THE IMPACT OF THE ENVIRONMENT AND CLIMATE CHANGE ON FUTURE INFRASTRUCTURE SUPPLY AND DEMAND

NATIONAL
INFRASTRUCTURE
COMMISSION

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1. INTRODUCTION

The National Infrastructure Commission has been tasked with putting together a National Infrastructure Assessment once a Parliament. This discussion paper, focused on the environment and climate change, forms part of a series looking at the drivers of future infrastructure supply and demand in the UK. Its conclusions are designed to aid the Commission in putting together plausible scenarios out to 2050 but will not set out policy options at this stage.

1.1 National Infrastructure Assessment

The National Infrastructure Assessment (NIA) will analyse the UK's long-term economic infrastructure needs, outline a strategic vision over a 30-year time horizon and set out recommendations for how identified needs should begin to be met. It will cover transport, digital, energy, water and wastewater, flood risk and solid waste, assessing the whole of each infrastructure system (including demand management options). It will look across sectors, identifying and exploring the most important interdependencies and cross-cutting themes.

The Assessment will consider a range of scenarios to help understand how the UK's infrastructure requirements could change in response to different assumptions about the future. Scenarios are a widely-used approach to addressing uncertainty. Quantifying scenarios also allows modelling of policy options. In the absence of a known probability distribution for all future outcomes, the scenarios will be based on available empirical evidence about past trends and quantitative and qualitative forecasts of changes in four key drivers of infrastructure: the economy, population and demography, technology, and the environment and climate change. Understanding trends and discontinuities in the past can help identify where variation in the set of scenarios may be most helpful. The drivers should not be thought of in isolation: readers might also wish to consider the related discussion papers on the other drivers and they will be brought together in the analysis for the NIA.

This paper explores the most significant interactions between the environment and infrastructure systems. It takes account of trends in key environmental parameters, including climate change, and their primary drivers. There are a multitude of important issues surrounding the environment but only the most important of those within the NIC's remit[1] have been discussed in detail.

At the same time other drivers such as increasing population, urbanisation and affluence will increase demand for infrastructure services. These changes in demand are explored in the Commission's population and economics papers and are likely to lead to changes in the pressures on the environment as well as increased demand for the services and goods supplied by natural assets. The Commission's technology paper identifies the potential to radically improve the way that we manage some infrastructure systems to offer a supply-side response, with the potential to alleviate future pressures. Similarly, environmental constraints, exacerbated by increasing pressures, have the potential to drive technological change – for example, the emergence of desalination technology in water scarce areas.

Building infrastructure that is resilient to the risks from future climate change requires consideration of likely future impacts. Therefore, an important objective for this paper is the identification of an appropriate set of climate projections for use in the NIA analysis. The approach proposed uses the current UK Climate Projections[2] (UKCP09) to gain an understanding of the likely variability in future climate across and within low, medium and high emissions scenarios. The impact of climate change on water is particularly marked and it is intended to use the existing Future Flows[3] data to understand the range for the medium emissions scenario and explore whether this can be adapted to give an understanding of the range for the high and low emissions scenarios. The evidence surrounding different scenarios will continue to be reviewed in order to ensure inputs into the modelling provide robust outputs, reflective of likely future outcomes. As further information becomes available on the updated UKCP18 projections expected to be published in 2018, consideration will be given to how these can be used in future analysis undertaken by the Commission. Similarly analysis of infrastructure requirements will take account of the legal commitment to cut UK greenhouse gas emissions by at least 80% from 1990 to 2050.

Further information on the overall scope and methodology for the NIA is available here.

The Commission would welcome comments on this paper. In particular, references to further sources of evidence on these issues would be helpful. Please send any comments to **NICdiscussionpapers@nic.gsi.gov.uk** by 28 July 2017.

2. THE ENVIRONMENT

There is very little of the natural environment in the UK today that has not been shaped or impacted in some way by human activity and the infrastructure that has been put in place to support it. Although there have been some major improvements (for example water quality in major rivers such as the Thames), trends over the last 60 years in many environmental parameters such as biodiversity show decline.

The National Infrastructure Commission has identified the natural environment as a major driver of infrastructure demand and supply. This reflects both the need to adapt to the changing climate and to protect and enhance the environment (and the services it provides) from the impact of detrimental human activities. For example flood management systems enable society to cope better with climate variability and change; similarly, waste water collection and treatment infrastructure ensures that discharges are less likely to damage the environment or human health. Therefore, when considering and planning for long term strategic infrastructure needs, it is important to understand the relationship that exists between infrastructure, the services provided and the environment.

In considering the environment the Commission will consider impacts on the environment in the light of the objectives set out in its charter[4] to: (i) support sustainable economic growth across all regions of the UK, (ii) improve competitiveness and (iii) improve quality of life.

People are at the centre of this approach to the environment, focussing on the value of Natural Capital to current and future generations. Many of the environmental standards that have influenced infrastructure over the past 50 years were established by the European Union. As the UK leaves the European Union there may be an opportunity to revisit some of these standards to ensure that they are well designed, unintended outcomes are avoided, and overall benefits secured.

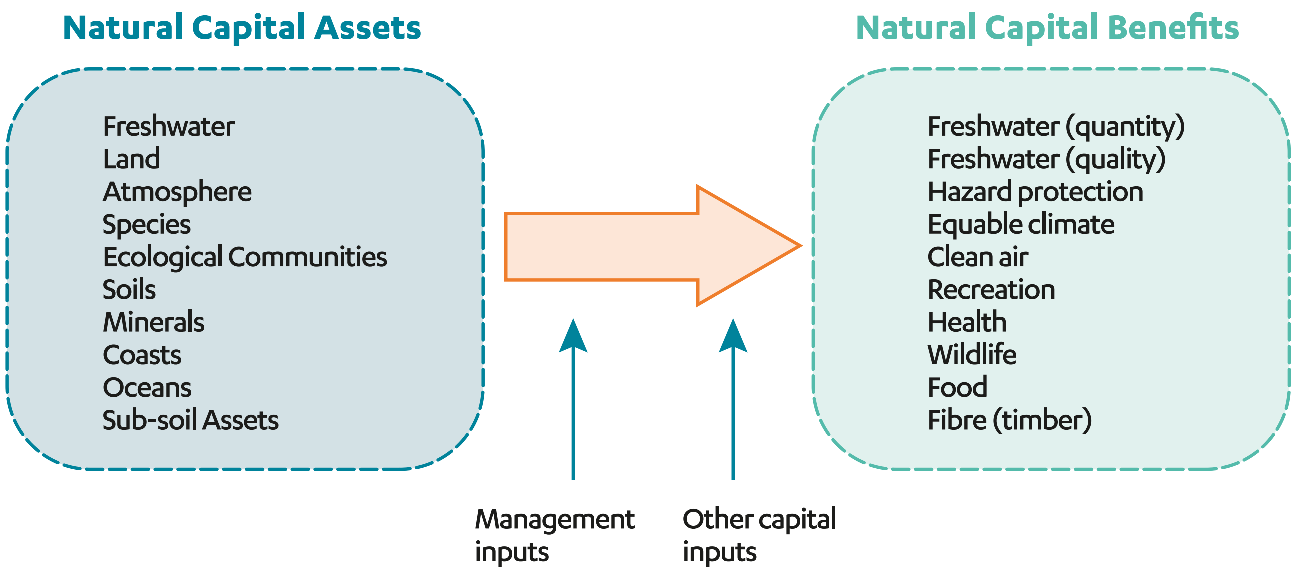
Strategic decisions made now will have long-lived and far-reaching environmental consequences, some of which are unlikely to be fully anticipated at the time. These decisions can generate significant adjustment costs e.g. the promotion of diesel fuelled vehicles in the 1990's in a bid to reduce carbon emissions is causing major air pollution problems now. Care should be taken to fully understand the possible spectrum of environmental consequences when planning the infrastructure of the future.

In the remainder of this paper key environmental parameters relevant to infrastructure are explored in a discussion framed by the concept of natural capital. Climate change is considered both in terms of the need to minimise greenhouse gas emissions (mitigation) and coping with the impacts of climate change on infrastructure and the environment (adaptation). The final sections provide a detailed discussion of the most important points of interaction and the implications for the National Infrastructure Assessment.

3. NATURAL CAPITAL

The framework provided by a natural capital approach allows the sustainable use of the environment to be considered and the Government has established the independent Natural Capital Committee to provide advice on this. In Scotland the Scottish Forum on Natural Capital, a membership organisation, performs a similar function. The Natural Capital Committee defines natural capital as the stock of natural assets that directly or indirectly produce value to people. Assets include the atmosphere, forests, rivers, land, minerals and oceans[5] as shown in Figure 1.

Figure 1: Flow from Natural Capital assets to Natural Capital Benefits[6]



3.1 Natural capital trends and benefits

As illustrated in Figure 1 it is the combination of natural capital with other inputs that delivers benefits[7] to society including:

- **Freshwater:** quantity and quality of water available for human use (e.g. drinking, bathing, industrial processes etc.) as well as the natural environment
- **Hazard protection:** reducing the risk of flooding, drought, heatwaves or landslips
- **Equable climate:** a comfortable climate that has no adverse impact on human health or wellbeing
- **Clean air:** air quality that does not adversely impact on human health or wellbeing
- **Recreation:** active enjoyment of the natural environment (e.g. walking, fishing, canoeing)
- **Health:** physical and mental health benefits e.g. from urban green spaces
- **Wildlife:** the diversity and abundance of wild species that has aesthetic and recreational value as well as cultural and spiritual significance
- **Food:** plant, animal and fungi (both wild and cultivated) consumed by people
- **Fibre:** plant and animal materials (including timber) used for building, clothing etc

A review of natural asset status and trends was published by the Natural Capital Committee in 2014[8] and is summarised in Table 1. This shows species that are not protected are in overall decline. The amount of greenhouse gases in the atmosphere continues to steadily rise but some aspects of air pollution are improving. There has also been no overall change in water quality.

