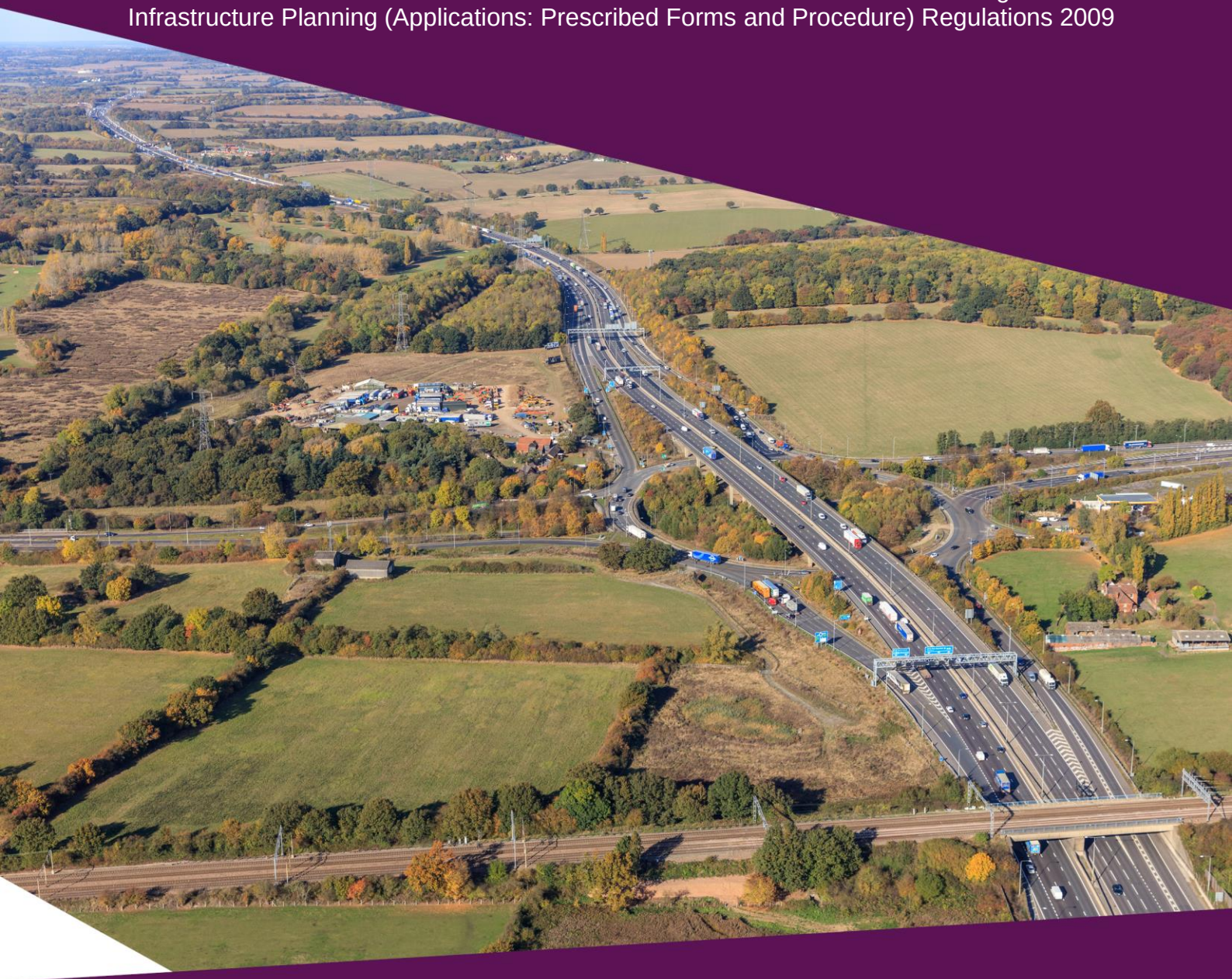
M25 junction 28 improvement scheme
TR010029
6.1 Environmental Statement
Chapter 14: Climate

APFP Regulation 5(2)(a)
Planning Act 2008
Infrastructure Planning (Applications: Prescribed Forms and Procedure) Regulations 2009



Volume 6
May 2020

Infrastructure Planning

Planning Act 2008

The Infrastructure Planning (Applications: Prescribed Forms and Procedure) Regulations 2009

The M25 junction 28 scheme
Development Consent Order 202[x]

6.1 ENVIRONMENTAL STATEMENT
CHAPTER 14: CLIMATE

Regulation Number:	Regulation 5(2)(a)
Planning Inspectorate Scheme Reference:	TR010029
Application Document Reference:	TR010029/APP/6.1
Author:	M25 junction 28 improvement scheme project team, Highways England

Version	Date	Status of Version
1	May 2020	Application issue

Table of contents

Tables

Executive summary

The Climate chapter is presented in two separate sub-chapters:

- Effects of the Scheme on climate (section 14.1)
- Vulnerability of the Scheme to climate change (section 14.2)

Effects of the Scheme on climate

The Scheme has the potential to affect the earth's climate by increasing the emission of greenhouse gases (GHGs) into the atmosphere, which will occur during construction and throughout its operational life.

The Scheme is likely to contribute 37,312 tCO2e to the UK's third carbon budget (2018 – 2022), representing 0.0015% of the budget. Whilst emissions from the Scheme will lead to a long-term negative effect on the atmosphere, the magnitude of emissions is considered to be minor. The Scheme is unlikely to cause significant effects on climate, or significantly affect the UK's ability to meet its emissions reduction targets. Despite this, further mitigation measures will be put in place in the construction phase to reduce emissions as far as possible.

Vulnerability of the Scheme to climate change

The Scheme has the potential to be affected by climate change.

The Climate Vulnerability section (section 15.2) includes an assessment of the vulnerability of the Scheme to climate change, providing:

- An examination of the current climate baseline using the Met Offices latest regional dataset of 30-year averages.
- A consideration of the projected future climate baseline for the period 2071-89.
- An assessment of how the Scheme may be vulnerable to the impacts of climate change during its construction and operation.
- Identification of specific mitigation to adapt the design and operational processes to reduce the Scheme's potential adverse climate vulnerabilities.
- An assessment of the residual climate change vulnerability of the Scheme that, in accordance with Highways England guidance, considers the likelihood and consequence of each potential vulnerability.

14. Climate

14.1 Effects of the Scheme on climate

14.1.1 Introduction

14.1.1.1 This sub-chapter details an assessment of the Scheme's effects on climate during construction and operation.

14.1.1.2 The Scheme has the potential to affect the earth's climate by increasing the emission of greenhouse gases (GHGs) into the atmosphere, which will occur during construction and throughout its operational life. The earth absorbs energy from the sun and re-emits it as thermal infrared radiation. GHGs in the atmosphere absorb this radiation, preventing it from escaping into space. The higher the concentration of GHGs, the more heat energy is retained, and the higher global temperatures become. Due to human activities the concentration of GHGs in the atmosphere has increased dramatically, leading to global warming. This leads to myriad indirect impacts as the climate responds to the increased atmospheric temperature.

14.1.1.3 This sub-chapter addresses regulation 5(2)(c) and paragraph 5(f) of Schedule 4 of The Infrastructure Planning (Environmental Impact Assessment) Regulations 2017 (SI 2017/572) (herein referred to as the 'EIA Regulations 2017'), which state that the assessment should consider the potential effects of the Scheme on climate, in particular the magnitude of GHGs emitted during both construction and operation.

14.1.2 Competent expert evidence

14.1.2.1 The assessment in this sub-chapter has been undertaken by a qualified Environmental Consultant (BSc Geography, specialising in climate science) with over five years' postgraduate experience in environmental and sustainability consultancy, including carrying out detailed carbon footprint calculations for major infrastructure projects.

14.1.3 Legislative and policy framework

14.1.3.1 The legislation, regulatory and policy relevant to the effects on climate assessment is provided in Table 14.1 below.

Table 14.1: Legislation, regulatory and policy framework for effects on climate

Scale	Legislation/regulation	Summary of requirements
National	Infrastructure Planning (Environmental Impact Assessment) Regulations 2017[1]	The Regulations require: "A description of the likely significant effects of the project on climate (for example the nature and magnitude of GHG emissions)."

[1] http://www.legislation.gov.uk/uksi/2017/572/contents/made

Scale	Legislation/regulation	Summary of requirements
	National Planning Policy Framework (NPPF) 2019[2]	The NPPF includes the mitigation of climate change as part of its overarching objectives for achieving sustainable development. It provides that the planning system should support the transition to a low carbon future, shaping places in ways that contribute to radical reductions in GHG emissions. This includes supporting low carbon infrastructure.
	National Policy Statement for National Networks (NPS NN)[3]	With relevance to this Chapter, the NPS NN (2014) highlights that the impact of road improvements on aggregate emission levels is likely to be small. However, it requires that applicants should both provide evidence of the carbon impacts of a proposed scheme and undertake an assessment of the proposed Scheme against the Government's carbon budgets. This is implemented through the methodology presented below.
	Road Investment Strategy (RIS) and Strategic Business Plan 2015[4]	The Government's RIS will see £15.2 billion invested in over 100 road schemes between 2015 and 2021 (Department for Transport, 2014b). Of this total, some £300 million has been allocated to address issues including flooding, carbon emissions, landscape and biodiversity.
	Road Investment Strategy (RIS): for the 2015/16 – 2019/20 Road Period	The Road Investment Strategy (2015), as amended in 2016, published by the Department for Transport (DfT), sets out the strategy for the transformation of the strategic road network (SRN) by 2040 to create a modern SRN that supports a modern Britain. The Strategy also specifies objectives to significantly reduce emissions across the SRN, including emissions reductions from SRN construction activities.
	Road Investment Strategy (RIS2): for the 2020 – 2025 Road Period[5]	RIS2 includes a vision to contribute to the Government's wider climate change strategy. It notes that the Government has adopted one of the most ambitious plans in the world to decarbonise road transport, committing to end the sale of new conventional petrol and diesel cars and vans by 2040, and taking steps to decarbonise freight. Provision is also being made to encourage alternative forms of transport, such as cycling and bus use. Through RIS 2, the SRN will be modernised to support the Government's ambitions.
	Highways England: Strategies and Frameworks[6]	Highways England has a range of strategies, frameworks and tools in place for carbon reduction, including carbon objectives in their Sustainable Development Strategy (2017), and the Highways Agency Carbon Routemap (2014). Such strategies, frameworks and tools provide emission (i.e. carbon) projections and are intended to enable options to be considered.

