) as the baseline against which we then compare projected costs. This cost baseline is presented through best efforts as an indication of sector capital and operating expenses. Historical costs have been derived from public accounts, other reporting statements, third-party reports and parliamentary questions. We have referred to outturn costs wherever possible. Where these costs are not available, there is some visibility of investments in the remainder of 2014 and in 2015. In some cases, where information is more limited, the baseline has been calculated using our own cost assumptions in relation to known infrastructure delivery. Please refer to individual sector chapters or the Model for additional detail.

A1.6 Important notice

We have used a wide range of data and sources in completing this report. We have noted these sources throughout the document and, in relation to primary assumptions, in this appendix. Underlying inputs, including population forecasts, GVA forecasts and demographic trend forecasts, have been provided by the GLA and/or GLA Intelligence. Our analysis of transport infrastructure costs relies on inputs provided by Transport for London (TfL). We have supplemented data where relevant through independent research and our own industry knowledge.

The costs presented by Arup are indicative projections only. The projections and conclusions set out within this report are dependent upon the validity of the assumptions and the data upon which they are based. Actual costs will be different from the projections shown, because events and circumstances frequently do not occur as expected. The difference between actual costs and our projections may be significant and material. The results shown in this report are for informational purposes only and are not intended to inform investment decisions, whether by the GLA, London government, national government or other public or private

investors. We accept no responsibility for the realisation of projected demand, projected costs or associated prospective financial results.

We explicitly do not permit circulation and/or reliance upon any of our reports or other deliverables, including but not limited to Arup's cost model, to/by retail investors, and we will not accept any extension of responsibility and/or liability to retail investors and you agree to expressly indemnify Arup against any such liability arising from such risk.

Ove Arup & Partners

July 2014

A2 Overarching inputs and assumptions

Overarching inputs and assumptions to the Model are found in two locations:

- in the 'General Settings' section of the main inputs sheet (In_Main) for scenario and inflation picks and employment and visitor numbers assumptions; and
- in the 'In_Macro' sheet for macro-economic assumptions, such as population, GVA, and inflation.

Primary overarching inputs and assumptions are set out below.

A2.1 Geographic areas

The Nomenclature of Units for Territorial Statistics (NUTS) is a hierarchical classification of administrative areas, used across the European Union for statistical purposes. London is one of 12 NUTS 1 areas in the UK. Inner and Outer London are 'NUTS 2' areas within 'London'.²⁶⁹

Inner London is defined as including the following western and eastern authorities: of Camden, City of London, Hammersmith and Fulham, Kensington and Chelsea, Wandsworth and Westminster ('West'); Hackney, Haringey, Islington, Lambeth, Newham, Southwark, Lewisham and Tower Hamlets ('East').

Outer London is defined as including authorities in three geographical areas: Barking and Dagenham, Bexley, Enfield, Greenwich, Havering, Redbridge and Waltham Forest ('East and North East'); Bromley, Croydon, Kingston upon Thames, Merton, Sutton ('South'); Barnet, Brent, Ealing, Harrow, Hillingdon, Hounslow, Richmond upon Thames ('West and North West').

A2.2 Population, demographics, employment and visitor number projections

We set out the total population according to the low, central and high cases in the below. The central population case forms the basis of this work and, in the model, is selected by default.

Population	2010	2015	2020	2025	2030
Low case					
Inner London	3,202,892	3,432,879	3,580,782	3,667,963	3,745,860
Greater London	4,904,182	5,236,869	5,490,521	5,673,665	5,825,316
Total	8,107,073	8,669,748	9,071,303	9,341,628	9,571,176
Central case					
Inner London	3,202,892	3,432,879	3,604,286	3,723,550	3,827,520
Greater London	4,904,182	5,236,869	5,523,280	5,756,814	5,954,635
Total	8,107,073	8,669,748	9,127,567	9,480,364	9,782,155
High case					
Inner London	3,202,892	3,432,879	3,627,876	3,779,792	3,910,700

²⁶⁹ Office for National Statistics, *NUTS: London Directory*, available: <http://www.ons.gov.uk/ons/guide-method/geography/beginner-s-guide/eurostat/london/index.html>.

Greater London	4,904,182	5,236,869	5,556,171	5,840,998	6,086,520
Total	8,107,073	8,669,748	9,184,047	9,620,790	9,997,220

Figure 70: Historical and forecast population, GLA area, 2010-2030. Each figure shown represents the forecast total population in the given year. Source: various GLA documents, as described in this chapter

Population	2035	2040	2045	2050
Low case				
Inner London	3,825,556	3,899,374	3,970,225	4,041,075
Greater London	5,958,143	6,077,520	5,771,461	5,465,401
Total	9,783,699	9,976,895	9,741,685	9,506,476
Central case				
Inner London	3,929,294	4,021,977	4,396,079	4,770,182
Greater London	6,129,345	6,285,895	6,393,033	6,500,172
Total	10,058,639	10,307,871	10,789,113	11,270,354
High case				
Inner London	4,035,558	4,148,174	4,896,836	5,645,498
Greater London	6,305,072	6,501,027	7,121,738	7,742,448
Total	10,340,630	10,649,201	12,018,573	13,387,946

Figure 71: Historical and forecast population, GLA area, 2035-2050. Each figure shown represents the forecast total population in the given year. Source: various GLA documents, as described in this chapter

Population forecasts are provided by the GLA until 2041.²⁷⁰ The GLA also has provided estimates of the total population forecast in 2050.²⁷¹ In order to estimate the population forecast in the 2045 period, we have taken the average of the population forecasts in 2040 and in 2050.

An estimate of the distribution of the forecast population, split between Inner London and Outer London, was provided for the central scenario by the GLA. We have assumed that the distribution between Inner and Outer London is the same in the low and high scenarios as in the central scenario.

The GLA has provided demographic projections according to Inner and Outer London areas. Age mix assumptions have been included from 2015 according to the two different population forecasts used. These are set out in the table below.

% population	2015	2020	2025	2030	2035	2040	2045	2050
Inner London								
Age 4-10	8.01%	8.09%	7.87%	7.55%	7.27%	7.12%	7.16%	7.20%
Age 11-16	5.46%	5.61%	5.86%	5.80%	5.59%	5.38%	5.36%	5.34%
Age 17-18	1.93%	1.78%	1.91%	1.96%	1.93%	1.86%	1.82%	1.78%
Outer London								
Age 4-10	9.43%	9.62%	9.23%	8.74%	8.38%	8.22%	8.25%	8.28%
Age 11-16	6.72%	7.20%	7.59%	7.47%	7.11%	6.82%	6.74%	6.66%

²⁷⁰ Mayor of London, GLA 2013 round population and household projections, March 2014, available: <http://data.london.gov.uk/datastore/package/gla-2013-round-population-and-household-projections>.

²⁷¹ GLA Intelligence, Population And Employment Projections to Support the IIP (update), November 2013.

Age 17-18	2.36%	2.14%	2.42%	2.49%	2.42%	2.32%	2.26%	2.20%
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Figure 72: Percentage of projected population represented by each age group, by area.
Source: various GLA documents, as described in this chapter

The GLA also has provided employment and visitor number projections. Employment has been assumed to grow at a rate of 3.19% per period, from a starting number of workers of 4,900,000 in 2010. Visitor numbers have been assumed to start at 13,893,926 in 2010 and grow at 3.90% per annum. These figures are presented for reference, especially in relation to transport infrastructure, and have not been included as the basis of modelled costs.

A2.3 Gross Value Added (GVA) projections

The Office of National Statistics reported London's GVA to be some £309 million in 2012 (2012 prices).²⁷² London GVA has been assumed to be some £325 billion per year in 2015 and grow at a rate of 3.5% per annum (real) throughout the period. The rate of growth presented outpaces levels seen in the economy historically and has been agreed as an input with the GLA and its infrastructure investment plan oversight group.

GVA is used only to provide ratios of expenditure as a portion of GVA, rather than as a driver to any of the expenditure calculations. Please note that GVA is stated and calculated in real terms.

A2.4 Indexation

Price inputs to the Model are stated in Q1 2014 prices. The Model currently assumes, for all sectors, that construction inflation is applied to capital expenditure. These are compounded for the correct number of years in a period, and correspond to the years 2017, 2022, 2027, 2032, 2037, 2042 and 2047 to provide a mid-point position to each period. We use this midpoint to avoid applying compounded five-yearly inflation to the entirety of a period.

The Model incorporates functionality to apply inflation from 2014 in three different ways:

1. Un-indexed: no real growth or general price inflation is applied at any stage.
2. Nominal: real growth and general price inflation is applied to costs.
3. 'Real'/Construction Inflation (non-RPI inflation): only real growth above (or below) general price inflation is applied. In the case of capital investment, we have increased values by 2% per annum on an underlying basis.

A2.5 Limitations and uncertainties

As with any model, there are a number of limitations to be borne in mind in relation to our overall approach.

²⁷² Office of National Statistics via London datastore, Regional Gross Value Added, December 2013, available: <http://data.london.gov.uk/datastore/package/regional-gross-value-added>.

We have endeavoured to provide a meaningful sense of historical costs in each of the sectors, using publicly available information. Nevertheless, historical cost information is limited for certain sectors. The 2015 base position is in some cases based upon a “best estimate” of historical costs according to available data, rather than known total cost.

Where stated, inflation has been applied as it would at the year two out of five point (as described in the above sub-section), rather than yearly. With this comes a loss of granularity which we have deemed acceptable for the purpose of what the model is seeking to achieve.

The transport, energy, and water sectors draw from sub-models that contain some hard-coded data based on Arup analysis and knowledge; the sub-models have to be consulted to understand these assumptions.

Our inputs are sourced as they are referenced and in some cases provided by the GLA. We have not sought to independently verify their accuracy. The Model includes some sources for reference; however it is the supporting notes from each sector which takes precedence and provides best referencing.

A2.6 Possible next steps

The model operates a number of scenarios over and above the population scenarios. These can be toggled in conjunction with one another to understand the impact of different scenarios on the bottom line result; furthermore, the GLA might want to review some of the inputs and assumptions used in the model and run sensitivity analyses on key inputs, such as population, employment growth, GVA or inflation.

A3 Housing infrastructure cost modelling

A3.1 Approach

The infrastructure plan has set out a requirement to meet the requirements identified in the *Further Alterations to the London Plan*. These projected requirements have informed two scenarios for cost projection, the “SHMA scenario” and the “*London Plan* scenario”, as described in section 1.13.1 of this report. These scenarios identify a requirement of some 48,840 dwellings or some 42,000 dwellings, respectively, to be built per annum up to 2050 to meet the backlog of housing needs and to cater for future growth.

Based on this requirement Arup profiled the number of houses to be delivered per annum. The methodology used to establish the social housing requirement:

- Split market and affordable housing requirements according to the mix of unit types;
- Apply cost per dwelling to the various mix of housing types to provide capital costs;
- Establish land costs as a share of total costs;
- Identify and project land remediation costs; and
- Model operational and maintenance costs for housing using benchmark data over the period.

A3.2 Affordable housing and unit type mix

Projected housing requirements include a mix of market rate and affordable housing. In the *London Plan*, 40% of projected housing is assumed to be affordable, whilst the SHMA identifies a requirement for approximately half of all units to be affordable (48%).

The figure below and overleaf details housing mix assumptions used in the cost model and provides a list of sources. These assumptions have been reviewed with the GLA.

Theme	Assumption	Source
Housing mix (Market rate - SHMA)	1 bed: 18%	Mayor of London, The 2013 London Strategic Housing Market Assessment, 2014.
	2 bed: 64%	
	3 bed: 67%	
	4 bed: 57%	
	5 bed: 57%	
Housing mix (Market rate –	All unit types: 60%	Mayor of London’s <i>Further Alterations to the London Plan</i> , as described by the

<i>London Plan</i>)	Greater London Authority
	1 bed: 34%
	2 bed: 19%
Housing mix (type)	3 bed: 26%
	4 bed: 15%
	5 bed: 7%

Figure 73: Housing mix assumptions and sources used in Arup's analysis

A3.3 Unit size assumptions

We have used the most recent space standards, as listed in the Mayor's *Supplementary Planning Guidance*, November 2012. We have created notional minimum sizes according to the different requirements for one, two, three, four and five-bedroom flats and houses, as set out by the Mayor. These "averages", based upon GLA planning guidance (2012), are reproduced in the table, below. In the table, "b" refers to bedroom and "p" to persons.