Table 1: Trends for natural capital assets[9]

Asset	England Biodiversity Indicators – Trend
Species	↘ BAP Species ↗ EU Protected Species (↘↘↘) (↗) (↔) Farmland (↘) (↗) (↔) Woodland (↘) (↔) Wetlands (↘) (↗) Marine (↘↘↘) Invasives
Ecological communities	↔ Protected Areas ↘ EU Protected Habitats (↘↘↘) Invasives
Freshwater	↔ Water quality
Oceans	↗ Fisheries ↘ Invasives ↗ Pollution
Atmosphere	↗ Sulphur deposition ↔ Nitrogen deposition ↘ Net greenhouse gases

No data available for soils, land, minerals & sub-soil assets or coasts
Key: ↗ upward trend (improving); ↘ downward trend (deteriorating); ↔ no real change
multiple arrows indicate multiple indicators for the asset / pressure

There are a wide range of different factors responsible for the changes in natural capital. The National Ecosystem Assessment in 2011[10] concluded that the biggest drivers of changes in ecosystems over the preceding 60 years were:

(i) Conversion and intensification of natural habitats to farmland

(ii) Exploitation of natural resources, especially marine fish

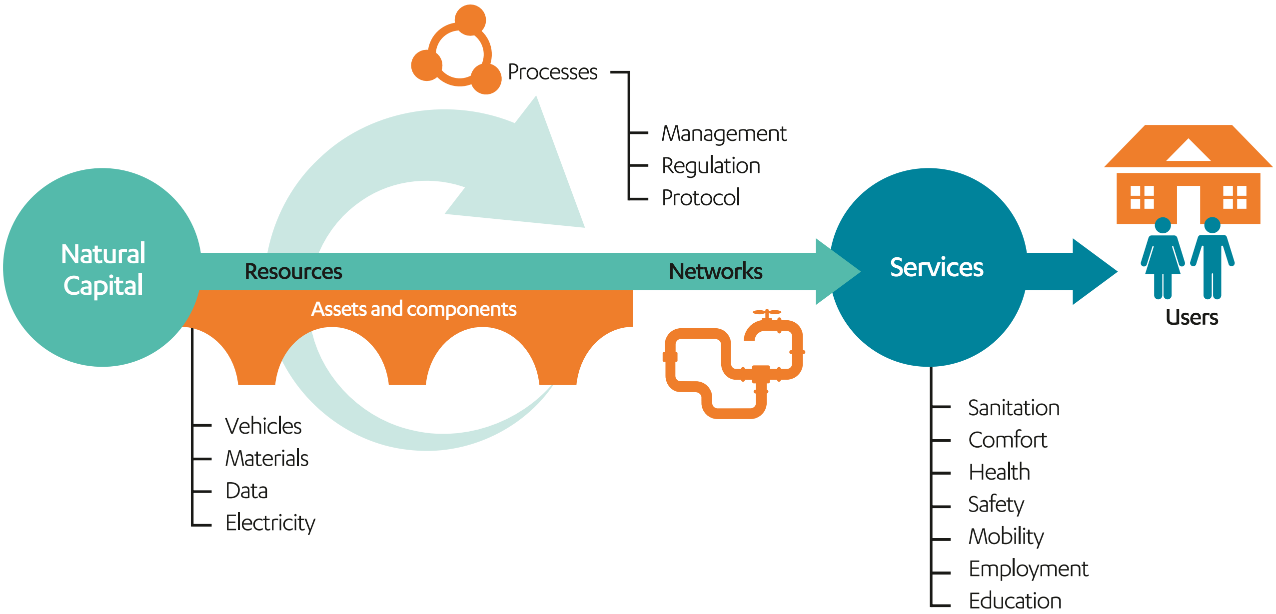
(iii) Air pollution, especially from certain nitrogen, sulphur and phosphorous - containing compounds

Infrastructure is only one of a number of factors affecting natural capital and its impact is not always negative or significant.

3.2 Infrastructure impacts

Infrastructure has both a direct impact on the environment through its footprint, and indirectly through people's use of it – for example, the use of roads by vehicles leading to air pollution. Figure 2 illustrates the relationship between natural capital, infrastructure, and the services provided.

Figure 2 – Natural capital, infrastructure and infrastructure services[11]



Infrastructure has a relationship at the local scale with all natural capital assets identified in Figure 1, but this isn't always significant at the national scale. The most important global impact of UK infrastructure is via the emissions of greenhouse gases that drive climate change. Analysis in the NIA will take account of the legal commitment to cut UK greenhouse gas emissions by at least 80% from 1990 to 2050. Other significant impacts at a national scale that are likely to need consideration as part of the analysis for the NIA include:

- freshwater quantity and quality
- protection from hazards such as flooding
- equable climate
- clean air
- noise

Each of these are considered in detail in section 5. Understanding of the relationship between infrastructure and the environment is constantly evolving with the study of impacts tending to follow, rather than lead, policy. The Commission will continue to review the literature in order to ensure analysis is taking proper consideration of all major infrastructure impacts.

The full range of significant impacts should be identified through the Strategic Environment Impact Assessment of relevant plans and programmes and, where relevant, Environmental Impact Assessment as part of the planning decision making process. This extends beyond natural capital assets to all aspects of the environment likely to be significantly affected, including material assets, architectural and archaeological heritage, landscape and the inter-relationship between factors. This is intended to protect the environment and help integrate environmental considerations into the preparation of plans and projects.[12] In some instances, this process can help to maximise wider benefits and can result in the achievement of 'net gain' for the environment. The NERC Act 2006 sets out a requirement for every public authority to conserve biodiversity, where biodiversity conservation refers to the restoration or enhancement of a population or habitat.[13]

Some important habitats may be disproportionately affected by particular types of infrastructure. For example, nationally and internationally important intertidal areas are affected by 'coastal squeeze' caused by rising sea levels and fixed coastal defences. Linear infrastructure (such as roads or railways) and development may fragment habitats, reducing opportunities for species migration.[14] However there can also be opportunities for linear infrastructure to act as connectors between habitats – for example, the inclusion of green verges alongside road corridors.

Important areas are protected at the European level by the EU Birds and Habitats Directives. The Birds Directive was adopted by the EU in April 1979 and provides comprehensive protection to all wild bird species naturally occurring in the European Union. The Habitats Directive was adopted in 1992 to help maintain biodiversity. It protects over 1,000 animals and plant species and over 200 types of habitat. It also established the EU-wide Natura 2000 network of protected areas. In the UK these areas are designated as Special Areas of Conservation and Special Protection Areas (SACs and SPAs).

4. CLIMATE CHANGE

There is an international scientific consensus[15] that global climate change is already happening. This is shown by the warming of our atmosphere and oceans, accompanied by increasing sea-levels and changes in global weather patterns. The Committee on Climate Change[16] reports a high degree of confidence that increases in the concentration of greenhouse gases, largely attributable to human emissions, have caused most of the observed warming since the mid-20th Century. The warming experienced over the past half-century can be largely be attributed to the greenhouse gas effect, whereby carbon dioxide and other 'greenhouse' gases have a warming effect on the atmosphere. Many of these trends are likely to continue for decades even in the most optimistic scenarios. Whilst the long term impacts cannot be precisely predicted there will be significant consequences for human welfare and the environment.

Observed changes in the UK climate as a result of global warming were identified by the Committee on Climate Change as:[17]

- Average land temperatures in the UK that were 0.9°C higher between 2005-2014 compared with 1961-1990 – the majority of warming in the UK having taken place since the 1970's
- Average UK sea levels that have risen at a rate of 1.4 +/- 0.2mm per year since 1901
- A significant upward trend in rainfall in Scotland of more than 10% above the early 20th century average (overall increases in average rainfall across the UK are not statistically significant, however winter rainfall has become heavier over the last 30 years)
- An increased frequency of severe autumn and winter wind storms between 1950 and 2003 (but storminess in recent decades is not unusual in the context of longer records)

The impact of climate change on economic growth was considered by the Stern Review in 2006. The review concluded that climate change is likely to have major impacts on economic growth towards the end of the 21st Century. Under a business as usual emissions scenario, the overall costs and risks of climate change will be equivalent to losing at least 5% of global per-capita consumption each year, now and forever. When impacts on human health were taken into account this estimate increased to an 11% per-capita reduction in consumption.[18]

Under the United Nations Framework Convention on Climate Change (UNFCCC) Paris agreement of 2015, many countries (including the UK) have agreed 'to keep global climate change to well under 2°C and to pursue efforts to limit increases to 1.5°C'.[19]

Climate change will have major impacts on infrastructure service provision in the UK both through the need to reduce emissions in order to mitigate the likelihood of extreme change as well as continuing to adapt to the effects of climate change that are already inevitable. In a world shifting to lower carbon growth, there are opportunities for the UK to be a leader in putting appropriate infrastructure in place to support this transition.

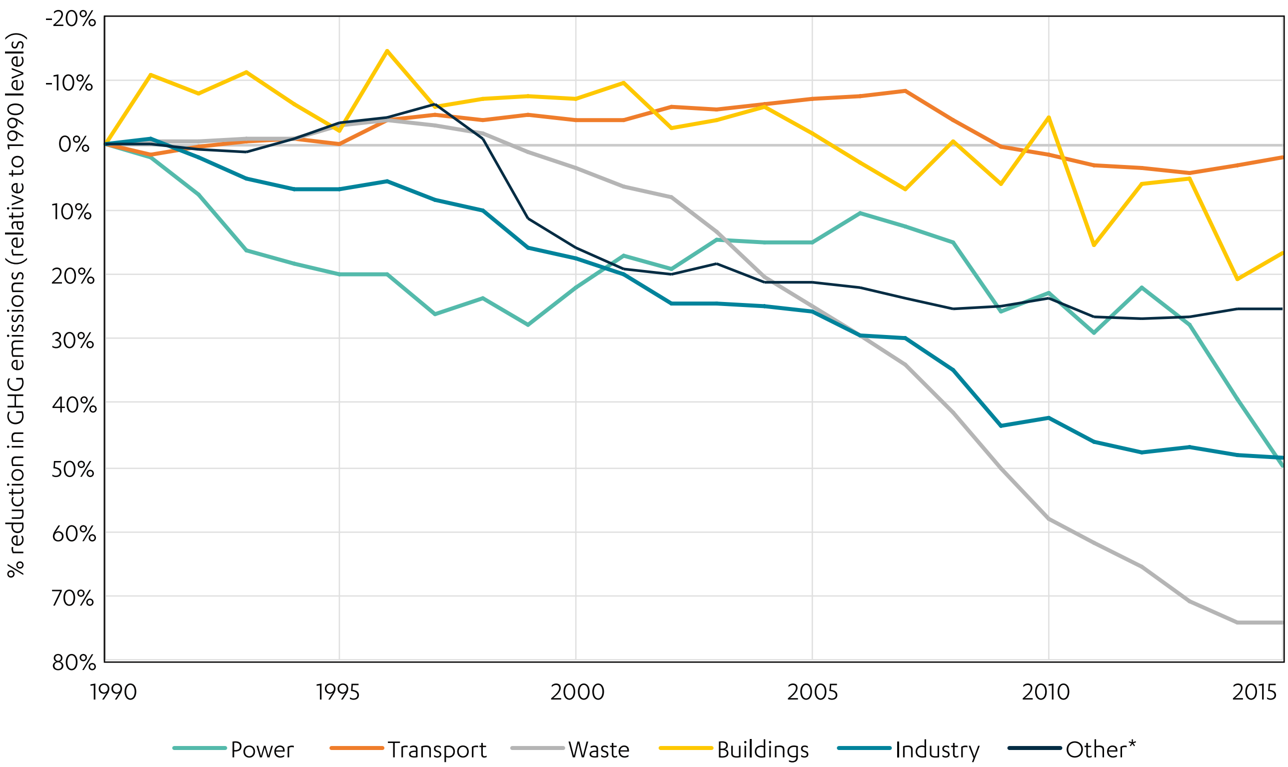
4.1 Mitigation: UK's carbon budget

Under the Climate Change Act of 2008 the UK is committed to reducing its carbon emissions by at least 80% by 2050 (from 1990 levels). The Act requires the government to set legally binding carbon budgets specifying the required limit on greenhouse gas emissions for each five year period, providing a trajectory towards the 2050 commitment. Current Carbon Budgets are equivalent to requiring net emissions to be reduced by about 37% by 2020, 51% by 2025 and 57% by 2030 relative to 1990s levels. Emissions cover a range of greenhouse gases. To allow like-for-like comparisons each gas is measured in terms of its global warming potential compared to carbon dioxide. Some gases, such as methane, are more damaging than carbon dioxide in the short term but persist for less time in the atmosphere once released. The UK's approach balances the differing impacts of different greenhouse gases.