[2] https://www.gov.uk/government/publications/national-planning-policy-framework--2
[3] https://www.gov.uk/government/publications/national-policy-statement-for-national-networks
[4] https://www.gov.uk/government/collections/road-investment-strategy
[5] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/872252/road-investment-strategy-2-2020-2025.pdf
[6] https://www.gov.uk/government/publications/highways-england-sustainable-development-strategy

Scale	Legislation/regulation	Summary of requirements
		The Scheme should support the implementation of the strategies, frameworks and tools by delivering mitigation measures of relevance to the Scheme.
	Highways Agency Carbon Routemap: opportunities for a national low carbon transportation system (2014)[7]	The Highways Agency Routemap covers the direct and indirect emissions associated with the Agency's organisational activity, the highway asset base and associated supply chain, and those arising from the use of the network by customers. It presents potential emissions scenarios based on different levels of take-up of low carbon technologies and practices by the Highways Agency, and highlights opportunities available for creating a low-carbon transport scheme.
	Climate Change Act 2008, as amended[8]	The Climate Change Act (2008) established legally binding carbon reduction targets through the Climate Change Act (2008) to drive the reduction requirements required by the Kyoto Protocol, as set out in Table 14.2. The overall objective was to reduce emissions by at least 80% of the 1990 base level year by 2050. In 2019, an amendment was passed which increased the target to at least a 100% reduction against the 1990 baseline by 2050.
	The Carbon Plan (Department of Energy and Climate Change (DECC), 2011[9]	The Carbon Plan (2011) sets out how the UK will achieve the emissions reduction commitment of 80% by 2050, made in the Climate Change Act (2008). It sets out how the UK will make the transition to a low carbon economy, maintain energy security and minimise costs to consumers. The Plan does not relate directly to road improvement schemes, but the Scheme should support implementation of the plan by prioritising low carbon materials and construction and operational energy efficiency, where practicable.
	Construction 2025 (July 2013) HM Government[10]	Construction 2025 (2013) sets out how efficiency improvements will be created in construction covering sustainability and carbon and including a target to reduce emissions by 50%. The emissions reduction target of 50% is not scheme specific, and the efficiency improvements are broad. In terms of the Scheme and emissions reduction, the reduction target should be taken into account when developing Scheme specific mitigation measures, where relevant.
	Infrastructure Carbon Review (2013) HM Treasury[11]	The Infrastructure Carbon Review sets out carbon reduction action required by infrastructure organisations that have formally endorsed the review; this includes Highways England. The Review shows that the infrastructure industry controls 16% of the UK's total carbon emissions, covering construction (A1-5), and operation and maintenance of assets (B1-8). It also highlights that a further 37% of carbon emissions are related to the use of infrastructure

[7] https://s3.eu-west-2.amazonaws.com/assets.highwaysengland.co.uk/specialist-information/knowledge-compendium/2013-2014-knowledge-programme/HACR_Opportunities%20for%20a%20national%20low%20carbon%20transport%20system.pdf
[8] http://www.legislation.gov.uk/ukpga/2008/27/contents
[9] https://www.gov.uk/government/publications/the-carbon-plan-reducing-greenhouse-gas-emissions--2
[10] https://www.gov.uk/government/publications/construction-2025-strategy
[11] https://www.gov.uk/government/publications/infrastructure-carbon-review

Scale	Legislation/regulation	Summary of requirements
		assets (B9), over which the industry can have some influence.
	Net Zero – The UK's contribution to stopping global warming (2019) Committee on Climate Change[12]	The Net Zero report sets out recommendations by the Committee on Climate Change (CCC) for setting a national net zero carbon by 2050 target, aligned to the UK's commitment to the 2015 Paris Agreement. The transport sector is highlighted as one of the major challenges and opportunities to reach a net zero target, as emissions from transport have increased by 6% since 2013 and are now 4% higher than in 1990.
Regional	The London Plan (2016)[13]	Paragraph 1.48 outlines the Plan's vison to address climate change, in terms of both adaptation and mitigation. Adaptation includes designing infrastructure with a changing climate in mind and protecting, enhancing and expanding the city's stock of green space to help cool parts of the city. Mitigation includes reducing our emissions of GHGs to minimise future warming and its impacts. Paragraph 6.49 concerns the need to safeguard existing and identify new facilities to distribute goods and service its people. Any development will be encouraged which eases congestion on the highway network and in turn contributes to combating climate change.
	The Mayor's Transport Strategy (2010)[14]	The Mayor, through Transport for London (TfL), will prepare adaptation strategies to improve safety and network resilience to threats posed by climate change, and ensure that new transport infrastructure is appropriately resilient. This will include 'guidelines for major procurement contracts (including design, construction and maintenance) to demonstrate a climate risk assessment for the lifetime of the investment'.
	Essex Local Transport Plan (LTP) (2011)[15]	The Essex LTP states that transport is one of the most significant contributors of the UK's CO_2 emissions. Therefore, the Council has a vital role to play in helping to deliver a reduction and in supporting the transition towards a low carbon future. This will be actioned through 'minimising emissions from our own operations' and by 'working with partners to deliver new development which enables and encourages low carbon travel choices'.
Local	London Borough of Havering Core Strategy (2008)[16]	Policy CP15 outlines the need for development to 'adapt to and mitigate the effects of climate change'. In order for this to take effect, new development should: • minimise use of natural resources • adopt high standards of sustainable construction and design and to incorporate on-site renewable energy equipment to reduce predicted CO2

[12] https://www.theccc.org.uk/publication/net-zero-the-uks-contribution-to-stopping-global-warming/
[13] https://www.london.gov.uk/what-we-do/planning/london-plan/current-london-plan
[14] https://www.london.gov.uk/what-we-do/transport/transport-publications/mayors-transport-strategy
[15] https://www.essexhighways.org/Highway-Schemes-and-Developments/Local-Transport-Plan.aspx
[16] https://www.havering.gov.uk/downloads/file/1632/core_strategy_development_control

Scale	Legislation/regulation	Summary of requirements
		emissions in line with regional and national policy.

Table 14.2: UK carbon reduction targets

Carbon budget period	Carbon budget level
3rd carbon budget (2018 to 2022)	2,544 $MtCO_2e$
4th carbon budget (2023 to 2027)	1,950 $MtCO_2e$
5th carbon budget (2028 to 2032)	1,725 $MtCO_2e$

Table Source: UK Government Carbon Reduction Targets 2008 (Committee on Climate Change, 2017)

14.1.4 Study area

14.1.4.1 The study area has been defined according to Highways England guidance, and covers the emission of GHGs ('emissions') resulting from the Scheme in its construction and operation phases, as well as opportunities for emissions reduction. The study area is not limited to the geographic extent of the Scheme itself, as many emissions will result from upstream and off-site activities such as materials production.

14.1.4.2 The activities for which emissions have been quantified in the assessment include the direct and supply chain activities for the Do Something scenario of the Scheme's life cycle, for both the construction and operation stages of the Scheme. The specific elements of the Scheme lifecycle, referred to as 'modules', included in the assessment boundary are listed in Table 14.3 and Table 14.4. The 'assessment boundary' defines the source of emissions considered, including direct or supply chain emissions.

14.1.4.3 The emissions boundaries are in line with the boundaries set out in the Publicly Available Standard (PAS) 2080:2016 'Carbon Management in Infrastructure[17]', which is the technical standard for measuring and managing emissions from infrastructure.

14.1.4.4 The timescale of the assessment covers:

1. Construction, as a single time period
2. Total annual operation for the Opening Year (2022)
3. Total annual operation for the Design Year (2037)

[17]PAS 2080:2016 *Carbon Management in Infrastructure*.

Table 14.3: Construction phase assessment boundary

Life cycle module		Assessment boundary
Materials		Emissions from the production of construction materials, including primary raw material extraction, manufacturing and intra-manufacturing transportation.
Transport		Direct vehicle emissions from the transportation of construction materials from the primary site of manufacturing to site.
Construction Processes	Construction plant use	Direct and well-to-tank emissions from the operation of construction plant on-site.
	Other construction energy use	On-/off-site construction worker facilities (temporary offices, etc) emissions (from lighting, heating, etc).
	Construction water use	Emissions from all activities for the treatment and supply of water to site.
	Construction waste transportation	Direct vehicle emissions from the transportation of bulk construction waste from the construction site to the primary processing site, as per the waste assessment.
	Construction waste off-site processing	Emissions from the processing of bulk construction waste, as per the waste assessment.
	Employee commuting	Direct vehicle emissions from the transportation of workers to the site for the duration of the construction works.

Table 14.4: Operational phase assessment boundary

Life cycle module	Assessment boundary
Road user carbon	Direct emissions from vehicles using the Scheme, as outlined in DMRB, Volume 11, Section 3, Part 1 Air Quality: HA 207/07.
Maintenance / Refurbishment	Emissions from the ongoing maintenance, repair, replacement and refurbishment activities. This potentially includes the same modules/activities as in the construction phase.
Operational energy use	Emissions from the generation and supply of electricity to operate lighting and technology on the Scheme.

14.1.4.5 The life cycle modules listed in Table 14.5 have been excluded from the assessment on the basis that the associated emissions are either negligible, or the module is not applicable to the Scheme.

Table 14.5: Exclusion from the assessment boundary

Life cycle module	Reason for exclusion
Preliminary studies and consultations	This module includes a very wide range of office activities and travel from a wide range of locations. Emissions for this life cycle stage are minimal in comparison to both construction and in-use emissions and it is therefore excluded from the assessment.
Direct operational emissions	This only covers emissions from the infrastructure itself whilst in use. It does not include emissions from traffic, nor does it include energy use, both which are accounted for elsewhere. Direct

Life cycle module	Reason for exclusion
	emissions from the infrastructure itself will be negligible and are therefore excluded from this assessment.
Operational water use	There is no specific water use for the operation of the Scheme, and it is therefore excluded from the assessment.
Other operational processes	There are no operational processes relevant to the Scheme emissions other than the use of the Scheme by traffic and infrastructure energy. This module is therefore excluded from the assessment.
End of life stages	There are no plans to decommission the Scheme, so no end of life activities will take place. This module is therefore excluded from the assessment.
Offsetting	Carbon offsetting – including vegetation for sequestration, solar PV for electricity export, or financial support of low-carbon projects – is specifically excluded from the study. Any carbon savings achieved through offsetting should be reported separately.

14.1.5 Assessment methodology

14.1.5.1 There is currently no guidance in the Design Manual for Roads and Bridges (DMRB) for what type or level of assessment is required regarding the effects of a scheme on climate. For this assessment, a proportionate approach has been adopted which focuses on capturing the principal contributing factors to the effects on climate, quantifying the magnitude of emissions and assessing the significance of these. The approach is in line with PAS 2080:2016.

14.1.5.2 It is key to note that whilst effects on climate is a wide-ranging topic in terms of potential sources, it is simple in terms of its receptors and impacts because:

- There is only one receptor, the atmosphere
- There is only one direct impact, global warming
- All units of carbon dioxide equivalent (CO_2e) can be considered to have the same impact no matter where they are emitted

14.1.5.3 Therefore, assessment of the effects of the Scheme on climate is limited to quantification of the magnitude of emissions, from individual sources and in total, and comparison of these to the baseline. Different GHGs have different global warming potentials, and to account for this they will be reported throughout this assessment as their CO_2e value. The goal of the assessment is to calculate the emissions anticipated to be generated by the Scheme to:

- Determine the magnitude of the Scheme's effect on climate, in comparison with the 'Do Minimum' scenario
- Assess the significance of the effect on climate by considering it in context with UK carbon reduction targets
- Enable identification of emissions hot spots within the Do Something scenario to inform identification of appropriate mitigation measures

14.1.5.4 Emissions calculations are carried out by multiplying activity data by an emission factor associated with the activity being measured. Activity data is a quantitative measure of an activity that results in emissions during a given

period of time, (e.g. kilometres driven, kWh electricity consumed, tonnes waste sent to landfill). An emission factor is a measure of the mass of emissions relative to a unit of activity.

14.1.5.5 Scheme emissions have been quantified by calculation, using project data from the emerging design and relevant carbon conversion factors.

Quantifying construction emissions

14.1.5.6 For the construction stage of the Scheme, calculations have been undertaken by using Highways England's Carbon Tool, which will allow comparison of the results to other highway scheme assessments using the same tool. The Carbon Tool is spreadsheet-based, and provides space to input material and non-material construction information under the following categories:

- Bulk materials
- Earthworks
- Fencing, barriers and road restraint systems
- Drainage
- Road pavements
- Street furniture
- Civil structures and retaining walls
- Fuel, electricity and water use
- Business and employee transport
- Waste

14.1.5.7 The Carbon Tool then uses a range of pre-programmed materials data (e.g. mass) and carbon factors to calculate an itemised and overall emissions total.

14.1.5.8 The design information for the assessment was obtained from the design team and contractor. Further detail of data sources, collection methodology, assumptions and calculation input data are described in section 14.1.6.

Quantifying operational emissions

14.1.5.9 Operational emissions are calculated separately from the Carbon Tool, which is focused specifically on construction-phase emissions. Road user carbon emissions have been modelled in accordance with DMRB, Volume 11, Section 3, Part 1 Air Quality: HA 207/07. This uses emission factors provided by the Department for Environment, Food and Rural Affairs in the Emissions Factors Toolkit v8, which makes assumptions about the makeup of future fleets based on DfT projections. This allows for predicted uptake of electric and hybrid vehicles as well as conventional vehicles (petrol and diesel).