We note that we have calculated the minimum space requirement for a five bedroom flat or house according to guidance in the planning documentation, which suggests an additional 10% of space should be provided for each additional person in a four bedroom unit. These sizes are shown in the figure, overleaf.

Type	Size (m ²)
1b2p	50
1 bedroom	50
2b3p	61
2b4p (flat)	70
2b4p (two storey house)	83
2 bedroom	71
3b4p (flat)	74
3b5p (flat)	86
3b5p (two storey house)	96
3b5p (three storey house)	102
3b6p	95
3 bedroom	91
4b5p	90
4b5p (two storey house)	100
4b5p (three storey house)	106
4b6p	99
4b6p (two storey house)	107
4b6p (three storey house)	113
4 bedroom	103
5 bedroom	113

Figure 74: Assumed unit sizes. Source: Arup analysis of London Plan guidance

A3.4 Capital cost assumptions

A3.4.1 Enhancement costs

To establish the enhancement cost for the various housing types, Arup used published data from the Cabinet Office report on Government Construction.²⁷³ This 'baseline' construction-related inflation was then adjusted for:

- Housing sector-specific construction inflation, using BCIS All In Tender Price Index data (inflating costs to Q1 2014 according to published rates);²⁷⁴
- London location factors, again using the BCIS published data;
- The inclusion of an uplift for professional fees associated with construction;²⁷⁵
- The inclusion of an uplift for sales and marketing fees; and
- The inclusion of an uplift for legal fees associated with development.

Our construction cost estimates are based upon the Cabinet Office report discussed above. This report sets out costs on the basis of bedroom count rather than unit size. In order to calculate the cost per square metre associated with the construction costs found in the Cabinet Office report, we have calculated an average price per square metre, assuming average unit sizes for each bedroom count as set out in the figure below. The implied price per square foot for the construction of market-rate and below-market-rate housing is shown in Figure 75 below.

	Private sector construction cost	Public sector construction cost	Assumed size	Private sector – implied £/s.m.	Public sector – implied £/s.m.
1b	52,636	49,210	35	1,504	1,406
2b	79,334	83,420	65	1,221	1,283
3b	111,501	117,631	90	1,239	1,307
4b	143,668	151,841	140	1,026	1,085

²⁷³ Cabinet Office, Cost Benchmarks & Cost Reduction Trajectories to March 2013, 2nd July 2013, Table 22.

²⁷⁴ Please refer to section A2.4 for a discussion of construction-related inflation.

²⁷⁵ Professional fees assumed to be 12% of construction costs; Sales and marketing costs assumed to be 2.5% of average sales value (of £300,000);

5b	175,836	186,051	200	879	930
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Figure 75: Implied construction cost per square metre using government construction report prices and current average market unit sizes. Source: Arup analysis

In order to calculate the construction costs associated with the unit sizes determined in the London Plan, we have multiplied the implied cost per square metre by the average minimum size per type stated in the Plan, as identified in section A3.3 above. The end result of this analysis is the construction cost input to the model for each unit type. These findings are shown in Figure 76 below.

	Assumed size	Private sector – implied £/s.m.	Public sector – implied £/s.m.	Private sector - Implied construction cost (excludes land)	Public sector – Implied construction cost (excludes land)
1b	50	1,504	1,406	75,194	70,300
2b	71	1,221	1,283	86,657	91,121
3b	91	1,239	1,307	112,740	118,938
4b	103	1,026	1,085	105,699	111,711
5b	113	879	930	99,347	105,119

Figure 76: Implied construction cost by unit type using government cost data and London Plan unit sizes. These costs form the basis of our housing enhancement cost analysis. Source: Arup analysis

A3.4.2 Land costs

Land costs are not included in the prices shown above. However, land costs are included in our enhancement cost estimates. Unit-related land costs have been calculated as a percentage of construction costs. It is assumed that land cost represents 45% of overall capital costs, and that construction cost represents 55% of total costs.

We also have included additional costs assumed to be incurred for land remediation. Our assumptions are based upon benchmarks of current London sites. We have assumed that the average site size will be some 20,000 square metres and that the cost associated with remediation is £400 per square metre. We have assumed one site is remediated every five years.

A3.4.3 Renewals costs

We have included the cost of renewing new market rate and affordable housing constructed during the study period. As in other sectors, we have assumed that these renewals costs will represent, on average, 1% of cumulative total enhancement (land plus construction) costs over the period.

We have also included the cost of renewing London's existing affordable and social housing asset base. Current housing stock statistics are available via the Office of National Statistics. At present, there are some 410,000 London borough dwellings and another 391,000 dwellings operated by private registered providers. After consulting with London Councils and the GLA and reviewing the Housing Revenue Account, we have found it most prudent to assume that renewals costs associated with London borough housing will be higher than those for PRP housing on a per unit basis. We have assumed that PRP stock renewals will occur at a cost of £1,000 per annum per unit, and we have assumed that London borough housing renewals will occur at a cost of £2,800 per annum per unit. The cost of renewing London's existing market-rate housing stock has been excluded from this analysis.

Finally, we have included additional renewals costs for the upgrade of existing housing to meet energy efficiency and other standards. Based on discussion with the GLA and London Councils, we determined that these renewals costs could be similar to Decent Homes initiative costs occurring over the previous five year period. After 2016, we have assumed some £1,000 million of such costs in every five year period.

A3.5 Operating cost assumptions

Operational and Maintenance costs have been based on benchmark data from BCIS. Benchmark data is adjusted for housing sector-specific construction inflation, using BCIS All In Tender Price Index data (inflating costs to Q1 2014 according to published rates). It also has been adjusted for London location factors, again using the BCIS published data.

We have assumed that maintenance costs total £22.9 per square metre per annum.

A3.6 Limitations and uncertainties

This model is limited to provide costs associated with Affordable Housing requirements only. The quantum of affordable housing required is based on a pro rata adjustment using the housing mix identified in the FALP and could be subject to change based on demographics.

Build costs do not vary between inner city and suburban development. A standard rate based on housing type has been applied. The costs may vary depending on whether the housing is delivered in inner London or in suburban locations.

Whilst the costs include for professional fees and legal fees these could vary depending on a number of factors:

- Change in legislation;
- Macro-economic climate;

- Taxation and levies;
- Project complexity;
- Land ownership structure; and
- Financing models.

It should be noted that the following are excluded from costs:

- VAT;
- Mayoral CIL;
- Section 106; and
- Planning costs.

There may be uncertainty around the cost of renewals. Future analysis could refine the estimates discussed above. The cost of renewing London's existing market-rate housing stock has been excluded from this analysis. These costs are likely to be considerable and would need to be required in a more detailed economic model.

A4 Transport infrastructure cost modelling

A4.1 Approach

Our approach to modelling indicative transport expenditure includes modelling of nine different scenarios, based upon two options for accommodating population growth – within the capital's current boundaries and beyond them, in new towns outside the conurbation. These scenarios also are based upon five options for aviation capacity development explored by the Davies Commission (including two options for no increase to this capacity). A key focus of the scenarios has been the development of the Thames Estuary Airport.

The scope of transport investment in London is wide. National, local and regional government bodies invest directly in transport in the London area, and this is supplemented by private sector investment. As such, in order to maintain a meaningful scope, after consultation with Transport for London and the Greater London Authority, we have limited our analysis to the spending listed in the figure below and overleaf.

Where spending is across a number of regions, we have deemed a “London share” based on the geographical spread of the asset and its users and beneficiaries.

	Theme	London share
Transport for London	Getting more out of the existing system	100%
	Improving radial links	
	Improving orbital links	
	Missing links	
	World city schemes	
	Complementary schemes	
	Beyond London schemes	
Non-TfL roads	London boroughs road spending	100%
	Highways Agency M25 Connect Plus PFI	100%
National Rail	Network Rail	15% of Network Rail's English spend
	Train Operators	50% of London and South East TOCs
High Speed Rail	High Speed 1	50% of total
	High Speed 2	50% of Phase 1 only

Aviation	Possible Davies Commission outcomes	100%
	Heathrow Airport	100%
	Gatwick Airport	100%
	City Airport	100%
	Luton Airport	100%
	Stansted Airport	100%

Figure 77: Description of projected transport costs by type. Source: Arup analysis

Thus we have not included London Borough spending on matters other than roads (such as parking and concessionary fares), Highways Agency spend other than the M25 Connect Plus PFI, or Southend Airport. We have also not included TfL income or expenditure on interest on current account balances.

From this scope, we have separated each theme into three categories:

- Capital enhancements;
- Capital renewals; and
- Operations and maintenance (O&M).

A4.2 Inputs and assumptions

A4.2.1 Capital expenditure

A4.2.1.1 Capital enhancements

A series of major projects has been proposed as part of the themes identified in Figure 77 above. Drawing upon a range of sources, we have identified possible costs associated with these projects. We then have accounted for phasing and indexation, applying construction industry price inflation to determine cost projections between 2016 and 2050. In chapter 3 of this report, we provide costs including construction industry price inflation (of some 2% per annum). In the figure overleaf, we present the costs associated with different projects as 'unindexed' values that do not account for real price growth (as they are often discussed).

Transport project type	Theme	Description	Amount, (£m) 2016-2050 (unindexed)	Method	Source
TfL	Improving Radial Links	Crossrail 1, 2 & 3	40,213	Crossrail 2 & 3 - £16bn per Crossrail, every 15 years	London First - Funding Crossrail 2
		Extension of existing tube lines	3,572	Bakerloo extension - full extension to Bromley - £2.5bn assumed every 20 years	TfL

Transport project type	Theme	Description	Amount, (£m) 2016-2050 (unindexed)	Method	Source
		Extension of existing light rail system into Central London	1,715	Extension of DLR - Bank to Victoria - £100m / km, every 10 years	Arup analysis
		Medium-scale extension of London Overground network	429	Overground Extension to Barking Riverside or similar, occurring every 10 years	TfL
		Large-scale extension of London Overground network (such as staged outer orbital route)	1,143	Extension of London Overground network, such as a staged outer orbital route.	TfL
	Improving Orbital Links	Large-scale extension of existing suburban light rail network	657	Sutton Tramlink extension – based on costs of existing link of £230million – assumed similar projects occurring every 10 years	Arup analysis
		Medium-scale extension of existing suburban light rail network	500	Crystal Palace and Bromley Tramlink extensions – costs estimated at £85million and £90 million respectively based on existing link – assumed similar projects occur every 10 years	Arup analysis
	Missing Links	New/enhanced stations (and intense development)	1,858	One new or enhanced station with intense development occurring every decade – based on costs of proposed schemes such as Custom House, Lewisham and Beam Reach	Arup Analysis
		New tube stations	79	Based on the proposed cost of renovating and opening old York Road station	Arup Analysis
		Connecting growth /	0	TfL suggested £50bn over 25 years	TfL

Transport project type	Theme	Description	Amount, (£m) 2016-2050 (unindexed)	Method	Source
		opportunity areas		– set to zero as other schemes separately costed such as further Crossrail projects will also connect growth areas	
		Roads Taskforce	52,020	Place making schemes from the Roads Task- force report totalling £30bn 2013 prices over 20 years including the Hammersmith fly-under, Silvertown tunnel and Gallions Reach bridge; Arup has rolled forward RTF spending to account for further investment within the study period (some £20 billion in total, from 2031-2050)	Roads Task- force report; Arup analysis
	World City	Cycling Quietways	399	Cycling schemes from the Mayors cycling vision (we understand this was excluded from Roads taskforce report) every ten years	Arup analysis
		Large scale cycling infrastructure such as opening cycling tunnels	173	Based on proposed Kings Cross to Finsbury Park Tunnel - £100m 2013 prices every 20 years	Arup analysis
		Additional river piers	191	Eleven additional piers planned at a cost of £5m 2013 prices per pier	Arup analysis
		Upgrade of existing river piers	104	Upgrade of existing piers	TfL
		World city schemes such as Garden Bridge or Highline	590	Estimate for place-making schemes such as a Garden Bridge or Highline project	TfL