By 2015 emissions in the UK had fallen by 38% compared to 1990 levels, largely as a result of the decline in use of coal for energy generation and its replacement with renewables, along with reductions in waste and improved industrial efficiency.[20] The Carbon Budgets require a steady reduction in emissions to ensure that the 2050 target is met cost-effectively. This will require new strategies in areas such as emissions from heating, land transport and power generation.[21]

Figure 3 shows that although there have been significant reductions in emissions across several sectors, particularly power, industry and waste, those in other sectors have been much slower. As of 2015, the transport sector is responsible for the largest share of UK emissions at 24%, closely followed by the industry and power sectors at 23% and 21% respectively. The increase of 1% in transport emissions during 2015 follows an average annual decrease of 0.6% from 2009-2014 as technological improvements in the efficiency of vehicles were outweighed by increased road travel.[22, 23]

Figure 3: Trend in UK emissions by sector[24]



* Includes emissions from agriculture; land use, land use change and forestry; and fluorinated gases.

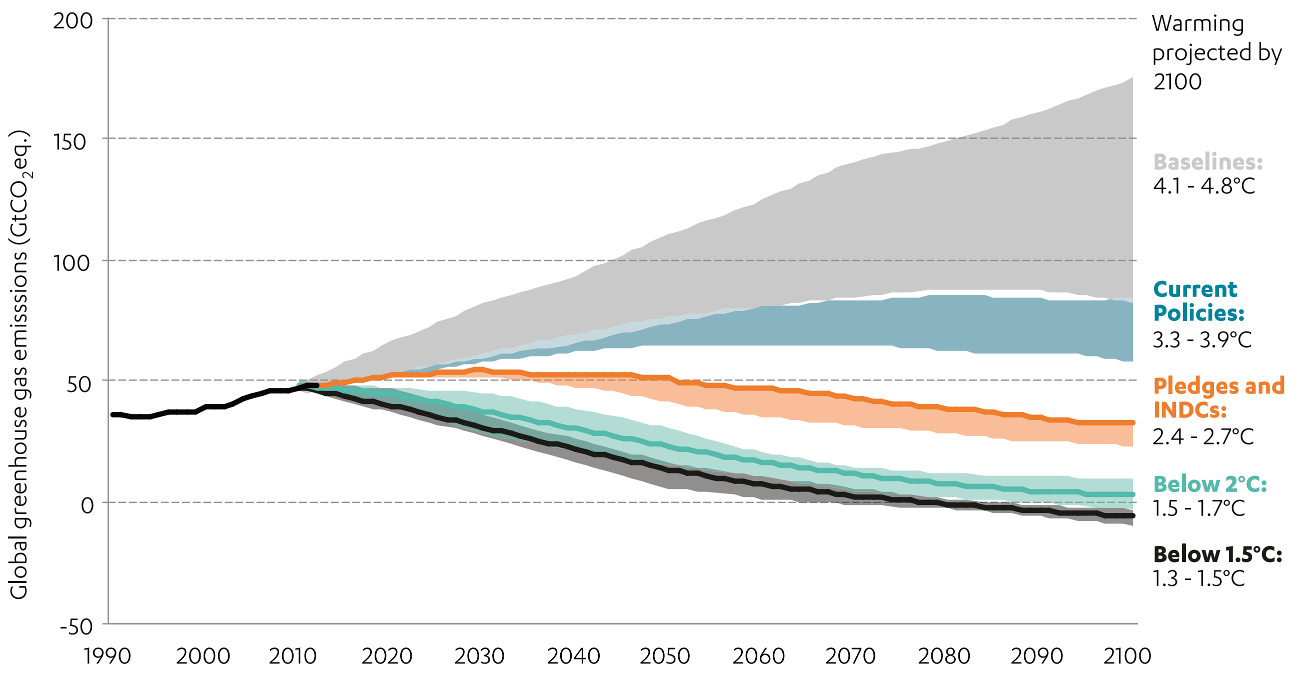
The Committee on Climate Change has suggested[25] priority areas for the NIA are smart low-carbon power, electric vehicle charging networks, heating, carbon capture and storage, flood risk management & drainage, and water resources management & supply. The requirement to cut UK greenhouse gas emissions will have a significant impact on infrastructure well within the time period considered for the NIA. The modelling of infrastructure will take account of greenhouse gas emissions and include options to meet the legal 80% reduction requirement, such as complete decarbonisation of the energy grid and electrification of the car fleet by 2050. There may be major implications for wider infrastructure systems, such as electricity distribution, roads and charging networks that will need to be incorporated into any strategic long term infrastructure planning.

4.2 Adapting to climate change

In determining scenarios for the NIA, assumptions need to be made about future global emissions to help understand future risks to UK infrastructure. The Intergovernmental Panel on Climate Change (IPCC) provides an international mechanism for assessing the science relating to climate change including emissions scenarios. The IPCC's SRES scenarios, that are the basis for UKCP09, are non-intervention scenarios that do not assume specific policy measures to mitigate the effects of climate change; differences reflect assumptions of future socioeconomic developments.

The 2009 UK Climate Projections (UKCP09)[26] funded by Defra used the IPCC emissions scenarios and are the most up-to-date projections for the UK. The projections use a range of scenarios comprising high, medium and low emissions. As Figure 4 shows, the possible ranges under future emissions scenarios are relatively consistent until the 2020s or 2030s but diverge dramatically in the second half of the century, leading to substantial differences within the expected lifetimes of much of the infrastructure being considered in the NIA.

Figure 4: Greenhouse gas emissions under UKCP09 scenarios[27]



A new set of scenarios, Representative Concentration Pathways, have been developed since 2009 using models developed for the IPCC's Fifth Assessment Report,[28] and outputs are generally consistent with the range from the UKCP09 scenarios. The development of these new scenarios together with evolving user needs have provided a driver for the government to commission the Met Office to develop new scenarios (UKCP18) that are expected to be published in 2018. These fall beyond the timescales for this NIA but may be appropriate for use in future NIAs.

As future emissions will be determined by human choices, relative likelihoods cannot be assigned to emissions scenarios, but the Commission will continue to review the evidence available. To incorporate climate change in infrastructure resilience planning a decision has to be made about how uncertainty in emissions, natural variability and climate change modelling will be taken into account. The Met Office suggest a cascade of confidence in climate projections, with:

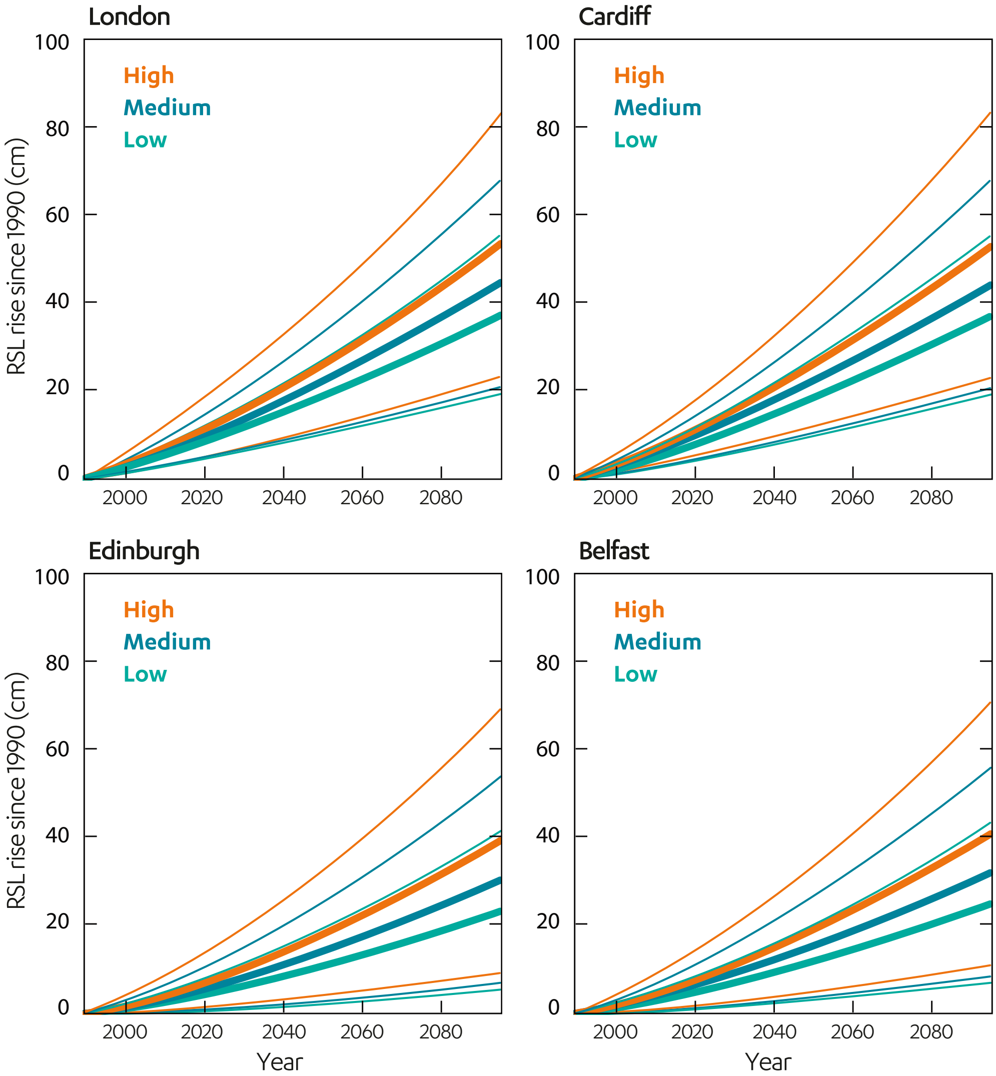
- Very high confidence in global warming due to human emissions of greenhouse gases
- Moderate confidence in aspects of continental-scale climate change projections

Whilst this uncertainty is inevitable it is notable that historical predictions based on climate models are consistent with observations; the IPCC's First Assessment Report in 1990 suggested annual temperature rises between 0.10°C to 0.35°C and measurements from 1990-2012 show annual temperature rise of approximately 0.15°C.[29]

To represent this uncertainty, probabilistic projections for several climate variables, including precipitation (rain and snow), were provided in UKCP09 for the high, medium and low scenarios. The probabilities reflect the weight of evidence and available climate science – indicating the degree to which a particular level of future climate change is consistent with the information used in the analysis.