14.1.5.10 There is no project-specific data available for operational energy use, or maintenance and refurbishment during the Scheme's operational life, so emissions cannot be calculated using the above methodology. Instead they have been estimated using published data from other highways schemes, based on the assumption that emissions from the operation and maintenance of similar highways is broadly consistent across the UK road network. Published

data from other highway schemes[18] shows that, proportionally, emissions from operational energy use and maintenance works equate to between 0.05 and 0.29% of in-use traffic emissions. 0.29% of road user emissions has been applied as a reasonable worst-case operation and maintenance figure, based on this limited data set.

Comparison to UK carbon budgets

14.1.5.11 The UK has in place, carbon budgets for five-year periods up to 2032.

14.1.5.12 Both the construction and Opening Year of the Scheme fall within the third budget period (2018 to 2022). The results of emissions calculations will therefore be presented in terms of their percentage contribution to the third carbon budget period.

14.1.5.13 The Design Year (2037) falls beyond the fifth budget period, and there is as yet no budget with which to compare emissions.

Significance assessment

14.1.5.14 There is no accepted technical guidance for determining a level of significance (i.e. major or minor) of the effect of a development on climate, and there are no legal limits for emissions from any one development. For this reason, professional judgement has been applied in determining significance, considering the Scheme's potential effects on the UK's ability to meet the emission reduction targets set out in its carbon budgets.

14.1.5.15 The National Policy Statement for National Networks (NPS NN) acknowledges that the emissions from the construction and operation of a road scheme are likely to be negligible compared to total UK emissions, and are unlikely to materially affect the UK Government's ability to meet its carbon reduction targets. The NPS NN specifically states that *'it is very unlikely that the effect of a road project will, in isolation, affect the ability of Government to meet its carbon reduction plan targets'*[19]. Based on this, it is considered unlikely that the Scheme's emissions will be of a quantity great enough to cause a significant effect on climate.

14.1.5.16 However, due to the global scale, long-term duration and cumulative and irreversible nature of the effect, the effects on climate of the Scheme are still considered important. Highways England is committed to reducing emissions where practicable, and therefore emissions have been quantified and presented as part of the Environmental Statement (ES).

14.1.6 Assumptions and limitations

14.1.6.1 The data for the assessment has been collected directly from the design team and is up-to-date at the time of writing following Highway England guidance outlined in 14.1.4.1. Where assumptions have been made, they have been selected to present the worst-case scenario for that particular item/factor.

14.1.6.2 This section presents the input data and assumptions which underpin the assessment.

[18] Welsh Government (2016). M4 Corridor around Newport, Environmental Statement: Volume 3, Appendix 2.4 Carbon Report
[19] https://www.gov.uk/government/publications/national-policy-statement-for-national-networks

Materials

14.1.6.3 Temporary and permanent construction materials data has been provided by the design team based on the current Scheme design. Where the design is not finalised, assumptions were made by engineering specialists based on professional judgement. The materials and quantities listed in Table 14.6 were included in the assessment; this is the complete list of materials provided by the design team. The carbon factors for materials integral to the Highways England Carbon Tool were used.

Table 14.6: Construction materials

Category	Item	Type	Unit	Quantity
Bulk materials	Ready mix concrete	C8/10	m^3	3,440
		C32/40	m^3	492
	Fill and aggregate	General fill/aggregate	tonnes	125,468
	Asphalt	General asphalt	tonnes	6,426
Fencing, barriers & road restraint systems	Road restraint system/ safety barrier	Steel RRS barrier single sided	metres	3,406
		Steel RRS barrier double sided	metres	42
		Pre-cast concrete step barrier	metres	96
Drainage	Plastic pipework (Polypropylene)	150 mm diameter	metres	24
		225 mm diameter	metres	517
		300 mm diameter	metres	1082
		375 mm diameter	metres	470
		450 mm diameter	metres	151
		500 mm diameter	metres	57
		525 mm diameter	metres	246
		600 mm diameter	metres	150
		675 mm diameter	metres	13
		750 mm diameter	metres	169
		900 mm diameter	metres	279
		1200 mm diameter	metres	294
	Plastic pipework (HDPE)	225 mm diameter	metres	236
		300 mm diameter	metres	250
		375 mm diameter	metres	108

Category	Item	Type	Unit	Quantity
	Precast concrete circular pipework	1200 mm diameter	metres	402
	Precast concrete manholes	2400 mm diameter, 3 m – 6m depth	no.	87
	Gullies	Plastic gully pots - PVC	no.	196
	Channel & slot drains	Precast concrete channel (heavy duty)	metres	488
Street furniture & electrical equipment	Road lighting and columns	LED light	no.	95
		Steel columns 8 m	no.	4
		Steel columns 10 m	no.	53
		Steel columns 12 m	no.	25
		Aluminium columns 12 m	no.	5
	Cable	Armoured cable / power cable	metres	13,200
		Miscellaneous cable	metres	1,034
	Plastic cable ducting	50 mm diameter	metres	166
		100 mm diameter	metres	9,350
	Cabinets	Any type	no.	5
Civils structures & retaining walls	Formwork / shuttering	Plywood	m^3	3,840
	Piling	Pre-cast concrete piles	tonnes	17,548
	Retaining walls	Steel sheet piles	tonnes	320
		Gabion wall (stone and wire mesh)	tonnes	1,346
	Gantries	14 m ADS tubular cantilever	no.	1
		33 m to 45 m Portal	no.	1
		57 m plus portal	no.	1
	Steelwork	General steel	tonnes	165
	Pre-cast concrete	High strength concrete	tonnes	11,779

Transport

14.1.6.4 Information relating to where materials will be sourced from is not yet available, as this will be determined at a later date by the contractor. Based on previous experience by specialists of materials transportation for infrastructure schemes, including highway schemes, it has been assumed that all materials have been transported an approximate worst-case distance of 200 km by HGV. Locally sourced materials are often preferentially used to reduce transportation cost and to minimise transport emissions, and many materials will be sourced from a distance of less than 200 km. However, not all required material is expected to be available locally and will have to be sourced from further afield. The emission factor used for transportation is based on a heavy goods vehicle having an assumed average load.

Construction processes

14.1.6.5 The construction period has been approximated at 27 months (spring 2022 to autumn 2024), based on the information provided by the buildability contractor (further details are provided in Chapter 2 of the ES).

14.1.6.6 Quantities of diesel used by construction plant have been estimated at 1,258 m^3 by the contractor. Water use was estimated by the contractor to be 50,000 m^3 for the Scheme. In a similar way, the electricity use for the construction phase has been estimated to be 21,333,333 kWh. The carbon factors for diesel, UK grid electricity and mains water integral to the Highways England Carbon Tool were used.

14.1.6.7 Waste is assumed to be transported 50 km, as specific details are not available at this stage of the project. As above, 50 km is based on previous experience by specialists. It is considered likely that waste will be dealt with within 50 km to adhere to the proximity principle. The waste transport has been assumed to be an HGV having an assumed average load. The disposal method 'recycled' has been selected as the most likely outcome. Table 14.7 below presents the data used to calculate emissions from waste transport and processing.

Table 14.7: Construction waste

Waste	Disposal method	Quantity (tonnes)
Aggregate and soil exported offsite	Recycled	147,262

14.1.6.8 Employee commuting has been based on data provided for another highway scheme, similar in terms of size and type of construction work. This assumes 150 people working at any one time, with 60% of the workforce travelling 40 km each way, 5 days per week, and 40% travelling 100 km each way, once per week. The carbon factors for car travel integral to the Highways England Carbon Tool were used.

14.1.7 Baseline conditions

14.1.7.1 Baseline conditions are defined by the:

- Total background emissions from all sources, i.e. all UK emissions, at all scales.
- Predicted total emissions occurring for both the Opening Year (2022), and the Design Year (2037), assuming the Scheme is not constructed, i.e. the Do Minimum scenarios.

National emissions baseline

14.1.7.2 Global GHG emissions, from all sources, currently amount to approximately 50 billion tonnes of CO_2e[20] per year. However, it is not considered representative to compare any UK scheme against this, as any scheme will always be negligible. Instead, it is considered most appropriate to use the national baseline for comparison as its magnitude is more relevant and UK specific. The UK is the world's eighth largest emitter of CO_2e, with the total background UK emissions for 2016 (the last reported year) being 467.9 million tonnes of CO_2e[21].

14.1.7.3 The UK has in place carbon budgets for five-year periods up to 2032. Both the construction and Opening Year of the Scheme fall within the third budget period (2018 to 2022), the budget level of which is 2,544 $MtCO_2e$.

14.1.7.4 The dataset for the fifth UK carbon budget central scenario[22] includes forecasts of emissions for different sectors, representing the best estimate of the least cost path to the UK's 2050 target of reducing emissions by 80% of 1990 levels. In this dataset, total domestic transport emissions (excluding domestic aviation and shipping) for the third budget period are 480 $MtCO_2e$.

Scheme emission baseline

14.1.7.5 Scheme-specific baseline emissions equate to emissions in the opening and design years assuming the Scheme was not constructed (the Do Minimum scenario). There are no construction emissions associated with the Do Minimum scenario; only the 'operation' life cycle modules presented in are included in the baseline, shown below for the opening and design years.

Table 14.8: Scheme Do Minimum emissions

Life cycle module	2022 Emissions (tCO_2e)	2037 Emissions (tCO_2e)
Road user carbon	834,010	1,020,747
Operation and maintenance	2,419	2,960
Total operation	836,429	1,023,707

[20] http://themasites.pbl.nl/publications/pbl-2017-summary-trends-in-global-co2-and-total-greenhouse-gas-emissions-2983.pdf
[21] www.UK.gov 2017 Final UK greenhouse gas emissions national statistics
[22] https://www.theccc.org.uk/publication/fifth-carbon-budget-dataset/

14.1.8 Potential impacts

14.1.8.1 The construction stage of the Scheme would have an overall adverse effect on climate, as it would give rise to emissions. These emissions would arise from the production of materials to be used in construction, their transportation to site, and onsite through construction activities (for example from emissions from diesel-fuelled construction plant).

14.1.8.2 The operational stage of the Scheme would give rise to emissions from road users and operational energy use (for example street lights). However, whilst the operation of the Scheme would certainly cause emissions and therefore have a negative effect on climate, the Scheme may cause a reduction in emissions compared with the Do Minimum scenario due to changes in traffic flow, which would result in the Scheme presenting an improvement in effects on climate. The results of the assessment are presented in Section 14.11.

14.1.9 Design, mitigation and enhancement measures

14.1.9.1 Emissions have been and will be mitigated by applying Highways England's carbon reduction hierarchy:

- Avoid / prevent:
  - Maximise potential for re-using and / or refurbishing existing assets to reduce the extent of new construction required.
  - Explore alternative lower carbon options to deliver the project objectives (i.e. shorter route options with smaller construction footprints).
- Reduce:
  - Apply low carbon solutions (including technologies, materials and products) to minimise resource consumption during the construction, operation, user's use of the project, and at end-of-life.
  - Construct efficiently, using techniques (e.g. during construction and operation) that reduce resource consumption over the life cycle of the project.
- Remediate:
  - After addressing steps 1 and 2 projects will identify, assess and integrate measures to further reduce carbon through on or off-site offsetting or sequestration.

14.1.9.2 Specific potential mitigation measures relevant to the construction and operational stages of the Scheme are suggested below. The defined measures are consistent with PAS 2080:2016, the carbon management technical standard relevant to all infrastructure projects.

Construction

14.1.9.3 Mitigation measures that will be used to reduce emissions in the construction life cycle modules are shown in Table 14.9.