Transport project type	Theme	Description	Amount, (£m) 2016-2050 (unindexed)	Method	Source
	Complementary	Upgrade of existing rail network to support Crossrail 2 / 3 (eastern end)	788	Lee Valley Enhancements to support Crossrail 2	TfL
		Upgrade of existing rail network to support Crossrail 2 / 3 (western end) + Crossrail upgrade	788	Release capacity through enhancements on the South West Main Line	TfL
		Re-alignment of an Underground line in outer suburbs	1,261	Realignment of the Redbridge arm of Central Line along existing transport corridors – costs assumed the same as Overground network extension	Arup analysis
	Beyond London	Upgrades to Crossrails	1,103	Crossrail upgrade - Train frequency increase, train lengthening, extensions to Gravesend/Reading/ other - Assume same as Overground 5 to 8 cars	TfL; Arup analysis
	Getting more out of the existing system	TfL's 2014-2020 enhancement budget: LUL	27,849	Pro-rated; TfL business plan / Q3 forecast	TfL; Arup analysis
		TfL's 2014-2020 enhancement budget: London Rail	835	Pro-rated; TfL business plan / Q3 forecast	TfL; Arup analysis
		TfL's 2014-2020 enhancement budget: surface	5,341	Pro-rated; TfL business plan / Q3 forecast	TfL; Arup analysis
National Rail		National Rail Enhancements	16,141	15% apportionment of National Rail enhancements per control period for England	Network Rail/ORR
High Speed Rail		High Speed 2 Euston and Old Oak	509	High Speed 2 Euston and Old Oak Common	Arup Analysis

Transport project type	Theme	Description	Amount, (£m) 2016-2050 (unindexed)	Method	Source
		Common hub		infrastructure (non HS2)	
		High Speed 2 Line	10,882	High Speed 2 Line – attributed 50% of the funding for phase 1 to London	HS2 Limited
Non-TfL road projects		M25 PFI/PPP	2,848	M25 PFI / PPP - Assume one-quarter of £320m 2013 prices annual payment is enhancements	Highways Agency
Aviation	Existing	LHR expenditure	7,942	£418 million per annum	Heathrow accounts and annual report 2012
		LHR expenditure	6,688	LHR expenditure 2035 and beyond - £1080.8m / annum	Heathrow accounts and annual report 2012
		LCY expenditure	89	£3 million per annum, assumed 50% of capex is enhancements	London City airport reports
		LGW expenditure	3,641	£208 million capex spend per annum, assumed 50% of capex is enhancements	Gatwick airport accounts
		STN expenditure	2,693	£77m capex spend per annum, pre-sale of Stansted, assumed 50% of capex is enhancements	(Pre-sale of Stansted)
		LTN expenditure	2,670	£76 million per annum - based on £1.5 billion masterplan spread out over 10 years, assumed 50% of capex is enhancements	Luton Airport website, BBC

Figure 78: Major enhancement projects, 2016-2050 (£ million). Unindexed prices. Some major projects, especially related to aviation capacity development, are not shown in this figure but are instead discussed below. Source: Arup analysis

Some enhancement projects and costs, which vary according to scenario, are not shown in the figure above. We discuss these enhancement projects in the section below.

A4.2.1.2 Capital enhancement costs included for specific scenarios (growth outside London's current boundaries; aviation expansion options)

We have modelled nine different scenarios based on two options for accommodating population growth - within central London and in new towns outside the conurbation – and five options on aviation capacity being considered by the Davies Commission, including options not to increase capacity.

Figure 79 provides estimates for the costs of providing infrastructure if population growth is accommodated in new towns outside London, including the option of developing Heathrow as a new town. We have assumed that these projects, if initiated, will occur between 2030 and 2039. Costs are only included under specific modelled scenarios – for example the cost of converting Heathrow stations for a new town is only incorporated under the new estuary airport scenario.

Description	Amount included (£m)	Method	Source
Rail link to new town	£5,085m between 2030 and 2039	Rail link to new town - Assume a third (approx.) of Crossrail 2 £5000	Arup analysis
Convert Heathrow stations for new town	£2,034m over 5 years between 2035 and 2039	Convert Heathrow stations for new town - Assume 4 x Tottenham Court Road Crossrail Tube Costs (4 x £500m)	Arup analysis
Build Green Belt new town stations	£2,034m over 5 years between 2035 and 2039	Build Green Belt new town stations - assume 4 x Tottenham Court Road Crossrail Tube Costs (4 x £500m)	Arup analysis
New town tram system	£468m over 5 years between 2035 and 2039	New town tram system - assume one-off at double cost of Sutton Tramlink	Arup analysis
New town bus system	£203m over 5 years between 2035 and 2039	New town bus system - Assume one-off cost for 5 bus corridors, based on double the cost of Leeds (5 x £40 m)	Arup analysis
New town ticketing and other infra	One-off £10 million in 2039	New town ticketing and other infra - Assume £10m - one off	Arup analysis

Figure 79: TfL Projects – Beyond London – description and sources, unindexed (before +2% indexation for construction industry price inflation). Source: Arup analysis

Figure 80 overleaf provides estimates for the costs of increasing aviation capacity. We have assumed that these options will occur between 2020 and 2040. Costs are only included under specific modelled scenarios.

Description	Amount included £m	Method	Source
New hub airport in Thames Estuary – airport cost	£46 million over 15 years between 2020 and 2034 ²⁷⁶	Average of estimated cost range between £39bn and £53bn over 15 years	Davies Commission
New hub airport in later enhancements	£6,680	Costs similar to LHR expansion	Arup analysis
New hub airport in Thames Estuary – additional costs	None	Assumed zero cost	TfL Planning Briefing Note Jan 2014
London Heathrow Runways 3 & 4	R3 £7.5bn over 2020 to 2024. R4 £11bn over 2036 to 2040.	Davies Commission (LHR) RW 3 & 4 - R3 £6-9bn =7.5bn avg (source Davies) R4 £11bn (source Heathrow)	Davies Commission, Heathrow website
London Heathrow Runways 3 & 4 additional costs	£25bn over 2020 to 2024 £12bn over 2036 to 2040	TfL RW 3 & 4 additional costs suggests £20-30bn for LHR R3 - assume 50% again for R4	TfL Planning Briefing Note Jan 2014, ²⁷⁷ Arup analysis
London Gatwick Runway 2 & Gatwick or Heathrow Runway 3	£5.5bn over 2020 to 2024 £7.5bn over 2036 to 2040	LGW R2 £5-6bn =5.5bn. LGW R3 / LHR R3 assumed as per LHR R3 costs of £7.5bn.	Davies Commission
London Gatwick Runway 2 & Gatwick or Heathrow Runway 3 additional costs	£25bn over 2036 to 2040	Additional costs of Gatwick option assumed toe zero as above. Additional costs of LGW R3 or LHR R3 as LHR R3.	TfL Planning Briefing Note Jan 2014, Arup analysis
Heathrow Hub Runways 3 & 4	R3 £7.5bn over 2020 to 2024. R4 £11bn over 2036 to 2040.	Heathrow Hub R3 £6-9bn = £7.5bn avg (source Davies), for R4 assume a further £11bn as per LHR proposal	Davies Commission, Heathrow website, Arup analysis
Heathrow Hub Runways 3 & 4 additional costs	£25bn over 2036 to 2040	Assume zero for first Heathrow hub additional runway, as LHR R3 for 2nd	TfL Planning Briefing Note Jan 2014, Arup analysis

Figure 80: Aviation – Davies options for increasing capacity – description and sources. Costs are given before +2% indexation for capital expenditure. Source: Arup analysis

²⁷⁶The Mayor of London estimates the cost of a New Thames Estuary Airport at £44.8bn which includes surface access costs, risk and optimism bias. A further £12 billion is planned to increase capacity in line with rising demand by 2050. This provides an airport with capacity for 150 million passengers p.a. which is comparable to that assumed in 2050 by the Davies Commission.

²⁷⁷This has been superseded by The Mayor's 'Response to Call for Evidence to the Davies Commission' of May 2014. Arup had completed its preliminary cost analysis prior to the release of the May 2014. Optimal surface access requirements that are comparable to the surface access costs assumed for the New Thames Estuary Airport: All Heathrow scenarios: £17.6bn; Gatwick: £12.4bn. Please see Table 5 of Mayor of London's Inner Thames Estuary Feasibility Study of May 2014.

A4.2.1.3 Capital renewals costs

The majority of Renewals costs have been calculated by assuming a percentage annual cost based on the cumulative capital investment. In most cases, our estimates of annual renewals spend varies from 0.3% to 1.3% of the initial capital. We have chosen a figure of 1%, which is towards the high end of the range, as we expect London-based assets to be more heavily used when compared with HS1 and National Rail benchmarks.

In a minority of cases we have included separate renewals costs based on available information. We summarise renewals costs in the figure below and overleaf. The totals presented do not include construction industry inflation. In the cost estimates presented in our report, construction industry price inflation has been included.

Sector	Theme	Description	Amount, (£m) 2016- 2050 (unindexed)	Method	Source
TfL	Getting More Out of the Existing System	Extrapolated from TfL 2013 Business plan and Q3 forecast			
	Improving Radial Links	1% of enhancement capex			
	Improving Orbital Links	1% of enhancement capex			
	Missing Links	1% of enhancement capex			
	World City	1% of enhancement capex			
	Complementary	1% of enhancement capex			
	Beyond London	1% of enhancement capex			
National Rail		National Rail	12,628	50% of London and South East TOCs expenditure and income, adjusted for subsidy	Transport Advisory Services and ORR
High Speed Rail		High Speed 1	3,691	Agreed maintenance and renewals spend for control period	HS1 CP2 outlook accounts table 82
Non-TfL Road Projects		London Borough Roads		Based on analysis of existing expenditure	TfL, Arup analysis
		M25 PFI/PPP	2,848	M25 PFI / PPP - Assume one-quarter of £320m annual payment 2013 prices	Highways Agency

Sector	Theme	Description	Amount, (£m) 2016- 2050 (unindexed)	Method	Source
				attributable to renewals	
Aviation	Existing	LHR Renewals	1,156	Based on current expenditure levels	Heathrow accounts
		LCY Renewals	89	Based on current expenditure levels	CAA
		LGW Renewals	3,641	Based on current expenditure levels	Gatwick accounts, CAA
		STN Renewals	2,693	Based on current expenditure levels	Stansted accounts annual report 2012
		LTN Renewals	2,670	Based on current expenditure levels	Luton accounts, Arup analysis
	Davies	No additional items of spend included			

Figure 81: Capital renewals -- description and sources (£ million), excluding construction industry inflation. Source: Arup analysis

A4.2.1.4 Operations and maintenance

For O&M, we again take the spend that has already been committed to, and add to that the O&M spend that is likely to result from the additional enhancements to the transport system. Where an assumption for O&M spend has not been available (which is in most cases), we have used approximations based on a benchmarking of similar sectors. Where assumptions for O&M and renewals have been used for the first few years but not for the later years, we have extrapolated the current spend.

Our estimates of annual O&M spend varies between 2.4% and 6.5% of original capital expenditure, as shown in Figure 82 below.

Previous O&M estimates as % of original capital (notes)

5.0% - Used in this study

4.0 to 5.6% - National Rail estimates (based on O&M as % of renewals, then applied to both Crossrail and HS1 renewals).

1.1% - HS1 actual, infrastructure O&M only (excludes costs that fall to train operators, HS1 is a relatively lightly used asset).

2.4% Crossrail actual (figure is for first two years of operation only).

Figure 82: Assumed operating expenses. Source: Arup analysis; TfL, McNulty, ORR, HS1

Whilst the 2.4% figure is for Crossrail, we suggest that Crossrail O&M might be low as a percentage of capital costs given the proportionally high capital costs of the tunnel, and the low incremental operating costs (as many of services are operating already). Further, this figure was available for the first two years of operations only, and we suggest that the longer term cost could be higher.

Hence, in seeking a long term average for the wider portfolio, we have used a figure towards the high end of the range. For the sake of prudence, we suggest that O&M costs would average 5% of capital per annum across the portfolio.

We set out full assumptions for O&M costs in the figure below and overleaf.

