

A47 North Tuddenham to Easton Dualling

Scheme Number: TR010038

Volume 6

6.1 Environmental Statement **Chapter 14 – Climate**

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Forms and Procedure) Regulations 2009

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Infrastructure Planning

Planning Act 2008

**The Infrastructure Planning
(Applications: Prescribed Forms and
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**ENVIRONMENTAL STATEMENT CHAPTER 14
CLIMATE**

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14. Climate

14.1. Introduction

- 14.1.1. Highways England (the Applicant) has submitted an application for an order to grant a development consent order (DCO) for the North Tuddenham to Easton Dualling Scheme (hereafter referred to as ‘the Proposed Scheme’). The Proposed Scheme comprises the dualling of a section of the A47 between North Tuddenham and Easton, including the creation of two grade separated junctions (Wood Lane junction and Norwich Road junction), associated side road alterations and walking, cycling and horse-riding connections. This section of A47 road is currently unable to cope with the high traffic volume and there are limited opportunities to overtake slower moving vehicles on the single carriageway. This section of the A47 also has a poor safety record. The Proposed Scheme aims to reduce congestion related delay, improve safety, improve journey time reliability and increase the overall capacity of the A47. Full details of the Proposed Scheme are provided in Environmental Statement Chapter 2 (The Proposed Scheme) (**TR010038/APP/6.1**).
- 14.1.2. As part of the EIA process, this ES chapter reports the potential significant effects for Climate as a result of the Proposed Scheme. This assessment includes a review of the existing baseline conditions, consideration of the potential impacts and identification of proportionate mitigation. This comprises a review of the existing climate information and identification of the potential climate impacts associated with the Proposed Scheme and also its resilience to climate change.
- 14.1.3. The approach to this assessment follows the Scoping Report (September 2019) (**TR010038/APP/6.5**) and subsequent agreed Scoping Opinion (November 2019) for the Proposed Scheme (**TR010038/APP/6.6**). The approach follows the most up to date Design Manual for Roads and Bridges LA 114 Climate (DMRB LA 114). To align with the requirements of the Infrastructure Planning (Environmental Impact Assessment) Regulations 2017, the National Policy Statement of National Networks (NPS NN) 2014, and DMRB LA 114, this chapter covers two separate aspects:
- **Effects on climate** - impacts on climate from carbon emissions arising from the Proposed Scheme, including whether the Proposed Scheme may affect the ability of the UK Government to meet its carbon reduction targets (in accordance with the NPS NN (Department for Transport, 2014)).
 - **Vulnerability of the Proposed Scheme to climate change** - the ability of the Proposed Scheme to operate as intended despite climate change impacts and associated weather effects, including how the Proposed Scheme will take account of the projected climate change (in accordance with NPS NN and the Infrastructure Planning (EIA) Regulations 2017).

- 14.1.4. The term 'carbon' is used as shorthand to refer to all greenhouse gas (GHG) emissions.
- 14.1.5. The main chapter text is supported by Appendix 14.1 (Embodied Carbon Report) (**TR010038/APP/6.3**), based on the preliminary design of the Proposed Scheme. The appendix contains further details of the carbon assessment as outlined in the Effects on Climate sections of this chapter.

14.2. Competent expert evidence

- 14.2.1. The climate competent expert, with over 20 years' experience, is a Fellow of the Institution of Civil Engineers, a Member of the Chartered Institution of Water and Environmental Management, a Chartered Engineer and a Chartered Environmentalist. They have used their EIA knowledge, experience with infrastructure projects and professional judgement in considering the likely significant impacts associated with the Proposed Scheme and providing technical guidance through the assessment process.

14.3. Legislation and policy framework

- 14.3.1. The legislative and planning context for the assessment of the effects of the Proposed Scheme on climate is outlined below.

National legislation

Climate Change Act 2008

- 14.3.2. The Climate Change Act 2008 is central to the UK Government's plan to reduce carbon emissions, committing the UK to a reduction of 80% against 1990 levels by 2050. On 1 May 2019, the UK Government declared a climate emergency, leading to updating the commitments in the 2008 Act to target net zero carbon emissions by 2050 under the Climate Change Act (2050 Target Amendment) Order 2019.
- 14.3.3. A key provision of the Act with respect to climate change **mitigation** is a requirement for the government to set legally binding carbon budgets limiting the amount of carbon emitted in the UK over a five-year period. These budgets currently cover the period to 2032 and were issued prior to the revision to the 2050 target in the Climate Change Act. At the time of writing the UK Government has yet to set further carbon budgets. The next (sixth) Carbon Budget, as recommended by the Committee on Climate Change on 9th December 2020, is due to be published by June 2021 and will be the first budget to take account of the UK Government's 2050 net zero target.
- 14.3.4. Key provisions of the Act with respect to climate change **adaptation** include:

- a requirement for the government to report, at least every six years, on climate change risks to the UK, and to publish a programme setting out how these will be addressed
- an Adaptation Sub-Committee of the Committee on Climate Change, to both advise and critically review the government's adaptation work.