Table 14.9: Construction emissions mitigation measures

Life cycle module		Mitigation measures
Materials		Reduction of materials consumption will be carried out in accordance with the mitigation measures outlined in the Materials and Waste chapter (Chapter 12, section 12.9). In addition, consideration will be given to alternative low carbon materials e.g. recycled aggregates, cement substitution etc.
Transport		Materials transportation will be reduced and/or avoided by minimising the quantity of materials required. Additionally, where possible detailed design and procurement measures will be specified to minimise the necessity to source materials from long distances.
Construction processes	Construction plant use	Construction plant emissions will be minimised by designing for efficient construction processes as part of design development. During construction plant emissions should be managed via the Construction Environmental Management Plan (CEMP), which should specify plant operator efficiency requirements.
	Construction water use	Construction water consumption will be minimised by designing for efficient construction processes as part of design development. During construction mains water consumption will be managed via the CEMP, which should specify reduction and re-use measures.
	Construction waste transportation	Reduction of waste generation should be carried out in accordance with the mitigation measures outlined in the Materials and Waste chapter (Chapter 12, section 12.9).
	Construction waste off-site processing	Suitable/ appropriate waste treatment/ disposal should be carried out in accordance with the mitigation measures outlined in the Materials and Waste chapter (Chapter 12, section 12.9).
	Employee commuting	Local contractors will be used where possible, reducing the distance driven by employees.

Operation

14.1.9.4 Operational emissions can be mitigated by designing a Scheme which minimises emissions from traffic and operational energy use. Mitigation measures that will be employed to reduce in-use emissions are shown in Table 14.10.

Table 14.10: Operation emissions mitigation measures

Life cycle module	Mitigation measures
Road user carbon	Mitigation of in-use emissions will be explored based on examination of traffic management scenarios over the network.
Maintenance and repair	The mitigation measures detailed in Table 14.9. Table 14.9for the construction stage are also applicable to ongoing maintenance and repair.

Life cycle module	Mitigation measures
Operational energy use	Operational energy use will be minimised by designing for use of low energy lighting and traffic management systems, specification of controls that minimise on-time, and use of low carbon energy sources, where practicable.

14.1.10 Assessment of effects

14.1.10.1 This assessment presents the emissions calculated for the Do Something scenario, a comparison against the Do Minimum baseline, and assessment against UK Government carbon budgets.

Do Something scenario emissions

Construction

14.1.10.2 Construction phase emissions are broken down in Table 14.11. The Carbon Tool used to calculate the emissions is provided in Appendix 14.1 (application document TR010029/APP/6.3). The construction of the Scheme will lead to the release of an additional 48,693 tCO_2e compared with the Do Minimum scenario.

14.1.10.3 The largest magnitude of emissions (43%) is likely to arise from construction processes, with fuel use in construction plant a key source of emissions. Emissions from the production of materials equates to 31% of emissions, with a further 21% from the transport of emissions to site.

Operation

14.1.10.4 Operational phase emissions for the opening and design years are shown in Table 14.11.

Table 14.11: Construction stage emissions[23]

Category	Item	Materials		Transport	
		Emissions (tCO_2e)	Percentage of construction total	Emissions (tCO_2e)	Percentage of construction total
Bulk materials	Ready mix concrete	833	2.25	413	1.12
	Asphalt	488	1.32	281	0.76
	Fill and aggregate	652	1.77	5,493	14.86
Civil structures & walls	Formwork / Shuttering	2,281	6.17	91	0.25
	Piling	3,159	8.55	768	2.08
	Retaining walls	579	1.57	73	0.20
	Gantries	187	0.51	5.0	0.014
	Steelwork	241	0.65	7.0	0.020

[23] Note that due to rounding, totals may not add to 100%.

Category	Item	Materials		Transport	
		Emissions (tCO_2e)	Percentage of construction total	Emissions (tCO_2e)	Percentage of construction total
	Precast concrete	2,120	5.74	516	1.40
Drainage	Plastic pipework (polypropylene)	302	0.82	3.0	0.0080
	Plastic pipework (HDPE)	10	0.028	0.18	0.00048
	Precast concrete circular pipework	102	0.27	25	0.067
	Precast concrete manholes	313	0.85	72	0.20
	Gullies	8.7	0.024	0.18	0.00049
	Channel & slot drains	13	0.036	3.2	0.0087
Fencing & barriers	Road restraint system / safety barrier	141	0.38	8	0.022
Street furniture & electrical equipment	Road lighting and columns	47	0.13	0.87	0.0024
	Cable	25	0.069	0.45	0.0012
	Plastic cable ducting	56	0.15	1.0	0.0026
	Cabinets	1.5	0.0044	0.044	0.000118
Total material		**11,561**	**31.29**	**-**	**-**
Total transport		**-**	**-**	**7,762**	**21.00**
Fuel, energy & water		14,564	39.41	46	0.13
Business and employee transport		1,262	3.42	-	-
Waste		147	0.40	1,612	4.36
Total construction processes		**15,973**	**43.22**	**1,658**	**4.49**
Construction phase total		**36,954**			

Table 14.12: Operational stage emissions for 2022 and 2037

Life Cycle Module	Emissions (tCO_2e)	
	2022	2037
Road user carbon	834,367	1,025,610
Maintenance and operation	2,420	2,974
Total operation	836,787	1,028,584

Comparing Do Minimum and Do Something scenarios

14.1.10.5 As emissions from construction do not occur in the Do Minimum scenario, it can be considered that the construction stage of the Scheme would have the effect of releasing an additional 36,954 tCO_2e into the atmosphere in the Do Something scenario.

14.1.10.6 The calculated operational stage emissions for the 2022 and 2037 Do Minimum and Do Something scenarios are compared below in Table 14.13.

Table 14.13: Do Something and Do Minimum operational emissions comparison

Life Cycle Module	Emissions (tCO_2e)					
	2022 Do Minimum	2022 Do Something	Difference	2037 Do Minimum	2037 Do Something	Difference
Total Operational Emissions	836,429	836,787	358	1,023,707	1,028,584	4,877

14.1.10.7 In both the opening and design years the Scheme will lead to an increase in operational emissions, of 358 tCO_2e and 4,877 tCO_2e respectively, due to increased vehicle kilometres generated by the Scheme.

Comparison to UK carbon budgets

14.1.10.8 The construction and Opening Year operation of the Scheme will contribute a total of 37,312 tCO2e to the UK's third carbon budget (2018 – 2022). This represents 0.0015% of the budget. It is considered that this magnitude of emissions from the Scheme will not have a significant effect on climate.

14.1.10.9 Whilst the emission of GHGs from the Scheme will lead to a long-term negative effect (global warming) on a highly sensitive international receptor (the atmosphere), the magnitude of emissions is considered to be minor. The Scheme is deemed to be unlikely to cause significant effects on climate, or significantly affect the UK's ability to meet its emissions reduction targets. This is in line with the position set out in the NPS NN, described in section 14.5.15 of this chapter.

14.1.10.10 Although the carbon budget associated with the Design Year has not been set, it is expected that emissions contributions of the Scheme will be also not be significant with respect to that budget.

Residual effects

14.1.10.11 Mitigation measures against effects on climate form an inherent part of the project's design and construction practices, therefore the assessment of emissions in this ES already takes into consideration the mitigation described in the assessment above.

14.1.11 Cumulative effects

14.1.11.1 There is only one receptor; the atmosphere. This is global in scale and equally affected by all emissions worldwide. It is therefore not appropriate to consider the effects of the Scheme cumulatively with other developments in the local area. However, it is noted that the effects of all GHG emissions are essentially cumulative, as it is their concentration in the atmosphere, rather than the level of emissions per time period, that determines the warming effect (i.e. it is the 'stock' rather than the 'flow' which is important). For this reason, the effects of the Scheme should be considered in the context of a global excess of emissions to which it contributes, however negligible the percentage contribution may be.

14.1.12 NPS NN compliance

14.1.12.1 The NPS NN acknowledges that the emissions from the construction and operation of a road scheme are likely to be negligible compared to total UK emissions, and are unlikely to materially impact the UK Government's ability to meet its carbon reduction targets. However, the NPS NN requires evidence of the emissions impact of a scheme, an assessment of the emissions against the Government's carbon budgets, and evidence of mitigation measures. The assessment presented in this chapter provides the required evidence and assessment against targets.

14.1.13 Monitoring

14.1.13.1 It is not possible to directly monitor GHG emissions. However, Highways England's Carbon Tool is designed to be populated on a quarterly / monthly return basis through the construction process. Completing this activity will allow tracking of construction emissions against those forecast in this assessment. For the operational phase, actual road user numbers could be modelled as per HA 207/07 to calculate emissions. Operational energy use data could be collected and converted into an emission figure, and maintenance works could be recorded and reported in the same way as the construction works, using the Carbon Tool.

14.1.14 Summary

14.1.14.1 The Scheme is likely to contribute 37,312tCO2e to the UK's third carbon budget (2018 – 2022), representing 0.0015% of the budget. Whilst emissions from the Scheme will lead to a long-term negative effect on the atmosphere, the magnitude of emissions is considered to be minor. The Scheme is unlikely to cause significant effects on climate, or significantly affect the UK's ability to meet its emissions reduction targets. Despite this, mitigation measures will be put in place to reduce emissions as far as possible.

14.2 Vulnerability of the Scheme to climate change

14.2.1 Introduction

14.2.1.1 This sub-chapter outlines the assessment of the vulnerability and resilience of the Scheme to climate change during construction and operation in accordance with Highways England guidance.

14.2.1.2 The approach adopted reviews how climate change could affect the Scheme and also assesses the resilience of the design to climate change. The aim of the assessment is to ensure climate change, and specifically the vulnerability of the Scheme to climate change and impacts associated with extreme weather are considered during the planning and implementation phases to mitigate any significant effects during the construction and operation of the Scheme.

14.2.2 Competent expert evidence

14.2.2.1 This sub-chapter has been prepared by a Chartered Water and Environmental Manager who is also a Chartered Environmentalist and holds professional memberships including Member of the Chartered Institution of Water and Environmental Management (M.CIWEM) and Fellowship of the Royal Geographical Society (FRGS). They have 12 years of knowledge and experience in environmental impact assessment and have used their knowledge and professional judgement to complete this assessment.

14.2.2.2 This sub-chapter was reviewed by a Chartered Environmentalist who holds professional memberships including Membership of Institute of Environment Management and Assessment and Engineer's Australia. They have 10 years professional experience.

14.2.3 Legislative and policy framework

14.2.3.1 The legislation and policy framework for the Scheme's vulnerability to climate changes is set out in Table 14.14.

