



MANAGING LONDON'S EXPOSURE TO CLIMATE CHANGE

Report

September 2016

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**FUTURE OF
LONDON**

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Future of London is an independent not-for-profit urban policy network focused on the challenges facing regeneration, housing, infrastructure and economic development practitioners in the capital. We are a borough-led membership organisation with a number of external partners, which provides top career development, expert-led policy research, and topical networking and speaker-led events.



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LIST OF CASE STUDIES

		Area			Risk						Response			Measure						
		Local	City	National	Flooding	Heat	Drought	Economy	Property	Infrastructure	Public health	Mitigation	Adaptation/resilience	Risk Transfer	Partnership	Business Engagement	Community Engagement	Funding	Green infrastructure	Education
Flood Re	18			✓	✓				✓		✓		✓	✓						✓
BIDs and resilience	24	✓			✓	✓		✓	✓		✓	✓		✓	✓				✓	
Swindon Common Farm Solar	26		✓					✓	✓		✓		✓			✓	✓			
New York MTA Catastrophe Bond	27		✓		✓			✓	✓			✓	✓					✓		
Herne Hill and Dulwich flood alleviation	29	✓			✓					✓		✓		✓					✓	✓
Water Saving City, Zaragoza	30		✓				✓				✓	✓		✓	✓	✓				✓
Australia Road SuDS, London	31	✓			✓							✓				✓	✓	✓		
Arup/Rockefeller Foundation City Resilience Index	33		✓					✓	✓	✓		✓		✓						✓



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INTRODUCTION

Despite the best will in the world, climate change risk is often considered a next-generation, nebulous affair – hard to address with certainty, and knocked down the priority list by housing shortages, economic woes or social ills. There are often more immediate crises needing investment.

It's becoming increasingly clear that that's a mistake, and not just one our grandchildren will blame us for. Failure to act on climate change can incur staggering costs now, with catastrophic events stripping funding from other needs.

As just one example, the Association of British Insurers predicts that a major flood in London could have economic impacts comparable to the 2009 recession, as well as endangering human life and crippling transport and services. New York's experience of Hurricane Sandy was a harsh reminder of what's at stake: in the city, that event killed 44 people and caused \$19bn in damages and lost economic activity.¹

In London, ageing infrastructure and buildings already struggle to cope with relatively minor heatwaves and rainfall, and climate change is set to increase the frequency of minor events and the probability of acute floods, droughts, extreme storms and heatwaves.² More than ever, the capital's public assets need significant investment for retrofit and adaptation to these threats.

This report is designed to help London public-asset owners and service providers like the Greater London Authority (GLA), Transport for London (TfL), housing associations and local authorities to take an area-based or systems approach to adaptation and resilience, in partnership with developers, utility companies, businesses and consumers. It looks at roles, responsibilities, mechanisms and partnerships for investing in adaptation and resilience, and offers ways to reframe climate risk management as an opportunity rather than a burden.

National regulations, standards and powers should be instilling resilience into all retrofit and new-build schemes across the spectrum of infrastructure, commercial and residential development, but are currently falling short, particularly around surface water flooding and protecting vulnerable communities from hot weather. Cities have taken up the slack in many countries – the 100 Resilient Cities programme has reached its full quota, and the C40 Cities Climate Leadership Group of global megacities is in its tenth year. Many have developed strong resilience strategies in the aftermath of a catastrophe. A more proactive approach would save money and lives, and demonstrate global leadership in adaptation and resilience. With the right approach, London could be this leader.

EXECUTIVE SUMMARY

Despite the best will in the world, climate change risk is often considered a next-generation, nebulous affair – hard to address with certainty, and knocked down the priority list by housing shortages, economic woes or social ills. Bank of England Governor Mark Carney recently called for more attention to be paid to the financial risks from climate change.³ At local level, projected costs can be staggering, with catastrophic events also stripping funding from other needs in their aftermath.

As just one example, the Association of British Insurers

predicts that a major flood in London could have economic impacts comparable to the 2009 recession, as well as endangering human life and crippling transport and services. New York's experience of Hurricane Sandy was a harsh reminder of what's at stake: that in the city that event killed 44 people and caused \$19bn in damages and lost economic activity.⁴

In London, ageing infrastructure and buildings already struggle to cope with relatively minor heatwaves and rainfall, and climate change is increasing the frequency of minor

events and the probability of acute flood, droughts, extreme storms and heatwaves.⁵ More than ever, the capital's public assets and services need significant investment for retrofit and adaptation to these threats.

This report is designed to help London public-asset owners, service providers and their partners build strong business cases for mitigating and adapting to climate change. It offers tried and tested area-based and systems approaches, and offers ways to reframe climate risk management as an opportunity.

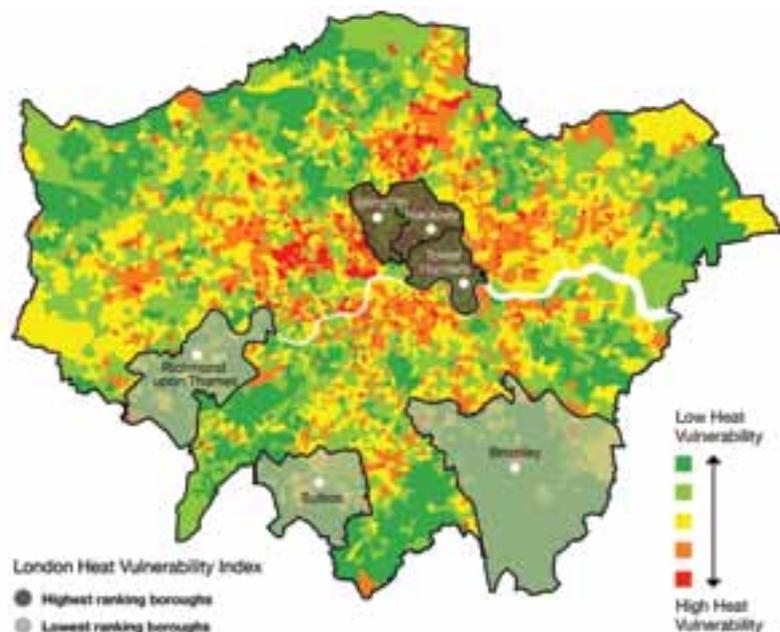
Part 1 – The Challenge

- The London city-region has a rapidly growing and ageing population, deteriorating housing stock and stressed infrastructure, as well as growing demands on land and specific climate vulnerabilities, particularly in flooding and overheating – all exacerbated by climate change.
- There are critical spatial and systemic risks to any large city, its businesses, citizens and economy. The interconnectedness and interdependency that make the capital hum are also a weakness, with one failure – or one refusal to act – able to tip the rest of the dominoes.
- Current public- and private-sector responses can be disjointed, and central government's advance-and-retreat, particularly on carbon policy and regulation, have hindered investment and action.

Part 2 – The Solutions

- There is a growing array of tools for regional/local authorities and service providers to audit their assets and identify areas of vulnerability. These allow organisations to develop solid business cases for implementing adaptation schemes and strategies.
- A number of initiatives now exist to incentivise the private sector to collaborate and provide vital funding for this work. This section includes suggested partnership approaches and funding mechanisms.
- One of the keys to motivating any sector is reframing risk management as an opportunity rather than a burden for local authorities, investors and communities.

Heatwave Vulnerability Index



Source: Arup⁶

Part 3 – Recommendations

- London’s local authorities and service providers need adaptation and resilience on a transformational scale. In these austere times, strategies need to be cost-effective, long-term and able to adapt to the effects of climate change as they occur.
- A checklist, influenced by the ‘adaptive pathways’ approach used in the Thames Estuary 2100 plan, guides the development of local resilience plans and strategies.

Resilience Strategy Pathway

- ✓ Audit physical assets and map interdependencies within a system
- ✓ Agree what is an acceptable level of current, intermediate and long-term risk for an area
- ✓ Analyse costs and benefits of resilience measures that manage immediate risks
- ✓ Set thresholds/triggers for measuring and monitoring intermediate and long-term risks
- ✓ Identify relevant owners, stakeholders and funding/delivery partners, including business and resident communities
- ✓ Bring stakeholders together in partnership, with working groups and champion/s
- ✓ Require partners/contractors to deliver chosen measures through procurement
- ✓ Monitor implementation
- ✓ Revisit intermediate and long-term risks when triggers are reached

The following key actions for specific stakeholders could accelerate a much-needed collective response to increasing London’s resilience.

National policymakers

- Mandate that all public retrofit programmes should specifically address surface-water flooding and overheating buildings, prioritising resilience measures such as drainage and night ventilation.
- Incentivise property owners, businesses and citizens to retrofit assets they own or manage through fiscal rewards such as tax credits and/or reduced business rates, council tax, stamp duty and VAT.

GLA

- Prioritise the update of London’s existing climate change adaptation plan and clarify roles, responsibilities and actions of all stakeholders.
- Develop a London-wide resilience plan that links up climate change mitigation, adaptation, preparedness and risk transfer strategies, and which quantifies and monetises the direct and indirect benefits of action where possible.
- With the London Enterprise Partnership (LEP), prepare for the post-Brexit funding environment: plan for and lobby government for alternative funding to replace or complement European structural and investment funds.

Local authorities and public service providers

- Produce up-to-date climate change risk assessments and strategies that use socio-economic and geo-spatial measures to focus on the most vulnerable communities.

- Develop area-based, cross-sector working groups for climate change hotspots to collectively reach mutually beneficial solutions and to pool funding.
- Explore options for using green and resilience bonds to raise funds and capital, individually or through the UK Municipal Bonds Agency.

Insurers and investors

- Recognise that integrating environmental factors into investment decisions is essential to responsible stewardship.
- Share modelled risks and losses data with local authorities to encourage dialogue and collaborative, area-based responses.
- Develop adaptation and resilience portfolios as alternatives to high-risk, time-limited fossil fuel assets.
- Develop products to share and transfer climate risks with local authorities, service providers and pan-London government.

Developers and house-builders

- Move sustainability strategies beyond carbon reduction; include approaches to long-term asset management and user education/engagement.
- Deliver area-based or systems improvements, for economies of scale and to increase asset values.

Educators and experts

- Develop resilience skills across the construction and development sectors through training and accreditation systems.
- Roll out efficient, low-cost systems for public service providers to audit their assets, with a view to making resilience enhancements where most needed.

PART 1: THE CHALLENGE

Context

Although the UK has a relatively stable climate, London is a city at significant environmental risk. There are a number of interlinked factors involved:

- Growing and ageing population
- Deteriorating housing stock and stressed infrastructure
- Growing demands on land
- Climate vulnerabilities

Growing and ageing population

London's historic population peak of 8.6m has been surpassed. According to GLA Intelligence, by the 2030s, the capital's population will reach 10m, and by 2050 they estimate a further 37% increase to 11.3m.⁷ This surge requires a significant upgrade of the city's infrastructure for it to cope even under normal circumstances.

London's population is also getting older. This means more people vulnerable to climate change effects such as longer, hotter summers, with over-65s more susceptible to related illnesses such as heat stroke and exhaustion.⁸

Deteriorating housing stock and stressed infrastructure

The UK's building stock is one of the oldest in the world and it is estimated that in 2050 around 70% of current stock will still be in use.⁹ A host of challenges hamper retrofit in London, including an ineffective policy environment, public dislike of disruption, lack of financial return for landlords, difficult access to leasehold properties (especially in mixed-tenure housing estates), conservation area restrictions, the construction of the buildings themselves and cost.

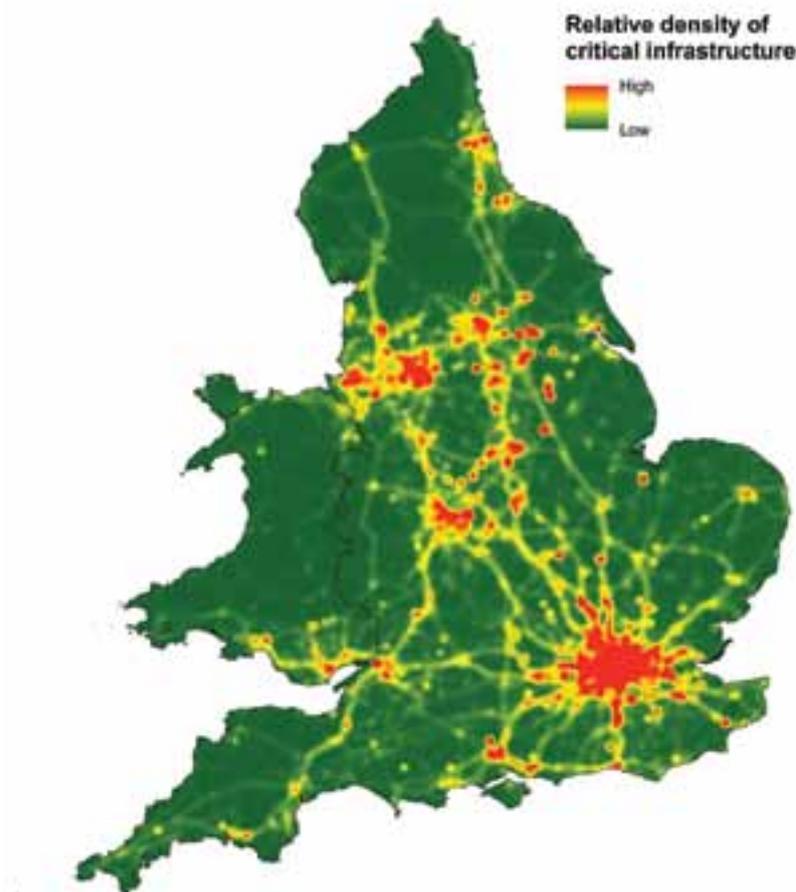
London's utility infrastructure faces similar challenges, but on a highly interdependent scale. Thames Water estimates that nearly a third of the pipes making up its network are more than 150 years old, and about half of them are more than 100 years old.¹⁰

As the population grows, these systems need to work harder and harder to cope. London's strained infrastructure is increasingly vulnerable to everyday changes in temperature and water flow, and becomes less resilient to acute events.