Sector	Theme	Description	Amount included, per decade unless otherwise stated (£m)	Method	Source
TfL	Getting More Out of the Existing System	£29,251m extrapolated from TfL 2013 Business plan and Q3 forecast			
	Improving Radial Links	5% of enhancement capex			
	Improving Orbital Links	5% of enhancement capex			
	Missing Links	5% of enhancement capex			
	World City	5% of enhancement capex			
	Complementary Beyond London	5% of enhancement capex			
National Rail		National Rail	10,084	50% of London and South East TOCs expenditure and income, adjusted for subsidy	Transport Advisory Services and ORR
High Speed Rail		High Speed 1	128	Agreed maintenance and renewals	HS1 CP2 outlook accounts

Sector	Theme	Description	Amount included, per decade unless otherwise stated (£m)	Method	Source
				spend for control period	
Non-TfL Road Projects		London Borough Roads	1,780	Based on analysis of existing expenditure	TfL, Arup analysis
		M25 PFI/PPP	814	M25 PFI / PPP - Assume half of £320m annual payment 2013 prices attributable to O&M	Highways Agency
Aviation	Existing	LHR Opex	7,765	Based on current expenditure levels	Heathrow accounts
		LCY Opex	102	Based on current expenditure levels	CAA
		LGW Opex	2,149	Based on current expenditure levels	Gatwick accounts, CAA
		STN Opex	885	Based on current expenditure levels	Stansted accounts annual report 2012
		LTN Opex	509	Based on current expenditure levels	Luton accounts, Arup analysis
		Davies	5% of enhancement capex		

Figure 83: Operations and maintenance – additional areas of spend – description and sources. Source: Arup analysis

A4.2.2 Transport expenditure baseline (2011-2015)

For each sector, we begin with the capital enhancements spend that has already been committed. For the period prior to 2014, we have used figures from published annual accounts. Where these have not been available, or where the figures for past spend do not appear congruent with the figures that we have for future spend (as is the case with TfL), we have used a sum equivalent to 2014 spend for the years 2011, 2012 and 2013.

A4.3 Limitations and uncertainties

There is inevitably a significant degree of uncertainty associated with the modelled spending profiles as many of the budget projections are not available beyond the 2020s. Timing and costs of the major schemes beyond that point are particularly uncertain. In particular, HS2, the Davies Commission outcomes and the additional costs triggered by the Davies Commission outcomes represent the greatest individual costs, as well as arguably the greatest areas of uncertainty. We can expect the degree of certainty around HS2 to continue until the bill passes through Parliament over the coming months. It will not be until the next parliament that HM Treasury is expected to provide firm funding for construction of the line.

The Davies Commission is due to report in 2015, which may remove some of the options available and allow sponsors to focus on development of a single option. Nevertheless, the proposals for an initial runway are likely to be controversial both in political and planning terms, and some certainty of the placement (and hence costs) of the second additional runway that Davies has identified is needed by 2050, will remain.

A4.4 Potential next steps

We would expect to develop the model as the policy framework develops. In the short term, we would look to explore the sensitivity of our assumptions to levels of optimism bias.

We would also look to work with TfL to further develop the list of projects that might be considered to be part of the “getting more out of the existing system”, and perhaps explore a bottom-up budget for items leading into the mid-late 2020s, potentially retaining the top-down approach beyond that period. We would also look to refine the model once we had tested affordability constraints with TfL, the GLA and potentially HM Treasury and the Department for Transport.

As mentioned above, we would also look to firm up cost inputs on HS2 and the Davies Commission projects as they develop over the coming years, and to refine the timing and cost of Crossrail 2 (and ultimately 3) as it develops.

A5 Energy infrastructure cost modelling

A5.1 Approach

The analysis uses the 2050 Pathways Calculator – originally developed by DECC in 2010 and since then regularly updated – to develop a baseline energy supply/demand system for the UK. The Pathways Calculator allows users to develop their own combination of levels of change to achieve an 80% reduction in greenhouse gas emissions by 2050, while ensuring that energy supply meets demand.

The output of the Calculator is then modified with London-specific ratios and factors to determine the amount and type of energy delivered by 2050 (and capacity to be built). The modification also enables sensitivities and scenarios to be developed around certain specific objectives, for example to achieve Mayor's Strategy Decentralisation target, as illustrated above.

The model based on the Calculator produces energy flows and capacity figures. The analysis then assesses the investment in capital infrastructure associated with such energy flows and capacity. We use publicly available sources to estimate total investment expenditure (using costs of existing projects and projected unit costs).

A5.2 Inputs and assumptions

The inputs used in the model to determine the energy flows are included in the table below.

Base Assumptions – Flows		
	Assumptions	Comment
Gas supply	<ul style="list-style-type: none"> Gas demand to final users from DECC 2050 tool – modified for London. We split between domestic and non-domestic. We adjust for London population growth (a) We can adjust for rate of energy efficiency achieved – scenario dependent (b) A minimum non domestic gas demand is fixed (taken from the DECC 2050 tool modified for London) Each scenario then determines the amount of decentralised heat in the system The amount of decentralised heat is determined exogenously – it depends on scenarios and is assumed to meet predetermined set targets. (c) 	<ul style="list-style-type: none"> a) Population in 2050 is 12% higher under central assumptions than under DECC 2050 tool assumptions b) High efficiency assumes final gas and electricity demand is 5% lower than central scenario; low efficiency assumes demand is 5% higher c) Three scenarios: <ol style="list-style-type: none"> no change scenario is based on DECC 2050 tool (lowest level of District heating); centralised scenario (33% of heat demand from district heating or CHP, 50% from renewable heat (heat pumps and solar thermal)); hybrid scenario (50%

	<ul style="list-style-type: none"> • The model also sets a maximum amount of decentralised heat – this is based on the total heat demand for London minus a minimum proportion of gas used in the non-domestic sector (the latter is taken from the DECC 2050 tool) • Each scenario then apportions the residual (i.e. centralised) heat between electric (heat pumps) and gas heating 	<p>from district heating or CHP, 20% from renewable heat (heat pumps and solar thermal)).</p>
<p>Electricity supply</p>	<ul style="list-style-type: none"> • Gas demand to final users from DECC 2050 tool – modified for London. • We split between domestic and non-domestic. • We adjust for London population growth (a) • We can adjust for rate of energy efficiency achieved – scenario dependent (b) • We adjust for additional heat pumps and electric vehicles demand (level of heat pumps demand is scenario dependent) 	<ul style="list-style-type: none"> a) Population in 2050 is 12% higher under central assumptions than under DECC 2050 tool assumptions b) High efficiency assumes final gas and electricity demand is 5% lower than central scenario; low efficiency assumes demand is 5% higher
<p>Electricity distribution – peak</p>	<ul style="list-style-type: none"> • We take UKPN peak load assumptions for the 2015-2023 period (from RIIO ED1 business plan submission) as the basis for the short term peak load figure. • We use the increase in total electricity demand post 2023 to estimate the increase in peak load. • We then modify it based on the penetration of heat pumps and electric vehicles. For residential heat pumps we assume a peak winter COP of 1; for heat pumps used in District Heating we assume a COP of 3. • Since different scenarios have different levels of heat pump penetration the final peak load is scenario dependent. 	
<p>EV</p>	<ul style="list-style-type: none"> • Penetration rates of Electric Vehicle is taken from DECC 2050 tool (applied to London) • 35% from combustion engine and 65% from electric vehicles (full electric, plug-in and hybrid) 	

Figure 84: Assumptions used to determine energy flows

The assumptions used in the analysis and in the model with regard to costs are included in the table below and overleaf.

Base Assumptions – Costs				
	Source	2015 value	2050 value	Comment
Gas supply	DECC 2050 tool (central estimate)	£17mn/TWh	£23mn/TWh	This estimate is used in the DECC 2050 tool. Whilst we believe it is out of date and we should be relying on a more recent DECC estimate, we have maintained it for modelling consistency
Electricity supply	Capex calculated from DECC 2050 tool Opex calculated from DECC 2050 tool	£20mn/TWh	£55mn/TWh	This numbers is derived from the DECC 2050 tool as annualised capex and opex costs divided by total electricity supply
Transmission (electricity) costs	Used capex and opex costs from RIIO T1 – National Grid “RIIO T1 Updated Business Plans”	£315mn (annual) – share of London	£458mn (annual) – share of London	Costs increase proportionally to the increase in peak load required to meet demand
Distribution costs (electricity)	Used capex and opex costs from RIIO ED1 – UKPN submission “ <i>Business plan for our electricity network for London. Draft for consultation – London network business plan for 2015 to 2023</i> ”	Scenario dependent	Scenario dependent	Costs increase proportionally to the increase in peak load required to meet demand. Scenarios have different assumptions with regard to distributed network peak demand depending on amount of heat pumps and EV in the system
Distribution costs (gas)	Used capex and opex costs from RIIO GD1 – Ofgem GD1 financial model			Costs are assumed to remain constant in real terms over time as gas network will require upgrade and maintenance throughout the period even if demand is falling. Costs will be borne via regulated charges by customers still connected to the gas grid. Unit costs are increasing over time.
EV	Capex costs for infrastructure (charging points) included in Transport sector figures Opex – costs of electricity	Unit costs derived from electricity supply costs as per above	Unit costs derived from electricity supply costs as per above	
Heat pumps costs	Capex – from DECC RHI Impact assessments, “RHI Tariff Review, Scheme Extensions and Budget Management”, (2013), and DECC, Impact assessment, “Renewable Heat Incentive – Domestic”, (2013) Opex – electricity price	ASHP £937/kW GSHP £1706/kW	Same as 2015 costs	Final costs for Heat Pumps for domestic and small commercial purposes will depend on blend of HP technology adopted. Different technology and different sizes of HP will have different costs. We have taken an average costs for small size

				(<100kW) HP. We have assumed costs stay constant in real terms over time
Industrial and commercial CHP	Capex – based on DECC generation costs analysis (Mott MacDonald, 2010 and PB Power, 2011) Opex – based on existing gas CHP plants from DEPDU and other London projects	Capex (LCOE) - £17.2/MWh Opex (LCOE) - £49/MWh	Capex (LCOE) - £17.2/MWh Opex (LCOE) - £49/MWh	CHP costs are assumed to remain constant in real terms. CHP fuel supply assumed to be gas. Capex costs are calculated on a levelled basis.
District heating	Capex – based on existing DH London projects from DEPDU Opex – based on existing DH London projects from DEPDU	Capex £100mn for projects delivering additional 890GWh heat output Opex - £13/MWh equivalent	Capex £175mn for projects delivering 920GWh heat output Opex - £13/MWh equivalent	DH costs are taken from existing DEPDU projects database. We assume costs stay constant in real terms over the period – though we recognise that costs will be dependent on type of fuel supply, the relative geographical consideration and the type of network.

Figure 85: Energy cost assumptions. Source: Arup analysis.

A6 Waste infrastructure cost modelling

A6.1 Approach

Two separate approaches have been developed for the calculation of the infrastructure costs for waste and resource management. The first is based on a conventional estimate of capital and operational expenditures, and the second on a gate fee costs per tonne of waste treated.

No costs have been included for street cleansing or the management of the excluded waste streams such as CDEW, healthcare and hazardous wastes.

A6.1.1 Capital expenditure

Information on the capital expenditure (CAPEX) has been based on a combination of public domain documents and Arup in-house project information. The CAPEX includes costs for the plant construction, process equipment, mobile plant, grid connection (thermal treatment plants), insurance and financing costs. A number of costs are not included such as planning/environmental permitting or life-cycle replacement costs.

A6.1.2 Operational expenditure

Information on the operational expenditure (OPEX) has also been based on a combination of public domain documents and Arup in-house project information. The OPEX includes costs for labour, consumables (e.g. fuel), planning/permitting, monitoring/sampling, maintenance, life-cycle replacement of plant components, disposal of process residues etc.

A6.1.2.1 Gate fees

The gate fees used in the cost model for the period of 2015 to 2050 have been taken from the Waste & Resources Action Programme 'Gate Fees Reports' for 2013.²⁷⁸ The mean values have been selected and kept constant for the whole period except for the 'secondary material sorting and bulking category where the average value of the mean gate fee for the years 2008 to 2013 was used. This is to reflect the volatile nature of the market prices for recyclables.

In the absence of detailed information on reuse infrastructure, the same gate fee as for secondary material sorting and bulking has been used for the reuse infrastructure.

A6.1.2.2 Collection costs

High level aggregated cost information of local authority collected waste (LACW) for 2011/12 was provided by the GLA. This information was obtained by the GLA directly from the London boroughs.

²⁷⁸ Waste & Resources Action Programme (2008 to 2013), Gate Fees Reports, <http://www.wrap.org.uk/content/wrap-annual-gate-fees-report>.

A6.2 Baseline costs

The total cost for waste collection and treatment/disposal was almost £500 million in 2011/12. This is for a population of 8.2 million people²⁷⁹ generating 3.6 million tonnes of LACW.²⁸⁰ A total of £164 million related to waste collection costs (about 33 per cent), and £335 million waste treatment/disposal costs (about 67 per cent). This equates to almost £45/tonne for waste collection and almost £93/tonne for waste treatment/disposal.