National policy

National Policy Statement for National Networks (2014)

- 14.3.5. The NPS NN covers delivery of Nationally Significant Infrastructure Projects (NSIPs) and contains a section on climate change **adaptation** (paragraph 4.40) which sets out how the effects of climate change should be considered when developing infrastructure, a section on the assessment of carbon emissions (paragraph 5.17) and a section on climate change **mitigation** of carbon emissions (paragraph 5.19).
- 14.3.6. NPS NN includes relevant guidance, stating that the latest UK climate projections should be used to assess the potential impacts of climate change and to influence **adaptation** measures, covering the estimated lifetime of the new infrastructure. The current UK climate projections, produced by the Met Office, are referred to as UKCP18, which were updated in 2018 from UKCP09.
- 14.3.7. Regarding climate change **mitigation**, the NPS NN notes that carbon emissions should be considered as part of an application for a DCO and assessed against the Government's carbon budgets (paragraph 5.17). It notes that significant emissions would be those that would have a material effect on the ability of the UK Government to meet its carbon reduction targets (paragraph 5.18), although a definition of 'material impact' is not given. It subsequently requires evidence of any mitigation efforts (e.g. use of materials or value engineering) be presented (paragraph 5.19).

The Road to Zero (2018)

- 14.3.8. With a focus on climate change **mitigation**, the Road to Zero strategy (Department for Transport, 2018) outlines plans to enable expansion of infrastructure across the UK, reduce the emissions from vehicles already being driven on the roads and encourage uptake of zero emissions vehicles. The UK Government has since updated its ambitions for the uptake of electric vehicles and have brought forward the date for banning the sale of new petrol, diesel and hybrid cars from 2040 to 2035 (this target date is expected to shortly be brought forward further to 2030).

National Planning Policy Framework (2019)

- 14.3.9. The National Planning Policy Framework (NPPF) sets out the government's planning policies for England and how these are to be applied. NPPF Chapter 14

(‘Meeting the challenge of climate change, flooding and coastal change’), published by the Ministry of Housing, Communities and Local Government (2019), includes the requirement for local authorities to adopt proactive strategies to **mitigate** and **adapt** to climate change. This is in line with the objectives and provisions of the Climate Change Act 2008 and takes into account water supply and demand considerations, flood risk and coastal change.

UK Climate Change Risk Assessment (2017)

14.3.10. Focusing on climate change **adaptation**, the UK Climate Change Risk Assessment (HM Government, 2017), which replaced its predecessor published in 2012, fulfils the Climate Change Act requirement for the government to report on climate change risks to the UK every five years.

14.3.11. The assessment identified six priority areas of risks and opportunities. One of the six priority areas relevant to the Proposed Scheme is *‘Flooding and coastal change risks to communities, business and infrastructure’*.

National Adaptation Programme

14.3.12. The National **Adaptation** Programme (HM Government, 2013) sets out over 370 actions for the UK Government, businesses, councils, civil society and academia to address the findings of the first UK Climate Change Risk Assessment (2012) and to build the nation’s resilience to climate change. The programme addresses the requirement in the Climate Change Act to publish a programme for adaptation to climate change.

14.3.13. The programme contains the following objectives relevant to the Proposed Scheme:

- Objective 1: To work with individuals, communities and organisations to reduce the threat of flooding and coastal erosion, including that resulting from climate change, by understanding the risks of flooding and coastal erosion, working together to put in place long-term plans to manage these risks and making sure that other plans take account of them.
- Objective 7: To ensure infrastructure is located, planned, designed and maintained to be resilient to climate change, including increasingly extreme weather events.
- Objective 9: To better understand the particular vulnerabilities facing local infrastructure from extreme weather and long-term climate change to determine actions to address the risks.

14.3.14. The National **Adaptation** Programme was updated in 2018 (HM Government, 2018), as well as building on the first programme this sets out the strategy until 2023 focusing on actions to address the most urgent risks from the second UK Climate Change Risk Assessment (2017). Key actions include:

- Flooding and coastal change risks to communities, businesses and infrastructure:
 - Making sure that decisions on land use, including development, reflect the level of current and future flood risk
 - Boosting the long-term resilience of our homes, businesses and infrastructure
 - Including flood risk as a key feature of adaptation reporting from infrastructure reporting organisations.
- Risks to health, well-being and productivity from high temperatures
 - Working with infrastructure operators included in the third cycle of adaptation reporting to outline risks posed to their productivity from climate impacts.

Local policy

14.3.15. The Joint Core Strategy for Broadland, Norwich and South Norfolk, adopted in January 2014, outlines the objectives for growth in the region with respect to the economy, housing and infrastructure until 2026.

14.3.16. The strategy contains the following climate change objectives and policies relevant to the Proposed Scheme:

- Spatial Planning Objective 1: To minimise the contributors to climate change and address its impact.
- Area-wide Policy 1: Addressing climate change and protecting environmental assets, specifically:
 - To address climate change and promote sustainability, all development will be located and designed to use resources efficiently, minimise greenhouse gas emissions and be adapted to a changing climate and more extreme weather.

Highways England requirements

Highways England Licence

14.3.17. The Highways England Licence (Department for Transport, 2015) states that, in complying with Section 4.2(g) and its general duty under Section 5(2) of the Infrastructure Act 2015 to have regard for the environment, the Licence holder should:

- (e) *“Calculate and consider the carbon impact of road projects and factor carbon into design decisions, and seek to minimise carbon emissions and other greenhouse gases from its operations [mitigation];*

- (f) *Adapt its network to operate in a changing climate, including assessing, managing, and mitigating the potential risks posed by climate change to the operation, maintenance and improvement of the network [adaptation];*
- (g) *Develop approaches to the construction, maintenance and operation of the Licence holder's network that are consistent with the government's plans for a low carbon future;*
- (h) *Take opportunities to influence road users to reduce the greenhouse gas emissions from their journey choices.”*

Industry Guidance

DMRB LA 114 Climate

14.3.18. The DMRB standard for Climate, LA 114 (Revision 0), sets out the requirements for assessing and reporting the vulnerability of a proposed scheme to climate change (**adaptation**) and the effect on climate of greenhouse gas emissions (**mitigation**) from construction, operation and maintenance of projects. DMRB LA 114 details how to scope, assess and monitor both carbon emissions reduction and resilience assessments as well as outlining the principles and purpose of both assessments. It also states significant effects shall only be identified where emissions will have a 'material impact' on the UK Government meeting its carbon reduction target.