The mayor has responded to London's multiple needs with the London Infrastructure Plan 2050. The plan identifies, prioritises and costs London's future infrastructure requirements. Those costs are daunting: a £135bn funding gap has been identified for housing and transport alone.¹¹

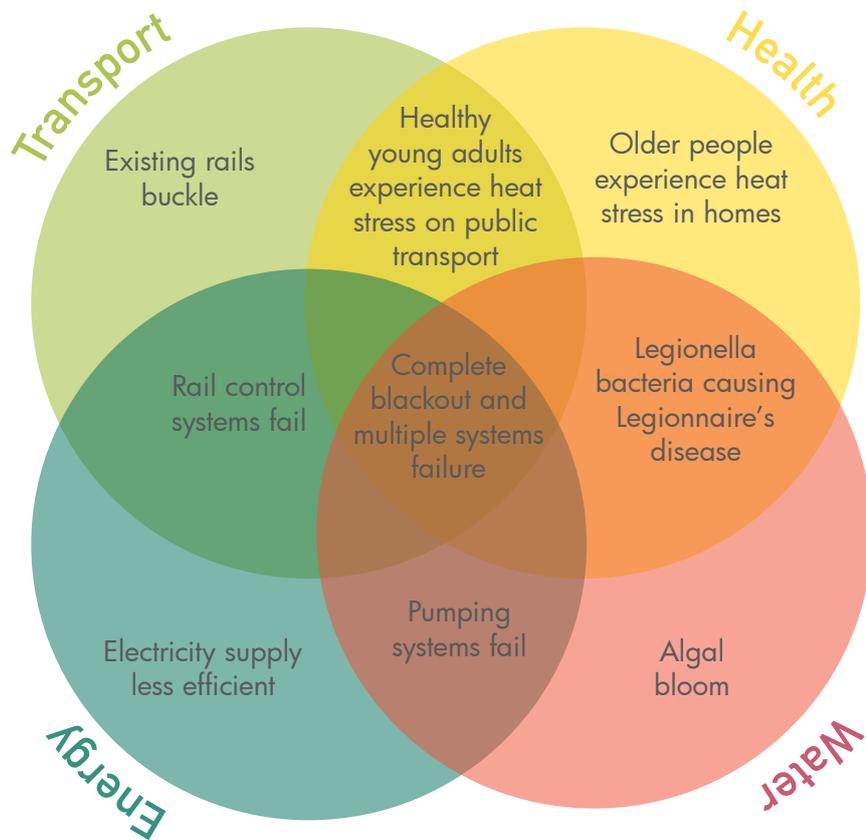
Figure 1 demonstrates that London's infrastructure is already under significant strain from the weight of its population. Many UK cities and conurbations experience stress, but London is much more densely populated, and hence far more users directly or indirectly depend on its infrastructure.

Figure 1: Relative density of critical infrastructure



Source: Committee on Climate Change¹²

Figure 2: Heat cascade failure



Source: London Climate Change Partnership¹³

A global city such as London is a set of complex interconnected systems; when something goes wrong in one system or area, its impacts can cascade spatially and systemically. The London Climate Change Partnership's heat thresholds report shows the different systems affected by a single heat event, and how they overlap and combine, resulting in additional – and sometimes unforeseen – impacts (see Figure 2).

Not only is this challenging to London as a city, it demonstrates the additional complexity of roles and responsibilities. Every system has a supply chain, and it only takes one element to fail to affect the entire system. This hugely

extends the number of actors involved in keeping London working and demonstrates the significant challenges the capital faces in its adaptation efforts.

For a system to adapt, all supply chain links must play their role, or the effort may not work. London-wide, a likely scenario might be that one operator will not invest in measures to make its system more resilient, since the measures will only be successful if other operators in the supply chain do the same. In a catch-22, that single refusal could topple the system during an incident. The whole effort depends on collective action.

Growing demands on land

London's population growth is also putting pressure on land. With housing seriously undersupplied, there is an understandable impetus to try to build at speed, and usually at greater density. While responding to one fundamental need, this densification makes parts of the city more vulnerable to surface water flooding by reducing the amount of absorbent ground. The push to build homes quickly also risks their individual resilience, particularly in developments which circumnavigate the planning system by using permitted development rights.

London's climate vulnerabilities

Flooding

Although London is at some risk of several types of flooding, the biggest threats are: tidal – the effect of North Sea surge on the tidal river Thames; fluvial – the effect of heavy rainfall on London's network of above- and below-ground rivers; and surface – the effect of excessive rainfall not being able to drain or 'run off' London's extensive hard surfaces. The third is arguably the hardest to manage, being so affected by building density and the effectiveness of individual drains or systems.

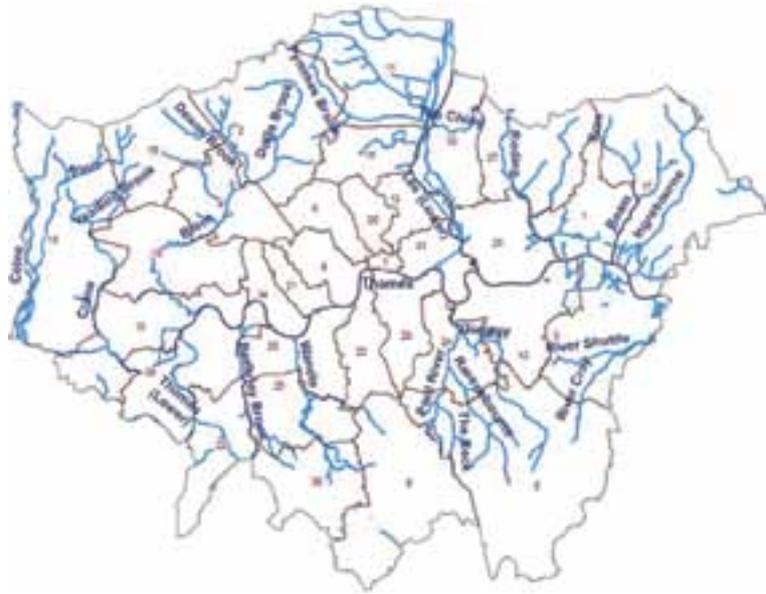
Drought

Perhaps surprisingly, London is drier per capita than Madrid or Istanbul.¹⁵ Effective water management is about maximising supply through capture and storage, as well as looking for ways to reduce demand. It takes two consecutive drier-than-normal winters to create water supply issues. However, in 2006 and 2012, London experienced significant droughts, and in 2012 only avoided serious water restrictions because of the wettest summer in a century.¹⁶

Cold

London is generally a few degrees warmer than the rest of the country, but cold snaps are common. Those on low incomes can find it particularly hard to pay their energy bills, putting them at higher risk of fuel poverty. Cold homes cause and exacerbate serious health problems including cardiovascular and respiratory diseases.¹⁷ The rise in excess winter deaths in 2014/15 was due to a number of factors in concert.

Figure 3: London's above-ground river network



Source: London Resilience Forum¹⁴

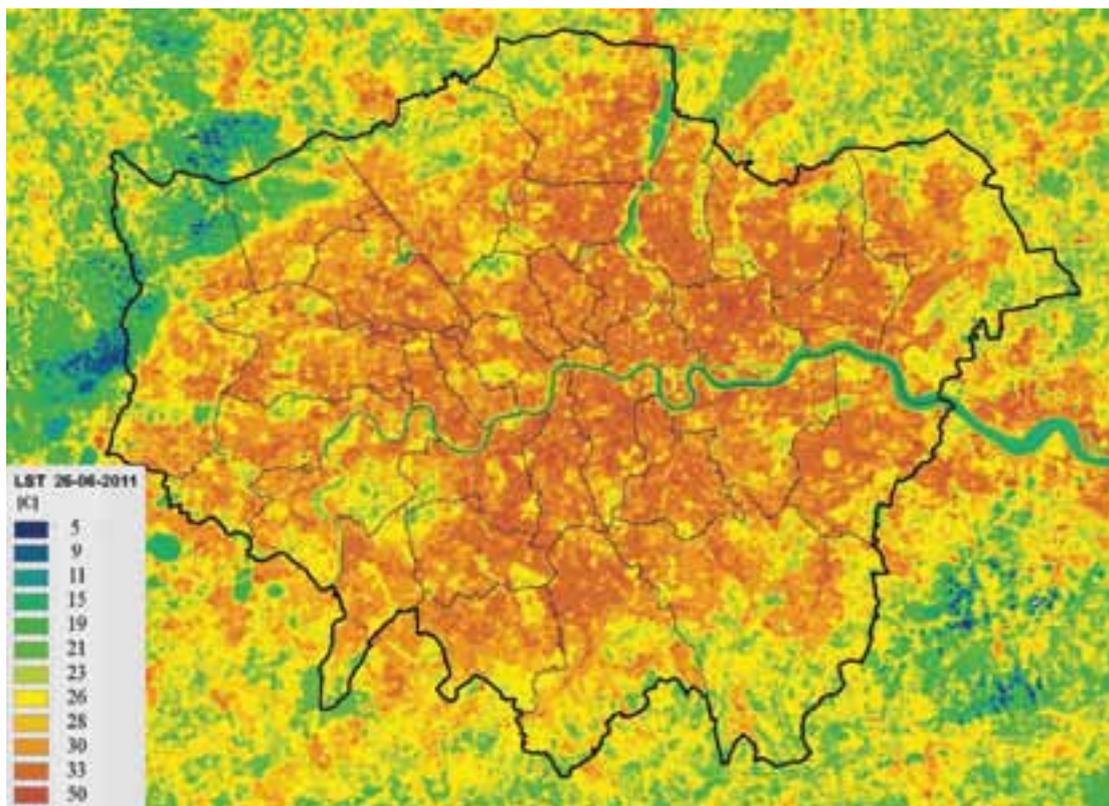
Heat

London is an urban heat island – its hard surfaces soak up heat during the day and release it overnight, keeping temperatures in the most urbanised parts of the city several degrees higher than the surrounding countryside. As temperatures in the city rise, it will be increasingly difficult to rid the city of its excess heat, leading to uncomfortable and dangerous temperatures, particularly for the very old and very young, people with respiratory and cardiovascular conditions and diabetes.¹⁸ The effect may also make air pollution worse by accelerating production of harmful pollutants, such as ozone.¹⁹ It is uncertain how London's infrastructure will cope if heat waves increase.

The Arup map opposite shows the concentration of high temperatures in built-up inner London. Temperatures drop fast on the outer London fringes and beyond.

The World Bank recently estimated that up to 80% of the expected \$80–100bn annual cost of climate change adaptation will be borne by urban regions.²⁴ This gives cities an impetus to act.

Figure 4: The Urban Heat Island effect on London



Source: Arup ²⁰

Climate change

Climate change adds dimensions of risk, complexity and uncertainty to this picture. The UK Climate Projections 09 report predicts that the southeast UK will experience warmer, wetter winters and hotter, drier summers. It also predicts that extreme weather, such as heatwaves and very heavy rainfall, will become more frequent and intense. Sea levels are expected to continue to rise for centuries. The next report, due in 2018, will provide new land and sea-level projections, and is expected to give greater regional detail, as well as further analysis of risks and climate change impacts.²¹

There is scientific consensus that a level of climate change is unstoppable due to emissions already released, and acknowledgement that more extreme weather events are set to occur as we move through the century.²² Halting further increases depends on when, and the extent to which,

the world responds with a shift away from 'business as usual' emissions. The Intergovernmental Panel on Climate Change (IPCC) models its projections to 2100 using four contrasting emissions pathways. The pathways include the effect of a proactive response, but forming a unified global response seems impossible. Even if one was reached, the Stern Review acknowledged that "pinpointing where and when these [climate change] events might occur, and predicting their individual impact, is not feasible with any degree of precision".²³ This uncertainty continues to hamper efforts to change at macro and micro scales.

Many of the impacts of climate change will be felt most sharply in the developing world, due to greater exposure and poorer infrastructure. However, the UK is also experiencing more damaging and costly extreme weather, with an

unprecedented number of incidents over the past three years.²⁵ In 2015, these included record high temperatures in December, two extreme rainfall and flood events and a heatwave, demonstrating the vagaries of our changing weather.

The effects of climate change will exacerbate London's propensity for flooding (tidal, fluvial and surface), heat and drought.