It has been assumed that the unit cost for waste collection of C&I waste is the same as that for LACW. This is considered to be a conservative assumptions since C&I waste is often stored in compactors or is being baled, which increases the waste collection efficiency and reduces costs.

A6.3 Inputs and assumptions

A6.3.1 Waste types and quantity

The demand for waste and resource management infrastructure is primarily driven by the permanent and transient population in London who generate solid waste.

The household solid waste generation rate of 0.355 tonnes per capita was based on FALP data up until 2035. Using information on the projected quantities of household waste generated in London and the projected population of London, a constant waste generation of 0.355 tonnes per capita was calculated up to 2035. As a simplification, it has been assumed that this waste generation rate for household waste remains constant up to 2050.

The commercial & industrial (C&I) waste generation rates were also based on FALP data up until 2035. Using information on the projected quantities of C&I waste generated in London and the projected employee population of London, a declining waste generation from 0.978 tonnes per employee in 2015 to 0.765 tonnes per employee in 2050 was calculated. The declining trend seen in the waste generation rate was extrapolated to 2050.

It has been assumed that the waste generated by visitors is included in the household and C&I waste generation rates.

A number of waste streams have been excluded from the review of the waste and resources management infrastructure requirements such as construction, demolition and excavation waste (CDEW), healthcare waste and hazardous waste. These waste streams either already benefit from a well-established recovery infrastructure or are relatively small in quantity.

²⁷⁹ Office for National Statistics (July 2012), <http://www.ons.gov.uk/ons/rel/mro/news-release/census-result-shows-increase-in-population-of-london-as-it-tops-8-million/censuslondonnr0712.html>.

²⁸⁰ Department for Environment, Food and Rural Affairs, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/277866/2012-13_ANNUAL_publication_WITHOUTLINKS_v0.1.xls.

A6.3.2 Waste treatment method

The transition from a linear economy to a circular economy model will have an impact on the type and quantity of waste and resources management infrastructure required in London. Progressively there will be less need for landfill disposal of waste as more waste is being moved up the waste hierarchy.

A scenario (base case) with no transition to a circular economy and three scenarios (low, central and high) for a transition to a circular economy have been defined in the cost model for waste and resources management infrastructure, as follows:

- Base case – reuse/repair/remanufacture of zero per cent in 2050;
- Low – reuse/repair/remanufacture of 10 per cent in 2050;
- Central – reuse/repair/remanufacture of 20 per cent in 2050; and
- High – reuse/repair/remanufacture of 40 per cent in 2050.

The waste treatment method split for the base case is based on the FALP waste forecast model which in turn is informed by the GLA targets for recycling/composting (including anaerobic digestion). For household waste, this means: 45 per cent of waste recycling in 2015; 50 per cent in 2020 and 60 per cent in 2031. For C&I waste, this means 70 per cent of waste recycling in 2020 maintaining this level to 2031. It has been assumed that these targets will be met by the relevant dates stated above.

For the low, central and high transition scenarios, the increase in reuse infrastructure is first compensated by a reduction in landfill and thermal treatment infrastructure and then a combination of landfill, thermal treatment, organic waste treatment and secondary material sorting and bulking infrastructure. This is in accordance with preferences set out in the waste hierarchy.

A6.3.2.1 Base case scenario

Household waste

The base case scenario for household waste is based on the FALP waste forecast model and assumes zero per cent reuse/repair/ remanufacture, 60 per cent of recycling/composting (including reuse), 14 per cent intermediate waste processing, 40 per cent thermal treatment and zero landfill disposal by 2050.

C&I waste

The base case scenario for C&I waste assumes zero per cent reuse/repair/ remanufacture, 70 per cent of recycling/composting (including reuse), five per cent intermediate waste processing, 33 per cent thermal treatment and zero landfill disposal by 2050.

A6.3.2.2 Low transition scenario

Household waste

The low transition scenario for household waste assumes 10 per cent reuse/repair/remanufacture, 55 per cent of recycling/composting, 14 per cent intermediate waste processing, 36 per cent thermal treatment and zero landfill disposal by 2050.

C&I waste

The low transition scenario for C&I waste assumes 10 per cent reuse/repair/remanufacture, 66 per cent of recycling/composting, five per cent intermediate waste processing, 27 per cent thermal treatment and zero landfill disposal by 2050.

A6.3.2.3 Central transition scenario

Household waste

The central transition scenario for household waste assumes 20 per cent reuse/repair/remanufacture, 49 per cent of recycling/composting, 14 per cent intermediate waste processing, 31 per cent thermal treatment and zero landfill disposal by 2050.

C&I waste

The central transition scenario for C&I waste assumes 20 per cent reuse/repair/remanufacture, 60 per cent of recycling/composting, 5 per cent intermediate waste processing, 23 per cent thermal treatment and zero landfill disposal by 2050.

A6.3.2.4 High transition scenario

Household waste

The high transition scenario for household waste assumes 40 per cent reuse/repair/remanufacture, 50 per cent of recycling/composting, 14 per cent intermediate waste processing, 10 per cent thermal treatment and zero landfill disposal by 2050.

C&I waste

The high transition scenario for C&I waste assumes 40 per cent reuse/repair/remanufacture, 49 per cent of recycling/composting, five per cent intermediate waste processing, 14 per cent thermal treatment and zero landfill disposal by 2050.

A6.3.2.5 Facility size

The facility sizes of the range of waste and resources management infrastructure is based on information published by the Office of the Deputy Prime Minister²⁸¹, Arup's experience and other public domain information as follows:

Facility Type	Typical Capacity (tonnes/annum)
Reuse infrastructure	50,000
Secondary material sorting and bulking	150,000
Organic waste treatment (e.g. in-vessel composting, anaerobic digestion)	60,000
Intermediate waste processing (e.g. mechanical biological treatment, mechanical heat treatment)	200,000
Thermal treatment (e.g. energy from waste, pyrolysis, gasification)	250,000
Landfill	350,000

Figure 86: Facility size assumptions. Source: Arup analysis

Whereas the facility size of conventional waste treatment facilities (e.g. secondary material sorting plants, anaerobic digestion plants, gasification plants etc.) is relatively well known, the facility size of reuse infrastructure is highly variable. It can range from, for example, small charity shops on the high street, warehouses for the storage and repair of white and brown goods to larger remanufacturing facilities.

A6.3.2.6 Facility lifespan

The average lifespan of the waste and resource treatment infrastructure is assumed to be 20 years, which is based on information published by the Office of the Deputy Prime Minister and Arup's experience. The facility lifespan greatly depends on the amount of maintenance that is being undertaken by an operator.

²⁸¹ ODPM (2004). Planning for Waste Management Facilities: A Research Study.

A7 Water infrastructure cost modelling

A7.1 Approach

The high-level cost estimates developed for the water sector include:

- Operating expenditure (both operating costs and maintenance)
- Capital renewals/ replacement costs (maintaining the standard of service)
- Capital enhancements (e.g. improvements in levels of service/ quality)

Our cost forecasts have been developed using public-domain information from the water companies, including their long term and AMP6 investment plans and from the Environment Agency for flood-defence related expenditure. These capture the majority of major project-areas and take into consideration many of the detailed assumptions from the water sector: for example on the level of water metering; leakage targets; and per capita use of water assumptions.

A7.2 Inputs and assumptions

We discuss key assumptions to our model in the sections below.

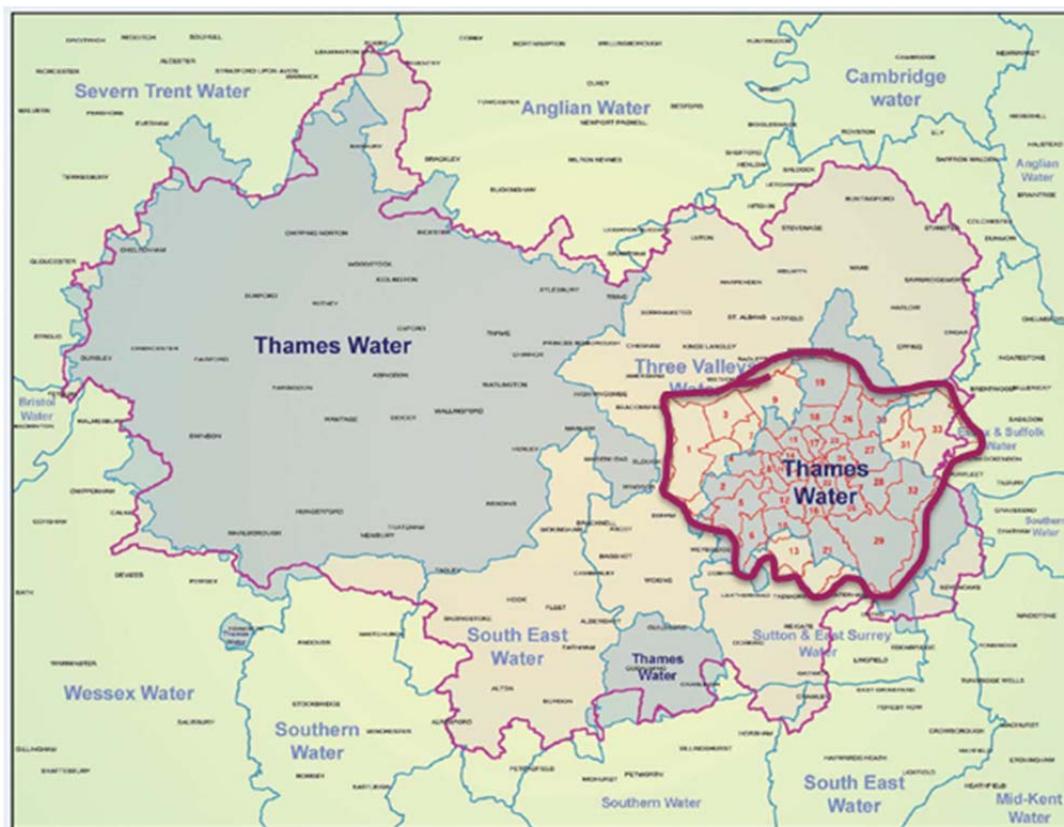


Figure 87: Areas served by the different major water companies, showing the GLA boundary in red. Source: Thames Water (adapted)

A7.2.1 Assessing the population served within the GLA boundary

As seen in Figure 87 (previous page), water and sewerage services within the Greater London boundary are provided by a number of privatised water companies. To avoid an overly-complex assessment of the boundaries between the companies, as a planning assumption, we have used Thames Water's cost information as the proxy for the other water companies in the region.

As a starting point, we have assumed that Thames is reasonably representative of the water sector in the region: acknowledging that Thames' own costs include the cost of providing services in both Greater London and more rural areas of Oxfordshire for example. The table below outlines our reasons for assuming this.

Why Thames Water might be a reasonable proxy for the GLA area	
Issue	Observation
Water Service bills (per property)	TWUL are comparable to peers on overall bills (Based on Ofwat data 2013/14 average bills) – although higher than average for water service
(Water) opex per property	Reported values at PR09 are similar for Thames (£91/prop), Veolia Central (£83/prop) and SESW (£95/prop)
Capex per property	For AMP5, TWUL is higher than other regional companies (water service), but we are going to cost this based on a more detailed basis
Meter penetration	Broadly similar at end of AMP5 (AMP5 forecast): Thames (37%), Veolia Central (44%), SESW (47%)
Water quality issues	Impact of differing water quality (e.g. softening at SESW) does not really show-up in opex per property metrics at this scale.
Maintenance	Based on PR09 high-level data, infrastructure and non-infrastructure maintenance appears comparable for the companies on a per-property basis

Figure 88: Motivation for using the Thames Water area

We have checked this boundary assumption using a number of comparators (e.g. water operating cost per property served) for the four companies. Whilst our approach might slightly over-estimate the required costs, we believe that it is a pragmatic approach, and it was broadly supported by the Water Advisory Group during a meeting held 13th March 2014.

A7.2.2 Accounting for water resources outside the GLA boundary

Using the Thames boundary raises questions around how best to account for water resources outside the GLA. We have assumed, for example, that future major resources in the Upper Thames are shared resources, and we have distributed costs on a population basis.

Similarly, in considering the cost of the Thames Tideway Tunnel, we have assumed that all Thames Water customers bear the cost—pro-rated for the GLA according to population.