DMRB GG 103 Introduction and general requirements for sustainable development and design

14.3.19. The DMRB standard for sustainable development and design (GG 103) outlines the general requirements for sustainable development and design to be aligned with designing motorways and all-purpose trunk roads. The standard details the goals of sustainable development and the principles of good road design, as well as outlining the importance of legal, environmental, economic, social and cultural factors in sustainable development and design as well as how to address the opportunities and risks.

14.4. Assessment methodology

14.4.1. This section describes the methodology used for the assessment of climate which may affect, or be affected by, the construction and operation of the Proposed Scheme.

Update to guidance and scope of assessment

14.4.2. Following a review of the updates to DMRB LA 114, introduced in 2019, the scope presented in the Scoping Report for the Proposed Scheme (2019) (**TR010038/APP/6.5**) is still valid and no change is required.

Consultation

14.4.3. No additional consultation specific to climate has been required beyond the Scoping Opinion (2019) (**TR010038/APP/6.6**) and Preliminary Environmental Information Report (2020) for the Proposed Scheme.

Assessment criteria

Effects on Climate

14.4.4. The EIA Directive (2014 / 52 / EU) and subsequent updates to UK EIA regulations includes a requirement to assess the impacts of projects on climate and their vulnerability to climate change.

14.4.5. The Climate Change Act (2050 Target Amendment) Order 2019 sets legally binding targets for reducing the UK's carbon emissions to net zero by 2050.

14.4.6. A key provision of the UK Climate Change Act (2050 Target Amendment) Order 2019 is a requirement for the government to set legally binding carbon budgets limiting the amount of carbon emitted in the UK over a five-year period.

14.4.7. There is currently no definitive EIA guidance on the assessment of significance based on quantified carbon emissions. However, DMRB LA 114 (paragraph 3.20) states "*The assessment of projects on climate shall only report significant effects where increases in [carbon] emissions will have a material impact on the ability of Government to meet its carbon reduction targets.*"

14.4.8. Assessors are required to determine whether the carbon emissions resulting from a scheme are likely to materially affect the UK in reaching the carbon budgets outlined in Table 14-1. These carbon budgets predate the Paris Agreement and at the time of writing do not consider the Climate Change Act (2050 Target Amendment) Order 2019. However, it is expected that the sixth carbon budget, and all subsequent carbon budgets, will accommodate both the Paris Agreement as well as the UK Government's commitment to net zero carbon emissions by 2050.

Table 14-1: UK carbon budgets and scheme appraisal period

Budget & Period	Carbon Limit	Reduction below 1990 levels	Scheme Appraisal Period
Third (2018 to 2022)	2,544MtCO ₂ e	37% by 2020	2025 to 2085
Fourth (2023 to 2027)	1,950MtCO ₂ e	50% by 2025	

Budget & Period	Carbon Limit	Reduction below 1990 levels	Scheme Appraisal Period
Fifth (2028 to 2032)	1,725MtCO ₂ e	57% by 2030	
Sixth to 16 th (2033 to 2087) ¹	Not yet set	Towards net zero	

14.4.9. The assessment of the effects of the Proposed Scheme on climate has included:

- Estimation of the carbon emissions associated with the Proposed Scheme construction using the Highways England Carbon Tool v2.3.
- Estimation of the carbon emissions associated with the Proposed Scheme operational energy, principally lighting, using the Highways England Carbon Tool v2.3.
- Estimation of the end user (vehicle) carbon emissions associated with the Proposed Scheme.
- Comparison between estimated carbon emissions arising from the Proposed Scheme and UK carbon budgets.
- Opportunities for mitigation in the Proposed Scheme design.

Vulnerability of the Proposed Scheme to climate change

14.4.10. The Proposed Scheme may be subject to weather extremes (as opposed to extreme weather events) during construction. However, it is not anticipated that verifiable climate change will occur between the time of design assessment and the end of the construction period (approximately 23 months). Construction works are therefore not considered to be vulnerable to climate change, thus no associated mitigation, other than what will be reasonable site practice (e.g. reviewing weather conditions before commencing work, providing appropriate Personal Protective Equipment, provision of shade and water on site etc) at the time of design finalisation, is considered to be necessary.

14.4.11. A qualitative methodology for assessing the vulnerability of Proposed Scheme assets to climate change during operation has been produced in line with DMRB LA 114. The methodology includes the following steps:

- Impacts (hazards and opportunities) for each scheme asset (e.g. highways, pavements, structures, as outlined in Table 14-11) have been identified using Met Office climate projection data. The vulnerability of the Proposed Scheme to both normal weather and extreme weather-related disaster scenarios throughout the project lifecycle have been identified and reported.
- Following identification of climate change impacts (hazards and benefits), a risk assessment of those impacts on the Proposed Scheme has been

¹ It is noted that the Committee on Climate Change released its recommendation for the Sixth Carbon Budget on the 9th December 2020. However, this recommendation is not yet implemented as law. It is anticipated that the Government will set the Sixth carbon Budget in law by the end of June 2021.

undertaken using the following framework outlined in Table 14-2 (likelihood categories) and Table 14-3 (measure of consequence).