London is an importer of climate change risk via its global supply chains. In 2014, the total value of commodity imports to London was around £68bn – a high (and increasing) proportion of those come from regions highly vulnerable to climate change.²⁶

Risks

Risk Management in London

In London, citywide risk monitoring and response fall to the mayor’s resilience team. In addition to general and threat-specific emergency planning, the team produces the London Resilience Risk Register. This tool ranks risks to the city based on a combination of probability and consequences.

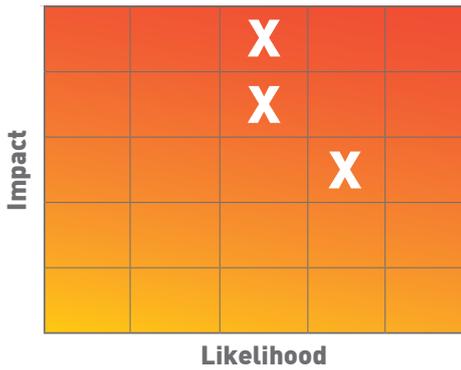
Figure 5: London Resilience Risk Register summary

Impact	<ul style="list-style-type: none"> • Toxic chemical release • Reservoir/dam failure 	<ul style="list-style-type: none"> • Coastal flooding • National electricity failure • Unconventional attack 	<ul style="list-style-type: none"> ▶ SEVERE INLAND FLOODING ◀ 		
	<ul style="list-style-type: none"> • Radioactive material release 	<ul style="list-style-type: none"> • Oil/gas upstream failure • Regional electricity failure ▶ DROUGHT ◀ • Hazardous goods accident 	<ul style="list-style-type: none"> ▶ FLUVIAL/SURFACE WATER FLOODING ◀ 	<ul style="list-style-type: none"> • Pandemic disease 	
	<ul style="list-style-type: none"> • Pipeline fire or explosion • Maritime transport incident • Land movement • Bridge collapse 	<ul style="list-style-type: none"> • Aviation incident • Road explosives accident • Building collapse • Fuel distribution site fire • Cyber security • Railway accident 	<ul style="list-style-type: none"> • Emerging infectious diseases • Storms and gales • Low temperatures and snow • Attacks on infrastructure • Severe space weather 	<ul style="list-style-type: none"> ▶ LOCAL FLUVIAL FLOODING ◀ • Non-availability of piped water supply • Essential service strike • Attack on crowded places ▶ HEATWAVE ◀ 	<ul style="list-style-type: none"> • Fire and rescue strike • Attack on transport system
	<ul style="list-style-type: none"> • Maritime pollution • Wildfire 	<ul style="list-style-type: none"> • Industrial Explosions and fires • Transport industrial action • Animal disease • Fuel supply constraint 	<ul style="list-style-type: none"> • Food chain contamination 		<ul style="list-style-type: none"> • Loss of telecommunications
				<ul style="list-style-type: none"> • Large road accident 	
					Likelihood

Source: London Resilience Forum²⁷

Climate change is not listed as a separate threat, but it is inherently included, since risk planning is based on “reasonable worst case scenarios informed by historical and scientific data, modelling and professional expert judgement of both the likelihood and impact of a risk”.²⁸

Flooding



London resilience risk rating:

- Tidal and fluvial/surface flooding as 'very high' or 'high', depending on scale and significance.
- Surface water run-off that affects sewers is 'very high' due to the serious public health impact of sewer overflows.
- Fluvial and surface water flooding are only surpassed by pandemic disease in terms of overall risk magnitude.

Lead authority: The Environment Agency (EA) takes strategic overview; local flood authorities manage risks and publish local flood-risk management strategies.

Metrics: As volume of development affects the level of flood risk, the EA identifies flood zones for the National Planning Policy Framework (Table 1). Local authorities are advised to avoid permitting numerous types of development in Zone 3b.

Table 1: Environment Agency tidal and river flood zones²⁹

Flood Zone 1	low probability	less than 1 in 1,000 per year
Flood Zone 2	medium	1 in 100 – 1 in 1,000 river / 1 in 200 – 1 in 1,000 sea per year
Flood Zone 3	high	more than 1 in 100 river / more than 1 in 200 sea
Flood Zone 3b	functional flood plain	varies; often more than 1 in 20

Challenges:

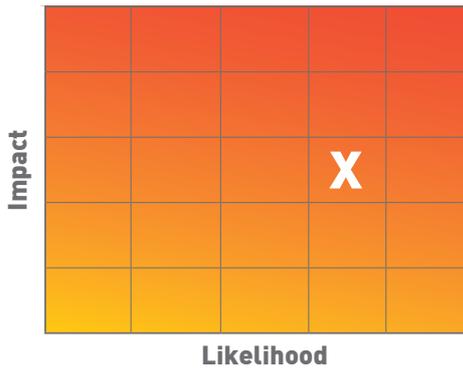
- Multiple types of flooding – some more interconnected than others, each with different thresholds.
- Complexity of surface water flooding – the type of weather system that causes surface water flooding is unpredictable and localised. The capacity of an area to cope with surface flooding is largely dependent on the ability of the ground to absorb it and the saturation of that ground. Developed land usually includes a lot of impermeable surfaces, though green spaces and other green infrastructure will improve performance at an ultra-local level.
- Clarity of risk 'ownership' – for example, although the EA is not responsible for surface water flooding, it has an online surface water flood map.³⁰
- Insufficient knowledge – there is a range of Sustainable Urban Drainage Systems (SuDS) measures and a bespoke approach is required in each case. Investment programmes such as Thames Water's Twenty for Twenty are producing an evidence base.³¹
- Ultra-local and up-to-date knowledge requirements – surface, ground water and sewer flooding are all interconnected, and affected largely by standards of individual systems. The mayor's Drain London project has improved understanding of ultra-local surface water flooding, and funds a number of projects to mitigate it.³² Figure 6 is an example of detailed surface flood risk in LB Hammersmith & Fulham, including an allowance for climate change. The map shows that risk level differs street by street and identifies flood hotspots.
- Growth itself – as London becomes more built up, its resilience diminishes. Between 2001 and 2014, approximately 68,000 new homes (3% of all new homes in England) were built in areas with a 1 in 100 or greater annual chance of flooding. Of these, 23,000 were built in areas of high flood risk (a 1 in 30 or greater annual chance of flooding, even accounting for any flood defences).³³ Building on a flood plain puts these properties at higher risk, and the displaced water can exacerbate problems elsewhere.

Figure 6: LBHF surface flood risk mapping



Source: London Borough of Hammersmith & Fulham³⁴

Heat



London resilience risk rating: Heatwave is ‘high’ overall; likelihood higher than impact.

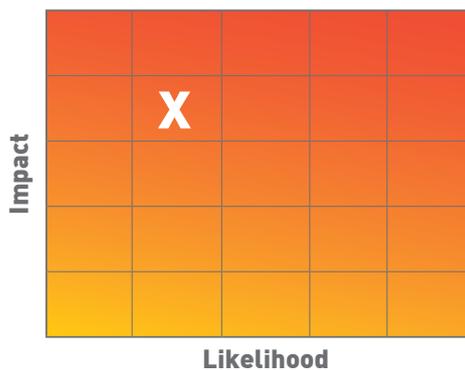
Lead authority: Different authorities are responsible for different aspects. Public Health England produces a national heatwave plan, while local authority public health directors are responsible for “population health outcomes”.³⁵

Metrics: There are two sets of guidance on temperatures that constitute overheating: the 2006 Chartered Institution of Building Services Engineers standards, updated in 2013; and the 2012 Standard Assessment Procedure.³⁶ Both sets of guidance are limited by the subjectiveness of overheating and people’s responses to it.

Challenges:

- Lack of statutory lead – no single authority on heat.
- Complexity of issue – how a property, piece of infrastructure or person reacts to exposure to heat varies hugely. Other factors, such as air quality, affect humans’ response to heat.
- Retrofit challenge – most problems are about modifying existing properties and infrastructure. Challenges of appetite, conservation, access and cost.³⁷
- Growth – reduction in green space increases urban heat island effect.
- Over-regulation – regulatory response to cold-proofing has made many new buildings too insulated, thus unable to remove excess heat.³⁸

Drought



London Resilience Risk Rating: Drought is ‘high’ overall – the probability is lower, but the impact is high. Although London is relatively resistant to drought, the Green Infrastructure Task Force, established following the publication of the London Infrastructure Plan 2050, predict a 10% water shortfall by 2025, rising to 21% by 2040.³⁹

Lead authority: Water is supplied by four suppliers, regulated by Ofwat. All water companies produce Water Resource Management Plans (WRMPs) and Drought Plans. The Environment Agency is responsible for advising Defra on the WRMPs, and Ofwat assesses the water companies’ business plans. There is no pan-London water management plan.

Metrics: Probability levels of scenarios where water supply would need to be restricted.

Challenges

- Lack of data – local information is needed for an accurate picture of risk.
- Multiple owners – four companies in London with separate water management strategies.
- Multiple utility regulators – water company regulator Ofwat does not align with other utility regulators such as energy regulator Ofgem, which could lead to missed opportunities.
- Impact of climate change – in its 2015–2040 plan, Thames Water predicts that climate change will reduce supply. In working out resources needed to meet demand, the company has established a headroom buffer, i.e. a contingency to provide certainty of meeting its obligations. It cites climate change uncertainty as one of the two most significant components of the headroom allowance.⁴¹

Table 2: Thames Water restriction levels and actions⁴⁰

Level	Frequency of Occurrence	Water use restrictions
Level 1	1 year in 5 on average	Intensive media campaign
Level 2	1 year in 10 on average	Sprinkler/unattended hosepipe ban, enhanced media campaign
Level 3	1 year in 20 on average	Temporary Use Ban (formerly hosepipe ban), Drought Direction 2011 (formerly non-essential use bans) requiring the granting of an Ordinary Drought Order.
Level 4	Never	Any extreme measures (e.g. standpipes or rota cuts) would require an Emergency Drought Order application to the UK government

Risks

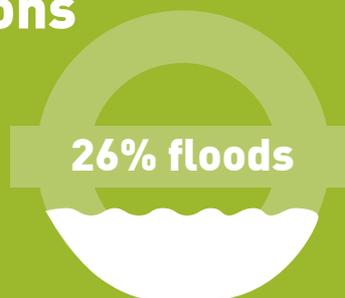
1.25m people and £200bn worth of property in London are at risk from tidal flooding⁴²

1.25m people

800000

More than 800,000 properties lie at risk of surface water flooding⁴³

Civil infrastructure at risk of tidal and fluvial floods includes **15% of railway stations, 26% of Underground/DLR stations and 29% of bus depots⁴⁴**



By 2025, there could be a **10% deficit in London's water supply⁴⁵**



By the 2050s, 80–92% of flats could experience internal temperatures over 28°C during a heatwave⁴⁶

Costs

There are obviously costs to making public assets, services, systems and places more resilient to the effects of flooding, heat and drought. But the cost of climate change-related impacts can be far higher.

As a developed country far in a temperate climate zone,⁴⁷ the UK is shielded from many of the worst effects of climate change. However, London's growing, ageing population and ageing infrastructure put the city's ability to function successfully, as well as its population, at risk. Economically, London has a global financial services industry at its heart, meaning that if climate change is

pegged against the potential losses to GDP, London is as if not more exposed than developing countries in more volatile climate zones. For example, London is ranked tenth globally for proportion of GDP at risk from flooding.⁴⁸ At the other end of the scale, London's SMEs – 99% of all its businesses – are particularly exposed to the effects of climate change.⁴⁹

Public health costs are harder to quantify, but Public Health England has acknowledged the mental health implications of flooding and overheating buildings are known to cause ill-health and even fatalities.⁵⁰ By the 2050s, UK-wide heat-related

deaths are projected to increase by around 250% on the current baseline.

An acute event, such as a serious storm, can have catastrophic effects on a city and its communities. Hurricane Sandy killed 44 New Yorkers and caused \$19bn in damages and lost economic activity.⁵¹

As extreme weather is becoming more common in the UK, this is a real threat. Even if London dodges extreme weather events, such as the winter flood episodes of 2013/14 and 2015/16, the increase in minor weather-related events means smaller, more frequent losses are stacking up, for victims large and small.⁵²

Table 3: Costs of inaction

Global losses

- **Warming of 5°C** could result in **\$7tn in global asset losses** – more than the total market capitalisation of the London Stock Exchange. **6°C of warming** could lead to a present-value loss of **\$13.8tn** of manageable financial assets, roughly **10%** of the global total. Global losses could wipe out up to **3.5% of GDP**.⁵³
- From 1980 to 2012, total reported global losses were **\$3.8tn**, with **74%** due to extreme weather.⁵⁴
- **17m people** were displaced by **natural hazards** in **2009**; **42m people** in **2010**.⁵⁶

UK losses

- Warming of **3 or 4°C** could increase annual flood losses from **0.1% of GDP** today to **0.2–0.4% of GDP**.⁵⁷
- Following the **2013/14 UK floods**, the ABI estimated **insurance claims of £1.1bn**, including **£446m** for flooded businesses and homes.⁵⁸
- UK-wide **heat-related deaths** are projected to **increase by around 250%** by the 2050s.^[vi] Annual heat-related mortality and morbidity costs in the UK could **increase** from 2012 levels by **£84m and £183m respectively**.⁵⁹

Local losses

- **18% of London's GDP is at risk from flood**, ranking London 10 out of 301 of the world's major cities for proportion of GDP at risk. **5% of GDP is at risk from drought**, placing London **fifth** in global risk rankings.⁶⁰
- **Staff time** lost due to flooding in London could cost up to **£10m per day**.⁶¹
- The financial impact of **reduced economic activity due to water rationing** in London could be **£236m–£329m per day**.⁶²
- Between **540 and 760 premature deaths** were caused by the **2013 London heatwave**.⁶³
- Costs of health impacts from **poor air quality** range from **£1.4bn to £3.7bn**.⁶⁴

Responses

The most effective responses to climate change are complementary and interconnected. This requires clarity of role and responsibility, and effective partnerships between lead risk 'owners' or authorities, and a web of relevant stakeholders.