We have assessed whether individual cost elements are fixed or variable costs (with population) and these are linked to overall GLA population forecasts.

A7.2.3 Accounting for flood defences

In reviewing the costs (and benefits) of flood risk management, we have considered Essex and Kent residents and industry. For flood-risk management related expenditure, we have based our estimates on information provided by the Environment Agency for the TE2100 project (tidal defences) and their programme of capital projects associated with the Grant in Aid (GiA) process for fluvial, surface and groundwater flood risk management. Some of these projects require significant private-sector contributions (partnership funding) before they will proceed, and therefore there is certainly a 'gap' in the funding for some of these investments in London.

A7.2.4 Accounting for fluvial risk management

Furthermore, for groundwater and surface-water flooding: the specific flooding mechanisms and investment requirement are still being developed by the Environment Agency and there is likely to be a further investment need once this requirement is better understood.

A7.2.5 Population and connected properties

GLA population data is the primary cost driver, but water company plans also make reference to the 'London Plan'. We have converted population to "connected properties" using occupancy (per property) from TWUL June Return Data.

It is important to note that we have assumed this rate to decline marginally in the long term (from 2.5 now, to 2.1 by 2050). We have assumed alignment of derived unit costs to appropriate cost drivers, with presumption of alignment to population/ housing demand where possible.

A7.2.6 Assumptions

We include a list of assumptions and their sources in the table below.

Water infrastructure development – detailed assumptions		
Area	Assumption	Source
Thames smart metres	Deployment of 900,000 smart meters across the network between 2015 – 2020 (AMP6)	Five-year Plan 2015 – 2020, page 8: http://www.thameswater.co.uk/tw/common/downloads/five-year-plan-summary-2015-2020.pdf Business Plan 2015 – 2020 Part A Summary, page 39: http://www.thameswater.co.uk/tw/common/downloads/about-us-financial/Part-A-Summary-Business-Plan-2015-2020.pdf
	Currently 31% of connections are metered; by installing more than 900,000 smart meters, the proportion of metered connections will rise from 31% to 56%	Five-year Plan 2015 – 2020, page 8: http://www.thameswater.co.uk/tw/common/downloads/five-year-plan-summary-2015-2020.pdf
	All meter installed since 2010 are smart meters, these will be activated from 2013 onwards	http://www.thameswater.co.uk/metering/17102.htm
		Business Plan 2015 – 2020 Part A Summary, page 54: http://www.thameswater.co.uk/tw/common/downloads/about-us-financial/Part-A-Summary-Business-Plan-2015-2020..pdf
	It costs £370 to install a 'traditional' meter	Arup in-house knowledge/analysis
Water supply enhancement	Beckton RO Plant (2010) costs £270m and took 2 years to construct	https://www.thameswater.co.uk/about-us/850_10885.htm
	Abingdon reservoir is said to have cost around £1bn	http://www.bbc.co.uk/news/uk-england-oxfordshire-12651131
London water companies	Greater London is currently supplied by four companies: Thames Water (76% of population), Affinity Water (14%), Essex and Suffolk Water (6.6%) and Sutton and East Surrey Water	http://www.london.gov.uk/mqt/public/question.do?id=15326

(3.7%)	
From the Base Year population figure, around two-thirds of Thames Water customers are based in London	Revised Draft Water Resources Management Plan - Page 10, table 3-2: http://www.thameswater.co.uk/tw/common/downloads/wrmp/Section_3_-_Current_and_Future.pdf

Figure 89: Water sector detailed assumptions. Source: Arup analysis

We have assumed that construction of the Upper Thames Reservoir is not initiated within the study period (to 2050). We have excluded this project on the basis of input from the GLA and its advisory group. A complete list of projects included is found in the main body of this report.

A7.3 Cost inputs

Our approach has been to utilise the best available public information on costs for key sectors of water, sewerage and flood risk management. These sources include:

- Ofwat Final Determination (2009) for 2010-15
- Annual cost returns (“June Return”) from water companies to Ofwat
- Company Business Plans for AMP6 (2015-20)
- Water Resource Management Plan(s) – January 2014
- Environment Agency Thames Estuary 2100 (TE2100) project plans
- Environment Agency FDGiA plans (Thames Region) 2014/15 to
- Environment Agency RFDCC Committee Minutes

Major enhancement and renewals costs are identified in detail in chapter 0 of the report. We therefore do not repeat these items in the appendix.

A8 Green infrastructure cost modelling

A8.1 Approach

Arup was asked to assist the GLA in establishing a baseline requirement for green infrastructure. Our approach has been to:

- Establish open space (i.e. more traditional recreational space) requirements on a per capita basis;
- Establish other infrastructure investment requirements in line with ecological and policy drivers, as specified by the GLA.

The main body of this report discusses the calculations made to determine per capita green space requirements. We also detail the different enhancement and renewals projects included in planned capital expenditure.

A8.2 Inputs and assumptions

The model has had to base the predictions on a number of inputs and undertake a number of assumptions which are listed below. Major enhancement and renewals costs are identified in detail in chapter 8 of the report. We therefore do not repeat these items in the appendix.

A8.2.1 Inputs

Our cost model relies upon the following inputs:

- Land mass information for London Boroughs.²⁸²
- Percentage of Greater London defined as publicly accessible open green space.²⁸³
- Average revenue and capital expenditure by each of 32 London Boroughs between 2001 – 2008.²⁸⁴
- Revitalisation and maintenance budget of Burgess Park, Southwark.²⁸⁵
- Funding for Greater London Authority The Mayor's Vision of Cycling in London²⁸⁶
- SusTrans high level costs for the development of a radial Quietway.²⁸⁷
- Cost Benchmarks for SuDs Retrofits and Rainscapes.²⁸⁸
- Capital and maintenance costs associated with Beam Parklands.²⁸⁹

²⁸² Office of National Statistics *2011 Census: Quick Statistics for England and Wales* March 2011.

²⁸³ Information provided from GLA March 2014

²⁸⁴ Data collated by the London Parks Benchmarking Group for the London Parks and Green Spaces Forum and provided to Arup by GLA

²⁸⁵ Southwark Council *Environment & Leisure Department Budget Book* February 2013

²⁸⁶ Greater London Authority *The Mayor's Vision of Cycling in London – An Olympic Legacy for all Londoners* 2013

²⁸⁷ Information provided by the GLA March 2014

²⁸⁸ Greater London Authority & Aecom *Haringey Green Streets: Campsbourne Estate SuDs Retrofit Concept Design Report* November 2013

²⁸⁹ Arup analysis of *Beam Parklands, Dagenham*, undertaken on behalf of *Environment Agency & Land Trust* 2011

A8.2.2 Assumptions

We have made several assumptions in order to project costs to 2050. These assumptions include:

- The supply of publicly accessible open green space is a constant through to 2050 set at 17.88% of the land mass of Greater London.²⁹⁰
- The predicted housing supply identified will be delivered in the assigned 5 year periods to 2050.
- The predicted population increase identified will be delivered in the assigned 5 year periods to 2050.
- New housing will supply 50% of its amenity requirement at grade.²⁹¹

A8.3 Limitations and uncertainties

Green Infrastructure includes both public and private green space, due to the varying nature, potential benefit and ability to influence private green space this area has not been included.

The demand for Green Infrastructure is derived from the predicted population growth as indicated by GLA Intelligence. Long-term forecasts could differ materially from the actual population at that time. Given our approach to modelling, based upon population growth, this difference could affect outturn costs materially.

The potential supply of Green Infrastructure takes in part the delivery of housing for both the public and private sector as indicated in the model. Should new housing delivery not occur to the levels projected, additional public green space could be required to achieve London Plan guidelines and other policy imperatives.

²⁹⁰ Information provided by GLA 2014

²⁹¹ Arup analysis of *Earls Court*, undertaken on behalf of *Capital and Counties PLC* 2013

A9 Education infrastructure cost modelling

A9.1 Approach

School expenditure has been derived as follows:

- Define the schooling requirements by using the relevant age groups of additional population per period;
- Apply an average school size per school type (primary, secondary and sixth form) to define the number of schools required;
- Estimate the percentage of projected capital expenditure that will be required to address the renewals backlog;
- Estimate capital expenditure on the basis of construction cost per school, multiplied by the required number of schools; and
- Estimate operating expenditure on the basis of cost per school place per annum, multiplied by number of additional students.

A9.1.1 Cost Benchmarking

We have reviewed government guidance, trade publications and project benchmarks in order to project costs on a per square metre basis.

Sources consulted for construction costs include:

- BCIS (mean, lowest, median, upper median construction cost per square metre for different school types);
- Recent cost estimates for new schools development;²⁹²
- Recent Department for Education cost and funding information released via Freedom of Information (FOI) requests;²⁹³ and
- Other consultancy reports.²⁹⁴

School prices are stated in Q1 2014. Operating costs are based on information from interviews with two finance directors of area schools.

Sources consulted for school sizes include:

- Department for Education standards;²⁹⁵ and

²⁹² Homes and Communities and Jones Lang LaSalle, *Northstowe*, February 2014

²⁹³ Department for Education, School capital building programmes and the Priority School Building Programme, 10 January 2014, available:

<https://www.gov.uk/government/publications/school-capital-building-programmes-and-the-priority-school-building-programme-psbp/school-capital-building-programmes-and-the-priority-school-building-programme-psbp>.

²⁹⁴ See for example, Talbot, Darren and Francis, Stuart, "Cost model: Primary schools", *Building Magazine*, 13 June 2013, available: <http://www.building.co.uk/cost-model-primary-schools/5056116.article>.

- Primary and secondary school sizes planned for new developments.²⁹⁶

A9.2 Inputs and assumptions

Primary assumptions have been discussed in the main body of this report. We note other inputs, assumptions and their sources in the table below.

Theme	Assumption	Source
Average school size (students per school)	Primary school - 450 Secondary school – 1,000 Sixth form - 250	Low estimates based on long-term London and UK class sizes, as reported by the Department for Education, uplifted upon GLA guidance. See for example, Department for Education, <i>School Type and Size</i> , 2012, [.xls] document.
Construction costs (build & fit-out, £m per school)	Primary school – 7.0 Secondary school – 27.0 Sixth form – 18.0	Arup analysis of capex cost benchmarks
Land costs	Land costs represent 60% of total costs, whilst construction costs represent 40% of total costs 20% of land assumed already under public ownership	GLA discussion with relevant bodies
Operating costs (£/place per annum)	Primary school – 5,800 Secondary school – 8,000 Sixth form - 6,500	Based on inner-London school benchmark; received via interview with schools finance director

Figure 90: Education cost modelling assumptions

We summarise cost assumptions for the different school types in the table overleaf.

²⁹⁵ Department for Education and Skills, *Briefing framework for primary school projects*, undated, available:

https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/288108/building_bulletin_99_-_briefing_framework_for_primary_school_projects.pdf.

²⁹⁶ Homes and Communities and Jones Lang LaSalle, *Northstowe*, February 2014

School type	Number of students	Size (m ²)	Construction cost per m ²	Total construction cost (£)
Primary	450	3,500	2,000	7,000,000
Secondary	1,000	12,000	2,250	27,000,000
Sixth form	250	7,000	2,570	17,990,000

Figure 91: School size and construction cost assumptions

A9.2.1 Renewals assumptions

The capital required for investment in existing schools has been calculated as a percentage of the book value of these assets, as estimated by the GLA. The GLA has estimated that the book value of existing assets is some £16.5 billion. Arup has assumed lifecycle renewal costs of 3.5% of this existing asset base. Renewal of new assets has been calculated as 3% of cumulative enhancement capital expenditure.

A10 Digital connectivity infrastructure cost modelling

The prospect of determining the future requirements of London's telecoms infrastructure, as has been explained within the main report, is hindered by the light-touch regulation of the sector, limiting requirements to collect data and the reluctance of the key companies in the sector to share information.

For this reason, Arup has developed its own appreciation of the scale of the unmet requirements for broadband in London. A paucity of information about costs in the sector is available in the public domain. In order to provide an indication of long-term costs, we have made a number of assumptions based upon our professional experience in order to inform the GLA's initial considerations around future investment. These costs in particular are likely to require additional analysis and review at a later stage, as specific schemes are analysed.