- Significance of effects has been reported using Table 14-4 (significance matrix).

Table 14-2: Likelihood categories

Likelihood category	Description (probability and frequency of occurrence)
Very high	The event occurs multiple times during the lifetime of the Proposed Scheme (60 years) for example approximately annually, typically 60 events.
High	The event occurs several times during the lifetime of the Proposed Scheme (60 years) for example approximately once every five years, typically 12 events.
Medium	The event occurs limited times during the lifetime of the Proposed Scheme (60 years) for example approximately once every 15 years, typically four events.
Low	The event occurs during the lifetime of the Proposed Scheme (60 years) for example once in 60 years.
Very low	The event may occur once during the lifetime of the Proposed Scheme (60 years).

Notes: Proposed Scheme lifetime is considered to include construction and operational stages. The Proposed Scheme appraisal period is taken to be 60 years or above in line with the WebTAG GHG Assessment and DMRB LA 114.

Table 14-3: Measure of consequence

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

Table 14-4: Significance matrix

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

Notes: NS = Not significant, S = Significant

14.5. Assumptions and limitations

Effects on Climate

- 14.5.1. The Highways England Carbon Tool (v2.3) estimates carbon emissions associated with plant processes using direct fuel usage entered by the contractor during the construction stage. Due to uncertainty regarding construction fuel use at this stage, plant emissions have only been included for site clearance, earthworks and drainage. Usage of plant fuel to calculate plant carbon emissions for all items will be confirmed at the detailed design stage.
- 14.5.2. Maintenance, for both baseline and future carbon estimate, has been excluded from this assessment as it is not considered likely to materially affect the baseline calculations and is therefore not anticipated to alter the outcome of this assessment. However, this will be included within the carbon estimate for the Scheme at the detailed design stage.
- 14.5.3. Traffic data forecasts are based on multiple assumptions in accordance with DMRB requirements and therefore the carbon emissions associated with vehicular end-users are estimates and subject to change due to changing behaviours of those using the road into the future.
- 14.5.4. Based on conversations with the Design Team, lighting operating hours have been assumed to be 4,080 hours per year with an estimated load of 13.5kW.
- 14.5.5. The UK climate policy landscape and the associated approach to gauging climate significance in EIA is evolving, with uncertainty as to how increases in emissions such as those from the Proposed Scheme may be compatible with recently introduced national net zero targets. There are also currently no quantitative criteria for determining the (EIA) significance of carbon emissions. However, DMRB LA 114 (paragraph 3.20) states “*The assessment of projects on climate shall only report significant effects where increases in [carbon] emissions will have a material impact on the ability of Government to meet its carbon reduction targets.*” This chapter follows DMRB LA 114, whereby predicted increases in emissions have been compared with published carbon budgets, which at the moment can be undertaken up to and including the end of the fifth carbon budget (2032).

Vulnerability of the Proposed Scheme to climate change

- 14.5.6. Climate projections are not predictions or forecasts but simulations of potential scenarios of future climate, under a range of hypothetical emissions scenarios and assumptions. Climate modelling results cannot be treated as exact or factual, but projection options, and their reliability differs between climate variables. Generally, global projections are more certain than regional, and

temperature projections are more certain than those for precipitation. Furthermore, the degree of uncertainty associated with all climate change projections increases for projections further into the future.

14.6. Study area

Effects on Climate

- 14.6.1. The assessment of effects on climate considers the extent to which carbon emissions resulting from the Proposed Scheme may impact the global climate and contribute towards climate change.
- 14.6.2. The study area considered for the **construction** phase comprises the physical infrastructure assets associated with Proposed Scheme and therefore includes the embodied carbon of Proposed Scheme materials and emissions associated with construction activities. These are defined in terms of lifecycle stages, detailed in Section 7 of Publicly Available Specification (PAS) 2080:2016, Carbon Management in Infrastructure, as follows:
- Products and materials (A1-3) - use of materials for temporary and permanent construction activities
 - Transport to works site (A4) – the transportation of materials to the Proposed Scheme site, e.g. by HGV
 - Construction and installation processes (A5) - construction plant use
- 14.6.3. The study area to be considered for the **operational** phase includes the operational energy requirements of the Proposed Scheme (i.e. road lighting), and the Affected Road Network (ARN) for road user carbon (vehicle emissions). These elements are also defined in terms of life cycle stages, as detailed in Section 7 of PAS 2080:2016 as follows:
- Operational energy use (B6) - operational lighting emissions
 - User utilisation of infrastructure (B9) – end user traffic emissions
- 14.6.4. In accordance with DMRB LA 114, this is summarised in Table 14-5 below.

Table 14-5: Sources and lifecycles stages for project carbon emissions

Main stage of project life cycle	Sub-stage of life cycle	Potential sources of GHG emissions (not exhaustive)	Examples of activity data
Construction stage	Products and materials (A1-3)	Use of materials for temporary and permanent construction activities	Material quantities
	Transport to works site (A4)	The transportation of materials to the Proposed Scheme site, e.g. by HGV	Assumed distances of materials from suppliers to site

Main stage of project life cycle	Sub-stage of life cycle	Potential sources of GHG emissions (not exhaustive)	Examples of activity data
	Construction and installation processes (A5)	Construction plant use	Fuel/electricity consumption of machinery
Operation stage (to extend 60 years in line with appraisal period)	Operational energy use (B6)	Lighting emissions	Lighting energy in kWh
	User utilisation of infrastructure (B9)	Vehicles using the infrastructure	Traffic data by vehicle type

Vulnerability of the Proposed Scheme to climate change

- 14.6.5. For the purposes of the climate change vulnerability assessment, the study area is considered to be the physical infrastructure assets associated with the Proposed Scheme. The Proposed Scheme appraisal period is taken to be 60 years or above in line with the WebTAG GHG Assessment and DMRB LA 114 (Climate).
- 14.6.6. The vulnerability assessment considers climate change effects on the Proposed Scheme assets such as pavements, drainage and geotechnical (e.g. earthworks, piles, etc) receptors. A list of receptors considered in this assessment, whilst not exhaustive, is included in Table 14-11.
- 14.6.7. To establish a climate baseline and future climate projections, the latest Met Office regional climate data pertinent to the Proposed Scheme area has been used (i.e. UKCP18 for the Eastern England region) (Met Office, 2016 and 2018).