Responses to climate change are two-fold: **mitigation** (the reduction of greenhouse gas emissions) and **adaptation** (adjusting to current or expected impacts). Whereas mitigation has global benefits, adaptation works on a systemic level, so is arguably best delivered locally.⁶⁵

Climate **resilience** could be said to be a consequence of effective mitigation or adaptation. However, it has additional meaning of the ability of a system to "bounce back after a shock".⁶⁶ Developing resilience minimises the costs of a shock event.

There are two further types of risk response that need to follow on from climate change-specific responses; these are **disaster preparedness** and **risk transfer**. In London, where the risks are particularly high, disaster preparedness is essential 'worst-case scenario' planning; while the ability to shift high risks from one party to another – for example through an insurance policy – is essential for protecting the city's citizens, businesses and economy.

Public sector responses

Global / EU

Global and European initiatives to mitigate climate change set the agenda for both reducing emissions and for adapting to current and future effects of climate change.

In 2015, the EU agreed to participate in the second commitment period of the Kyoto

Protocol, which commits member states to reduce combined emissions by 20% between 2013 and 2020.⁶⁷

National

The UK government signed the Paris Agreement to reduce pollution from greenhouse gases and prevent global temperatures from increasing more than 2°C above pre-industrial levels by 2100.⁶⁸ Signatory countries set their own targets and review them every five years.

Nationally, the 2008 Climate Change Act requires the UK to reduce emissions by at least 80% from 1990 levels by 2050, set emission caps ('carbon budgets') over a five-year period and mandates the development of a National Adaptation Programme. The current programme includes sections on the built environment and infrastructure, and emphasises the role of London and the core cities.⁶⁹ The next report is due in 2018, one year after the UK Committee on Climate Change's 2017 risk assessment.

Although the government has both mitigation and adaptation commitments, it is arguably more supportive of the former. For example, the UK government-funded Green Investment Bank's (GIB) purpose is to accelerate the UK's transition to a greener economy. It primarily invests in offshore wind, waste and bioenergy, and energy efficiency markets. These are useful areas, but restricted to mitigation, rather than funding or leveraging investment in adaptation schemes. At the same time, shifting retrofit policy, such as the support for and then withdrawal of Green Deal finance and zero carbon targets, has increased costs and reduced incentives for suppliers and consumers.⁷⁰

Pan-London

The GLA is committed to reducing carbon emissions by 60% by 2025.⁷¹ It aims to meet these through two strategies, published in 2011: climate change mitigation and energy and adaptation to climate change. The GLA has drafted London Local Air Quality Management 2016 – policy guidance for local authorities creating and monitoring local Air Quality Action Plans.⁷²

With spatial planning a key lever in reducing emissions and adapting to climate change, The 2015 London Plan is a particularly powerful tool. It supports a wide range of measures, such as minimising emissions from buildings, increasing urban greening, implementing SuDS and reducing the urban heat island effect – to strengthen London against climate risks and reach the 60% reduction target.⁷³

A number of other bodies coordinate London-wide and cross-sector action on mitigation and adaptation. These include the cross-sector London Climate Change Partnership and the London Enterprise Panel (LEP), which coordinates the European Structural and Investment Funds. These are released by the European Investment Bank, a major funder of UK infrastructure. They bring scale and investor security, but are now at risk from Brexit. Infrastructure projects without access to these funds could see resilience – both short- and long-term – drop down the priority list.

Local

Local authorities have statutory duties relating to flooding, air quality and drought. As Lead Local Flood Authorities, they must produce flood risk management strategies which include flood risk from surface water, ground water and watercourses. They are also required to develop and monitor air quality action plans. Finally, they must prepare emergency responses to severe drought.

Strategies vary: around two-thirds of London councils have pulled their actions on climate change into one overarching strategy, though around half of these were written before 2010. Other councils focus on tackling climate change through planning, by promoting sustainable development in their core strategies. A few have no demonstrable strategies.⁷⁴

Table 4: Local authority statutory duties

Flood risk	<ul style="list-style-type: none">• Act as Lead Local Flood Authorities• Prepare flood risk management strategies (Flood and Water Management Act 2010)• Avoid permitting various types of development in high flood risk areas
Drought	<ul style="list-style-type: none">• Prepare emergency responses to severe drought through natural disaster plan
Air quality	<ul style="list-style-type: none">• Create and monitor Air Quality Action Plans

“It is no longer possible to claim ignorance about environmental risks.”
Senior roundtable participant

Private sector responses

With scientists and governments now unanimous that climate change is a reasonably foreseeable threat, the related **investor, insurance, legal** and **property** industries are evolving.

Investors

Investors inherently have an interest in the long-term potential of assets. However, according to estimates by the Asset Owners Disclosure Project, only 7% of asset owners calculate the carbon footprint of their portfolios, and only 1.4% have an explicit target to reduce it.⁷⁵ The Economist’s The Costs of Inaction report suggested that by overemphasising short-term performance rather than long-term returns, the industry’s ‘fiduciary duty’ is at risk. The report called on the Organisation of Economic Cooperation Development to consider an amendment to the Convention on Fiduciary Duty that prioritises long-term outcomes.⁷⁶

“Clients of investment firms and beneficiaries of pension funds might have a legal case to bring if those who manage money for them stand idly by as emissions erode the value of their stock,” said Howard Covington, the former CEO of a £20bn asset management company and a trustee of environmental law organisation, ClientEarth.⁷⁷

Insurance

The Bank of England has investigated the responsibility of the global insurance industry to alleviate vast financial losses that have occurred through lack of insurance in high-risk areas. There is a particular risk to areas where the probability of a severe event increases, with the consequence that insurers withdraw their services.

The Bank’s 2015 report cites the Bahamas as an example, where people were forced to self-insure or fund their own adaptation work due to the withdrawal of insurance

cover. The lack of insurability caused mortgage offers to dry up and property values to collapse, resulting in many properties being abandoned.⁷⁸

Although a similar scenario could occur in high-risk areas of London following a series of acute events, the UK government has stepped in to avoid this sort of occurrence, with the Flood Re insurance scheme an example (see case study).

Another issue with the industry is its ‘reinstatement’ policy. In the event of damages to buildings, an insurer company will generally provide funds for a like-for-like replacement. This is counter-intuitive to mitigating future risk and sets the asset up for further damages.

Zurich, a major insurer of London property, is “very amenable to having that conversation about putting a building back in a more sustainable or sensible way”, suggesting that the industry could be more flexible.⁸¹

Legal

The legal landscape is changing in both Europe and the USA, with communities, legal experts and insurance companies raising important questions around who should be liable for the costs of climate change. A stronger case is likely to be made for a company or government's failure to adapt to climate change than mitigate.⁸²

In 2015, a court in The Hague ordered the Dutch government to cut its emissions by at least 25% within five years. This is the first climate change case to be founded on human rights, with the Urgenda Foundation accusing the Dutch government of "knowingly contributing" to a breach of the 2°C maximum target for global warming, and thus failing to protect its citizens from climate change.

The Dutch government is appealing the verdict, and the case is likely to go to the Supreme Court.⁸³ The precedent has led to a similar citizen-led human rights case in Belgium, and others will follow.

Lawsuits against governments triggered by the physical effects of climate change could also become more common. In 2015, Farmers Insurance Co. filed nine class-action lawsuits arguing that local governments in the Chicago area are aware that climate change is leading to heavier rainfall but are failing to prepare accordingly. The lawsuits alleged that the localities failed to adapt sewers and stormwater drains that flooded during a storm. The case was withdrawn.⁸⁴

In the UK, central government has already been in battle with the Supreme Court and legal activist organisation ClientEarth over illegal levels of air pollution in the UK. The Supreme Court ordered Defra to bring air pollution in the UK to within legal levels as soon as possible. The case will be heard in the High Court in October 2016.⁸⁵

Property

Flooding has a tangible effect on property. Therefore, flood risk is often included in valuations. Impacts to wider climate risks such as overheating or water shortages are often not factored in. Property valuation follows the marketplace and predicts the value a prospective buyer would be willing to pay. Consumers trust valuers to factor in what's important. Without regulation, this vicious circle is unlikely to be broken.

In 2013, the Royal Institute of Chartered Surveyors suggested that regulation would increase alongside the increase in hard scientific evidence on climate change, but three years on little has changed.⁸⁶

CASE STUDY: FLOOD RE⁷⁹

In areas prone to flooding, insuring a house can be unaffordable for owners as insurers seek to avoid financial loss by charging high fees and excesses. In April 2016, the UK government and insurance industry unveiled Flood Re, a risk transfer scheme intended to help reduce flood insurance costs for homeowners. The scheme allows insurance companies to shift the risks associated with covering flood-prone homes to reinsurer Flood Re, which is owned and managed by the insurance industry and accountable to parliament.

Funding for Flood Re comes from two sources. The first is from owners of at-risk homes who pay premiums tied to council tax bands. The second is an annual levy of £180m on the insurance industry, which is passed down to all home insurance policyholders through premiums regardless of their flood risk. This method of low-risk customers subsidising high-risk customers is known as an 'insurance pool' and it allows homeowners in flood risk areas to access affordable insurance. In London, an estimated 38,500 households could benefit from Flood Re.⁸⁰

Flood Re was designed as a stopgap, and will come to an end in 2041. As the effects of climate change will make funding the scheme more costly towards its end, it is not a viable long-term solution. Other efforts must be made to improve flood resilience through effective planning, flood risk management, greater awareness among residents and sustainability measures.

While the main objective of Flood Re is to assist the households who cannot get regular flood insurance, it contributes to long-term national flood resilience in two ways. Firstly, anyone who takes out insurance through scheme is given information on how to adapt their properties. Secondly, by limiting the scheme to homes built before 2009, owners of new homes will not be able to rely on Flood Re, thus discouraging new development in high flood risk areas.

✔ **Keywords** flooding, national, risk transfer, partnership, education

Summary

London's old housing stock and critical infrastructure are under systemic stress as they struggle to cope with minor weather events, such as temperature increases and heavy rainfall. As climate change increases the frequency of minor events, and the probability of an acute flood, storm or heatwave, London's assets and infrastructure more than ever need significant investment for retrofit and adaptation.

Although the GLA's 2011 adaptation plan reported the biggest challenges to London's overall resilience, many have not reduced significantly. Local Government budgets have been cut, skills and capacity vary across local authorities and housing associations, and local knowledge of impacts and risks is often insufficient.

In addition, many lines of responsibility for managing risks and delivering responses are unclear, and developer, housing association, local authority and service provider business plans do not always align.

There are weighty economic, social and functional costs of inaction for public service providers, with potential legal challenges a further risk as citizens become increasingly aware that policy and activity are often weak. But there are also huge costs tied to implementing adaptation schemes and strategies.

The solutions are threefold: **new approaches and mechanisms for funding** adaptation and resilience; **effective cross-sector collaboration and partnership**; and seeing the opportunity in action by **reframing resilience**.

PART 2: SOLUTIONS

Funding resilience

Continued stress on London property and infrastructure is making the city less prepared for an acute weather event, such as a major flood or heatwave. Public and private sectors need to find new ways of working together to fund measures to make assets and services more resilient.

Public sector

Key players

National government

The Department for Energy, Farming and Rural Areas (Defra) is responsible for climate change, flood protection and other environmental risk management. It is investing £370m per year on protecting homes and businesses from flooding, rising to £400m by 2021.⁸⁷

Defra also worked with insurers to develop Flood Re, which helps owners of properties at high risk of flooding to protect their properties. This is a good example of government and the insurance industry working together to provide protection through the private market to properties that the industry would not cover with traditional insurance products (see case study on p20), avoiding mental health and other issues that would result from uninsured properties suffering from flood damage.

The mayor

The mayor and the GLA are best placed to bring together key players to jointly develop a London-wide response. The GLA can also provide strategic direction by including resilience as a key aspect of its long term infrastructure planning.

As well as providing strategic leadership for adaptation projects

across the capital, the GLA funds a range of projects, including pocket parks and tree planting, plus major investment in green investment showcase projects. RE:FIT, a scheme funded by the EU and GLA, has completed or committed to works on 600 buildings.⁸⁸

“Adaptation policy needs to do more to address social vulnerability.”

Katharine Knox, JRF⁹¹

LEP

The London Enterprise Panel manages €745m of European Structural and Investment Funds, released by the European Investment Bank, and guided by its Sustainable Urban Development Strategy for London 2014–20.⁸⁹ Investing in London’s infrastructure is one of four priorities, including the financing of green infrastructure, with the rationale of economic performance, access to adequate, accessible and affordable workspace and addressing the green infrastructure funding gap.