Table 14.14: Legislation, regulatory and policy framework for the Scheme's vulnerability to climate change

Scale	Legislation/regulation	Summary of requirements
National	Infrastructure Planning (Environmental Impact Assessment) Regulations 2017[24]	The Regulations require: "A description of the likely significant effects of the project on climate (for example the nature and magnitude of greenhouse gas emissions) and the vulnerability of the project to climate change."[25]
	Climate Change Act 2008[26]	The UK passed legislation that introduced the world's first long term legally binding framework to tackle the risks posed by climate change. The Climate Change Act (2008) created a new approach to managing and responding to climate change in the UK, by:

[24] The Infrastructure Planning (Environmental Impact Assessment) Regulations 2017 http://www.legislation.gov.uk/uksi/2017/572/pdfs/uksi_20170572_en.pdf
[25] Environmental Impact Assessment Directive 2014/52/EU, Annex IV, 5(f) (information to be included within the EIA report)
[26] Climate Change Act 2008 http://www.legislation.gov.uk/ukpga/2008/27/contents

Scale	Legislation/regulation	Summary of requirements
		• Setting ambitious, legally binding reduction targets • Taking powers to help meet those targets • Strengthening the institutional framework • Enhancing the UK's ability to adapt to the impacts of climate change, and • Establishing clear and regular accountability to the UK Parliament and to the developed legislatures. Key provisions of the Act in respect of climate change adaptation include a requirement for Government to report, at least every five years, on the risks to the UK of climate change, and to publish a programme setting out how these will be addressed. This Act also introduces powers for Government to require public bodies and statutory undertakers to carry out their own risk assessment and make plans to address those risks. The Adaptation Sub-Committee of the Committee on Climate Change will provide advice to, and scrutiny of, the Government's adaptation work.
	National Planning Policy Framework (NPPF) 2019[27]	The NPPF develops a planning system that contributes to radical reductions in greenhouse gas emissions, minimises vulnerability and improve resilience; encourages the reuse of existing resources, including the conversion of existing buildings; and supports renewable and low carbon energy and associated infrastructure. The NPPF states that "New development should be planned for in ways that avoid increased vulnerability to the range of impacts arising from climate change. When new development is brought forward in areas which are vulnerable, care should be taken to ensure that risks can be managed through suitable adaptation measures, including through the planning of green infrastructure"[28].
	National Policy Statement for National Networks (NPS NN), 2014[29]	Paragraph 4.41 explains that new national networks infrastructure should be typically long-term investments which should remain operational over many decades in the face of a changing climate. It goes onto say that applications should therefore consider the impacts of climate change when planning location, design, build and operation. Paragraph 5.19 outlines the need for appropriate mitigation measures to be implemented in both design and construction.
	The Highways Agency Climate Change Adaptation Strategy and	The Climate Change Act (2008) has led to modifications in existing standards on the national network. The Highways Agency has committed to assessing the potential risks that climatic changes

[27] National Planning Policy Framework, 2019, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/810197/NPPF_Feb_2019_revised.pdf
[28] National Planning Policy Framework, 2019, Planning for climate change, 150 (a)
[29] National Policy Statement for National Networks, 2014, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/387222/npsnn-print.pdf

Scale	Legislation/regulation	Summary of requirements
	Framework (2009)[30]	pose to the ongoing management, maintenance, improvement, and operation of the strategic road network. It will factor anticipated climatic changes into the delivery of their business and develop appropriate management and mitigation solutions to remove or reduce these risks.
	Highways England Sustainable Development Strategy (2017)[31]	The report sets out Highways England's vision for climate adaptation which is to become more resilient to future changes in climate, that may result in more frequent and severe weather events. Highways England recognise in the report that it is important to adapt the network and make effective investment decisions as climate adaptation today is tomorrow's resilience.
Regional	The London Plan (2016)[32]	Paragraph 1.48 outlines the Plan's vison to address climate change, in terms of both adaptation and mitigation. Adaptation includes designing infrastructure with a changing climate in mind and protecting, enhancing and expanding the city's stock of green space to help cool parts of the city. Mitigation includes reducing our emissions of greenhouse gases to minimise future warming and its impacts. Paragraph 6.49 concerns the need to safeguard existing and identify new facilities to distribute goods and service its people. Any development will be encouraged which eases congestion on the highway network and in turn contributes to combating climate change.
	The Mayor's Transport Strategy (2010)[33]	The Mayor, through TfL, will prepare adaptation strategies to improve safety and network resilience to threats posed by climate change, and ensure that new transport infrastructure is appropriately resilient. This will include guidelines for major procurement contracts (including design, construction and maintenance) to demonstrate a climate risk assessment for the lifetime of investments.
Local	Havering London Borough - 3-year Action Plan for Tackling Climate Change and Improving Energy Efficiency	The report recognises that as the climate changes the Council has a responsibility to improve the borough's ability to deal with anticipated weather impacts (i.e. drier summers, higher severe flooding incidences, severe winter weather spells). Detailed actions set out in the report address both the Councils own preparedness as well as borough wide resilience.
Local	Brentwood Borough Council Climate Change	The report is not yet available online. Consultation with the Council revealed that it is currently in draft

[30] The Highways Agency Climate Change Adaptation Strategy and Framework, 2009, https://webarchive.nationalarchives.gov.uk/20110606090935/http://www.highways.gov.uk/aboutus/documents/CCAF-Strategy_and_Vol_1-Rev_B_Nov.pdf
[31] Sustainable development strategy, 2017, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/605079/Sustainable_Development_Strategy_6.pdf
[32] The London Plan, 2016, https://www.london.gov.uk/sites/default/files/the_london_plan_2016_jan_2017_fix.pdf
[33] The Mayor's Transport Strategy, 2010, https://www.london.gov.uk/what-we-do/transport/transport-publications/mayors-transport-strategy

Scale	Legislation/regulation	Summary of requirements
	Strategy	and will include commitments to undertake climate vulnerability actions.

14.2.4 Study area

14.2.4.1 The spatial boundary of the assessment incorporates the areas of all the receptors examined by the other topics in this ES. Most potential climate vulnerability impacts occur within the Scheme Development Consent Order (DCO) boundary (as shown on Figure 1.1 (application document TR010029/APP/6.2)).

14.2.5 Assessment methodology

14.2.5.1 The assessment method of the Scheme's vulnerability to climate change is set out below. It follows Highways England's guidance.

14.2.5.2 There are four stages to the assessment process:

- Stage 1 – Identify the receptors.
- Stage 2 – Assess the likelihood of impacts on each receptor.
- Stage 3 – Assess the consequence of impacts for each receptor.
- Stage 4 – Determine the significance of each impact based on a combination of the likelihood of an impact occurring and the consequences of that impact.

Stage 1 – Identification of receptors

14.2.5.3 Receptors which may be affected by climate change have been identified with consideration of both extreme weather events and gradual climatic changes in the study area over the Scheme's design life. In accordance with Highway England's guidance the assessment considers impacts on the following receptors:

- Construction process (including workforce, plant, machinery etc.).
- The assets and their operation, maintenance and refurbishment (including: pavements, structures, earthworks, drainage and technology assets such as signs, signals and traffic sensors).
- End-users (nearby residential properties, members of the public, commercial operators, road user safety and experience).

14.2.5.4 Where it is not already covered in the relevant topic chapters consequential loss or damage to environmental receptors as a result of the Scheme's vulnerability to climate change is discussed in the cumulative effects section of this chapter.

Stage 2 – Assess the likelihood of impacts

14.2.5.5 In line with the Highways England guidance, the likelihood of potential climate impacts occurring has been determined using available data (e.g. the known recurrence interval of extreme weather events) and professional judgement. The likelihood categories and associated frequencies are provided in Table 14.15 below.

Table 14.15 Likelihood categories

Likelihood category	Description (probability and frequency of occurrence)
Very high likelihood	The impact occurs multiple times during the lifetime of the project (60 years) e.g. approximately annually, typically 60 events.
High likelihood	The impact occurs several times during the lifetime of the project (60 years) e.g. approximately once every five years, typically 12 events.
Medium likelihood	The impact occurs limited times during the lifetime of the project (60 years) e.g. approximately once every 15 years, typically 4 events.
Low likelihood	The impact occurs once during the lifetime of the project (60 years) e.g. once in 60 years.
Very low likelihood	The impact may occur once during the lifetime of the project (60 years).
Table Notes: Project lifetime is considered to include construction and operational phases; project lifetime is taken to be 60 years in line with Highways England guidance and WebTAG	

Table Source: Highways England guidance (May, 2018)

14.2.5.6 The likelihood of impact assessment is undertaken with consideration of the Scheme design and embedded mitigation.

Stage 3 – Assess the consequence of impacts

14.2.5.7 The consequence of climate change impacts on the Scheme receptors has been categorised using the criteria in Table 14.16.

Table 14.16: Measure of consequence

Consequence of impact	Example description
Very large adverse	National level (or greater) disruption to strategic route(s) lasting more than 1 week.
Large adverse	National level disruption to strategic route(s) lasting more than 1 day but less than 1 week OR Regional level disruption to strategic route(s) lasting more than 1 week.
Moderate adverse	Regional level disruption to strategic route(s) lasting more than 1 day but less than 1 week.
Minor adverse	Regional level disruption to strategic route(s) lasting less than 1 day.
Negligible	Disruption to an isolated section of a strategic route lasting less than 1 day.
Minor beneficial	Reduction in regional level disruption to strategic route(s) lasting less than 1 day.

Table Source: Highways England guidance (May, 2018)

Stage 4 – Determine significance of impacts

14.2.5.8 The results of the likelihood and consequence assessments are combined to derive a significance classification as outlined in Highways England guidance, this is reproduced in Table 14.17.

Table 14.17: Significance matrix

Impact consequence	Impact likelihood				
	Very low	Low	Medium	High	Very high
Negligible	NS	NS	NS	NS	NS
Minor	NS	NS	NS	S	S
Moderate	NS	NS	S	S	S
Large	NS	S	S	S	S
Very large	NS	S	S	S	S

Table notes:
NS = Not significant, S = Significant
Impacts can be adverse or beneficial.

Table Source: Highways England guidance (May, 2018)

14.2.5.9 Where mitigation in addition to that which is embedded in the design is required, i.e. adaption measures, to reduce significant impacts this is identified in the residual effects section. The assessment is informed by best practice approaches, climate guidance and literature as well as professional judgement.

14.2.6 Assumptions and limitations

14.2.6.1 The assessment provides a broad, high-level indication of the potential impacts of climate change on the Scheme based on professional judgement.

14.2.6.2 The climate projections used are from UKCP18 (United Kingdom Climate Projections 2018). These projections have been developed by the Met Office Hadley Centre Climate Programme which is supported by the Department of Business, Energy and Industrial Strategy (BEIS) and the Department for Environment, Food and Rural Affairs (Defra). They provide the most up-to-date assessment of how the climate of the UK may change over the 21st century[34].

14.2.6.3 The UKCP18 projections do not provide a single precise prediction of how weather and climate will change years into the future. Instead UKCP18 provides ranges that aim to capture a spread of possible climate responses. This better represents the uncertainty of climate prediction science. It should be noted that the level of uncertainty of the projections is dependent on the climate variable, for example, there is greater confidence around changes in temperature than there is in wind. In this assessment this is considered when assessing the likelihood of impacts. This assessment is based on data from Representative Concentration Pathway (RCP) 8.5. This is a greenhouse gas concentration

[34] UKCP18 Climate Projections https://www.metoffice.gov.uk/research/collaboration/ukcp

trajectory under which it is assumed that emissions continue to rise throughout the 21st century.

14.2.6.4 Other key caveats and limitations of UKCP18 data are presented on the Met Office website[35].

14.2.7 Baseline conditions

14.2.7.1 Climate is defined as the typical weather conditions experienced in a place over a period of time, conventionally expressed as average weather over a 30-year period.

14.2.7.2 The baseline for climate change vulnerability is presented in two parts:

- The first section describes the current climatic conditions in the study area.
- The second presents a range of possible future climate projections.

14.2.7.3 It should be noted, however, that climate change is not only a challenge of the future. We are already observing changes in the UK climate, for example average temperatures have risen by approximately 1ºC over the last century.

14.2.7.4 The full climate vulnerability baseline and methodology is included in Appendix 14.2 (application document TR010029/APP/6.3), a brief summary is provided below.

Current climate

14.2.7.5 The climate in the study area is one of relatively mild winters and warm summers. Monthly average and mean maximum temperatures are amongst the highest in the UK (Appendix 14.2, Figure 14.1). Long-term average monthly rainfall is close to the lowest in the UK (Appendix 14.2, Figure 14.4) and the study area receives fewer heavy rainfall days than is usual for the UK (Appendix 14.2, Figure 14.5).

Projected future climate

14.2.7.6 The study area is likely to experience hotter (Appendix 14.2, Figure 14.7) and drier (Appendix 14.2, Figure 14.8) summers and warmer (see Appendix 14.2, Figure 14.6) and wetter (Appendix 14.2, Figure 14.9) winters. Alongside these changes in the average conditions, it is possible, but less certain, that climate change will also increase the frequency and severity of extreme weather events, such as heavy rainfall, storms and heatwaves (Appendix 14.2, section 14.1.21).