14.7. Baseline conditions

Effects on Climate

- 14.7.1. The carbon baseline has been taken as the current situation in which no proposed additional infrastructure is built, considering existing travel and traffic patterns. Potential impacts from emissions associated with the construction and operation of the road infrastructure has been assessed against this baseline.

Existing scheme emissions

- 14.7.2. The baseline against which the Proposed Scheme has been compared with is the Do-Minimum scenario, the future baseline without the Proposed Scheme in place. In the Do-Minimum scenario, typical carbon emission sources include maintenance works (e.g. the embodied carbon of materials used for resurfacing), operational energy (e.g. lighting) and end-user emissions (i.e. emissions from vehicles using the road). However, maintenance has been excluded at this stage it is unlikely to materially affect baseline conditions. This will be included within the detailed design stage carbon calculations.

- 14.7.3. Baseline end-user carbon emissions have been estimated based on outputs from an appropriate validated traffic model for the existing road and wider network, collectively referred to as the ARN. These comprise emissions from the ARN over three key years: base year (2015), opening year (2025) and design year (2040).
- 14.7.4. Design year emissions have been extrapolated to provide a baseline estimate for the 60-year appraisal period. These emissions are summarised in Table 14-6, in which the effect of a predicted increase in electric vehicles can be seen to result in a reduction in vehicular emissions in this baseline scenario.

Table 14-6: Affected road network baseline emissions (Do-Minimum Scenario)

Year	End-user emissions (tCO ₂ e)
Baseline (2015)	1,095,563
Opening Year (2025)	954,647
Design Year (2040)	875,102
Whole Appraisal Period (60 years - cumulative)	53,142,467

Vulnerability of the Proposed Scheme to climate change

- 14.7.5. As per DMRB LA 114, a current climate baseline for the wider region has been compiled using Met Office (2016) historical regional climate data. High-level climate observations over a 30-year averaging period (1981 to 2010) are presented in Table 14-7 for Eastern England, which comprises the counties of Bedfordshire, Cambridgeshire, Norfolk, Suffolk, Lincolnshire, the East Riding of Yorkshire and parts of Essex and Hertfordshire. This information has been used by the Design Team as a baseline against which to determine the potential vulnerability of the proposed scheme when subjected to the climate change projected by the Met office (see below).

Table 14-7: Climate baseline for Eastern England (1981 to 2010)

Climate variables	Climate observations
Temperature	Mean daily minimum temperatures can range from 0°C to 2°C in winter, whilst summer daily maximum temperatures are in the region of 22°C.
Rainfall	Eastern England includes some of the driest areas in the country, with the majority of the region receiving less than 700mm of rainfall annually, distributed fairly evenly throughout the year. On average, the region experiences approximately 30 rain days during the winter months (December to February) and under 25 days during the summer period (June to August). Despite generally low levels of precipitation, the area has encountered a number of severe storms which can contribute significantly to total annual rainfall and may also result in the occurrence of hail.
Wind	Eastern England is one of the more sheltered parts of the UK, however the winter months are when the strongest winds are experienced. Wind direction is fairly consistent across the region; speeds are generally greater in coastal locations than inland, and gusts exceeding 167 km/h have been recorded

Climate variables	Climate observations
	in East Anglia. The frequency of tornadoes is greatest in Eastern England relative to other parts of the UK, nevertheless, the intensity of these events remains minor.
Sunshine	Average annual sunshine in the wider region ranges from approximately 1,450 hours over Lincolnshire and East Yorkshire, to over 1,600 hours in east Norfolk, Suffolk and Essex.
Air Frost	The average number of days with air frost ranges from less than 30 (coastal) to 55 (inland) per year.

Source: Met Office (2016) Regional Climate Data

Climate Projections

14.7.6. The UK Climate Projections (UKCP18) provide regional climate projection information, within the East of England Administrative Region (within which the Proposed Scheme is located). The East of England region is predicted to experience changes in temperature, rainfall, and increase in frequency of extreme weather events as consequence of climate change. These changes are predicted to occur under all emissions scenarios (i.e. low, medium and high levels of GHG emissions), which are incorporated into the climate change models used by the Inter-governmental Panel on Climate Change (IPCC). The general trend for the region is warmer, drier summers and milder, wetter winters.

14.7.7. Under the highest emissions scenario (RCP8.5) for the 2080s (2080 to 2099), estimated changes in climatic conditions are as outlined in Table 14-8.