Local authorities and housing associations

Both local authorities and housing associations have the dual incentive of maintaining the long-term viability of their properties with the need to protect their communities. Many housing associations are both developer and multi-tenure manager.

Business case

If the public sector does not address the market failures predicated by climate change, assets and communities will be at risk. Whether it is exposure to fuel poverty, air pollution or uninsurability, the costs are high. But at this period of continued economic uncertainty and public austerity, local authorities and housing associations need to make a sound business case for adaptation work. They can do this by:

Auditing their asset portfolios

Identifying vulnerability

Analysing costs and benefits

▶ Auditing their asset portfolios

An audit of their asset portfolio will help to attach realistic costs to the installation of certain measures, find cost-savings through installing measures at scale and prioritise investment. However, data on existing stock is often poor and not up to date, and gathering can be very difficult, particularly for holders of large portfolios. It will be cost-effective to use tools and systems that have been developed for this purpose.

For example, to help Marks & Spencer meet the commitments in their ‘Plan A’ strategy, Arup developed a practical framework and training materials to assess and reduce climate change related risks to its UK stores.⁹⁰ The tool allowed M&S to assess current and future climate risks across their store portfolio, and

estimate the costs and benefits of measures to reduce these risks. Arup provided climate adaptation and resilience recommendations for the company’s biggest stores and major new store development projects. To ensure M&S staff members understood the context and process, they also developed an e-learning module.

► **Identifying vulnerability**

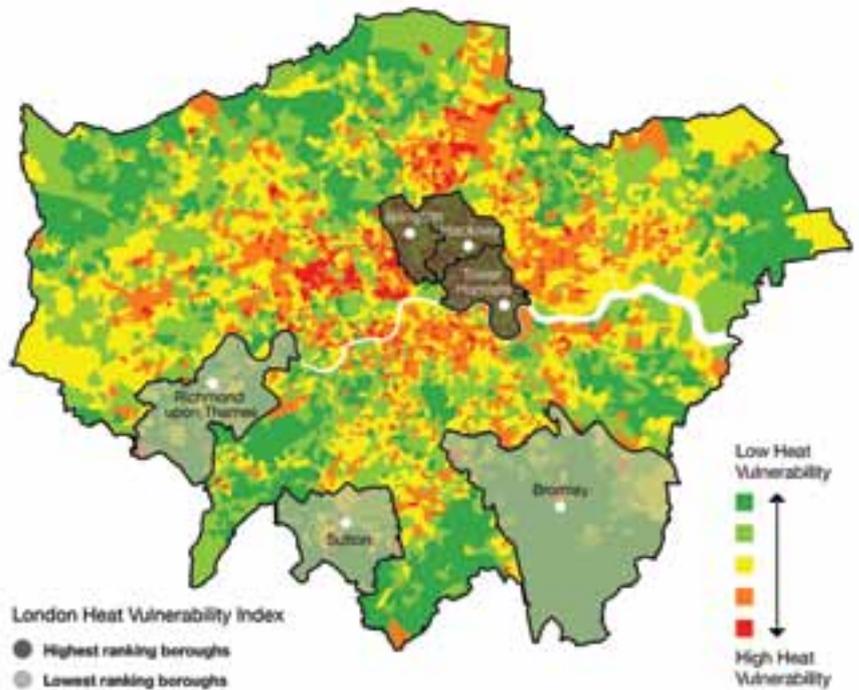
Once an organisation has a strong physical understanding of their portfolio, layering it with socioeconomic data will help to prioritise the properties and communities most in need.

Arup developed the Heat Vulnerability Index, which combines data on physical factors, building form and clusters of vulnerable people. ‘Triple risk’ areas have the highest HVI, and indicate where resources should be directed. See also Climate Just example in Appendix 1.

► **Analysing costs and benefits**

The costs of installing adaptation or resilience measures to assets are dependent on many factors: age, design, materials, size of portfolio, etc. While a bottom-up

Figure 7: Heat wave vulnerability in London



Source: Arup⁹²

model of analysis and decision-making therefore makes sense, more models and guidance would help. This analysis should be tied to risk – what are the most cost-efficient ways of reducing risk to an acceptable level?

As an example, London-based housing association Octavia Housing measured the comparative costs of

adapting the different kinds of stock in their housing portfolio to achieve the same risk-based outcomes: a 50% and 90% reduction in the number of hours a house would be at a temperature classed as overheating. The table below demonstrates the range of costs dependent on proposed level of risk reduction, housing type and methods.

Table 5 Octavia Housing cost-benefit analysis across housing types. ⁹³		
Housing type	50% reduction overheating hours (cost and method)	90% reduction in overheating hours (cost and method)
Top floor flat	£3,000 (external shutters and night ventilation)	£8,000 (external shutters, fixed external shading above windows, night ventilation, window rules, upgraded roof and light walls)
Ground/mid-floor	£6,500 (as above)	£9,500 (as above)
Modern housing	£500 (night ventilation and curtains)	£6,000 (external shutters, night ventilation, triple e-glazing, light roof, extra roof insulation and window rules)
1930s–50s house	£2,000 (night ventilation and internal blinds)	£16,000 (external shutters, night ventilation and window rules)

Private sector

Key players

Institutional investors, pension funds

The investment industry is becoming increasingly aware of its duty to consider the long-term resilience of assets, as well as the opportunity to invest in adaptation and resilience schemes.

The industry already has sophisticated modelling systems to measure physical asset risks. The Prudential Regulation Authority, the Bank of England's regulatory organisation, recognises that more speculative risks, such as increased third-party public liability claims, could increase.⁹⁴

Investing in adaptation and resilience could also be a good contribution to the shift away from fossil fuels. Carbon Tracker reported in 2011 that London was holding 10 times more carbon in investment reserves than the UK carbon budget agreed in the 2008 Climate Change Act.⁹⁵ As this failure to act on a commitment comes to light, the fossil fuels market could experience huge losses in value. Shifting towards low-carbon alternatives while values are still high makes sense.

Aside from pushing for regulatory changes, the industry has a role in developing and using investment mechanisms suitable for adaptation and resilience investment. The Bank of England has called on institutional investors to play an active role in mitigating the effects of climate change, such as through investment in green bonds.⁹⁶

Investors can also fund resilience by choosing to invest in developers with strong sustainability credentials. For example, Aviva Investors supports Igloo, a regeneration and property company with a focus

“Banks are funding everything you're trying to do. You need to engage them.”
Senior roundtable participant

on all facets of sustainability: economic, environmental, social and financial.⁹⁷

Insurers

As more extreme weather events hit London, insurance premiums in risky areas will rise, and the most high-risk areas could become uninsurable. Recovery costs for uninsured areas can be high, hitting consumers and government, increasing the likelihood of liability claims being developed and making an area less attractive for further investment.

The insurance industry can lead the way in accelerating public-sector resilience, having influence over both investors and consumers. If an insurer can provide a product that protects an investor from the most extreme risks, it will support the investor's whole portfolio. As insurance companies often invest in real estate themselves, solutions could also support their own interests.

On the other hand, if vulnerability is caused by the withdrawal of insurers from certain areas due to flood risk, then a cost-spreading scheme like Flood Re is arguably a reactive rather than proactive scheme. While the scheme is laudable for its collective approach to tackling vulnerability, it tackles the effect rather than the cause of climate change, and does not directly enhance assets' resilience.

The industry is also creating new financial mechanisms such as bonds which offer alternatives for uninsurable areas. As extreme weather incidents become more frequent in London, these tools may become more prevalent.

Public sector or 'municipal' insurance is a relatively small segment of the UK's £29bn insurance industry.⁹⁸ A reason for this could be the public sector being comfortable keeping risk in-house, though the level of risk may not be understood. Insurers have more sophisticated techniques for modelling the probability of asset losses. Sharing the data would help organisations understand the extent of risk, as well as incentivising them to take out insurer products. This would encourage them to use insurers' products to transfer risk.

Opportunities to encourage dialogue between insurers and the public sector could lead the way to a more cohesive relationship.

Developers

For larger developers in particular, sustainability has become mainstream. The ability to charge higher rents, reduce voids and operating costs and future-proof against changes to building regulation are all valid reasons for developers to invest in sustainability. Further, many developers are incorporating resilience measures to build a progressive, trustworthy brand. On schemes where developers have a long-term interest, long-term success of a scheme is key to investors and users fostering positive associations with the company. Figure 8 shows developer Derwent's approach to measuring its sustainability performance across its full range of working practices.

Figure 8: Derwent’s sustainability performance matrix



Source: Derwent⁹⁹

Consumers

Consumers contribute to resilient infrastructure through taxes and user charges (e.g. bills, TfL fares), creating funds to be used to improve resilience at the discretion of the owner/operating company.

Exposing consumers to the financial impacts of their decisions can incentivise behaviour change – for example, Thames Water metered customers tend to use 12% less water on average.¹⁰⁰ The 15-year roll-out of smart meters across their customer base began in 2014. Other examples aimed at changing behaviour include councils (such as LB Islington) offering lower-cost parking permits for less polluting vehicles.¹⁰¹

Individuals can campaign for adaptation and resilience schemes in their areas, adapt their own homes and, with appropriate mechanisms, even contribute to the funding of schemes. But the experience of the Green Deal shows that this will not work without the right combination of awareness-raising and incentives.

Businesses

The business community is reliant on London’s economic and physical resilience. The London Assembly’s Weathering the Storm report said London SMEs would be particularly vulnerable to the effects of climate change.¹⁰² Some – including many in the capital’s Business Improvement Districts (BIDs) – are working collectively to improve assets and places (see case study on p.74).

Business Case

In order to fund more than quick wins and lower-cost measures, local authorities and housing associations need private-sector finance. How can they convince businesses and institutions to invest?

The most effective resilience work is area-based and masterplanned. Not only is this the most efficient way of creating transformational change, it could also be the solution to the adaptation funding gap, by increasing the number of parties who may be prepared to invest.

Working on a number of assets offers a range of benefits.

Numerous retrofit programmes, including Community Energy Savings Programme (CESP), the precursor to the Green Deal and the Energy Company Obligation (ECO), have shown that area-based programmes are most cost-efficient.¹⁰³ From the perspective of investors, whose performances are measured by social returns as well as economic, “New investment for climate adaptation will be more attractive to investors to the extent that it is leveraged not only to mitigate risks but to develop more productive, healthy, serviceable and value-creating urban areas.”

Business Improvement Districts have both place-making and economic development at their core, are effective fundraisers and many work collaboratively with neighbours or other BIDs. The following case study provides some examples.



CASE STUDY: BIDS AND RESILIENCE

Business Improvement Districts coordinate business responses to the needs of a defined area. With local economic development and place-making at their core, they are increasingly recognising the value of green infrastructure. Working in partnership with the GLA, public agencies and each other, BIDs are leveraging significant investment in adaptation and resilience initiatives, and engaging the business and resident communities in their endeavours.

Greening the BIDs is a cross-sector partnership to scale up the amount of green infrastructure in London by investing in BID areas. With £150,000 from Drain London, 15 central London BIDs have completed green infrastructure audits, identifying opportunities for 300 rain gardens, 200 green walls and more than 100ha of green roofs. A further £210,000 of Natural England, Drain London and mayoral funding secured by Cross River Partnership levered £440,000 of private-sector investment to increase biodiversity and enhance environmental resilience. BIDs are often neighbours,

so working in partnership enables regeneration projects on a larger scale.¹⁰⁵

The Low Line is a sequence of projects across the chain of BIDs on the south bank of the Thames, coordinated by Better Bankside. Partners include Network Rail and other property owners, the Bankside neighbourhood forum and developers. Improving the public realm through green infrastructure is a core objective: the project will provide 45sqm of green wall, 100sqm of green roof, and four rain gardens.¹⁰⁶

As well as adaptation, BIDs also contribute to mitigation.¹⁰⁷ BIDs in high retail areas are delivering emissions reduction programmes from the perspective of improving a BID area's air quality, improving pedestrians' experience and encouraging footfall. Team London Bridge's **Fresh Air Square** has created a new micro-park in place of two parking spaces, while visibly tracking emissions in the area with an air quality monitor.¹⁰⁸

✔ **Keywords** flooding, drought, local, adaptation/resilience, business engagement, community engagement

Innovative financial instruments

Cost-benefit analysis for adaptation and resilience measures calls for financial instruments offering varied interest rates, payback periods etc. Financial service providers have an opportunity to offer this flexibility, by creating a portfolio of products.

On top of standard grants and loans, local and pan-London entities have access to a range of alternative financial mechanisms to raise finance for resilience and retrofit schemes.

Green bonds

Bonds are loans used by governments, agencies and companies to finance projects. The issuer of the bond owes a debt to the holder, and is obliged to repay the amount lent, plus interest.¹⁰⁹ Green bonds finance projects in the same way, though proceeds are allocated to environmental projects.

Investment banks have been the biggest issuers of green bonds, including the European Investment Bank issuing \$11.6bn through its Climate Awareness Bonds programme.¹¹⁰ In the UK, corporate green bonds are also on the rise: in 2014, Transport for London issued a £400m bond to contribute to a range of transport priorities.