A10.1 Approach

The Mayor's Super-Connected Cities Plan (SCCP)²⁹⁷ aims to 'future-proof' London by provisioning people and commerce with ultra-fast broadband. The way of achieving this is to transition from Fibre to the Cabinet (FTTC) to Fibre to the Premises (FTTP).

Arup's approach has been to create a scenario to, first, plug the gap of businesses without any form of broadband (i.e. completing provision of a FTTC network) and secondly to transition to a FTTP network for commerce.

Further to this, we have attempted to provide high level cost estimates for projects to roll out Wi-Fi hotspots across London; to enhance 4G mobile coverage throughout the capital by 2020; and finally, similarly, to provide 5G cover to the entirety of capital by 2030.

A10.2 Inputs and assumptions

A10.2.1 Scale of projected demand for broadband

A10.2.1.1 Residential

Ofcom has estimated that the current plans of BT's Openreach will leave 5% of residents without access to superfast broadband. This number is likely to diminish as new homes are built, as it is virtually certain that all new homes in London will be provided with fibre to the home (FTTH) access. Over the period to 2050, this means that the number of homes without access to superfast broadband is likely to fall to some 3% of residential premises. It is estimated that some 150,000 homes in all will require supplementary infrastructure.²⁹⁸

²⁹⁷ Greater London Authority, *London Super Connected Cities Urban Broadband Fund*, 3 August 2012, available:

<http://www.london.gov.uk/sites/default/files/London%20Super%20Connected%20Cities%20proposal%20%28cg%29.pdf>.

²⁹⁸ There are about 5.2m households in the GLA area.

A10.2.1.2 Commercial

For the future-proofing transition to FTTP networks, Arup has worked on the assumption that there are approximately 850,000 private sector businesses operating in London.²⁹⁹ Then, in order to create the scenario model, Arup has assumed that approximately 3% of all businesses within London that require FTTC connections and are unable to be connected by BT or other communications provider. This estimate of about 25,000 unconnected businesses is based on Arup's sector experience and analysis undertaken on behalf of a confidential client in 2013. The key factors underlying the estimate are outlined below.

Large business users are likely to have a sufficiently large requirement for broadband to make it worth their while to meet the cost of connection, however large, or to persuade a communications provider to invest in network extension to be able to connect them.

To provide Wi-Fi coverage to the entirety of the capital – excluding large open spaces such as parks, but including more than just main high streets – it is estimated we would need to provide an additional c. 1,062,500 hotspots.

4G coverage is estimated to require a further 1,500 sites, with 15 switches per site. We have used the same assumption for 5G coverage given the likely similarity in technology.

A10.2.1.3 Density and unit cost assumptions for broadband

Residential

Homes in London currently are distributed at an average density of approximately 350 residences per kilometre of street. Unserved homes are likely to be less concentrated than average, constructed in less dense areas. Arup therefore has assumed a “density” of 300 residences per kilometre of road. The average cost per residence would then be the cost of one kilometre of network extension divided by the number of homes per kilometre, assumed to be 300 per each 1,000 metres of road.

Commercial

Several small business users in the same geographical area may together represent sufficient demand to encourage a communications provider to extend its optical fibre network far enough to reach them.

These factors suggest that unmet demand for broadband is likely to be concentrated among small firms located away from urban centres. Accordingly, Arup has assumed that, on average, each unserved business premises is 800 metres from the nearest point of connection to a public network. Arup's capital expenditure estimation is therefore based upon the trench and duct installation from points of connection to premises of each of these businesses.

²⁹⁹ 841,000 Private Sector Businesses in London at start of 2013. Source: BIS.

Arup estimates that a network extension of 800 metres would on average enable 20 additional businesses to be connected, with each requiring on average a further 10 metres of trench and duct installation. This implies 50 metres of network extension per connectable business.

Costs range between £100 and £150 per metre for installing broadband fibre in an urban area, depending on ground conditions and ducts.

Number of ducts	Rate (£/m) including duct, trench, disposal and draw pit (Q1 2014)
1	115
2	115
4	129
10	172
5	245

Figure 92: Broadband connection cost assumptions per number of ducts required

To determine the unit cost inputs shown above, a standard BT network design has been assumed (with, for example, a jointing chamber every 50 metres).³⁰⁰ The cost of enabling connection to a broadband network is estimated at £6,500 per business.³⁰¹ We note that no allowance for on-costs has been made in the estimate (way leaves, compensation, traffic management etc.). The costs are for London conditions and are materially higher than for other parts of the country.

BT's Openreach uses the same network to serve residential customers as for business customers. However, businesses tend to be located in places that are physically separate from homes. It is therefore assumed that the same network infrastructure costs as have been developed for business premises apply to residential premises, but that separate network extensions are necessary for connecting residential premises.

The cost of an additional hotspot is estimated at around £2,000 per unit.

Based on precedent, we estimate the cost of completing 4G coverage to be around the £350 million mark. This would place the cost per switch at £17,111, which appears realistic.

5G technology is likely to be more expensive, coming in the range nearer to £500 million, for a cost per additional switch of £22,222.

³⁰⁰ Arup has assumed 4 ducts per trench to fulfil 'increase competition through market intervention', but could require 8, 12 or as few as 2.

³⁰¹ The cost of infrastructure installation has been estimated against a standard BT specification. Other communications providers may well have lower costs per metre for network installation.

A10.2.2 Other capital expenditure items

The main body of this report discusses the cost inputs associated with Wi-Fi, 4G, 5G, digital security and other digital connectivity investments. Please refer to section 9.2 for more detail.

A10.3 Risks and uncertainties

Arup's model has limitations and areas of material uncertainty. Our inputs, largely derived from professional experience given the lack of publicly available information, may be inaccurate. These inaccuracies could have a material effect on cost estimates, over or under-stating projected future costs.

Assumptions regarding Wi-Fi, 4G and 5G are broad-brush in nature and may be subject to significant variation. It is also likely that London would not seek to provide all three measures with complete coverage all across the capital, as there would be a level of redundancy in having different types of internet connections with comparable performance levels, which means London is unlikely to face the full extent of the cost estimated in our cost model.

There is some uncertainty around GLA broadband policy. In particular, the Authority may not prioritise a comprehensive programme to connect all businesses. If the policy focus is on particular geographic areas or clusters, the number of businesses may be much smaller. Our assumptions about the number of businesses in London unable to connect to super-fast broadband may be inaccurate, and the businesses may be more or less concentrated than assumed. Arup has assumed communications providers' business decision making procedures continue as they are understood to be today. Competitive pressure may lead to greater investment in FTTP in future, reducing the unmet requirement.

The assumptions of distance from businesses to points of connection may be untrue. If the estimates made are too small, the implications for the capital cost of the programme could be significant.

A11 Infrastructure funding

A11.1 Approach

The aim of the funding work has been to identify the extent to which infrastructure costs to 2050 may ultimately fall on London Government to put in place the funding arrangements. We have also set out the extent to which these cost obligations are currently passed on to direct users e.g. fares and rentals and the residual costs which are likely to rest on London Government to identify other sources, e.g. developer contributions, grants, council tax, business rates, etc. We have also estimated a 'gap' when these residual costs are compared to current sources of revenue and capital funding where known.

This has been approached predominantly by analysing the infrastructure costs on a top down basis into three buckets:

- 1) Costs to be met by the private sector – where costs are incurred and financed *directly* by the private sector who also puts in the place the necessary funding, e.g. regulated water bills and private housing sales;
- 2) Costs to be met by central government/agencies - where costs are incurred and financed *directly* by a public sector body not related to the GLA or London Boroughs, to be recovered through a mix of user charges and national taxes (e.g. Network Rail and the Environment Agency); and
- 3) Costs to be met by London Government - where costs are incurred and financed *directly* by the GLA or London Boroughs, who have to establish the necessary funding arrangements.

Costs to be met by London Government have been further analysed to determine who ultimately bears the cost of the infrastructure investment under current governance structures:

- 1) Costs to be funded by users – where funding is ultimately provided by the direct users of infrastructure, e.g. through transport fares or housing rentals; and
- 2) Costs to be funded by grants and taxes - where funding is provided on an ad hoc basis by central government or socialised through local taxpayers (the source of tax, e.g. council tax, business rates, has not been estimated rather this represents the balance of funding that is required for London Government to deliver the projects set out in the plan after taking into account costs funded by direct users).

When considering the funding greatest focus was given to Transport and Housing which represent the significant part of London Government's spending and control.

A11.1.1.1 Transport

The costs for all none TfL and London borough highways projects are assumed to be fully met by either the private sector or other government bodies/agencies, e.g. Network Rail or Highways Agency.

The contribution from future fares on the existing TfL network has been estimated based on the real growth achieved between 2014 and 2020 in the existing business plan on the four core modes (approximately 3.5% per annum for both London Underground and London Rail and 2.4% for London Buses and Other Surface). Fares are assumed to be capped at RPI and the real terms growth for all modes has been 'dampened' from 2034 to 1% per annum.

For new capital schemes, each scheme was assigned to one of the four core modes. The contribution from fares on new schemes was estimated by applying a mode-specific ratio of fares: opex – calculated from the existing network - to the estimated operating costs of these new schemes. Fares are assumed to be capped at RPI and the real terms growth for all modes has been 'dampened' from 2034 to 1% per annum.

An assumption of future revenue and capital grants was built up from the existing TfL business plan. In most cases this assumes that there is no real terms growth beyond the final period of the business plan in 2021 or that certain project specific funding streams will not continue, e.g. Crossrail and the Northern Line extension. Borrowing is assumed to continue at a level of £600m per annum based on the currently agreed limit, however no assessment has been made as to the implication on debt servicing costs and the capacity to meet these obligations. The remaining 'gap' identified will need to be funded from structuring fares, new sources of revenue or access to new capital receipts, e.g. grant streams, developer or third party contributions.

A11.1.1.2 Energy

The costs for all Centralised Energy projects are assumed to be fully met by the private sector.

Over the appraisal period we have assumed that capital costs for Decentralised Energy will fall 100% on tariff payers (i.e. all are commercially viable schemes). Ongoing operating costs are assumed to be fully borne by tariff payers with no residual support from London Government sponsors.

It is assumed that the burden falling on London Government is currently unfunded and that the 'gap' identified will need to be funded from new sources of revenue or access to new capital receipts, e.g. grant streams, developer or third party contributions.

A11.1.1.3 Green

Over the appraisal period we have assumed that 100% of both capital and operating costs will be met by London Government sponsors (albeit specific enhancement projects may receive developer contributions to cover this commitment).

It is assumed that the burden falling on London Government is currently unfunded and that the 'gap' identified will need to be funded from new sources of revenue or access to new capital receipts, e.g. donations, grant streams, developer or third party contributions.

A11.1.1.4 Water

The costs for water supply and sewerage projects are assumed to be fully met by the private sector.

Over the appraisal period we have assumed that 85% of capital costs for flood risk projects will be met by the Environment Agency and 15% by London Government through 'Partnership Funding'. Flood risk operating costs are assumed to be fully met by the Environment Agency.

It is assumed that the burden falling on London Government is currently unfunded and that the 'gap' identified will need to be funded from new sources of revenue or access to new capital receipts, e.g. developer or third party contributions. In particular where the benefits of investment can be articulated, then the private sector may participate to reduce the overall impact on London Government.

A11.1.1.5 Schools

Based upon current Education Funding Agency methodology, over the appraisal period we have assumed that two thirds of capital enhancements will be met by central government. The Department for Education provides funding based on an assumption about need, but in practice in the past this has left a shortfall.

Operating costs are assumed to be fully met by central government/individual schools through revenue grants (e.g. Dedicated Schools Grant) directly awarded to schools as well as schools' own resources.

It is assumed that the 'gap' identified will need to be funded (or closed) by central government, local authorities resources and through efficiencies.

A11.1.1.6 Housing

The costs for all private housing projects are assumed to be fully met by the private sector.

Over the appraisal period we have assumed that 40% of social housing capital costs will relate to Affordable Ownerships and 60% to Affordable Rent (Mayor's Housing Strategy).

The capital costs for Affordable Ownership properties are assumed to require a 15% upfront capital subsidy from London Government to deliver, with the remaining sum being recovered by private registered providers (including boroughs who own their own housing stock) through future sales.

The capital costs for Affordable Rent properties are assumed to require a 30% upfront capital subsidy from London Government to deliver, with the remaining sum being recovered by private registered providers (including boroughs who own their own housing stock) through future rentals (a combination of higher 'social' subsidy homes and lower 'affordable' subsidy homes). Costs related to 'Decent Homes' renewals (until 2016) are assumed to be funded via a grant from London Government and not recovered through rents. Post 2016, decent homes type renewals are unfunded and expected to create a gap.