Table 14-8: Future climate projection data for East of England (2080s; RCP8.5)

Climate variables	Climate projections
Temperature	The average summer temperature is projected to increase by 6-7°C under the central estimate, which represents 'as likely as not' probability of change (50th percentile), and average winter temperature is estimated to increase by 3-4°C (50th percentile).
Rainfall	The average summer rainfall rate is projected to decrease by 30-40%, whereas the average winter rainfall rate is estimated to increase by 20-30% (in the 50th percentile or central estimate for both).
Wind	Climate projections for wind are more uncertain than those for temperature and precipitation, due to inherent difficulty in modelling future wind conditions. However, overall an increase in extreme weather including wind is projected (Committee on Climate Change, 2017).

Source: UKCP18 UK Climate Projections

14.7.8. Climate projection data corresponding to the 2080s (2070 to 2099) under a high emissions scenario has been selected in line with NPS NN (2014) paragraph 4.41, which states:

“Where transport infrastructure has safety-critical elements and the design life of the asset is 60 years or greater, the applicant should apply the UK Climate Projections 2009 (UKCP09) high emissions scenario (high impact, low likelihood) against the 2080 projections at the 50% probability level.”

- 14.7.9. Since 2014, when the NPS NN was written, the UKCP09 projections referred to in the above statement have been updated to UKCP18 projections (published November 2018). The most recent projections (UKCP18) have been used in this assessment (as outlined in Table 14-8).

14.8. Potential impacts

Effects on climate

- 14.8.1. The following sub-section presents the results of the carbon emissions assessment associated with Proposed Scheme in accordance with DMRB LA 114 and NPS NN (2014) (paragraph 5.18).

Construction

- 14.8.2. The proposed construction duration for the Proposed Scheme is anticipated to be approximately 23 months. Embodied carbon emissions from construction materials are the main contributor to climate change, with additional emissions arising from the direct use of plant and transport of materials.
- 14.8.3. A carbon assessment using the Highways England Carbon Tool (v2.3) has estimated emissions of approximately **87,727 tCO₂e** in association with Proposed Scheme construction. Further information on the derivation of this value is contained within Appendix 14.1 (Carbon Assessment Report) (**TR010038/APP/6.3**).

Operation

- 14.8.4. The Highways England Carbon Tool (v 2.3 published in 2019) predicts emissions associated with operational energy for the Proposed Scheme to be approximately 13 tCO₂e per annum, based on the annual kWh electricity demand of lighting columns, i.e. **780 tCO₂e** over the 60-year appraisal period.
- 14.8.5. For end user traffic emissions, a comparison of Do-Minimum (without the Proposed Scheme) and Do-Something (with the Proposed Scheme in place) scenarios has been undertaken based on the Proposed Scheme opening year (2025) and design year (2040). The estimated Do-Minimum emissions total over the 60-year appraisal period is 53,142,467 tCO₂e, the corresponding Do-Something emissions total is 53,650,750 tCO₂e. Therefore the total increase in vehicle carbon emissions associated with the Proposed Scheme (comparison of Do-Minimum and Do-Something scenarios) over the 60-year appraisal period (2025 to 2085) is estimated to be **508,283 tCO₂e**.

Summary

- 14.8.6. Construction and operational emissions associated with the Proposed Scheme have been presented against UK carbon budgets, as set out in Table 14-9 below in accordance with DMRB LA 114. As construction is not planned to start until 2023, the third carbon budget (accounting for 2018-2022) is not relevant for the Proposed Scheme. Existing carbon budgets (one to five) predate the net zero carbon target (by 2050) legislated in 2019 and do not accommodate increases in transportation infrastructure emissions.
- 14.8.7. The net change in emissions has been calculated by comparing the baseline (Do Minimum) emissions with those predicted to result from the Proposed Scheme (Do-Something).

Table 14-9: Proposed Scheme carbon emissions against relevant carbon budgets (LA 114)

Project Stage	Estimated total carbon over carbon budget (tCO ₂ e) ('Do something' Scenario)*	Net CO ₂ project GHG emissions (tCO ₂ e) (Do something – Do minimum)*	Relevant carbon budget	
Construction	87,727	+87,727	Fourth (2023 to 2027) 1,950 MtCO ₂ e	Fifth (2028 to 2032) 1,725 MtCO ₂ e
Operation	7,553,285	+64,594		
Total	7,641,012	+152,321		

* Totals over the fourth and fifth carbon budget periods (2025-2032)

- 14.8.8. The increase in carbon emissions resulting from the Proposed Scheme represents up to approximately 0.004% of the UK's Fourth and Fifth carbon budgets over their respective periods.
- 14.8.9. Table 14-10 below provides further context to the above results by including the change in emissions against each carbon budget period.

Table 14-10: Proposed Scheme carbon emissions against relevant carbon budgets (detailed)

Project Stage	Carbon emissions distributed per relevant carbon budget (tCO ₂ e)			Estimated total emissions over 60-year appraisal period (tCO ₂ e)
	Fourth (2023 to 2027)	Fifth (2028 to 2032)	Beyond last set carbon budget (2033 onwards)	
Baseline (DM)	2,848,032	4,640,659	45,653,776	53,142,467
Construction (DS)	87,727	-	-	87,727
Operation (DS)	2,871,931	4,681,354	46,098,245	53,651,530

Project Stage	Carbon emissions distributed per relevant carbon budget (tCO _{2e})			Estimated total emissions over 60-year appraisal period (tCO _{2e})
	Fourth (2023 to 2027)	Fifth (2028 to 2032)	Beyond last set carbon budget (2033 onwards)	
Total (DS)	2,959,658	4,681,354	46,098,245	53,739,257
Difference (DS-DM)	+111,626	+40,695	+444,469	+596,790

Note: The construction carbon value is representative of the Highways England Carbon Tool assessment. The operational carbon value is representative of estimated operational energy plus estimated user utilisation emissions for the ARN over the 60-year appraisal period. DM = Do Minimum, DS = Do Something

14.8.10. Comparison between the increase in Proposed Scheme emissions and published UK carbon budgets, following DMRB LA 114 guidance on gauging significance, can be undertaken for approximately 26% of the emissions increase resulting from the Proposed Scheme. The remaining increase in carbon emissions is predicted to occur after 2032 (the end of the last currently published UK carbon budget).