The extent to which green bonds are different from regular bonds is debatable. An executive committee led by the International Capital Market Association has developed green bond principles and a governance framework, though these are voluntary.¹¹¹

The Climate Bond Initiative demonstrates that there is a large market of 'climate-aligned' bonds i.e. those financing sustainability projects, without being recognised as green bonds. Figure 9 shows that a large proportion of these are financing transport projects, but the extent to which these are contributing

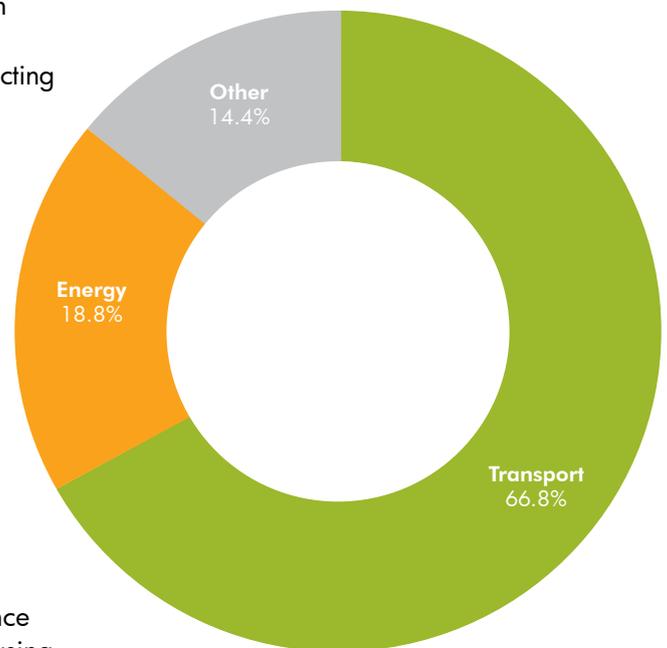
to 'business as usual', as opposed to directly making transport networks more resilient, is unclear.

While a functioning transport network contributes to a city's resilience in many ways, it will not withstand climate pressures if it is not itself resilient. In many cases around the world, the best resilience strategies and funding packages are reactions to catastrophic events, rather than proactive and adaptive measures. In the wake of Hurricane Sandy, New York's Metropolitan Transportation Authority is spending nearly \$1bn on resilience projects alone, aimed at protecting trains, buses, stations, tunnels and rail yards from storm surges and flooding.¹¹²

In terms of issuing municipal bonds, local authorities in the UK are still finding their feet. The UK Municipal Bonds Agency Plc was established in June 2014, with the aim of helping local authorities finance infrastructure and housing investment projects efficiently and cost effectively. It is owned by local authorities and the Local Government Association (LGA).¹¹⁴ The objective is to reduce loan costs by getting a higher credit rating for a bond than would be possible if issued by a single authority. In June 2016, nine local authorities, including LB Camden, had approved the borrowing framework and the first Agency bond is due to be issued this autumn, though details have not yet been announced.¹¹⁵ Issuing bonds through the agency could be a vital way for local authorities to raise large amounts of

“There is great potential for the UK to follow the Scandinavian or North America models.”
Sir Roger Gifford,
Chair, Green Finance Initiative¹¹⁶

Figure 9: 'Climate-aligned' global green bond themes



Source: Climate Bonds Initiative¹¹³

finance for adaptation and resilience schemes.

Municipal green bonds can also be issued by single authorities. Although the size of bond is likely to be smaller, and therefore ineffective for largescale adaptation schemes, it may have additional benefits. For example, LB Swindon recently became the first council in the UK to issue a solar bond (see case study on p26). These sorts of bonds are a popular way of funding mitigation activity in the US and Sweden.

CASE STUDY: SWINDON COMMON FARM SOLAR¹¹⁷

In summer 2016, Swindon borough council constructed Swindon Common Farm, a 4.8 megawatt solar farm capable of supplying 1,200 homes and saving 2000 tonnes of CO₂ per year. £3m of the £4.8m required for the scheme came from the council itself. The remaining £1.8m was raised from the general public using green bonds.

The green bond, issued by the council in partnership with peer-to-peer investment platform Abundance, allowed individuals to invest as little as £5 in the project. For their investment, they receive a 6% rate of return, paid twice yearly, over a term of 20 years. Green bond purchases opened in February 2016 and closed at the end of May 2016. The public

showed huge interest: the council's invested more than £100,000 in the first 24 hours and reached SBC's £1.8m target a month early. Of the 708 investors, around a third were from the Swindon area.

Selling electricity and feed-in tariff will generate revenue, of which 35% will be returned to SBC and 65% will be funnelled into community initiatives. In addition to the financial benefits for the council, Swindon Common Farm contributes to the council's target of installing 200 megawatts of renewable capacity by 2020.

✓ **Keywords** city, economy, mitigation, partnership, community engagement, funding

Catastrophe Bonds/ Resilience Bonds

Catastrophe bonds were developed in the US in the mid-1990s, in the aftermath of two catastrophic events: Hurricane Andrew and the Northridge earthquake.¹¹⁸ Bonds are issued to investors who pay a premium if no damage occurs (akin to traditional insurance). Although the first bond-issuers were the insurance companies, more recently they have been issued by governments and the World Bank, in the shape of 'Resilience bonds'

(see case study for New York bond). Not only is this a more palatable brand, resilience bonds offer the additional benefit of rewarding adaptation and resilience work through an insurance premium reduction, as well as offering financial protection.¹¹⁹

As they are high-risk bonds, investors tend to be institutional investors with varied risk portfolios. If an event occurs, funds are available immediately, and are not bound by like-for-like replacement. With purported lower transaction costs

than many traditional insurance products, these bonds could overall be a more progressive and proactive response for many areas, as well as fulfilling their original aim of minimising costs in less insurable areas.

In February 2016, the UK government launched a consultation into the viability and appetite for catastrophe bonds and other index-linked securities.¹²⁰ However, the extent to which this has been driven by the desire to transfer risks from natural hazards is unclear.



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CASE STUDY: NEW YORK MTA CATASTROPHE BOND¹²¹

Background

During Hurricane Sandy in October 2012, storm surges swamped New York City. The New York Metropolitan Transport Authority (MTA), responsible for the city's buses, subways, rail network, road tunnels and bridges, faced \$4.8bn in damages and losses.

Afterwards, with its £1bn property insurance policy expiring in May 2014, the MTA struggled to find affordable coverage for that amount. A consultant suggested investigating the catastrophe bond market as an alternative to traditional insurance.

Process

Working with insurance consultants, risk modellers, and financial advisors, the MTA created a \$125m catastrophe bond. Investors purchased a share of the bonds for a three-year bond period from August 2013 to August 2016.

If there had been another storm surge within the bond period that pushed the sea level above agreed thresholds (e.g. storm surge of 8.5ft or more at Rockaway Inlet), the MTA could have used some or all of the money for disaster management and repairs. In this scenario, investors would have lost some or all of their investment. However, as there was no storm surge that breached the thresholds, investors got their initial investment back plus around 13.5% interest.

Outcomes and benefits

When the bonds went on sale in July 2013, they attracted more interest than anticipated, with 20 investors eventually buying \$200m worth of bonds. For investors, catastrophe bonds are high-risk, high-reward. For the MTA, the bond offered an affordable way to complement coverage from traditional insurance, which became more expensive after the hurricane.

Lessons and replicability

The \$200m catastrophe bond is small compared to the MTA's pre-hurricane insurance coverage of \$1bn or the damage bill of \$4.8bn. However, selling a more modest bond allowed the MTA to test investors' appetites, and the success of the product could encourage the MTA to seek a higher figure if issuing future bonds.

Catastrophe bonds are being used elsewhere. Amtrak, another large asset owner, has issued a catastrophe bond of \$275m for storm surge protection. Groups such as the Texas Windstorm Insurance Association and California Earthquake Authority issue state-wide bonds. In Europe, EDF previously used catastrophe bonds to cover itself against wind storms in France, and insurer UnipolSai is currently using one to cover itself against earthquakes in Italy.

✔ **Keywords** flooding, city, adaptation/resilience, finance

Working together

When creating and managing London's built environment assets, much of the onus for driving resilience is on local authorities and the GLA. The involvement of developers, designers and architects is often short-term, with little incentive to think about long-term resilience. Organisations undertaking or commissioning design work have an opportunity to drive resilience into schemes and strategies. They can facilitate this by:

Taking an area-based or systems approach

Establishing effective partnerships

Fostering resilience champions

► Taking an area-based or systems approach

Local planning authorities, the GLA and housing associations undertaking or commissioning design work – such as for development sites, infrastructure projects, city-wide strategies or neighbourhood plans – have an opportunity to drive resilience by creating a clear strategy or masterplan.

Effective resilience strategies work across an entire system, rather than at the individual asset level. London's transport network, for example, comprises rail stations, tube stations, bus garages, train/bus stock, operational buildings, tracks/tunnels and roads. A neighbourhood also functions as a system, with numerous interdependencies between its housing, commercial buildings, health centres, roads and public transport amenities.

Table 6: Examples of assets, systems and their stakeholders

Assets	
<ul style="list-style-type: none"> • Commercial buildings • Housing • Health centres/hospitals 	<ul style="list-style-type: none"> • Tube/rail/bus stations • Roads/tunnels/bridges
Systems	
<ul style="list-style-type: none"> • High Street/town centre • Transport network 	<ul style="list-style-type: none"> • Utility network • Green/blue infrastructure
Stakeholders	
<ul style="list-style-type: none"> • Businesses/business groups • Residents/community groups • NHS 	<ul style="list-style-type: none"> • London Fire Brigade • Utility companies

A systems approach to resilience emphasises relationships and interdependencies within a place or system. Overheating, poor air quality, flooding and water stress are cross-boundary issues whose impacts do not stop at a single asset.

London's June 2016 floods illustrate this. Heavy overnight rain on 22–23 June submerged

transport infrastructure and electrical equipment throughout the city. While the owners of these assets – Network Rail, TfL, UK Power Networks – foot the bill for clean-up and repairs, there were additional costs. Disrupted supply chains and transport routes prevented movement of goods and people, impacting London's economy. Flooded electrical

Figure 10: Accessible Open Space in London



Source: All London Green Grid¹²³

equipment caused power cuts, further interrupting London's ability to operate.

Increasing the resilience of systems instead of assets will have a larger transformational effect. A string of well-planned small projects could have as transformative effect on the city as a major project, whilst being easier to fund, build and manage.

For example, the All London Green Grid Supplementary Planning Guidance describes the strengths, weaknesses and roles of key green spaces. It suggests opportunities for enhancements and additional green infrastructure throughout London, recognising the cumulative impact of small projects on the entire system: "By being connected, the value and function of the [green grid] is significantly enhanced so that it can be used in many different ways including by pedestrians, for water management, for cooling the grey urban spaces and as an ecological corridor."¹²² (see Figure 10).

► Establishing effective partnerships

Working in partnerships with stakeholders can bring in additional skills and close resource gaps. Partnerships can also open more routes to funding (see Herne Hill case study and Section 2a).

Choosing contractors with experience of the desired resilience measures is key, and they can be compelled to comply with strategies through procurement. Other stakeholders may understand the importance of contributing to improved resilience and readily take on a partner role. For those who need a nudge, appealing to a partner's corporate, social or financial targets can achieve buy-in.

Working groups are especially helpful in managing partnerships. Working groups give all delivery partners a forum to swap ideas and skills, ensure the scheme or plan is delivered to detail and contributing to monitoring.

Of course, all of this requires a contractor pool with the skills to comply. Government, trade associations and membership bodies must ensure that adaptation and resilience are at the heart of skills and training programmes to produce these leaders.

CASE STUDY: HERNE HILL AND DULWICH FLOOD ALLEVIATION¹²⁴

The south London neighbourhoods of Herne Hill and Dulwich are located within the valley of the former river Effra. In 1984, 2004 and 2007, heavy rain resulted in extensive flooding, as local green spaces Dulwich Park, Bel-Air Park, and Dulwich Sports Ground were unable to absorb all rainwater. To address this, in 2014 Southwark Council and Thames Water jointly developed a flood alleviation scheme. Consultees included the Environment Agency, landowners at Bel-Air Park and Dulwich Sports Ground, residents, and park users.

Each partner brought different strengths and investment to the project: Thames Water provided contractor management, site supervision and over £2m funding; Southwark led on stakeholder engagement and provided £200,000 funding. Defra's Flood Defence Grant in Aid covered the remaining costs of the £4.28m scheme.

Infrastructure consultant Mouchel designed and delivered the scheme, consisting of earth bunds capable of holding up to 51,000m³ of water and sub-surface storage areas within established green spaces. This protects over 280 homes and businesses from flooding. Additional benefits include the creation of a 3,750m² wetland, a 6,400m² wildflower meadow, and children's play areas. A Flood and Coastal Erosion Risk Management Appraisal calculated the economic benefits of the scheme to be around £12m – nearly three times as much as the cost.

For its approach to urban surface water management, the scheme has received an ICE London Civil Engineering Award and an Environment Agency Project Excellence Award.

✓ **Keywords** flooding, local, adaptation, partnership

► Fostering resilience champions

Resilience is most effective when understood and implemented by everyone. Finding skilled and trusted champions of sustainability and resilience throughout the construction period will help to ensure measures are installed correctly. A champion can bring working groups together

and is further insurance that the vision will be carried through. Both can help the scheme evolve in response to changes in personnel, policy, technology or climate.