The extremes of the projections are less robust than the central estimates. Advice from the Met Office[30] is that for most climatic variables the range between the 10 and 90 percentile limits should be used and the extremes beyond this (up to 1% and 99%) only with caution. There is greater certainty about sea level rise and the 5 and 95 percentile limits are generally presented for this. Figure 5 shows the Relative Sea Level (RSL) rise from 1990 values for four locations around the UK. The charts include the central estimate values (thick lines) and 5th and 95th percentile limits of the range of uncertainty (thin lines) for the three emissions scenarios.

Figure 5: Relative sea level rise over the 21st century under different emissions scenarios[31]



In addition to the high, medium and low scenarios, UKCP09 provided a High++ scenario for sea level rise and storm surge. This took into account increased sea level rises from faster melting of ice sheets and extreme projections of storminess that are still plausible from the climate model. It provides an extreme but physically plausible range for contingency planning and is useful for exploring the limits of adaptation, but it should be noted that, "it is thought very unlikely that the upper end of the H++ ranges for sea level rise and surges will be realised during the 21st century".[32] This High++ approach was extended in work by the Met Office for the 2017 Climate Change Risk Assessment Evidence Report to provide extreme scenarios for heatwaves, droughts, floods, windstorms and cold snaps to allow stress testing of adaptation plans. The use of such scenarios for 'stress testing' allows a fuller range of possibilities to be considered and can be particularly helpful in allowing low probability, high consequence risks to be considered alongside more likely, lower consequence ones.[33]

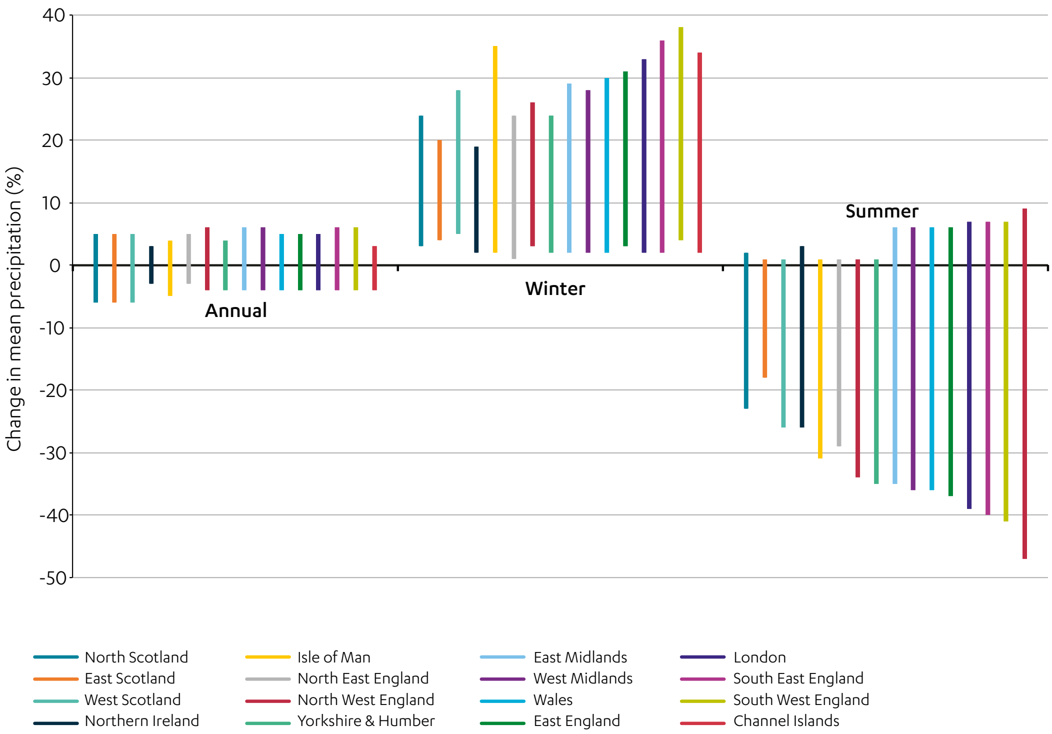
The design of future infrastructure systems needs to take account of the changing climate, to ensure they continue providing services and enhancing, or at least not limiting, the UK's capacity to adapt to these changes. Some of these changes have been known about for a long time, but many others have only been understood more recently. For example, the design and construction of the Thames Barrier in the 1970s allowed for some sea level rise but did not provide for increasing river flows or storm surges.[34]

As there is still considerable uncertainty in many aspects of climate change it is important to consider the performance of infrastructure across different scenarios and to put in place a framework for decisions that takes account of uncertainty and the lead time needed for planning and construction of infrastructure. This is often referred to as a 'managed adaptive' approach.

The 'managed adaptive' approach proposed requires the use of different climate projections to allow the uncertainty to be investigated. It is proposed that current UK Climate Projections (UKCP09 described above) are used to gain an understanding of the variability across and within the low, medium and high emissions scenarios. These will be used directly where the modelling allows (particularly for water supplies and flood risk).

The impact of climate change on water is both significant and particularly uncertain. On average, UKCP09 projections give a greater likelihood of wetter winters and drier summers. This means that the same amount of rain is expected to fall on fewer days across the year leading to more days on which very heavy rainfall occurs.[35] Figure 6 shows ranges for seasonal changes in precipitation across different regions of the UK for 2040-2069 relative to 1961-1990. While the overall change in annual average rainfall is relatively small there is both regional and seasonal variability.

Figure 6: Change in average annual, summer and winter precipitation[36]



For the water supply modelling it is intended that Future Flows[37] data will be used to understand the range of uncertainty for the medium emissions scenario. The use of Future Flows allows comparison of results across a range of scales and geographical regions. The possibility of whether Future Flows can be adapted to give an understanding of the range of uncertainty for the high and low emissions scenarios will also be explored. As further information becomes available on the UKCP18 projections expected to be published in 2018, consideration will be given to how these can be used in future analysis undertaken by the Commission.

5. INTERACTIONS BETWEEN INFRASTRUCTURE AND THE ENVIRONMENT

As previously stated the environment is both a major driver of infrastructure demand and a constraint, reflecting the need to protect it (and the services it provides) from the impact of human activities and to adapt to the realities of a changing climate. The environment, as well as people, can benefit from the provision of green infrastructure that can deliver wider benefits. This section considers climate change before going on to set out the relationship between infrastructure, the environment and the services provided, including trends in key environmental parameters, to identify potential impacts on different types of infrastructure over the next thirty years.

5.1 Climate change

Climate change is expected to increase the frequency and severity of extreme weather including both high and low rainfall, and heatwaves. In January 2017 the government published its second Climate Change Risk Assessment (CCRA)[38] identifying key impacts in the UK, including on infrastructure. This is largely based on the evidence report provided by the Adaptation Sub-Committee of the Committee on Climate Change. The main climate-related risks to infrastructure identified are summarised in Table 2 below and comprise both increases in demand for some infrastructure services (e.g. flood management, cooling) and reductions in the resilience of other services (e.g. power supplies, communications).

Table 2: Climate variables, extremes and potential risks to infrastructure[39]

Climate variable	Climate extreme	Risks to infrastructure
Temperature	Heatwaves	High temperatures create a risk of buckling on the rail network, cause electricity cables to sag, road tarmac to soften and rut and signalling equipment to overheat and fail – all likely to increase demand for cooling
Precipitation	Extended period and intensity of rainfall	Increase risk of slope and embankment failure, risks to transport and road network
	Flooding	Exposure of infrastructure assets (energy, transport, water, waste-water and digital communications) to flood risk increases
	High river flows	Can lead to bankside erosion, putting river crossings at risk
	Drought	Supply/demand deficits in water resource zones, increased risk of subsidence
Sea level	Rising sea levels and surges	Increase coastal flooding and erosion risk as well as damage to ports and other coastal infrastructure
Wind	Storms and increases in maximum wind speeds	Significant risks for overhead power lines, data network cabling, rail network, offshore infrastructure

The CCRA 2017 Evidence Report[40] included views from experts setting out the impact of each extreme event across different infrastructure sectors, summarised in Table 3 below. Although the scale of the impact of these hazards on infrastructure is uncertain (and will depend on the extent to which climate change materialises) the table highlights key risks.

Table 3: Overview of key climate risks for different infrastructure sectors[41]

Infrastructure Sector	Floods	Water scarcity	High temperature	(Wind) Storms	Geohazards (subsidence / landslides)
Water and waste water	**	**	*		*
Transport	**		*	**	**
Energy generation	**	*	*	*	
Energy distribution	**		*	**	*
Flood and coastal defences	**			*	*
Solid waste	*		*		
Digital and communications	**		*	**	*

Note: a single asterisk denotes a relationship, double asterisk denotes a strong relationship. These do not consider interdependencies between infrastructures.

Although the above table indicates many risks across multiple infrastructure sectors, overall the 2017 UK Climate Change Risk Assessment placed flood risk, drought, cascading failures from interdependent infrastructure networks and risks to transport from embankment failure as the greatest direct climate change-related threats for the UK.[42]

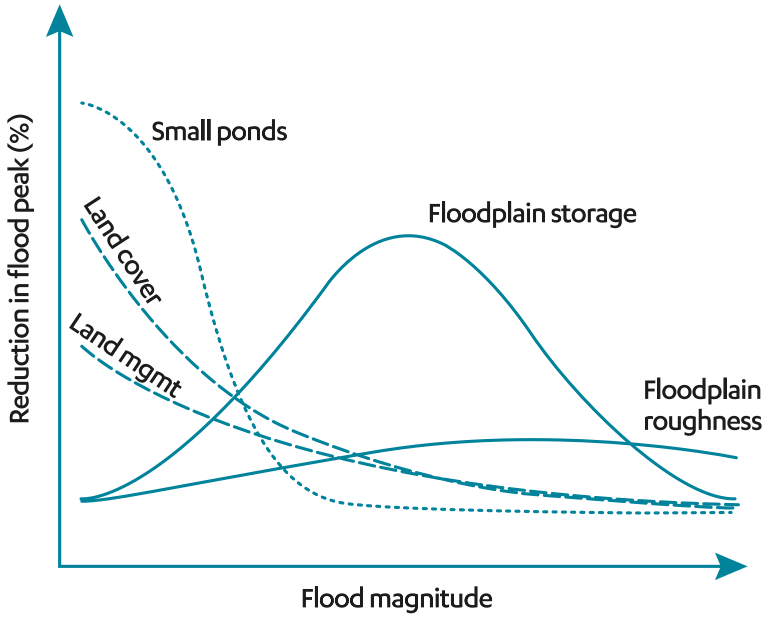
5.2 Flood risk management

Flooding is one of the most significant civil emergency risks faced in UK[43] and climate change is a key driver, alongside population and development, of increasing flood risk in the UK.[44] The Committee on Climate Change puts flooding from all sources as the most significant risk to UK infrastructure across all of the sectors considered within the NIA.[45] Research commissioned to support the 2017 Climate Change Risk Assessment[46] estimates that 1.8 million people in the UK currently live in properties at significant risk (greater than 1:75 or 1.3% annual probability) of flooding. This number is expected to increase to 2.5 million with a 2°C increase in global temperatures and to as many as 3.5 million under a scenario of a 4°C increase in global temperatures by the 2080s, assuming current levels of adaptation are continued and before any effects from population growth. Coastal erosion, exacerbated by increasing intensity of storms and sea level rise, is a significant risk. Of the 4,500 km of coastline in England, 1,800 km is liable to erosion, 340km of which are defended.[47] Infrastructure assets are also likely to be subject to significant increased risk of flooding with the number of sites exposed to an annual likelihood of flooding of more than 1:75 increasing by 10% (under 2°C climate change projection) and 160% (4°C climate change projection) by the 2080s.[48]

Since World War II there has been extensive change to land use in the UK, largely due to increases in intensive farming but also housing and urban development. People have made many physical changes to rivers, lakes and estuaries in the UK, for example, flood defences and weirs, and changes to the size and shape of natural river channels for land drainage and navigation. The Environment Agency report that 39% of water bodies in England have had physical modifications that impact on their ecology at a large scale.[49] These modifications often interfere with natural processes, resulting in the build-up of sediment and loss of habitats. This can reduce the resilience of the system to extreme events as well as reducing wider biodiversity and recreational benefits. For example, fragmentation of wetlands, particularly the separation of rivers from their flood plains, has had a detrimental impact on natural flood regulation.[50]

The 2008 Pitt Review[51] highlighted the potential to work with natural processes in catchments to hold back water. The effectiveness of such approaches in reducing flood risk depends on the scale of the catchment and the type of intervention. A recent study[52] comprehensively reviewed the evidence for whole catchment approaches and the conclusions are summarised in Figure 7. Storage (in ponds, floodplains or large detention basins) and improved floodplain conveyance (through reconnecting floodplains or setting back flood defences) can be effective if located in the right place and at the right scale.