Vulnerability of the Proposed Scheme to climate change

- 14.8.11. The Proposed Scheme’s vulnerability to climate change during construction and operation has been assessed through consideration of projected climate changes.
- 14.8.12. The vulnerability of Proposed Scheme assets (e.g. highways, pavement, structures) to projected climate changes (Table 14-8) was assessed through consultation with the Design Team. Table 14-11 lists the key climate change effects that could occur to various scheme assets, with corresponding likelihoods, significance and whether specific mitigation is required. This list was provided to design teams for them to use their respective knowledge and expertise in assessing the vulnerability of the Proposed Scheme. Design Team was also requested to consider any other potential effects beyond those listed in Table 14-11, although no further such effects were identified.
- 14.8.13. Particular attention was paid to the potential vulnerability of Proposed Scheme drainage systems; however it was concluded that there are no significant effects and no increased risks caused by the climate projections. The current drainage design has been designed to a 1 in 100-year storm event which includes a 20% climate change allowance to allow for changes in peak rainfall intensity. The sensitivity of the design has been checked with a 40% increase in peak rainfall intensity due to climate change, in line with the Environment Agency’s upper estimates for the 2080s. In addition, existing surface water flood flow pathways (caused by rainfall) will be maintained to allow natural overland drainage through the construction of ‘dry culverts’ designed to 1 in 100-year plus 65% climate change allowance, and new culverts and the River Tud crossing are to be

designed to 1 in 100-year flow including an additional 65 % climate change allowance, including headroom, in order to convey the required flow and consider fluvial flood risk impacts.

Table 14-11: Vulnerability of Proposed Scheme assets to climate change – Summary of Effects and Mitigation

Asset	Life cycle asset aspect	Potential effect description	Likelihood category	Consequence of impact	Significance	Mitigation measures
Pavements	Foundation	Increases in winter precipitation result in increased sub-surface moisture content, decreasing foundation strength.	Very low	Large adverse	Not Significant	N/A
		Changes in moisture content as a result of decreases in summer rainfall combined with increases in winter rainfall cause soil to expand and shrink, causing pavement layers to heave.	Very low	Moderate adverse	Not Significant	N/A
		Increased rainfall saturates the road sub-base or other structural granular materials, causing loss of fine material and settlement and subsequent premature pavement failure.	Very low	Moderate adverse	Not Significant	N/A
	Surface	Increased summer temperatures result in surface failure, e.g. warping of slabs, excessive movement at joints and difficulty in maintaining asphalt surface profile during compaction.	Low	Minor adverse	Not Significant	N/A
		Increases in winter precipitation result in a build-up of particulates in the road surface, which compromises the surface's skid resistance as skid resistance decreases in flooded areas.	Medium	Minor adverse	Not Significant	N/A
Structures (e.g. gantries, overbridges)	Above Ground Structures	Increased temperatures result in joint and bearing failure.	Very low	Large adverse	Not Significant	N/A
		Increases in precipitation results in increased deterioration rates for joints and surfacing, requiring more frequent replacement and traffic disruption.	Low	Moderate adverse	Not Significant	N/A
		Increased winter precipitation results in increased groundwater levels, causing ground movements and soil settlement.	Very low	Moderate adverse	Not Significant	N/A
		Increased precipitation results in flooding and scouring around foundations.	Very low	Moderate adverse	Not Significant	N/A
		Increases in temperature and more variable precipitation result in increased frequency of maintenance painting of structural steelwork.	Low	Minor adverse	Not Significant	N/A
		Increases in wind speed and frequency of extreme wind events results in the failure of lighter structures by overturning.	Very low	Large adverse	Not Significant	N/A

Asset	Life cycle asset aspect	Potential effect description	Likelihood category	Consequence of impact	Significance	Mitigation measures
	Foundations and substructure	Increased winter precipitation results in increased groundwater levels causing ground movements and soil settlement.	Very low	Moderate adverse	Not Significant	N/A
		Increased precipitation results in flooding and scouring around foundations.	Very low	Moderate adverse	Not Significant	N/A
Drainage	Drainage System	Increases in winter precipitation result in increased flood risk and the need for attenuation.	Medium	Minor Disruption	Not Significant	N/A
Geotechnics	Earthworks	Increased precipitation results in increased risk to the earthworks stability.	Low	Moderate adverse	Not Significant	N/A
		Reductions in summer precipitation and increases in temperature would reduce soil moisture, which demands a greater effort for compaction of soils.	Very Low	Moderate adverse	Not Significant	N/A
Signs and Signals	Advance Direction Sign (ADS)	Increased wind speeds and frequency of extreme wind events affect the stability of ADSs, which have a design life of 15 years (Highways England, 2011).	Very Low	Moderate adverse	Not Significant	N/A
	Road Markings	Increases in precipitation and temperature affect road markings.	Low	Minor adverse	Not Significant	N/A
Walking, cycling and horse-riding (WCH) Facilities	Underpasses	Increased precipitation results in flooding of underpasses, deterring WCHs from their journey.	Medium	Minor adverse	Not Significant	N/A
	WCH Routes	Increases in temperature and reductions in summer rainfall encourage a greater number of WCHs to use WCH facilities.	Medium	Beneficial – N/A	N/A	N/A
		Increases in winter rainfall and frequency of extreme wind events discourage WCHs from undertaking journeys using WCH facilities.	Low	Minor adverse	Not Significant	N/A
Vehicle Restraint Systems	Safety Barriers	More frequent extreme weather events and changes in temperature and precipitation result in an increased rate of deterioration of vehicle restraint systems.	Low	Moderate adverse	Not Significant	N/A