It is arguably as important when the building or service is in use. In London, the London Legacy Development Corporation has

recognised individual impact on resilience (see case study, Appendix 1) as have some housing associations; Catalyst Housing Group has developed a Green Guide for tenants, trains resident 'sustainability champions' to advise neighbours and visits tenants to help them make energy-efficient choices.

CASE STUDY: WATER SAVING CITY, ZARAGOZA, SPAIN¹²⁵

Zaragoza is Spain's fifth largest city, with a population of nearly 800,000 situated in a drought-prone, semi-arid climate zone. Following severe droughts throughout Spain in the early 90s, the Ecology and Development Foundation (Fundación Ecología y Desarrollo, or FED) developed the Water Saving City project in partnership with the EU, Aragón regional government, Zaragoza city council, Ibercaja bank, and four private companies. The project was designed as a collective challenge for Zaragoza to save 1bn litres of water a year, an ambition dependent on participation of all stakeholders: consumers, businesses, developers, plumbers, water equipment retailers and manufacturers and financial institutions.

The project ran from 1997 to 2008. The first two years focused on individual behaviour and attitude changes through initiatives such as providing information, training and advice for consumers,

residents, and owners of buildings with high water consumption; replacing old fittings with modern water-saving models; installing household water meters; and domestic water recycling. The latter years of the project focused on establishing best practices in public institutions, industries and parks/gardens.

Over the project period, the city's population grew by 12%, but water consumption decreased by 27%. Most of the reduction is attributed to behaviour change rather than technology or user charges, demonstrating the success of the project's community engagement. At the start of the Water Saving City, 40% of the public were aware of water-saving measures; by the end this figure had risen to 72%.

✔ **Keywords** drought, city, adaptation, partnership, education, community engagement, business engagement

Reframing resilience

Cities around the world are implementing climate adaptation and resilience measures to manage climate change impacts and reduce climate change risks. These measures can be broadly categorised into the following groups: strategic, operational, physical and social. Delivered holistically, these strategies and measures can go beyond adaptation and mitigation to improve health and well-being, contribute to better air quality and stimulate the economy.

Identifying additional benefits

Additional benefits, or 'co-benefits', are the indirect impacts of implementing strategies and measures to tackle weather and climate change related issues. As well as the direct impact of reducing the risk of heatwaves or flooding in a specific area, they can create other benefits for local people, communities and businesses. Although these co-benefits may be indirect, they can be designed into strategies and measures from the outset.

Co-benefits may be:

Economic – such as external shading leading to cost savings on cooling energy bills in office buildings, or increased takings for local cafes located next to a sustainable drainage system.

Environmental – such as a green roof keeping internal spaces cooler, making solar panels more efficient, preventing run-off and increasing biodiversity in a relatively small space.

Social – such as a 'cool hub' vulnerable residents in hot weather improving physical health, but also mental health, wellbeing and community cohesion through social interaction and reduced isolation.

Though environmental and human factors are often harder to quantify than harder economic indicators, they are also essential to the functioning of a city, its liveability and attractiveness for living, working and investment. However, as these impacts may be experienced in less tangible ways, or by future generations, these

co-benefits are often overlooked in conventional cost-benefit analyses and policy mechanisms.

Attributing risks to climate change or the weather may inadvertently cause them to be pushed down the political or corporate agenda. This is because they are often compared to and evaluated against seemingly more immediate risks or statutory priorities, such as jobs, housing or quarterly profits.

Emphasising the wider benefits and co-benefits of investing in climate change resilience measures, as well as the potential costs of doing nothing in response to climate risks, could help to attract investment from other sources with a shared interest in strengthening a sector, asset, service or area.

CASE STUDY: SUSTAINABLE URBAN DRAINAGE (SUDS) SCHEME, AUSTRALIA ROAD, WHITE CITY, LONDON¹²⁶

In 2013, LB Hammersmith & Fulham identified a section of the Australia Road area of White City as a flood risk hotspot. In consultation with the local community, a need for more green community space, safer streets and better links between local schools and playgrounds was identified. By matching the two priorities and emphasising the community benefits, the council created an initiative that responded to both needs.

Working in partnership with designers and contractors, the council implemented a series of sustainable drainage systems (SuDS) including rain gardens, permeable pavements, rainwater harvesting and bio-retention basins. Branded as a community park, the concept was designed to provide safer pedestrian and cyclist access and a community space, as well as improved drainage, better air quality and increased opportunities for children's education. Local residents were involved

in the process, from choosing the kinds of trees to be planted to deciding where street seating and lighting should be placed.

The result was a successful series of sustainable drainage systems (SuDS) including rain gardens, permeable pavements, rainwater harvesting, and bio-retention basins, as well as a new and accessible park for the local community.

As well as the direct benefit of reduced flood risk, the project improved air quality, and community safety, as well as better social cohesion through the creation of communal green spaces, strong public engagement and awareness raising around the systems installed.

✔ **Keywords** local, flooding, community engagement, adaptation/resilience, green infrastructure, education, partnership

Valuing and monetising resilience

Attaching a value – whether monetary or not – to the benefits and co-benefits of resilience provides an important signal to governments, investors and private sector organisations. These sorts of holistic valuations are not easy, but there are a growing number of cases.

For example, the recent London iTree urban forest survey estimates that London's trees provide at least £133m–£147m of benefits to Londoners every year in terms of air pollution removal, carbon sequestration and reducing the amount of water going into drains. Other known benefits of trees, such as improving physical and mental health, reducing air temperatures and higher property prices were not quantified, so this is a conservative calculation of the resilience value of trees for London.¹²⁷

Unlike capital assets, the value of green infrastructure assets is not routinely assessed. In 2015, the government's Natural Capital Committee designed a framework to address this gap comparing asset values with liabilities. Although it was piloted on corporate landholdings, it estimated that urban green infrastructure could save £2.1bn in health costs alone.¹²⁸ In July 2016, the Natural Capital Committee and Adaptation to Climate Change Sub-Committee (ASC) held a joint meeting, in light of the fact that most of the risks identified in the latest climate change risk assessment are directly related to natural capital.¹²⁹

Adaptation and resilience knowledge, products and services also have a value to London's economy. In 2011/12, London's climate change industry had a turnover of £431m and employed nearly 4,000 people, demonstrating the potential for growth.¹³⁰ The

GLA and London Climate Change Partnership are analysing its current value, in order to forecast how this value will grow as local, national and international demand for these services also grows.

Climate change resilience versus city resilience

Climate change is not the only factor affecting the city's ability to be resilient. London has to cope with occasional acute shocks such as terrorism, major infrastructure failure and public protest; as well as chronic stresses such as population growth, greater demands on services and inequality. Many of these shocks and stresses are interdependent, with one event or trend having knock-on effects for a wide range of people, organisations and sectors. An assessment of the overall resilience of a city or place could help to target investment accordingly (see case study on p.33).

CASE STUDY: THE ARUP/ROCKEFELLER FOUNDATION CITY RESILIENCE INDEX¹³¹

Working with the Rockefeller Foundation, Arup has developed the City Resilience Index (CRI).

The CRI is designed to help cities assess all the risks they face, be they climate-related, economic, social or a combination. The process helps them understand the actions that could have the greatest benefits on each city, and interdependency between systems and impacts.

The index is a qualitative and quantitative assessment and

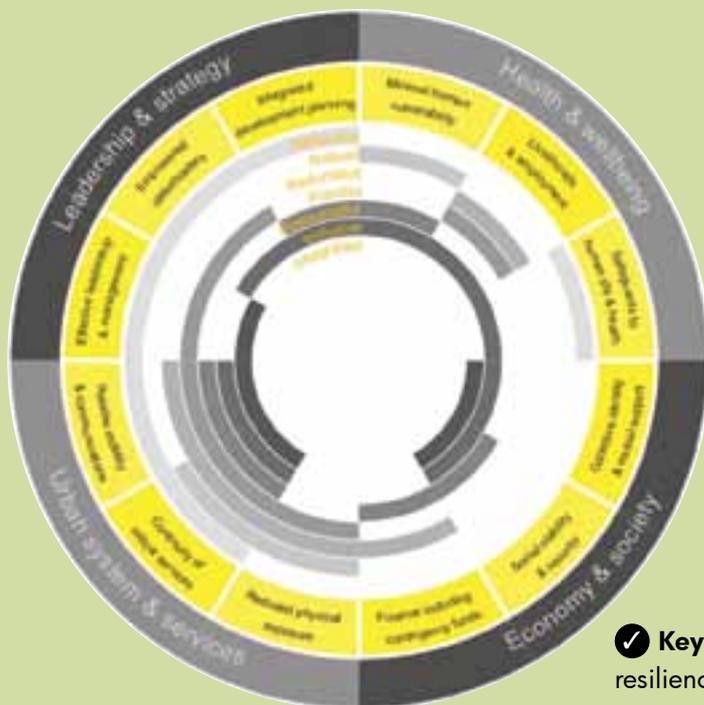
measurement tool based on 156 metrics. The resulting resilience profile provides a holistic overview of a city's resilience across four dimensions: leadership and strategy; health and well-being; economy and society; and place and knowledge.

The CRI looks at the potential range of factors affecting the resilience of a city. In doing so, it illustrates how resilience actions can contribute to benefits for other sectors and the city as a whole.

This systems approach helps cities to develop resilience strategies and target resilience actions in order to have the greatest impact across the city. As well as being used at the city level, local authorities and/or housing associations would also be able to adapt the CRI for their own purposes and priorities.

In the UK, the CRI has begun to inform resilience thinking and action in Glasgow and Bristol as part of the 100 Resilient Cities programme, and is set to be used by London in 2017.

Figure 11: The City Resilience Index



✓ **Keywords** city, partnership, economy, adaptation/resilience, infrastructure, education

PART 3: MAKING IT HAPPEN

Adapting to uncertainty

London’s local authorities and service providers need adaptation and resilience on a transformational scale. In these austere times, strategies need to be cost-effective, long-term and able to adapt to the effects of climate change as they occur.

The Thames Estuary 2100 plan, developed by the Environment Agency in 2012, proved that this is possible. Recognising the uncertain effects of climate change, it proposes solutions to a range of possible impacts.

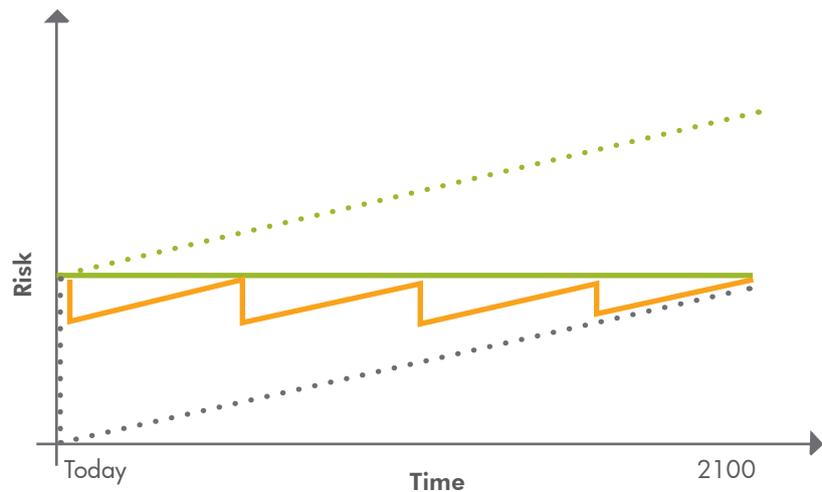
10 climate-related milestones, such as sea level rise and peak river flows, are used to reappraise the plan throughout its life. In response to these milestones, actions can be escalated or scaled back as appropriate, ensuring that the most beneficial and cost-effective choices are implemented at the right times.¹³²

The TE2100 is the result of years of multi-agency work and political will, spurred by the gravity of tidal flood risk on the Thames. Still, this ‘adaptive pathways’ approach could be used for other strategic

resilience projects for London. The checklist below is influenced by the TE2100 approach. It could easily guide the development of local

resilience plans and strategies, not least since it ties into existing partnership, consultation and procurement processes.

Figure 12: Thames Estuary 2100 adaptive approach



Source: Environment Agency

- Key**
- Precautionary approach: single intervention point at start, to manage risk over the whole life
 - **Managed adaptive approach:** several interventions over time to manage risk
 - Flood risk is managed so that it does not exceed this level (set by the “policy”)
 - Flood risk increases with time if not managed by active interventions

Resilience strategy pathway

- ✓ Audit physical assets and map interdependencies within a system
- ✓ Agree what is an acceptable level of current, intermediate and long-term risk for an area
- ✓ Analyse costs and benefits of resilience measures that manage immediate risks
- ✓ Set thresholds/triggers for measuring and monitoring intermediate and long-term risks
- ✓ Identify relevant owners, stakeholders and funding/delivery partners, including business and resident communities
- ✓ Bring stakeholders together in partnership, with working groups and champion/s
- ✓ Require partners/contractors to deliver chosen measures through procurement
- ✓ Monitor implementation
- ✓ Revisit intermediate and long-term risks when triggers are reached

Skills and capacity

Where adaptation and resilience are concerned, there is a clear cross-sector skills and capacity gap. Professional bodies with a training remit can respond, as can higher education, especially when it bridges the gap between research and practice. University College London's Institute for Risk and Disaster Reduction, for example, has launched two courses on urgent and important matters of risk, resilience and recovery, developed by a cross-disciplinary group of experts.¹³³

“Will it take a catastrophe to make us act?”
Senior roundtable participant

Organisations such as the Royal Institute of Chartered Surveyors, the Institution of Civil Engineers, the Royal Town Planning Institute, the UK Green Building Council and the Royal Institute of British Architects also have a role in setting professional standards for members

and raising awareness of best practice and innovation in the built environment. Membership criteria and continuing professional development requirements can further enhance up-to-date sector knowledge of adaptation and resilience.