14.2.8 Potential impacts

14.2.8.1 Chapter 14 of the Scheme's Environmental Scoping Report[36] sets out the extent of potential impacts to be considered in the climate vulnerability assessment.

[35] www.metoffice.gov.uk/binaries/content/assets/metofficegovuk/pdf/research/ukcp/ukcp18-guidance---caveats-and-limitations.pdf
[36] Highways England, 2017. M25 Junction 28 Environmental Scoping Report.

Impacts scoped out

14.2.8.2 After consideration the impacts scoped out of further assessment are summarised below:

- All impacts associated with changes to the average value of climate variables (e.g. increases in average temperature). Noting that impacts associated with projected extreme changes to climate variables (e.g. changes to minimum and maximum temperatures) remain a part of the assessment.
- All impacts associated with sea level rise – the Scheme is inland.
- All impacts associated with changes to humidity and water availability (drought) – no related significant impacts are foreseen.

14.2.8.3 In addition to the above construction impacts are also scoped out of this assessment. Although the climate of the study area has already changed from its natural state, as a result of climate change, the Scheme's construction is not expected to be so far in the future that climate will notably change any further prior to construction. Climate change is therefore not expected to affect construction. All potential construction climate vulnerability impacts are therefore considered to be negligible. It is noted that if construction coincides with extreme weather there may be impacts. Assessment of extreme weather under the current climate is included within the other chapters of this ES with mitigation included in the CEMP as required. For example, the Road Drainage and the Water Environment chapter (Chapter 8) of the ES identifies potential adverse impacts associated with surface water runoff from construction sites. The mitigation proposed for these is conservative, taking account of a worst-case extreme weather scenario.

14.2.8.4 Some extreme weather impacts may not affect environmental receptors. Risks posed by these would be managed by construction risk assessments which will set out how extreme weather events are monitored so construction activities can be planned accordingly. This will include emergency planning for disastrous weather impacts. Some examples of potential non-environmental extreme weather construction impacts are provided below:

- During a heatwave the construction programme and activity schedule may need to be reviewed with those activities that are less vulnerable to the hot weather being prioritised.
- During extended periods of hot, sunny conditions, asphalt can remain workable for a considerable time, making it difficult to maintain profile during compaction and, in the case of hot rolled asphalt surface course with added pre-coated chippings; it may be difficult to achieve the required texture depth. Additionally, newly laid surfacing layers of a pavement may also maintain temperatures after opening to traffic that are high enough to allow excessive rutting and the rapid embedment of any chippings, with the latter again causing a reduction of texture depth.

- Construction staff health issues (e.g. heat stroke, dehydration, respiratory problems) could accompany work during a heatwave and/or time of reduced air quality. If construction coincided with a heatwave then personal protective equipment provision may need to be reviewed, extra drinking water provided etc. In extreme cases night work may be necessary to complete works.
- During fog, lightning or high winds it may not be possible to work safely, for example operating tall cranes or erecting scaffolding for work on bridges. Some construction activities may need to be delayed on health and safety grounds.
- During drought the construction schedule may be vulnerable to disruption if water availability is limited.

Impacts scoped in

14.2.8.5 The potential climate vulnerability impacts assessed in this Chapter are summarised below, they are separated by receptor type:

Potential operational impacts on asset receptors (including their operation, maintenance and refurbishment):

- Road surfaces and pavements:
  - Warmer winters could reduce winter maintenance and associated traffic disruption (less road salting and freeze thaw damage).
  - Hotter summers could damage materials (rutting, shrinkage and expansion) increasing maintenance requirements and associated traffic disruption.
  - Heavier rain and wetter winters could increase pot hole formation (by weakening the soil beneath the carriageway) increasing maintenance requirements and associated traffic disruption.
- Structures (including embankments, earthworks and bridges):
  - Hotter summers could reduce the asset lives of structures (over expansion and buckling) increasing maintenance requirements and associated traffic disruption.
  - Drier summers could cause soil instability (intensify and extend soil moisture deficits and impact groundwater levels and earth pressures) increasing maintenance requirements and associated traffic disruption.
- Drainage infrastructure:
  - Drier summers in combination with hotter temperatures could dry out soils and so increases erosion. This may cause sedimentation within the Scheme's drainage infrastructure that reduces its drainage capacity and so increases the risk of flooding which causes traffic disruption. Additional maintenance work to prevent flooding may also cause traffic disruption.
  - Heavier rain and wetter winters could increase the risk of pluvial or surface flooding. Flooding and additional maintenance requirements could both cause traffic disruption.
  - Warmer winters could reduce freeze thaw erosion which can damage

underground assets. Reducing maintenance requirements and associated traffic disruption.

- Road technology and street furniture:
  - The frequency of extreme weather impacts on electrical equipment may increase as for example lightning strikes become more regular and extreme hot temperatures more common causing thermal over loading of circuits. Repair and maintenance may cause traffic disruption.
  - High winds in more regular storms could overload small structures and signage and damage roadside planting and furniture. Repair and maintenance may cause traffic disruption.
- Landscaping:
  - Drier summers could damage the Scheme's landscaping. More regular maintenance may cause traffic disruption.

Potential operational impacts on end-user receptors:

- Driver experience:
  - Warmer winters could improve winter driver safety and so reduce traffic disruption caused by accidents.
  - Hotter summers could increase the number of vehicle breakdowns and so increase traffic disruption and the number of associated accidents.
  - Hotter summers could increase accident rates and so increase traffic disruption.
  - Heavier rain and wetter winters could reduce driver safety and so increase traffic disruption associated with accidents.
  - Storms and high winds could reduce driver safety and so increase traffic disruption associated with accidents.

14.2.9 Design, mitigation and enhancement measures

14.2.9.1 To understand the vulnerability and resilience of the Scheme design to climate change, information has been gathered from the design team and the environmental team about the mitigation measures already built into the design (i.e. embedded mitigation).

14.2.9.2 The assessment of climate vulnerability impacts is undertaken after consideration of the Scheme design and its embedded mitigation. Relevant embedded mitigation is set out in section 14.2.10. Where mitigation in addition to this adaption is required to reduce otherwise significant climate vulnerabilities this is identified in section 14.2.10.2.

14.2.10 Assessment of effects

14.2.10.1 The likelihood of each potential impact, with embedded mitigation in place, has been assessed along with the consequence of that impact if it occurred. These assessments along with the resulting significance of each impact are presented in two tables, one for each of the two types of receptor (see the methodology section 14.2.5 for details):

- The assets and their operation, maintenance and refurbishment (Table 14.18)
- End-users (Table 14.19)

Table 14.18: Potential operational impacts on asset receptors (including their operation, maintenance and refurbishment)

Climate trend	Potential impact	Embedded mitigation	Likelihood	Consequence	Significance
Road surfaces and pavements					
Warmer winters	The projected increase in winter temperatures and decrease in snowfall suggests a reduction in frequency of winter road maintenance (salting). Additionally, since freeze thaw erosion can damage underground assets, milder temperatures projected in the future may reduce the need for maintenance work that would otherwise disturb road surfaces and pavements.	NA	**Medium** – Following Highways England guidance and in line with the UKCP18 projections and the precautionary principle it is considered that there is high certainty that winter mean temperatures will increase over the Scheme's lifetime (in winter, under RCP 8.5, mean temperature is likely to increase by approximately 3ºC [central estimate]). However, projected changes to snowfall and the number of nights below freezing are less certain so the likelihood of this impact is found to be Medium.	**Minor beneficial** - During the Scheme's operation, road and pavement maintenance and upgrade works and associated road traffic delays could reduce (minor beneficial). The reduced requirement for the operation of slow-moving salting vehicles would also avoid potential minor traffic disruption.	Not significant
Hotter summers	Hotter summers could damage materials, for example: • Ageing bituminous binders (deformation and rutting of road surfaces); • Softening, deforming and damaging bitumen in asphalt; • Over expansion and buckling of concrete roads; • Failure of expansion joints;	Best practice construction techniques and appropriate material quality standards will be followed to ensure the design lives specified can be met. For example, since pavement surfaces are susceptible to rutting in hot weather the design specifies that polymer modified bitumen will be used in the surface course and a resistance to permanent deformation requirement is specified. The design also specifies the use of heavy-duty macadam in the binder and base course which has an increased rut resistance. Furthermore, the drainage design will ensure the bound material is	**Medium** - Following Highways England guidance and in line with the UKCP18 projections and the precautionary principle it is considered that there is high certainty that summer mean temperatures will increase over the Scheme's lifetime (by 2071-89 summer mean daily maximum temperatures could be up to +5.4ºC warmer [central estimate under emissions scenario RCP8.5]). With embedded mitigation in place	**Minor adverse** - Emergency repairs and more regular maintenance interventions may be required, in response to changes in deterioration rates. These would create associated traffic delays (minor adverse). Under extreme temperature, certain maintenance activities may be required to be undertaken at night, to	Not significant

Climate trend	Potential impact	Embedded mitigation	Likelihood	Consequence	Significance
	• Wider temperature variations causing shrinkage and expansion that leads to cracking.	constructed on a sound foundation that should perform at its optimum over the design life.	the likelihood of impact is medium. There is still likely to be some damage to assets during the lifespan of the Scheme.	keep work to schedule, thus incurring higher programme costs (e.g. labour and illumination) but causing less traffic disruption (negligible).	
Heavier rain and wetter winters	Heavier rain and wetter winters will weaken the soil beneath the carriageway. Loads from traffic may then stress the surface past its breaking point.	The design mitigates the risk of water getting trapped in the foundation layers of roads and pavements which could lead to an increase in moisture content and thus a decrease in performance i.e. lack of sufficient support to the overlaying bound material. The design specifies a thin surface course system with a water sensitivity category of minimum 80%. Where reflective cracking is considered a high risk (i.e. at the tie-in of the new and existing pavement sections) it is proposed that a geosynthetic (i.e. a geogrid) will be used to mitigate the risk, thus stopping surface water penetrating the bound layers through the reflective cracks. In accordance with the Design Manual for Roads and Bridges (DMRB) recommendations the surfacing on the bridge decks is specified as a hot rolled asphalt which is less permeable when compared to the thin surface course system and should provide the durability required.	**Negligible** - Following Highways England guidance and in line with the UKCP18 projections and the precautionary principle it is considered that there is medium certainty that winter rainfall will increase over the Scheme's lifetime. Emission scenario RCP 8.5 suggests that a central estimate of mean winter precipitation change is an increase of 0.5 mm by 2071-89. Changes to extreme rainfall are less clear. The effect on pothole formation may be offset by the summers being drier and the winters being warmer (less freeze thaw erosion and less frost heaving; which are both significant contributors to pot hole formation). It is therefore uncertain what the net impact of climate change will be. With the embedded mitigation the likelihood of impact is negligible.	**Minor adverse** - There may, in the future, be an increase in the number and severity of pot holes in the study area. Pot holes can damage tires, wheels, and vehicle suspension. In extreme circumstances they can also cause road accidents, particularly where there are higher speed limits. To avoid this there would need to be an increase in maintenance and repair works. All of the above could create traffic disruption (minor adverse).	Not significant

Climate trend	Potential impact	Embedded mitigation	Likelihood	Consequence	Significance
Structures (including embankments, earthworks, bridges)					
Hotter summers	Hotter summers could reduce the asset lives of structures, for example causing: • Over expansion and buckling (e.g. of culverts or kerbs); or • Failure of expansion joints.	The design will ensure structures can adapt to expected future variations in temperature. The bridges and subways are designed as fully integral structures, meaning there are no bridge bearings, and no movement joints. Temperature effects in the structure will be taken into account through the soil & structure interaction in accordance with Eurocodes[37] and DMRB standards. Structures will be routinely monitored by their operators throughout the life of the Scheme.	**Medium** - Following Highways England Guidance and in line with the UKCP18 projections and the precautionary principle it is considered that there is high certainty that summer mean temperatures will increase over the Scheme's lifetime (by 2071-89 summer mean daily maximum temperatures could be up to +5.4ºC warmer [central estimate under emissions scenario RCP8.5]). With embedded mitigation in place the likelihood of impact is medium. There is still likely to be some damage to assets during the lifespan of the Scheme.	**Minor adverse** - Emergency repairs and more regular maintenance interventions may be required, in response to changes in deterioration rates. These would create associated traffic delays (minor adverse). Under extreme temperature, certain maintenance activities may be required to be undertaken at night, to keep work to schedule, thus incurring higher programme costs (e.g. labour and illumination) but causing less traffic disruption (negligible).	Not significant
Drier summers	The expected reduction in summer average rainfall is likely to intensify and extend soil moisture deficits and impact groundwater levels. This could impact soil stability, for example increasing earth pressures, affecting structures – including embankments. Natural structures, such as drought vulnerable tree species, e.g. Beach, could	Risk will be managed by best practice design, for example, embankments will be designed from slope-stability analysis using site specific soil parameters, and compacted and constructed in line with best practice including alignment with DMBR Volume 10 Section 1, Landform and Alignment. The Geology and Soils chapter (Chapter 10) of this Environmental Statement (ES) sets out in further detail how these risks	**Low** - Following Highways England guidance and in line with UKCP18 projections and the precautionary principle it is considered that there is medium certainty that summers will get drier over the Scheme's lifetime. The central estimate of change in mean summer precipitation by 2071-89 is -34% under RCP 8.5. However, the uncertainty	**Minor adverse** - Drier summers could damage assets and increase maintenance and upgrade works causing associated traffic disruption (minor adverse).	Not significant

[37] The Eurocodes are European standards specifying how structural design should be conducted within the European Union. These were developed by the European Committee for Standardisation upon the request of the European Commission.