The operating costs for Affordable Ownership properties are assumed to require no ongoing subsidies as the costs will be incurred by future owners. The capital renewals and operating costs for Affordable Rent properties are assumed to be fully met by private registered providers (including boroughs who own their own housing stock), 100% of which will be recovered through rent received from tenants in line with the principles of self-financing.

An estimate of the future capital grants was built up from GLA's historic spending and existing Budgets based on the National Affordable Housing Programme. This equates to around £500m per annum. The gap in housing grant/capital funding has been identified in the context of leveraging the upfront support to attract further private sector participation from private registered providers. Based on the assumptions above this results in £3 of private sector contribution for every £1 of public sector grant contribution (a combination of £6 for Affordable Ownership properties and £2 for Affordable Rent properties).

Given the substantial additional spend of boroughs in this sector in their role as landlords, we have also assumed that borough capital spend on housing in 2013/14, net of £200m assumed to relate to non-recurring Decent Homes grant (supposed to finish in 2016), relates substantially to renewals and is fully funded over the appraisal period through borrowing against the HRA, government support and capital receipts, e.g. property sales. This equates to c.£1.3bn per annum and results in an on-going gap of £200m per annum in relation to the need to spend on Decent Homes standards, estate regeneration and any other policy climate change related.

The remaining grant 'gap' identified will need to be funded from newly committed central government grant, new sources of funding or access to new capital receipts.

A11.1.1.7 Waste

Over the appraisal period the capital costs for waste facilities are assumed to be fully met by London Government. The capital costs are forecast to relate

approximately 60% to commercial and industrial waste and 40% to household waste based on quantity of waste generated. We have assumed that commercial and industrial waste costs are met by user charges to the commercial users and that household waste costs are met by local taxation.

Similarly the operating costs are forecast to relate 60% to commercial and industrial waste and 40% to household waste; therefore we have assumed that commercial waste costs are met by user charges to the commercial users and that household waste costs are met by local taxation.

It is assumed that the burden falling on London Government is currently unfunded and that the 'gap' identified will need to be funded from new sources of revenue or access to new capital receipts, e.g. developer or third party contributions.

A11.1.1.8 Digital connectivity

The costs for digital connectivity projects are assumed to be fully met by the private sector.

A11.2 Risks and uncertainties

Arup's model has limitations and areas of material uncertainty. These are summarised in this section.

Where possible our inputs have been formulated on publicly available information, discussion with sector leads or derived from professional experience. There may be inaccuracies which could have a material effect on estimates.

We have not sought to determine all the current funding sources or quantum thereof for the 33 London Boroughs or to allocate general revenue and capital grants and receipts across all the sectors in determining the 'gaps'. In addition we have broadly reflected existing funding structures and not made any judgements on future policy choices (e.g. user charges on new roads).

Importantly, our approach does not take into account how the upfront costs might be *financed* (in reality users are not expected to fund the infrastructure costs as they arise, rather will pay over the asset life). Therefore our approach does not include any assumptions for the cost of financing, the future profile the servicing of finance may take or the capacity to meet these additional costs.

In addition unless specifically set out, we have not assessed the capacity of the market to bear these additional costs, identified the precise source of London Government funding (e.g. council tax vs. business rates) or reconciled to where sources may already be 'spent', e.g. Crossrail CIL.

A11.3 Bibliography

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TfL Business Plan 2013, December 2013.

April 2014 to March 2015 Flood and Coastal Erosion Risk Management (FCRM) schemes programme, February 2014.

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Homes For London, The London Housing Strategy, November 2013.

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A12 International Infrastructure Plans

A12.1 Overview

In order to understand the context for the scale of the GLA's vision we have examined three cities which place a similar importance on infrastructural planning and development. These cities – New York, Paris and Hong Kong – also have closely related populations and urban characteristics which form the basis for the comparative study. From initial analysis it is clear that each of these cities have some form of infrastructural plan in place in order to establish their future requirements and form an implementation and funding strategy for these programmes.

New York City has a detailed ten year capital strategy which accounts for schools, infrastructure and government operations³⁰², with a total cost of \$53.7 billion. This plan will run concurrently with the PlaNYC, a sustainability and resilience blueprint set to run until 2030 with these costs accounted for in the capital strategy. The plan is seen as a complementary piece of work to the ten year strategy, which is aimed at making the city cleaner and more sustainable through infrastructural improvements to reduce road congestion and increase the provision of green space. However, the PlaNYC has a longer period of implementation than the cities capital strategy so it will require renewed funding after ten years.³⁰³ In addition, the city produces a yearly executive budget in May, similar to the GLA annual budget, which established the cities expenditure for the coming fiscal year.

Paris does not appear to have a long term infrastructure plan in place, but rather sector and project specific plans for development. The Société du Grand Paris (SGP)³⁰⁴ has been tasked with the development of Paris's transport infrastructure for the next fifteen years, which has led to several major infrastructure projects under the €32 billion Grand Paris Express programme.³⁰⁵ This plan will lead to further development within Greater Paris in order to support the growth in activities around these new metro stations, including improved housing and social infrastructure.

Hong Kong's publication of the 2007/8 Policy Address set-out the cities aspirations for infrastructural development in the city. This included ten major infrastructure projects which the city would pursue in the coming five years³⁰⁶, with the aim of addressing transport and urban development needs in the state. These projects have had their execution hindered by the recent financial crisis and as a result increased spending will be required over the next 5 years in order to ensure their completion³⁰⁷. The city of Hong Kong's development policy is

³⁰² http://www.nyc.gov/html/omb/downloads/pdf/typ5_13.pdf

³⁰³

http://nytelecom.vo.llnwd.net/o15/agencies/planyc2030/pdf/planyc_2011_planyc_full_report.pdf

³⁰⁴ <http://www.legifrance.gouv.fr/affichTexte.do?cidTexte=JORFTEXT000022308227&dateTexte=&categorieLien=id>

³⁰⁵ <http://www.societedugrandparis.fr/english>

³⁰⁶ <http://www.policyaddress.gov.hk/07-08/eng/docs/policy.pdf>

³⁰⁷ http://www.budget.gov.hk/2014/eng/pdf/e_appendices_a.pdf

overseen by the Chief Executive of the Hong Kong Special Administrative Region, a position based on five year terms. This term driven approach to policy has so far hindered their development of a longer term infrastructural plan.

A12.2 New York City

When comparing New York and London it is important to place their governance structures and expenditure patterns in context in order to form an understanding of how they establish their future plans.

In New York City housing is provided primarily by the private sector which differs from London's approach to both a public and private sector delivery of housing stock. Approximately £420 billion of expenditure on housing is forecast in London to 2050, which is 36.1% of the total expected infrastructure spending (based on this report), which includes both private and public sector delivery. By contrast, New York City has budgeted for a total of £31.56 billion of capital expenditure on housing stock from 2014 to 2023, but this is related to public expenditure and not inclusive of private development costs.

This lack of housing spending is reflected in past budgets as well; for example, the four year spending plan published in January 2010 (i.e. covering July 2010-June 2013) demonstrates that New York City only spent an average of £0.22 billion³⁰⁸ per year on housing (with an additional £0.02 billion allocated to the New York housing authority, though not designated to be spent on housing upkeep or development). These figures are significantly below the expenditure that London undertook on housing stock in the same period.

In the New York ten year capital strategy the single largest sector for future spending is education with a projected expenditure of £11.55 billion, forming 37% of the projected total. In comparison Arup suggests that London plans to spend £30 billion until 2050, a thirty five year period versus New York's ten years.

In this report it is estimated that the largest sector for expenditure will be transport, with a total expenditure of £475bn, forming 41% of the total. It is difficult to make a valid comparison between New York City and London as much of this projected expenditure is born out of the expectation that a new hub airport will be developed in the Thames Estuary with the cost of the airport and its associated infrastructure projected to take up a large amount of the budget for transport. In New York City all of the major airports, roads and bridges are controlled and paid for by the Port Authority; this authority is appointed by the state and hence its budget isn't included in these figures.³⁰⁹ Similarly, many of the other transport projects planned for London would not fall under the authority of the City in a New York context but rest under centralised US federal governance. In fact, New York City raises most of its own funds with a total of £23.3 billion – 73.9% of total funds – coming from General Obligation bonds (GO), The New

³⁰⁸ http://www.nyc.gov/html/omb/downloads/pdf/pcb1_10.pdf (p.11)

³⁰⁹ In the original ARUP draft there is a comparison made between the MTA and the TFL's spending, hence I will avoid any other comparisons.

York City Transitional Finance Authority and The New York City Municipal Water Finance Authority. The remainder comes from the state and federal government, £6 billion and £2 billion respectively.

In real terms New York City plans to reduce the amount it spends on infrastructure over the next ten years. The expenditure (in terms of the percentage of tax revenue it absorbs) is set to peak at narrowly above 15% of tax revenue in 2016, before gradually dropping annually until it reaches just over 13% of tax revenue by 2023. This estimation predicts an opposing trend to the one we see for London, in which it is predicted that until 2025 the percentage of GVA that will be spent on infrastructure will sharply rise. This is a result of the large investments which will be undertaken by London during this period across all sectors.

A12.3 Paris

As mentioned in the overview, the long term plans for Paris are mainly orientated towards the transport sector. Both London and Paris plan to undertake major new transport projects to improve connectivity within the city, as well as regional connectivity to the growing suburbs and commuter towns; for example, the regional Crossrail programme and the Grand Paris Express.

Between 2011 – when the plans for the Grand Paris Express were announced – and 2025, Paris has pledged to spend £16.4 billion on the Grand Paris Express project with an extension to Metro Line 14 and 3 entirely new lines planned for construction.³¹⁰ In comparison, the Crossrail project is expected to cost just under £16 billion, with a regional reach beyond Greater London. Furthermore, the City of Paris plans to spend approximately £10 billion on system upgrades between 2011 and 2025, with TfL planning to spend over £15 billion on upgrades during the same period.

A clear funding strategy has been outlined for the Grand Paris Express with £5.6 billion coming from loans and new commercial activity and real estate taxes respectively. Furthermore, £3.2 billion will come from national government grants, £0.8 billion from existing taxes and the remaining £1.2 billion from the local government.

There are intentions in Paris to develop housing and other social infrastructure around the newly planned lines, however, there is little published information on the funding strategy for these developments.

A12.4 Hong Kong

A recent report by the Government of Hong Kong, Financial Services and Treasury Bureau, on Long-Term Fiscal Planning (looking ahead to 2041/2)³¹¹ projected that infrastructure expenditure in Hong Kong will rise from 3.2% of

³¹⁰ <http://www.thetransportpolitic.com/2011/05/27/paris-region-moves-ahead-with-125-miles-of-new-metro-lines/>

³¹¹ http://www.fstb.gov.hk/tb/en/docs/english_report_online_version.pdf

nominal GDP in 2014/5 to 7.2% of nominal GDP in 2041/2. This is assuming that expenditure remains a constant in terms of real GDP at 3.4% over the past 30 years. This is due to the fact that the GDP deflator has historically risen at a slower rate than public construction output prices. This would lead to a 7.6% nominal per annum increase in capital works expenditure, meaning that by 2041-2 Hong Kong would be spending £39 billion on infrastructure, rising from £5 billion in 2014/5.

However, this rate of real spending is a contentious issue due to the fact that its growth on infrastructural expenditure has been so rapid over the past 30 years that there simply isn't the capacity within the economy to support this future, particularly with an aging population.

Looking over a shorter period of time, in a recent 6 year medium range forecast³¹², Hong Kong believed it would spend £6.7 billion on infrastructure expenditure in revised 2013-14 estimation, rising to £7.4 billion in 2018/19. However, as a percentage of GDP this would represent a fall in spending from 4.17% to 3.56%, which opposes the trend suggested above by the HK Treasury Bureau. This could be related to the fact that expenditure by authorities such as the airport authority and the MTR Corporation Limited isn't included in public expenditure figures.

³¹² http://www.budget.gov.hk/2014/eng/pdf/e_appendices_a.pdf

A13 Key contact

Alexander Jan
Director

Arup
13 Fitzroy Street
London
W1T 4BQ
Email: alexander.jan@arup.com
T +44(0)20 7755 6358
M +44(0)75 4574 2003