Learning from other cities

A lot of learning is derived from events in other major cities. The blackout following Hurricane Sandy resulted in New York State leaders, energy providers, utilities, technology companies and consumers coming together in a public-private partnership – the New York State Smart Grid Consortium.¹³⁴ The result is a flexible and resilient system that serves New York City's evolving needs for energy in a more responsive and efficient way.

This is useful, but begs the question: can London form such partnerships and build business cases **before** a major catastrophe occurs? New private-sector vehicles such as Thames Water's delivery alliance with five firms suggest that it can.¹³⁵ But there is still a long way to go in collectively understanding risks and making change – both major transformational schemes and area-based strategies – a reality.

The GLA has a role to play in providing a strategic vision and action plan. In addition to the London Infrastructure 2050 plan, the ICE recently called for the mayor to develop a London Resilience Plan 2050 to map out how the capital's infrastructure will adapt to long-term climate changes and environmental disasters.¹³⁶ This could guide the collective effort required to make London a truly resilient city.

Recommendations

Although there is a wealth of work underway to protect London's communities, businesses and economy, this report has found that risks to the capital's public assets, services, communities and economy remain high. London's existing assets and infrastructure should be better prepared for climate shocks and stresses.

The following key actions for specific stakeholders could accelerate a collective response.

National policymakers

- Mandate that all public retrofit programmes should specifically address surface-water flooding and overheating buildings, prioritising resilience measures such as drainage and night ventilation
- Incentivise property owners, businesses and citizens to retrofit assets they own or manage through fiscal rewards such as tax credits and/or reduced business rates, council tax, stamp duty and VAT.

GLA

- Prioritise the update of London's existing climate change adaptation plan and clarify roles, responsibilities and actions of all stakeholders.
- Develop a London-wide resilience plan that links up climate change mitigation, adaptation, preparedness and risk transfer strategies, and which quantifies and monetises the direct and indirect benefits of action where possible.

- With the London Enterprise Partnership, prepare for the post-Brexit funding environment: plan for and lobby government for alternative funding to replace or complement European structural and investment funds.

Local authorities and public service providers

- Produce up-to-date climate change risk assessments and strategies that use socio-economic and geo-spatial data to focus on adaptation and resilience measures to identify the most vulnerable communities.
- Develop area-based, cross-sector working groups for climate change hotspots to collectively reach mutually beneficial solutions and to pool funding.
- Explore options for using green and resilience bonds to raise funds and capital, individually or through the UK Municipal Bonds Agency.

Insurers and investors

- Recognise that integrating environmental factors into investment decisions is essential to responsible stewardship.
- Share modelled risks and losses data with local authorities to encourage dialogue and collaborative, area-based responses.
- Develop adaptation and resilience portfolios as alternatives to high-risk, time-limited fossil fuel assets.
- Develop products to share and transfer climate risks with local authorities, service providers and pan-London government.

Developers and house-builders

- Move sustainability strategies beyond carbon reduction; include approaches to long-term asset management and user education/engagement.
- Deliver systems or area-based improvements, for economies of scale and to increase asset values.

Educators and experts

- Develop resilience skills across the construction and development sectors through training and accreditation systems.
- Roll out efficient, low-cost systems for public service providers to audit their assets, with a view to making resilience enhancements where most needed.

APPENDIX 1: ADDITIONAL CASE STUDIES

Schemes and strategies

Elgin flood defence

In 2001, Moray Council commissioned Royal HaskoningDHV and Morrison Construction to form a partnership with the council: the Moray Flood Alleviation Group. The group proposed a series of flood alleviation schemes to reduce flood risk over a 15-year period. The largest of these schemes was at Elgin, a town historically prone to flooding. Elgin's flood alleviation scheme aimed to reduce risk of flooding in one year from 20% to 0.5% plus an allowance for climate change.

The Group started by identifying local stakeholders, including residents, businesses, statutory regulators, other organisations (e.g. Network Rail, nature charities) and the media. Following a three-day open consultation on these options, it developed a preferred scheme to re-establish the river Lossie's natural corridor and reconnect it to its floodplain. Key aspects of the scheme included creating a 21 ha downstream floodplain, diverting a tributary, rebuilding three bridges, constructing a conveyance corridor through Elgin and reinforcing flood walls.

Through liaising with the Scottish government, the council secured 80% of the funding for the £86m programme, contributing the remaining 20% itself. Construction in Elgin began in April 2011 and finished in January 2016. The whole life cost of the scheme was £64m with benefits of £88m, giving a cost-benefit ratio of 1:1.4.

Elgin's new defences were tested prematurely in August 2014, when heavy rain from Hurricane Bertha caused a surge in the river and threatened Elgin with flooding. The partially-completed defences withstood the impact, protecting 270 residences and 75 businesses and avoiding estimated damages of £29m.

Keywords: local, flooding, partnership, community engagement, green infrastructure

Grosvenor Passivhaus retrofit, west London

In 2014, Grosvenor embarked on a trial scheme to retrofit rental units to the Passivhaus EnerPHit Standard. Three central London properties were refitted with triple glazing, mechanical ventilation with heat recovery, new insulation and sensors to measure temperature, humidity, and CO₂.

Although costs were higher than a standard retrofit, the experience will drive future retrofit costs down. The retrofit has saved a significant amount on energy costs, created a more comfortable living environment for tenants, and will reduce emissions by 840t over the 60-year lifespan of the interventions.

Further Information: Grosvenor
<http://bit.ly/2cMXXzH>

Keywords: heat, property, public health, local, adaptation/resilience

London Legacy Development Corporation carbon reduction strategy

The LLDC is responsible for guiding the development on the Queen Elizabeth Olympic Park. With 225 hectares expected to provide 8,000 homes and new community amenities by 2031, it is one of London's largest development sites.

Sustainability is embedded into LLDC's strategies. One aspect is its carbon reduction strategy (CRS). This requires development partners to install sustainability features into buildings, such as smart meters, A-rated appliances, and efficient lighting. Recognising the impact individuals have on energy consumption, the CRS also requires development partners to educate building owners and occupiers about using energy more efficiently, such as the use of smart meters and thermostats, ventilation and sustainable travel options.

LLDC will also conduct a trial to review how occupants respond to smart homes technology and energy efficiency measures. Findings will inform best practice for development partners fulfilling their CRS obligations.

Further information: LLDC <http://bit.ly/2dcT173>

Keywords: adaptation, mitigation, property, local, partnerships, community engagement, education

Nine Elms integrated water management strategy, Wandsworth

The Nine Elms redevelopment project will create 20,000 homes and 25,000 jobs, in addition to an eightfold increase in local water demand. Arup developed water management strategies to balance water supply and demand by optimising rainwater, stormwater, and greywater at the development, building, and community levels as well as integrating SuDS. This involved close collaboration with the Greater London Authority (GLA), Thames Water, local authorities, developers and other stakeholders in the Nine Elms Partnership.

The benefits from implementing these solutions over the course of the 15-year redevelopment phase and longer-term operation of the site include reduced costs and disruption, reduced requirements for infrastructure reinforcement, better management of water supply and demand issues, allowance for future integration of sustainable water solutions and enhanced environmental standards and resilience.

Further Information: Thames Water <http://bit.ly/2cTqIXx>; LB Wandsworth <http://bit.ly/2dcNNZ0>

Keywords: flooding, drought, infrastructure, local, adaptation/resilience, partnership

RE:FIT

In the past, a lack of in-house expertise and capacity, as well as the concern that energy savings may not cover costs, has discouraged public sector organisations from retrofitting their buildings. The GLA's RE:FIT programme was launched in 2009 to overcome these challenges, enabling public sector buildings to benefit from retrofitting and improved energy efficiency. In this programme, a GLA team gives free expert advice on the procurement and technical retrofitting process, and an energy reduction is guaranteed.

By March 2016, 205 public sector organisations in the capital had received the support of RE:FIT. Completed projects and those in progress will reduce CO₂ emissions in the capital by 30,000 tonnes/year, and save client organisations a total of £7.1m annually. Since 2014, Local Partnerships has expanded the scheme across England and Wales, and the GLA has also advised the Scottish government on how they can develop an energy saving offer for buildings.

Further Information: GLA, <http://bit.ly/2d3jxwv>

Keywords: property, mitigation, city, partnership

Zero Emissions Network, LB Hackney

Responding to the high level of pollution around Shoreditch and Old Street, LB Hackney began the Zero Emissions Network (ZEN) in 2013. Neighbouring boroughs Tower Hamlets and Islington joined ZEN in October 2014. It is an initiative that helps local businesses to reduce travel-related emissions. Businesses register for free as ZEN members to receive advice and services for adopting more sustainable travel habits. Membership benefits include free car club memberships, trials of cargo bikes and electric vehicles, discounts on zero emission taxis, free staff cycle training and grants of up to £1,000 to promote sustainable travel.

To date, 69 grants have been issued for initiatives such as pool bikes, cycle parking and shower facilities. Funding for ZEN comes from the mayor's Air Quality Fund and partnership boroughs. The annual budget is around £600,000, half of which comes from the mayor. Each borough has a dedicated ZEN officer, with LB Hackney as the lead partner.

Over 700 businesses have joined ZEN and taken advantage of over 250 pollution-reducing measures, resulting in an estimated reduction of at least 126 kg of NO_x per year. Based on the success of the Shoreditch model, Islington recently received £300,000 from the mayor's Air Quality Fund to set up a ZEN in Archway.

Further Information: LB Islington <http://bit.ly/2d3kvce>; <http://bit.ly/2d68RA3>

Keywords: public health, local, mitigation, business engagement, partnership, education

Tools and reports

Climate Just

Climate Just is an online map resource developed in response to a Joseph Rowntree Foundation research programme on climate change, poverty and vulnerability. The research called for socially-just approaches to adaptation, as climate change has the potential to increase inequality by hitting more vulnerable people hardest.

The resource was developed by a cross-sector team of academics and technical experts. It layers environmental risk maps with numerous socio-economic datasets, in order to pinpoint risk areas. The resource is targeted at people working with vulnerable communities such as local authorities and their partners in social care, health, housing and the voluntary and community sectors.

Further Information: Climate Just

<http://www.climatejust.org.uk/>

Keywords: flooding, drought, heat, property, public health

Crossrail climate change adaptation report and risk assessment

Crossrail commissioned Arup to undertake a study that assessed the climate change risks to Crossrail as required by the UK Climate Change Act 2008. The report identified increased flooding, higher temperatures and greater water stress as potential climate change risks which could affect the construction and operation of Crossrail.

Liaison with Crossrail's engineering and design team, as well as Transport for London and Network Rail, ensured that data, flood levels and design standards were clarified and resilient and that key interfaces between infrastructure and assets were addressed. Areas of residual risk were identified and entered into the Crossrail risk management system and necessary adaptation and resilience measures were recommended.

Further Information: Crossrail

<http://bit.ly/2cap9Hm>; <http://bit.ly/2dbfbCj>

Keywords: flooding, drought, heat, infrastructure, city, adaptation/resilience, partnership

Measuring urban climate benefits of green infrastructure

Examining green infrastructure projects from around the world, Arup created a library of data which illustrated ecosystem services, values, and construction and maintenance costs of green infrastructure. Arup used this to define metrics to quantify the benefits of reduced flood risk, job creation, aesthetic improvement, improved health, reduced wastewater treatment, reduced temperatures, energy and emissions reduction, improved water quality, and improved ecology. This included quantifying direct benefits such as avoided CO₂ and the monetised value of the CO₂. The data can be used to create a cost-benefit analysis which takes into account the economic, social and environmental benefits.

The tool is adaptable for different geographies, spatial scaling and project lifecycles. Arup used this tool to compare five green infrastructure retrofit masterplans for a public housing development with 6,000 residents in Brooklyn, New York. The analysis was integral to deciding which masterplan to implement.

Further Information: Arup <http://bit.ly/2aGeSO3>

Keywords: flooding, drought, heat, economy, infrastructure, local, city, green infrastructure

Reducing urban heat risk for London

The GLA, London Climate Change Partnership, University College London, LB Islington and Arup worked collaboratively on this project which identifies the factors that contribute to urban heat risk and presents steps to reduce the risk in a clear and visual way. Recommendations are categorised as physical, social, strategic, or operational interventions, and by the scale of implementation.

It is aimed at helping decision-makers, including housing and public health professionals, planners, developers, and local politicians, to be well-informed about the risks of hot weather and understand how they can protect the most vulnerable people. The project highlights 'triple risk hot spots' which are the areas and buildings where the most vulnerable people, including those with chronic diseases, could be at greatest risk.

Further Information: Arup, <http://bit.ly/2cW7pPw>

Keywords: heat, public health, city, education.

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