Climate trend	Potential impact	Embedded mitigation	Likelihood	Consequence	Significance
	also become unstable and potentially a safety risk if not managed properly.	will be controlled, this includes: • Completing stability assessments as part of design; • Undertaking an appropriate ground investigation; • Design of the temporary and permanent works to minimise movement; and • Appropriate analysis to predict magnitude of movements. In addition to the above the following may be recommended during later design stages when further information is available: • Inspection of existing infrastructure and assessment of movements which can be tolerated; • Monitoring during the construction works to measure movements, with agreed trigger level and action plan.	around this estimate ranges from approximately -68% to 0% (represented by the 10th and 90th percentile respectively). With embedded mitigation in place the likelihood of impact is reduced to low.		
Drainage infrastructure					
Drier summers	Drier summers combined with the projected increase in summer temperatures could lead to increased erosion as soils and their substrates dry out.	Any steep embankments will be compacted and planted, topsoil retention systems may be used if necessary. • The 3 attenuation/treatment ponds will allow sediment to settle out of the main flow • The design will assist operational maintenance by including accessible sediment traps (catch pits) that will be regularly cleared. The majority of the drainage chambers will be catch pits instead of manholes. Catch pits have sumps where silt can be	**Low** - Following Highways England Guidance and in line with UKCP18 projections and the precautionary principle it is considered that there is medium certainty that summers will get drier over the Scheme's lifetime. The central estimate of change in mean summer precipitation by 2071-89 is -34% under emissions scenario RCP8.5. However, the uncertainty around this	**Minor adverse** - Mobilisation of debris could lead to increased sedimentation within the Scheme's drainage infrastructure adversely affecting its capacity and so increasing maintenance requirements and risk of flooding which could both cause traffic disruption (minor	Not significant

Climate trend	Potential impact	Embedded mitigation	Likelihood	Consequence	Significance
		trapped and are therefore better at removing silt/sediment compared to manholes • The largest part of the surface water collection system will be gullies that will add to the silt-trapping capacity of the treatment ponds and catch pits. The Landscape and Visual chapter (Chapter 9) of this ES has proposed the following embedded mitigation: • Retain existing trees and vegetation wherever possible • Replace areas of trees and grass lost to facilitate the works wherever practicable • Plant woodland and seed grass, to contribute to screening and amenity value and mitigate the loss of tree cover in the landscape.	estimate ranges from approximately -68% to 0% (represented by the 10th and 90th percentile respectively). With embedded mitigation in place the likelihood of impact is reduced to low.	adverse).	
Heavier rain and wetter winters	The projected climate trend of increasing frequency and intensity of heavy rainfall events is likely to increase the risk of pluvial or surface flooding as surface run-off inundates small catchments and the urban landscape. Prolonged periods of excessive precipitation (e.g. wetter winters) saturates soil, increasing the risk of fluvial or river flooding. Above average precipitation for long periods can also lead to a raised water table, which can result	The drainage system will be designed in line with current standards set out in the DMRB (HA, 2009). This provides guidance for surface drainage for trunk roads including motorways. Specifically, for drainage DMRB Volume 4, Section 2 will be followed as well as DMRB Volume 11, Section 3, Part 10 (HD45). The design will use an appropriate camber to assist drainage from the road surface. Although there are various design storm-periods for different aspects of highway construction, ultimately the absolute rainfall thresholds are highly dependent on the local	**Low** - Following Highways England guidance and in line with the UKCP18 projections and the precautionary principle it is considered that there is medium certainty that rainfall will get heavier over the Scheme's lifetime. Emission scenario RCP 8.5 suggests that a central estimate of mean winter precipitation change is an increase of 0.5 mm by 2071-89. Changes to extreme rainfall are less clear. With embedded mitigation in place	**Minor adverse** - New assets could be damaged, for example by scour around structures, which would then require maintenance. Both flooding and additional maintenance/repair could cause road closures and associated traffic delays (minor adverse).	Not significant

Climate trend	Potential impact	Embedded mitigation	Likelihood	Consequence	Significance
	in groundwater flooding in areas where the geological characteristics are favourable.	topography, adjacent land-use, gradient and location within the wider catchment. The DMRB highlights the importance of local information to assess absolute rainfall thresholds. This chapter does not include such detailed analysis but it is provided in the Scheme's Flood Risk Assessment (FRA) (application document TR010029/APP/6.6). This sets out the climate change allowance that has been used for the surface water drainage design with adjustment factors in line with the latest information in the Planning Practice Guidance and Environment Agency (EA) and Lead Local Flood Authority (LLFA) requirements. In summary a 20% climate change allowance has been used for the preliminary design. Further information is provided in the Road Drainage and the Water Environment chapter (Chapter 8) of this ES. A climate change allowance has also been applied to fluvial flows for the design of the flood compensation areas (to determine their volume) and to determine the distance needed between the soffit of structures and the design flood water level of the rivers being crossed. As the purpose of the Scheme is a major junction upgrade for a key motorway of strategic importance it is considered essential infrastructure and therefore, in consultation with the EA, the "upper end" allowance of +70% to peak flows has been used when investigating the designs resilience to climate change and the "higher central" allowance used	the likelihood of impact is low.		

Climate trend	Potential impact	Embedded mitigation	Likelihood	Consequence	Significance
		to determine design levels. Further information is presented in the Scheme's FRA (application document TR010029/APP/6.6). Where foundations extend below the existing groundwater table or could extend below the future groundwater level they are designed in accordance with industry standards - taking into account the site-specific water level and flow monitoring data obtained from historic intrusive ground investigation carried out along the A12 and M25 alignments adjacent to the Scheme. Further targeted ground investigation will be undertaken prior to detailed design.			
Warmer winters	Warmer winters reduce freeze thaw erosion which can damage underground assets.	NA	**Medium** - Following Highways England guidance and in line with the UKCP18 projections and the precautionary principle it is considered that there is high certainty that winter mean temperatures will increase over the Scheme's lifetime (in winter, under the RCP8.5 emissions scenario, mean temperature is likely to increase by approximately 3ºC [central estimate]). However, projected changes to snowfall and the number of nights below freezing are less certain so the likelihood of this impact is found to be Medium.	**Minor beneficial** - During the Scheme's operation maintenance and repair works and associated traffic disruption could reduce.	Not significant

Climate trend	Potential impact	Embedded mitigation	Likelihood	Consequence	Significance
Road technology and street furniture (including signs and signals)					
Changes to extreme weather	Extreme weather impacts on electrical equipment: • More regular and intense storms in the future could increase the regularity of lightning strikes on infrastructure which could damage electrical equipment • Extreme hot temperatures increase thermal loadings on electrical and control equipment reducing their life.	Extreme weather mitigation: • Electrical equipment on the M25 anti-clockwise entry slip road, two lane loop road and roundabout will be protected against main electrical supply surge and lightning current by Surge Protection Devices. • Calculations will be carried out at the detailed design stage for electrical equipment on the new A12 eastbound exit slip road as part of the risk assessment detailed in section 443 of BS7671:2018 (standards for electrical installations) to determine if protection against transient overvoltage (lighting strike) is required. In advance of this, based on professional judgement and consideration of the location of the lighting power supplies/feeder pillars, it is expected at this stage that transient overvoltage protection will be included in the final design. • Key electrical components will be regularly checked by their operators, and replacement cycles may be shortened if deterioration rates increase.	**Very low** – Climate projections show there is low certainty of how climate change will alter extreme weather in the future. With embedded mitigation in place the likelihood of impact is very low.	**Minor adverse** - Power loss for the Scheme's lighting and electronic display equipment (signs) could cause traffic delays (minor adverse). Road closures for major repairs to structures e.g. gantries would cause traffic disruption. To avoid this more regular maintenance may be required for example shorter intervention/ strengthening intervals. This may still cause traffic disruption (minor adverse).	Not significant
Changes to extreme weather	High winds in more regular and intense storms could overload small structures and damage roadside planting and furniture, for example traffic signs.	• The landscape design will adhere to the Specification for Highways Works set out in Series 3000 (Landscape and Ecology) of the Manual of Contract Documents for	**Very low** – Climate projections show there is low certainty of how climate change will alter extreme weather in the future. With embedded mitigation in place the likelihood of impact	**Minor adverse** – Partial road closures for unplanned minor repairs could cause traffic disruption (minor adverse). To avoid this	Not significant

Climate trend	Potential impact	Embedded mitigation	Likelihood	Consequence	Significance
		Highway Works[38]. Where required, in Appendix 30/6 of the above listed document, root barriers shall be provided at the time of planting, in order to constrain the growth of tree roots. The design will also adhere to DMRB Volume 10 Section 1 – New Roads Planting Vegetation and Soils – Chapter 12.1 of which set out that shrubs must be not planted within 3 m of the carriageway and trees not within 5 m of it. • DMRB Volume 8 Section 2 Part 2 (TD 25/15) sets out that wind loading risks for signage is minimal. Furthermore, Highways England's own Adaptation Assessment[39] found that the effect of wind on bridges is minimal as it is not the dominant load.	is very low.	more regular maintenance may be required for example shorter intervention/ strengthening intervals.	
Landscaping					
Hotter and drier summers	Hotter and drier summers will increase soil moisture deficits in the future which could negatively impact the Scheme's landscaping. The landscaping has aesthetic benefits but also prevents excessive aeolian soil erosion and protects structures from surface water runoff scour.	The proposed landscape design will futureproof the Scheme in terms of climate change as well as in terms of pests/diseases by adhering to best practice. This will include diversifying planting species as much as possible, including drought tolerant species, whilst still having regard to the local character, and generally planting only native species. It will also adhere to best ecological practice.	**Low** - Following Highways England guidance and in line with UKCP18 projections and the precautionary principle it is considered that there is medium certainty that summers will get drier over the Scheme's lifetime. The central estimate of change in mean summer precipitation by 2071-89 is -34% under the emissions scenario RCP 8.5. However, the uncertainty	**Negligible** – Additional maintenance would cause minimal traffic disruption as it is unlikely to require lane closures.	Not significant

[38] Manual of Contract Documents for Highway Works (MCHW), 2019, www.standardsforhighways.co.uk/ha/standards/mchw/index.htm
[39] Highways England Climate Adaptation Risk Assessment, 2016, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/596812/climate-adrep-highways-england.pdf

Climate trend	Potential impact	Embedded mitigation	Likelihood	Consequence	Significance
			around this estimate ranges from approximately -68% to 0% (represented by the 10th and 90th percentile respectively). With embedded mitigation in place the likelihood of impact is reduced to low.		