Figure 7: The effectiveness of whole catchment approaches to managing flood risk[53]



This shows that land cover and land management (both of which can increase the ability of soils to absorb and retain water) are most effective for small events and scales. Floodplain roughness (vegetation and trees that dissipate energy and provides resistance to flows) can have a local effect but tend to be small at the larger scale. Storage (in ponds, floodplains or large detention basins) can be effective if located in the right place and used in the right way. Current evidence on upstream restoration and storage indicates they can be effective in reducing peak flows in small catchments for moderate rainfall events but that there is less scope for reducing the hazard at a larger scale or for major flood events. There is an argument that many small scale interventions would accumulate local benefits to provide flood risk reduction at a large scale, however this theory is untested.

5.2.1 Impacts of flooding

The National Flood Resilience Review[54] focussed on the risks to infrastructure of flooding from rivers and the sea. It looked at extreme rainfall scenarios developed by the Met Office and used Environment Agency models to predict flood events. Whilst the events were more extreme than those regularly observed, flooding was largely consistent with existing risk areas. The study found that a significant number of key local infrastructure assets (in energy, water, health, transport and telecommunications sectors) are located in risk areas but are not fully protected against flooding. Work was undertaken following the review to ensure that protection is provided to infrastructure identified as being at risk, initially focussing on the use of temporary barriers where these are appropriate.

Flooding also illustrates the interdependencies between different infrastructure and their significance for many aspects of modern life. A case study published by the Royal Academy of Engineering[55] details the wide ranging impacts following the flooding of an electricity substation in December 2015. This loss of power affected services that people take for granted; mobile phone coverage was lost and whilst the landline network was largely available, people could only use traditional wired (rather than cordless) phones. The internet, electronic payment systems and cash machines didn't work. The television booster station lost power and digital radio was also affected. Households were not only left without lighting and electrical appliances, but also gas fired heating that relies on electricity for controls and pumping, and some lost their water supplies. Shops were unable to open and although the railway line had power (supplied from outside the affected area) the station had to close at 4pm as there was no lighting. The lack of electricity meant there were no traffic lights and garages could not sell petrol or diesel as the pumps would not work. The impact on the community was exacerbated as few knew what was happening. Although power was restored over the following few days, the incident highlights the need to consider the complex interactions between modern infrastructure and the potential for a single point of failure to trigger a cascading failure.

5.3 Water resources

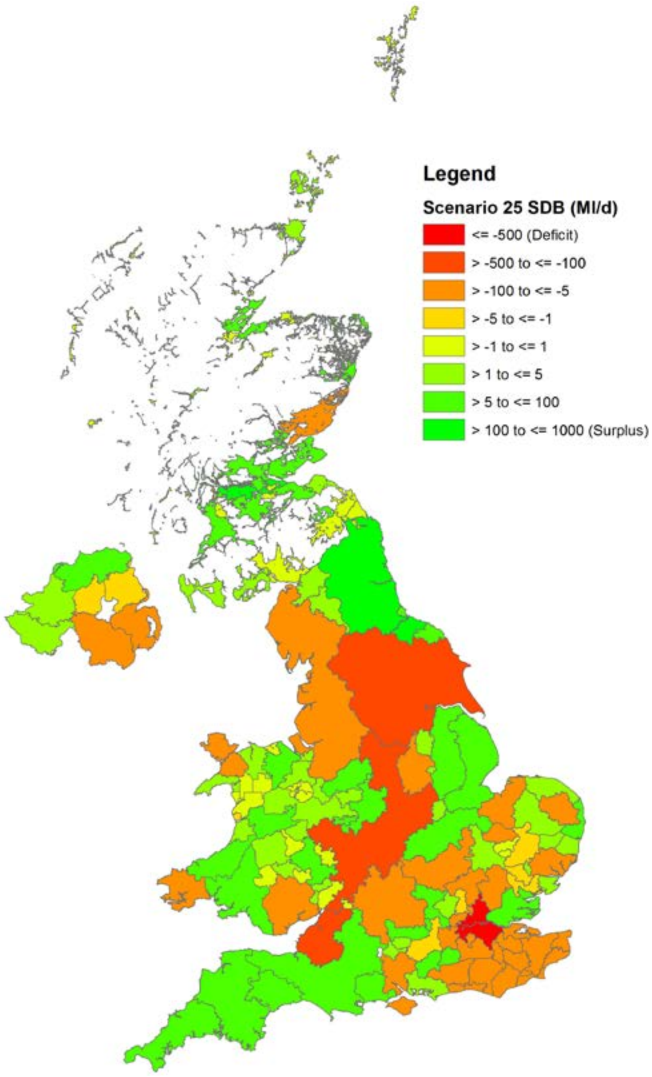
As a whole the UK total public water supply currently exceeds demand by a little more than 10%. However, some water resources zones have modest deficits presenting a risk of drought within the short to medium term. Although households dominate the demand in most locations, some local industries and infrastructure have particularly high requirements for water. Leakage also accounts for an average of 22% of total water supply in most water resources zones (despite recent reductions).[56]

Two key studies have been undertaken recently to model the impacts of climate change and population on water supplies. The evidence suggests that unless there is a step-change in the response to these pressures, there is likely to be a significant supply deficit in the long term.

A study for Water UK looking out to 2065 suggests that climate change will significantly reduce water resource availability.[57] If actions to reduce emissions are not taken this will undermine the long term resilience of water supplies and increase the risk of drought. The report shows that those areas for which groundwater makes up a large part of raw water resource are likely to be less vulnerable to the impacts of climate change, with areas that are heavily reliant on surface water likely to be more affected. The overall deficit for the UK is predicted to be between 5% and 16% by the 2050s, taking account of population increases as well as climate change. This will result in widespread deficits across many water resources zones if there are no adaptation interventions – most acutely in London and the South East.

A similar study using a different model was undertaken for the 2017 Climate Change Risk Assessment[58] to update projections of water availability for the UK. Figure 8 shows the results for one of the scenarios (low population, medium climate change projections and 'no additional action' adaptation) and demonstrates that the impact of climate change and population growth on supply demand balances is likely to vary across different water resources zones in UK. These results show that water resources pressures don't just affect the south-east of England – all areas may be affected by deficits depending on the scenarios considered. The contribution of different factors (population, adaptation decisions and climate) vary with location, but the report suggests population and adaptation decisions frequently have a greater impact than climate.

Figure 8: Example 2050s supply-demand balance for current water resource systems[59]



5.3.1 Impacts of reduced water availability

Water is not only important for human life; it is critical for the environment. By the 2050s many catchments (particularly in the west of England) are projected not to meet environmental flow requirements. Discharges (e.g. of treated water from sewage works) may be important in maintaining flow rates into the future. Maintenance of environmental flows is not only important for the ecological health of the environment, but also for the long term hydrological sustainability of water sources.

5.4 Water Quality

There have been significant improvements in the quality of the UK's water bodies (defined by the Environment Agency as a stream, river or canal, lake or reservoir, estuary or stretch of coastal water and including groundwater bodies) over recent decades. Success stories such as the clean-up of the River Thames are now international examples of best practice. A major driver of this improvement in the quality of water in the environment has been investment in sewage treatment works since 1990 that have resulted in major reductions in biological and chemical pollutants in wastewater effluent. The Water Framework Directive (WFD) introduced in 2000 brought in higher standards than previous legislation driving further improvements in water quality standards.

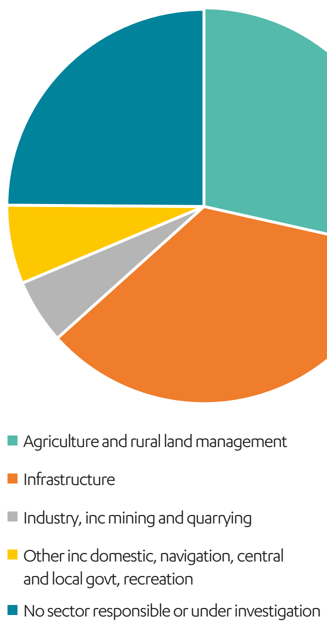
However, a number of pertinent issues still remain that mean only 17% of water bodies in England are achieving good ecological status or higher as of 2015, with 63% of water bodies achieving moderate ecological status.[60] An assessment by the Natural Capital Committee in 2014 identified water from mountains, moors and heaths, and water from current and projected extents of urban areas at very high risk (that is to say that the current status of the natural asset is poor and the trends are strongly negative). Key pressures preventing water bodies from achieving good status include:

- Pollution from waste water – affecting 35% of water bodies in England
- Pollution from towns, cities and transport – affecting 11% of water bodies in England
- Pollution from rural areas – affecting 35% of water bodies in England

Wastewater and pollution from urban surface water runoff present significant pressures to water bodies and their ability to maintain good ecological status. However pollution from rural areas can be attributed largely to agricultural activity and not infrastructure.

Figure 9 highlights the sectors responsible for the pressures that prevented water bodies in England from achieving good ecological status in 2015. Further examination of infrastructure responsible for preventing water bodies reaching good ecological status[61] shows less than 1% is attributable to waste treatment and disposal, nearly 30% to urban and transport and the balance of more than 70% to the water industry.

Figure 9: Sectors responsible for total pressures preventing waters reaching good status[62]



5.4.1 Impacts of Water Quality

Contamination of raw water sources from human activity has a downstream impact on water treatment requirements for water companies. This has implications on costs and, linked to this, energy consumption.