Table 14.19: Potential operational impacts on end user receptors

Climate trend	Potential impact	Embedded mitigation	Likelihood	Consequence	Significance
Driver experience					
Warmer winters	Warmer winters will improve winter driver safety by reducing driving risks for road users as roads will be less icy and snowfall will reduce visibility less often.	NA	**High** - Following Highways England guidance and in line with the UKCP18 projections and the precautionary principle it is considered that there is high certainty that winter temperatures will increase over the Scheme's lifetime (in winter, under emissions scenario RCP8.5, mean temperature is likely to increase by approximately 3ºC [central estimate]). The likelihood of impact is therefore high.	**Minor beneficial** - Reduction in road traffic accidents and associated traffic disruption. Although it is noted that this beneficial impact would be equally present both with and without the Scheme.	**Significant beneficial**
Hotter summers	Climate change will increase average summer temperatures. Vehicle breakdowns are more common during warm weather because the heat puts stress on critical components.	The section of M25 in which the Scheme is located already operates as a Smart Motorway, as defined by the requirements of IAN161[40]. Safety technology covering the area includes: enhanced message signs, advanced matrix indicators, MIDAS Radar & Loops and CCTV (Pan, tilt zoom variety). The Scheme will extend the coverage of the CCTV to the two lane loop road and new A12 eastbound exit slip road. Slow or stranded vehicles can refuge on the hard shoulder. There is not a significant distance for vehicles to travel	**Medium** - Following Highways England guidance and in line with the UKCP18 projections and the precautionary principle it is considered that there is high certainty that summer mean temperatures will increase over the Scheme's lifetime (by 2071-89 summer mean daily maximum temperatures could be up to +5.4ºC warmer [central estimate under emissions scenario RCP8.5]). With embedded mitigation in	**Minor adverse** - Breakdowns can have the following adverse effects: • Cause drivers to lose control of their vehicle - e.g. in the event of a tyre blowout or brake failure (both can be associated with warmer weather) • Increase the likelihood of vehicle fires and associated risks for road users	**Not significant**

[40] Smart Motorways Interim Advice Note 161/15, 2015, http://www.standardsforhighways.co.uk/ha/standards/ians/pdfs/IAN161_15.pdf

Climate trend	Potential impact	Embedded mitigation	Likelihood	Consequence	Significance
		to the nearest exits either side of the junction - junction 29 is approximately 5 km south of junction 28 and junction 27 is approximately 15 km north of junction 28.	place the likelihood of impact is medium.	• Be very dangerous for drivers stranded in a live traffic lane, and • Cause secondary accidents involving other road users. All the above can cause minor adverse traffic disruption consequences (due to obstruction of lanes or as traffic slows to pass).	
Hotter drier weather	Climate change will increase average summer temperatures. During warm weather, accident rates typically increase. This is attributable to more solar glare, more people being out (particularly in the evening), more pedestrians and bikes on the road and an increase in fine particulates on the road surface which reduces skid resistance. Additionally, other contaminants, such as oil and tyre rubber can build up in drier weather acting as lubricants further reducing skid resistance.	The section of M25 in which the Scheme is located already operates as a Smart Motorway, as defined by the requirements of IAN161[41]. Safety technology covering the area includes: enhanced message signs, advanced matrix indicators, MIDAS Radar & Loops and CCTV (Pan, tilt zoom variety). The Scheme will extend the coverage of the CCTV to the two lane loop road and new A12 eastbound exit slip road. Maintenance assessments of the road will follow the Highways England skid policy which takes into account climate change[42]. The long-term landscape design does not include large areas of exposed soil that could become mobile in hot dry weather (blowing onto the road and reducing skid resistance).	**Medium** - Following Highways England guidance and in line with the UKCP18 projections and the precautionary principle it is considered that there is high certainty that summer mean temperatures will increase over the Scheme's lifetime (by 2071-89 summer mean daily maximum temperatures could be up to +5.4ºC warmer [central estimate under emissions scenario RCP8.5]). With embedded mitigation in place the likelihood of impact is medium.	**Minor adverse** – More dangerous driving conditions in the future could increase road traffic accidents and associated traffic disruption (minor adverse).	**Not significant**

[41] Smart Motorways Interim Advice Note 161/15, 2015, http://www.standardsforhighways.co.uk/ha/standards/ians/pdfs/IAN161_15.pdf
[42] Skidding resistance requirements, 2019, http://www.standardsforhighways.co.uk/ha/standards/dmrb/vol7/section3/CS%20228%20Skidding%20resistance-web.pdf

Climate trend	Potential impact	Embedded mitigation	Likelihood	Consequence	Significance
		It is noted that risks associated with driving cannot be fully removed by changes to the Scheme design. This reflects the fact that the cause of most traffic accidents is composite and often includes driver error.			
Heavier rain and wetter winters	In the future heavier rain resulting from climate change will create dangerous driving conditions more often as spray reduces visibility, stopping distances increase and standing water creates an aquaplaning risk.	To inform the design of the Scheme a FRA (application document TR010029/APP/6.6) has been completed along with a detailed Drainage Strategy (application document TR010029/APP/6.8). This describes how the Scheme has ensured drainage will be sufficient for future rainfall. The section of M25 in which the Scheme is located already operates as a Smart Motorway, as defined by the requirements of IAN161. Safety technology covering the area includes: enhanced message signs, advanced matrix indicators, MIDAS Radar & Loops and CCTV (Pan, tilt zoom variety). The Scheme will extend the coverage of the CCTV to the two lane loop road and new slip road. It is noted that risks associated with driving cannot be fully removed by changes to the Scheme design. This reflects the fact that the cause of most traffic accidents is composite and often includes driver error.	**Low** - Following Highways England guidance and in line with the UKCP18 projections and the precautionary principle it is considered that there is medium certainty that rainfall will get heavier over the Scheme's lifetime. Emissions scenario RCP8.5 suggests that a central estimate of mean winter precipitation change is an increase of 0.5 mm by 2071-89. Changes to extreme rainfall are less clear. With embedded mitigation in place the likelihood of this impact is reduced to low.	**Minor adverse** - Accident rates could increase creating more traffic disruption (minor adverse).	**Not significant**
Changes to extreme weather	More frequent storms and high wind events could affect road user safety. High-sided vehicles can	The existing motorway route is not being changed. The alignment does not currently contribute to significant traffic disruption related to wind exposure.	**Very low** – Climate projections show there is very low certainty of how climate change will alter	**Minor adverse** - road traffic accidents and associated traffic disruption (minor adverse).	**Not significant**

Climate trend	Potential impact	Embedded mitigation	Likelihood	Consequence	Significance
	become unstable in gusts of wind over 45mph. Windblown debris, including loads detached from vehicles and third party structures blowing onto the network, as well as fallen trees could also be a hazard to vehicles traveling at speed.	The section of M25 in which the Scheme is located already operates as a Smart Motorway, as defined by the requirements of IAN161. Safety technology covering the area includes: enhanced message signs, advanced matrix indicators, MIDAS Radar & Loops and CCTV (Pan, tilt zoom variety). The Scheme will extend the coverage of the CCTV to the two lane loop road and new slip road. The landscape design will adhere to the Specification for Highways Works set out in Series 3000 (Landscape and Ecology) of the Manual of Contract Documents for Highway Works[43]. Where required, in Appendix 30/6 of the above listed document, root barriers shall be provided at the time of planting, in order to constrain the growth of tree roots. The design will also adhere to DMRB Volume 10 Section 1 – New Roads Planting Vegetation and Soils – Chapter 12.1 of which sets out that shrubs must be not planted within 3 m of the carriageway and trees not within 5 m of it. Risks associated with driving cannot be fully removed by changes to the Scheme design. This reflects the fact that the cause of most traffic accidents is composite and often includes driver error.	extreme weather in the future.		

[43] Manual of Contract Documents for Highway Works (MCHW), 2019, www.standardsforhighways.co.uk/ha/standards/mchw/index.htm

Significant and residual effects

14.2.10.2 No significant adverse vulnerabilities of the Scheme to climate change are identified as being likely to arise and accordingly no adaption measures are required beyond the embedded mitigation identified in Table 14.18 and Table 14.19 .

14.2.11 Cumulative effects

14.2.11.1 Cumulative effects associated with potential operational impacts related to climate change that affect the water environment are considered in the Road Drainage and the Water Environment chapter (Chapter 8) of this ES. Relevant impacts not considered in that chapter, because they would be the same with and without the Scheme, are summarised below:

- Warmer winters in the future will reduce the requirement for road salting. This may have benefits for water quality in the Weald Brook and the Ingrebourne River as road salt can be transported in surface water runoff and, in large quantities, can be harmful to aquatic life.
- Climate change is projected to make summers drier, with occasional heavy convectional rainfall. Water quality in the Weald Brook and the Ingrebourne River may therefore in the future become more vulnerable to impacts from first flush events. This is when long periods of dry weather enable contaminants to build up on road surfaces which then mobilise in surface water runoff following a heavy rainfall event and enter aquatic systems via surface water runoff and drainage infrastructure en-masse. Pollutants in this runoff can be harmful to aquatic life.
- Hotter and drier summer may lower water levels in the Weald Brook and Ingrebourne River. In the future water quality impacts related to surface water drainage discharges to the Weald Brook and the Ingrebourne River could increase as the capability of these watercourses to dilute discharges reduces.

14.2.11.2 Cumulative effects associated with potential operational impacts on air quality from the Scheme traffic emissions could occur. In the future, impacts caused by the Scheme's vehicle emissions will be intensified as hotter summers brought on by climate change will increase the formation of ground-level ozone. A detailed assessment of local air quality impacts associated with the Scheme is provided in the Air Quality chapter (Chapter 5) of this ES. The assessment does not identify any significant adverse effects on air quality arising from the Scheme. It is noted that the modelling upon which this assessment is based does not account for expected climate changes that will intensify air quality impacts in the future (this would be beyond the level of detail required at this stage). However, this may be offset by the predicted increase in electric vehicle usage in the future. The net impact of the Scheme's emissions on air quality receptors following climate change is therefore uncertain but is expected to be minor.

14.2.12 NPS NN compliance

14.2.12.1 Paragraph 4.40 of the NPS NN (Department for Transport, 2014) sets out that "new national networks infrastructure should be typically long-term investments which should remain operational over 'many decades in the face of a changing climate". As per the NPS NN requirement this chapter therefore considers how projected climate changes in the project area (section 14.2.3) could alter the design and operation of the Scheme (section 14.2.9).

14.2.13 Monitoring

14.2.13.1 No significant adverse vulnerabilities of the Scheme to climate change are identified however, it is recommended that monitoring and evaluation of the Scheme's major assets' resilience to climate change be part of regular asset inspections to inform climate change adaptation decision-making in the future.

14.2.14 Summary

14.2.14.1 This sub-section has presented the Schemes climate change vulnerability assessment. The assessment considers impacts of future climatic conditions on the Scheme during both its construction and operation and has been undertaken in compliance with Highways England Guidance.

14.2.14.2 Climate projections from UKCP18 have been examined. They confirm that the study areas climate is expected to change in the future. The assessment finds that the Scheme could be vulnerable to operational impacts linked to these changes in the climate. Mitigation measures built into the design (i.e. embedded mitigation) that either avoids these impacts, minimises them or reduces their consequences are presented. After consideration of this mitigation none of the potential climate vulnerability impacts are found to be significant adverse.

Printed on paper from well-managed forests and other controlled sources.

Registered office Bridge House, 1 Walnut Tree Close, Guildford GU1 4LZ
Highways England Company Limited registered in England and Wales number 09346363