5.5 Air Quality

Air quality is a long standing issue in the UK with a history patterned by high profile events of acute air pollution causing step changes in the way the country manages emissions. The "Great Smog" of London in 1952, and the subsequent public backlash, propagated the introduction of the Clean Air Act in 1956. This was followed by the establishment of the National Survey in 1961 – the first co-ordinated pollution monitoring network in the world.[63] Since this time, air quality has improved significantly, largely driven by these major legislative changes. As depicted in Figure 10, social, fuel and technology transitions have led to a reduction in certain pollutants, and to the emergence of others.[64] As fuel sources have changed and the location of power plants has moved away from urban centres, public exposure to associated pollutants such as sulphur dioxide has reduced. Despite the progress that has been made, the emergence of particulates (PM_{10} and $PM_{2.5}$) from the combustion of diesel are now the most significant air quality threat to human health, alongside oxides of nitrogen and ozone. The UK has consistently breached obligations under European Union Ambient Air Quality Directive 2008/50/EC for both particulates and oxides of nitrogen. Ozone is not emitted in significant quantities directly from any source in the UK but is formed through reactions of other pollutants,[65] including nitrogen dioxide, with sunlight. Therefore emissions data presented here does not capture ozone.[66] 'Ozone' as outlined here refers to ground level ozone rather than stratospheric ozone. Ground level ozone is a key component of photochemical smog.

Figure 10: Illustration showing atmospheric pollutants over time[67]

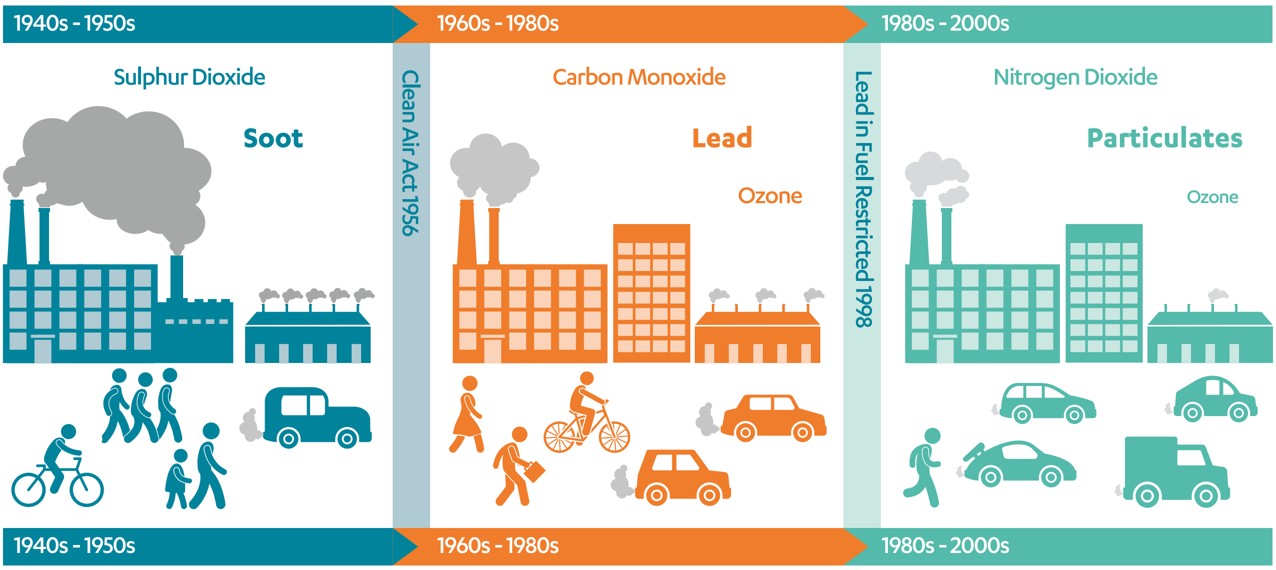


Figure 11 provides an overview of the trends in key pollutants from 1970-2015. Some key points of interest include:

- The recent decline in sulphur dioxides and nitrous oxides from 2012-15 can be attributed to the closing down of a number of major coal fired power stations.
- The introduction of catalytic converters in cars in 1990 accounts for the steady decline of nitrous oxides since this time.

Figure 11: Key atmospheric pollutants from 1970-2015[68]

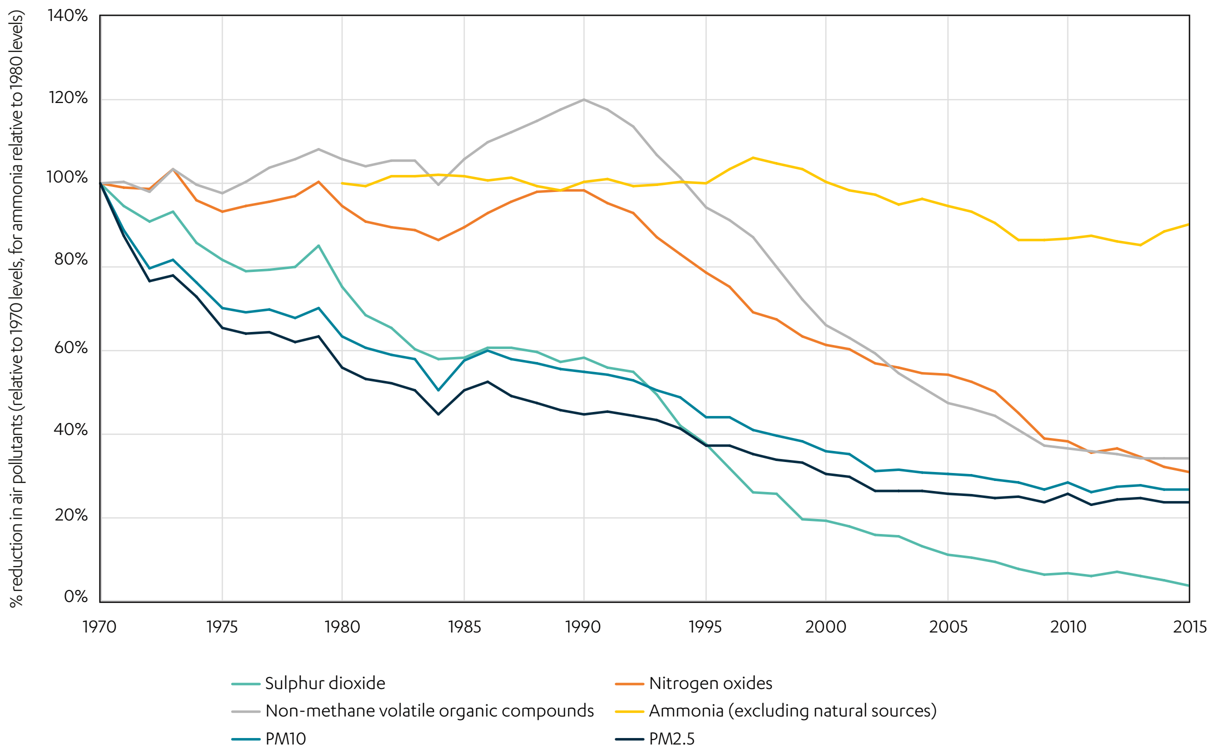
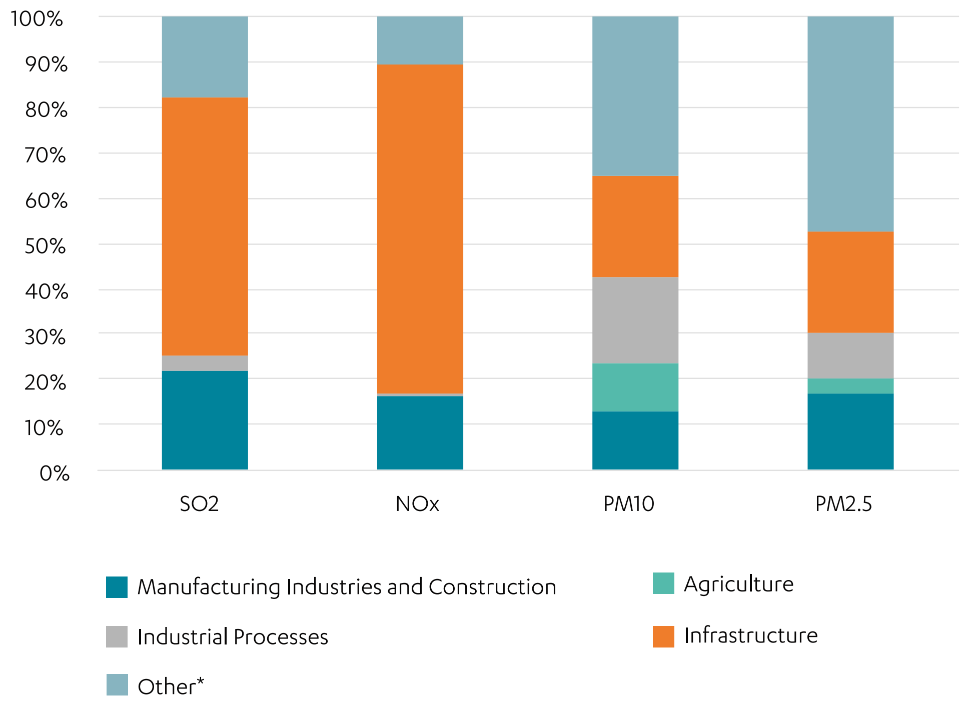


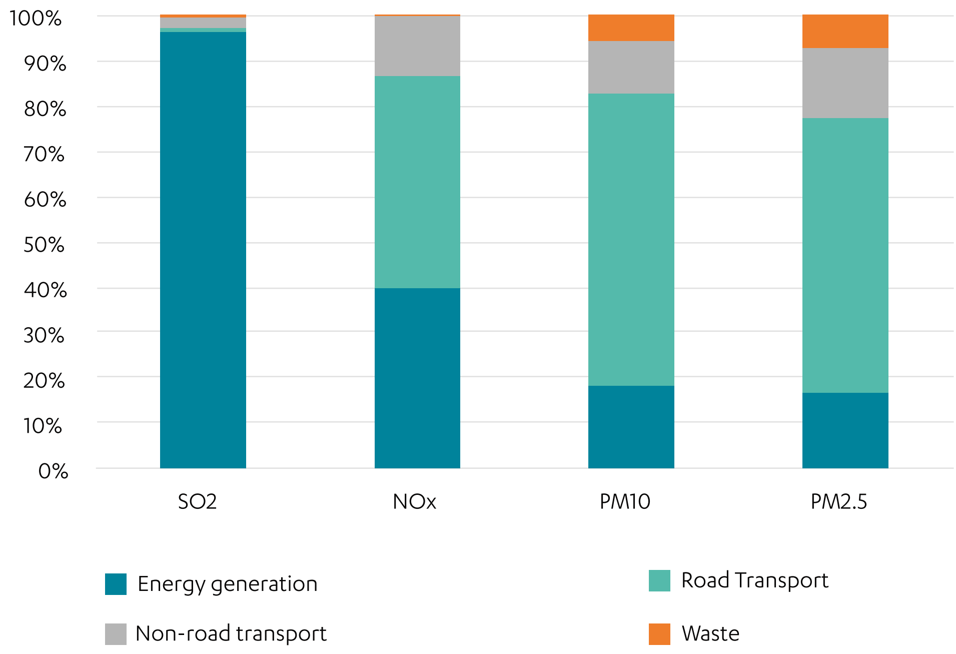
Figure 12 shows the sources of key atmospheric pollutants and Figure 13 shows the impact of different infrastructure related sectors.

Figure 12: Key atmospheric pollutants by source[69]



* Commercial, residential, agriculture and fishing stationary and mobile combustion, International & National Aircraft, International Shipping, forest fires, natural emissions, NH3 emissions from wild animals and humans.

Figure 13: Infrastructure sector emissions by source[70]



5.5.1 Road Transport

Road transport is not the main source of any of the key pollutants considered, producing only 34% of total emissions of NO_X and as little as 14% and 13% of total $PM_{2.5}$ and PM_{10} emissions respectively.[71] However, approximately 80% of breaches in the legal limit of NO_X, $PM_{2.5}$ and PM_{10}[72] concentrations annually can be attributed to road transport. Of additional significance is the important distinction between road transport and other sources of pollution on human health. Emissions from road transport are released in close proximity to people and concentrations in most city centres are exacerbated by the presence of buildings along the roadside that shelter the road from wind.[73] These factors result in diminished opportunity for dilution of pollutants in the atmosphere and an increase in the risk to human health. In general $PM_{2.5}$, PM_{10} and NO_2 concentrations are focussed around urban areas whilst concentrations of SO_2 are found around energy power plants. The emergence of electric vehicles as a low carbon technology is likely to have a significant impact on air quality and thus, human health.

5.5.2 Impacts of Air Pollution

The evidence for the negative impact of air pollution on the productivity of working age adults is well documented. In 2012, it is estimated that pollution levels in the UK had an estimated total cost of £2.7 bn[74] through losses in productivity (through absenteeism and reduced productivity whilst at work).[75] There is also a potential link between the effect of pollution on the academic performance of school children and therefore future productivity and future earnings. One study found that there was a statistically significant relationship between school absenteeism and air pollution.[76]

The mortality impacts of air pollution are well documented and include accelerated decline in lung function, asthma, heart attacks, strokes and lung cancer.[77] Children and the elderly are more vulnerable to the negative health impacts of air pollution and there is evidence to suggest that people on low incomes are also disproportionately affected due to relatively high levels of exposure.[78] Attributable deaths in the UK caused through PM exposure are estimated at 29,000 a year.[79] Recent studies that include the mortality impacts of Nitrogen Dioxide (NO_2) increase this estimate to 40,000 deaths.[80, 81] The associated mortality cost of this (based on the maximum amount that people are willing to pay for another year of life) is estimated to be between £25 and £30 billion.[82]

5.6 Heat

Heating is a major component of domestic energy consumption and whilst climate change is expected to increase average temperatures by approximately 0.5°C-3.5°C in winter (by 2040-2069 relative to 1961-1990) reducing the demand, it is likely to increase demand for cooling as temperatures are also expected to increase by 1°C-4.5°C in summer. A study that modelled the impact of temperature rise as a result of climate change on the demand for heating and cooling demands in office buildings in three key locations across the UK concluded that the fall in heating demand in winter would be equalled by the rise in cooling demand.[83] However, this does not discount the challenges presented by the potential increases in peak demand and it may be that summer and winter peak demand is met by different energy sources.

5.6.1 Impacts of temperature

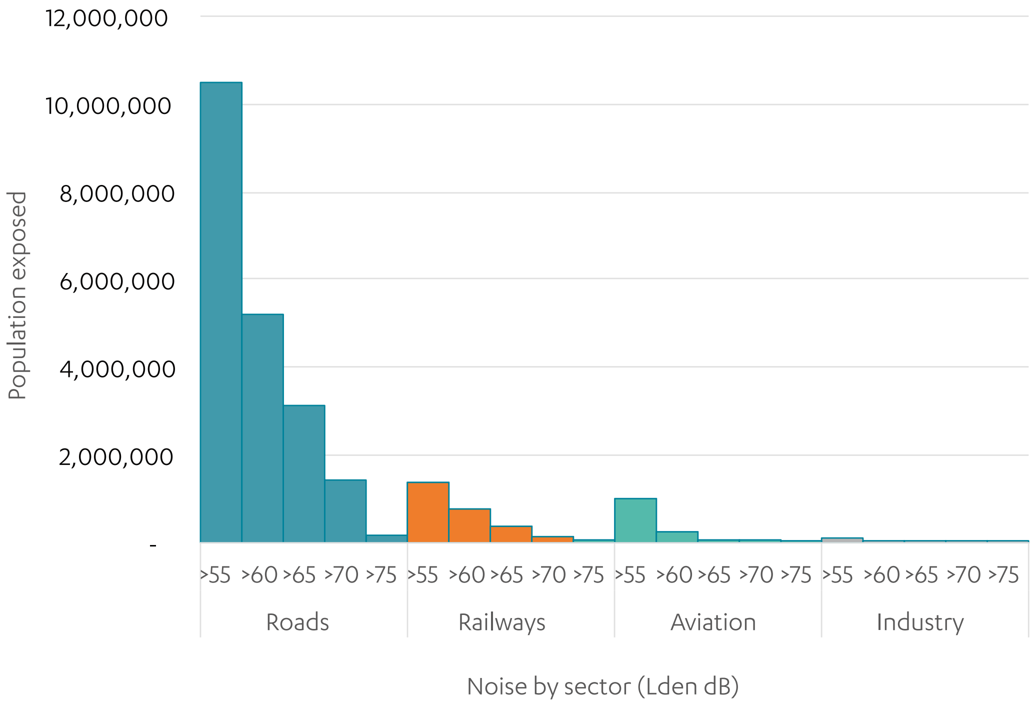
Temperature extremes can also have direct impacts on infrastructure. Network Rail's Weather Resilience and Climate Change Adaptation Strategy[84] identifies both the expected increases in temperature as a result of climate change as well as the associated risks. Adaptation actions include ensuring climate change allowances are accounted for in capital works and setting up controls for temperature extremes, such as reduced operating speeds and limiting heavy manual work during the hottest part of the day. It also sets out how probabilistic projections have changed over time. A very hot summer similar to that experienced in 2003 is now expected to have a 20% annual chance rather than the 2% at that time. The strategy also illustrates the impact of cold as well as hot weather, showing the failure rate of point operating equipment doubles or triples at temperatures below 3°C or above 25°C respectively.

5.7 Noise

Noise can be defined as any unwanted sound.[85] Noise is distinct from the other environmental parameters discussed in this paper as discussion cannot be focused on the quantity and quality of a Natural Capital asset or a Natural Capital benefit, as with water quality or air quality, but rather as a by-product of human activity that can have negative impacts on human health, amenity, productivity and the natural environment.

The noise metric used is essentially a 24 hour average with penalties during the evening (5 decibels from 1900-2300) and at night (10 decibels from 2300-0700hrs) to reflect the increased impact that noise has during these times relative to the day (0700-1900hrs), known as L_{DEN}. Environmental noise can be attributed mainly to transport sources including road, rail and aviation[86] however road transport is the major driver of public exposure to noise as can be seen from Figure 14.

Figure 14: Public exposure to noise by sector[87]



Noise from cars is disaggregated into exhaust, aerodynamic and rolling sound noise. There is limited evidence around the disaggregated contribution of each of these noise elements to overall noise, nor on the impact of each noise element on human health and wellbeing. This information gap is likely to be filled with the emergence of electric vehicles that do not have an exhaust noise element. This is relevant when considering potential future trends – were technology to move away from the internal combustion engine, aerodynamic and rolling noise from cars would likely still present an issue, however the extent of this is currently unknown. It should be noted that there is active concern from the disabled and partially sighted communities about the dangers of vehicles with less noise that may lead to regulation that mandates a form of added noise in order to mitigate these concerns.

5.7.1 Impacts of Noise Pollution

The impact of noise was identified as the second largest environmental risk to human health in Western Europe after air pollution.[88] Health effects in relation to noise exposure include sleep disturbance, stress and high blood pressure with possible links to stroke, dementia and cardio-vascular effects.[89] It is estimated that the mortality costs of noise in the UK are £7-£10 bn annually. This is based on disability adjusted life years that can be thought of as the number of years of 'healthy' life years lost and differs from the attributable deaths presented in relation to air quality in that it takes account of years lost due to disability. The associated impact on productivity has been estimated to be £2-£4bn annually.[90] As with air pollution, children are more susceptible to the impacts of noise pollution with exposure affecting speech, communication and learning.[91] This may have a potential impact on future productivity and future earnings.

6. GREEN INFRASTRUCTURE

There are different definitions and approaches to green infrastructure, but for the purpose of this paper the focus is on environmental features, often managed, that provide Natural Capital benefits such as reducing flood risk or improving water or air quality. In this way green infrastructure can deliver or contribute to the provision of some infrastructure services, reducing the amount and cost of conventional infrastructure required as well as providing wider benefits such as enhancing biodiversity. As well as contributing to the provision of infrastructure services, green infrastructure offers important well-being outcomes, directly contributing to people's health and quality of life.

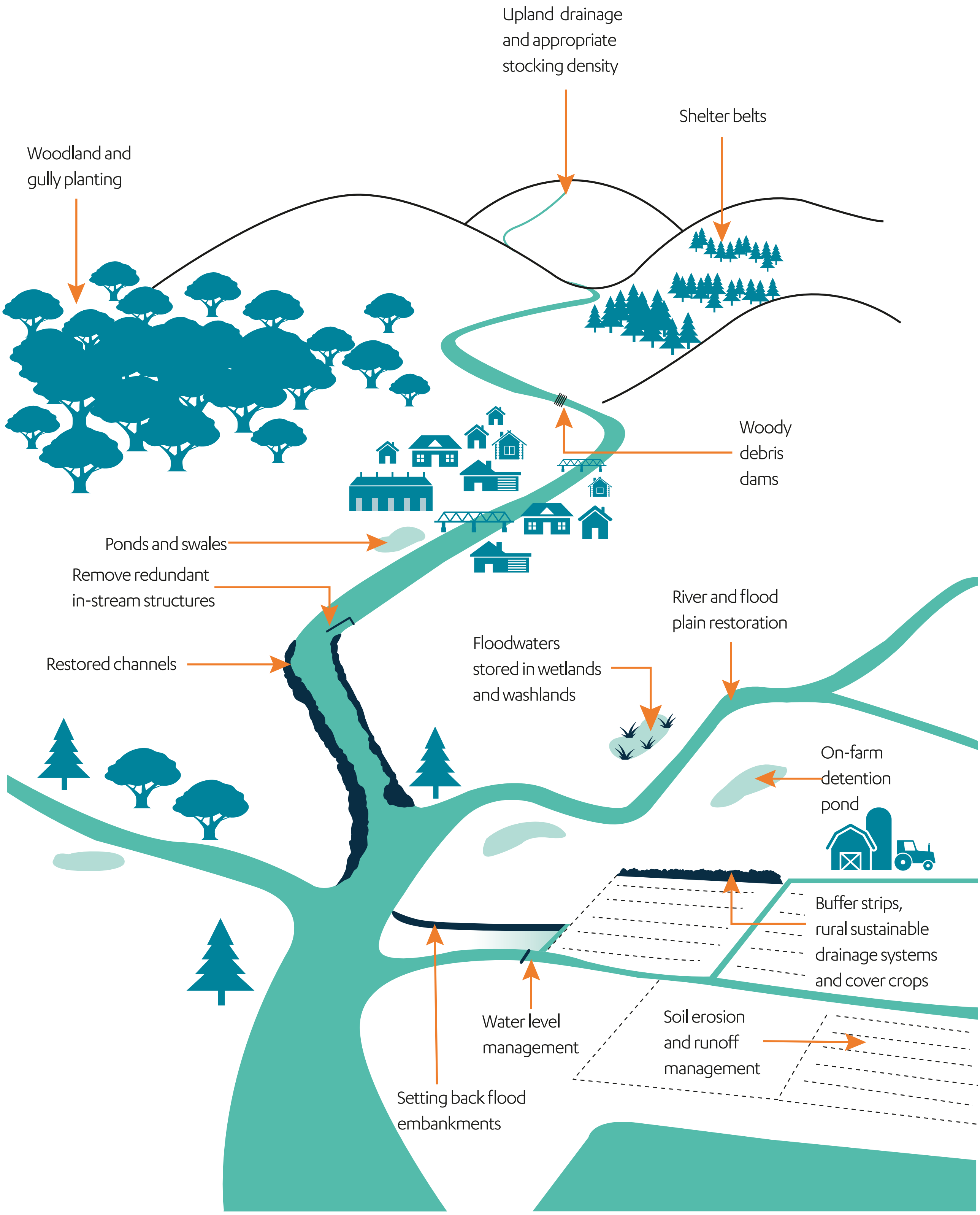
6.1 Flood and water management

Some of the best developed examples of green infrastructure are in flood and water management. A recent study for the Committee on Climate Change identified catchment management and urban runoff management through sustainable drainage systems as two of the most effective adaptation measures for reducing the risks of increased flooding from the effects of climate change.[92] These surface water management approaches also have a role in recharging groundwater and improving water quality.[93, 94]

There is increasing use of approaches to manage water across the whole catchment, rather than at the point at which flooding occurs or pollution becomes a problem, through modification of land use, land management and upstream river channels and floodplains.[95] Figure 15 illustrates flood risk interventions across the catchment. As well as mitigating flood risk, this approach can deliver wider benefits such as remediation of pollution, mitigation of soil erosion, habitat restoration and carbon storage.

Similar approaches can be adopted at the local scale for drainage. The traditional approach to urban drainage is to use underground pipes to channel water away from the site as quickly as possible. Sustainable Drainage Systems (SuDS) mimic natural hydrological processes to minimise the negative impacts of surface water runoff to downstream areas while also delivering additional benefits including water quality, amenity and biodiversity. This is achieved by managing surface water as close as possible to where it lands; collecting water for other uses, encouraging flow into aquifers or slowing and storing surface water on site.[97] SuDS reduce peak flows and volumes of runoff entering drainage and combined networks, reducing the chances that these systems back up and cause flooding.[98] They are effective up to their design standards (which in England requires systems to cope with a rainfall event with a 1% likelihood of occurrence – see Defra non-statutory guidance). There is a lack of systematic assessment of the costs and benefits of SuDS systems at a UK scale[99, 100] (largely due to an absence of post construction monitoring. Co-benefits from the systems are also often not accounted for)[101] however a number of examples point to the effectiveness of reducing peak flows at a local scale both in the UK[102] and elsewhere.[103] At catchment scale, a study for the United States Environmental Protection Agency found that the approach reduces the overall flood risk, in terms of average annual losses. In terms of specific events, the study found that losses are reduced during moderate rainfall events but less so for extreme rainfall events.[104] It should be noted that this study was based on models rather than on observed impacts.

Figure 15: Flood management interventions across a catchment[96]



Pollutants that run off agricultural land during rainfall events are a major contributor to upstream pollution of water sources.[105] Conventional water treatment methods are not effective for some new pollutants such as metaldehyde. Anglian Water estimated that the capital costs for establishing metaldehyde treatment across the Anglian region would be £600M with an additional £17M annual operational costs. In response, the water utility set up a catchment management programme to prevent metaldehyde runoff from farms that led to a 60% reduction in metaldehyde levels detected in reservoir tributaries.[106] A number of additional case studies have pointed to the potential of upstream land management in ameliorating pollutant loads downstream.[107, 108]

The use of SuDS in managing urban runoff has the potential to significantly reduce pollutant loads by capturing them in local sediments and vegetation rather than requiring treatment before discharge further downstream.[109] In the USA, where SuDS has been widely adopted, the primary driver behind the implementation of the approach has largely been the water quality benefits that they provide.

6.2 Air quality

There is potential to utilise the natural environment to mitigate some of the negative impacts of air pollution. Natural processes of plants and trees absorb atmospheric pollutants, removing them from the air. However, a large number of trees would be required in order to realise a significant improvement in air quality as a result; a study that modelled the effect of increasing tree cover in the West Midlands from 3.7%-16.5% estimated a reduction in PM10 concentrations by 10%.[110]

6.3 Heat

The 'urban heat island effect' refers to a phenomenon whereby urban areas are significantly warmer than neighbouring rural areas, particularly at night.[111] Increases in temperatures due to climate change may exacerbate this effect, though the exact impact is highly uncertain. A study that reviewed meta-analysis across a range of studies found that urban parks can reduce temperatures by approximately 1°C up to 1km beyond the park boundary.[112] There is also evidence that trees can have the reverse effect in cold conditions by providing shelter from wind.[113] Therefore, it is possible that both the cooling and warming effects of urban greenery could play a role in reducing the demand for cooling and heating respectively.

6.4 Noise

Green spaces have the potential to both buffer noise as well as reduce people's negative perception of noise.[114] A study in Belgium found that the addition of natural sounds, such as birds or the sound of water, reduced the perceived loudness of road traffic noise.[115]

7. CONCLUSION

The environment and climate change are major drivers of infrastructure demand as well as a constraint in the way infrastructure is delivered. This paper has explored the environment through the lens of natural capital and shown the relationships that exist with the delivery of infrastructure services through water (including floods and droughts), the atmosphere, heat and noise. It has shown that infrastructure can have both a positive impact (e.g. through connecting ecosystems) and a negative impact (e.g. through noise pollution) on the natural environment. It has also highlighted the changing climate and the increasing pressure this puts on natural assets and thus on the infrastructure that relies on the services they provide.

Table 4 provides a summary of the key points of interaction between the environment and infrastructure across the six sectors considered within the NIA.

Table 4: Relationship between key environmental parameters and NIA sectors

	Water & Wastewater	Flood Risk	Energy	Transport	Waste	Digital
Water quantity & quality	**		*		*	
Atmosphere			**	**	*	
Natural hazard protection	*	**	*	*		*
Noise			*	**		
Climate Change	**	**	**	**	*	*

Note: single asterisk denotes a relationship, double asterisk denotes a strong relationship.

Key themes have been developed that summarise these relationships:

7.1 Infrastructure can harness the environment to deliver multiple benefits

If properly planned infrastructure can have beneficial impacts – for instance, through the provision of protected natural habitats and the provision of connecting corridors for species along linear infrastructure delivering biodiversity benefits.

The use of sustainable drainage can both contribute to flood risk mitigation, capture and treat surface water runoff from roads and provide biodiversity and amenity benefits.

Green infrastructure can also mitigate the negative impacts of infrastructure use – the presence of trees in an urban context has been shown to both reduce pollutants in the air and mitigate the negative impacts of noise.

7.2 The environment can reduce the demand for infrastructure

Design of infrastructure to work in concert with environmental processes has the potential to contribute positively to the delivery of infrastructure services as well as building the resilience of the infrastructure system itself, particularly in managing flood risk and improving water quality. Natural catchment management could provide protection in rural areas by helping to hold back the flow of water within the catchment or by reconnecting rivers with their floodplain. In urban areas, the implementation of sustainable drainage systems adopts similar strategies to managing surface water.

7.3 Infrastructure can have a negative impact on the environment

Some infrastructure has a negative impact on the environment through air quality, water quality, and noise pollution. Although trends in many of these environmental parameters have shown improvement over past few decades, infrastructure continues to be the primary cause of several remaining problems:

- Water quality: effluent from wastewater treatment plants continues to be a major contributor of phosphate and nitrate pollution into UK water bodies
- Air quality: infrastructure is the primary source of total NO_X and SO_2 emissions and road transport is the primary driver of human exposure to PM_{10} and $PM_{2.5}$
- Noise: road transport is, overwhelmingly, the biggest driver of human exposure to noise
- Greenhouse gas emissions: through transport, energy generation and heating

If unmanaged, infrastructure also has the potential to lock-in high emissions that may put at risk the ability of the UK to meet its statutory obligations to reduce emissions by 80% by 2050.

7.4 Changes in the environment can increase the costs of infrastructure

When planning strategic infrastructure over the next 30 years it is important to consider potential changes in the environment and the impact these may have on the cost of infrastructure delivery, quality and reliability of service, and risks to the infrastructure. This could be through increasing the cost of operation and maintenance such as dealing with algal blooms in water supply reservoirs or ensuring capital assets such as roads or railways are able to withstand more extreme temperatures. Cost may also be incurred through an increase in the demand for an infrastructure services, such as flood management, due to increasing risk. The major drivers of some of the changes in environmental parameters may not be from infrastructure but influenced by other sectors, such as the contamination of water sources through agricultural runoff.

7.5 Implications for the Assessment

Within the timescale of the NIA there will be significant changes, with a large amount of uncertainty surrounding them. New and improved infrastructure is likely to be needed well before 2050 to cope with more severe flooding and droughts, as well as new hazards such as an increase in extreme temperatures. The modelling undertaken for the NIA will use the current UK Climate Projections to explore variability across and within the low, medium and high emissions scenarios directly where the modelling allows (particularly for water supplies and flood risk). The modelling will also take account of greenhouse gas emissions and include options enabling the legal requirement to reduce UK emissions by at least 80%

from 1990 to 2050 to be met, such as reducing demand for services, complete decarbonisation of the energy grid, and electrification of the car fleet. The evidence surrounding different scenarios will continue to be reviewed in order to ensure inputs into the modelling provide robust outputs, reflective of likely future outcomes.

Alongside the modelling process, analysis will be undertaken to understand how policy options are likely to impact the natural environment and, conversely, how policy options that encourage infrastructure that works in concert with natural processes can contribute to the delivery of infrastructure services.

These drivers should not be thought of in isolation: the impact of changes in the environment and climate will need to be considered in context alongside other drivers of infrastructure demand and supply, notably technological, economic, and population and demographic change.

The Commission would welcome comments on this discussion paper. In particular, references to further sources of evidence on these issues would be helpful. Please send any comments to **NICdiscussionpapers@nic.gsi.gov.uk** by 28 July 2017.

Further information on the overall scope and methodology of the National Infrastructure Assessment is available here.

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