14.9. Design interventions and mitigation

Effects on climate

- 14.9.1. In accordance with the DMRB LA 114, projects shall seek to minimise carbon emissions as far as possible in all cases in order to contribute to the UK's net reduction in carbon emissions.
- 14.9.2. An assessment using the Highways England Carbon Tool (v2.3) has been carried out as part of the development of the Proposed Scheme. This has ensured that carbon has been considered throughout the design process, resulting in the development of a carbon baseline. This provides a baseline from which further reductions will be made.
- 14.9.3. A hierarchical approach to carbon management has been applied to the Proposed Scheme, i.e. build nothing, build less, build clever, build efficiently, as is described in PAS 2080. Throughout the design of the project, opportunities for carbon reduction have been considered.
- 14.9.4. Reductions in carbon emissions have already been made through this design process, including the following:
- Efficiencies associated with road surfacing, where select locations may need a surface course replacement only, as opposed to a full replacement of all layers of pavement. Locations identified for surface course replacement were the existing A47 north of Honingham and the existing A47 between St Andrew's Church and Taverham Road. The total length identified was 1650m which results in approximate savings of 226 tCO₂e.
 - Removal of one kilometre of earthworks at the most westerly point of the Proposed Scheme which has resulted in savings of general fill and topsoil. Depending on whether this material would have been site won or imported fill would see carbon savings of between 64 tCO₂e (site won) and 934 tCO₂e (imported fill). An assessment of updated earthworks volumes will be included in the final design which will inform the earthworks balance and will give confirmation to whether site won or imported material savings have been realised.
 - A design change on the Easton footbridge due to safety concerns. This meant the proposal went from a steel warren truss spanning 36m over the A47 with steel approach ramps to the north and south to tie in with the walking and cycling route design, to a composite steel girder footbridge integral with reinforced concrete bankseat abutments supported on reinforced earth embankments. This change has resulted in carbon savings of 36tCO₂e.

- 14.9.5. The future design phases and subsequent construction of the scheme will aim to further reduce and minimise carbon emissions associated with construction, as far as possible. In this regard, an integrated and holistic approach to assessing carbon emissions associated with the scheme will be delivered. The largest carbon areas of the Proposed Scheme include earthworks, pavement and drainage elements. These areas have been communicated with the Design Team to ensure efficiencies can be made before the Proposed Scheme reaches Stage 5.
- 14.9.6. Opportunities for reducing carbon during the construction phase will be considered at each key design stage (PCF Stage 4, PCF Stage 5 and PCF Stage 6), reviewing the baseline provided within this chapter and the reductions that have and will be made. Specific measures that will be further developed at these subsequent stages include:
- Optimise re-use of existing site won and recycled materials thereby minimising as far as possible the use of primary aggregates and other off-site sourced construction materials. This will be done pursuant to WRAP protocols, UK Government initiatives and other applicable standards and guidance for the use of recycled and secondary aggregates and bituminous materials (e.g. BS EN 1308 and PD6691).
 - Develop a comprehensive and holistic materials management plan that allows for optimised re-use of site won earthworks materials and thereby minimising earthworks import. This will involve the processing and stabilisation of soils to minimise mass haul and may include the use of recycled tyre bales to facilitate core earthworks construction pursuant to PAS108 standards and current UK construction best practice.
 - Undertake an appropriate intrusive pavement survey (expected Spring 2021) and engagement with supply chain and by implementing industry best practice seek to optimise pavement construction for both the mainline and offline works. With appropriate recycling and reuse of existing pavement and optimised design for both reconstructed and new highway, the overall volume of pavement construction may be lowered, with concomitant reduction in importation and movement of materials and associated construction activity.
 - Use innovative applications to reduce the carbon emissions associated with construction compounds and support facilities. Considering options such as EcoSmart Welfare cabins which harness green energy (Solar and hydrogen cells) avoiding the use of conventional on-site power sources (diesel generators).

- 14.9.7. Although beyond the direct control of the design and construction of the Proposed Scheme, it is expected that the recent UK government announcement on ending the sale of new petrol and diesel vehicles by 2030 will further reduce the Proposed Scheme's end use carbon emissions.
- 14.9.8. Monitoring and reporting on carbon emissions associated with energy and fuel use during the construction process is stipulated as a requirement and this has been included in the Environmental Management Plan (EMP) (TR010038/APP/7.4).

Vulnerability of the Proposed Scheme to climate change

- 14.9.9. During the design stage, the Design Team were briefed on projected climate changes (Table 14-8) to ensure that the Proposed Scheme would be accordingly resilient.
- 14.9.10. The potential vulnerability of Proposed Scheme assets to climate change have been assessed through iterative consultation between the Design Team and the Climate Change Coordinator. Specific assets assessed are shown in Table 14-11 with design considerations detailed within the individual topic chapters (e.g. ES Chapter 13 Road drainage and the water environment), although it is noted that no aspect of the Proposed Scheme is considered to be vulnerable to projected climate change over the appraisal period.

14.10. Assessment of likely significant effects

- 14.10.1. The increase in carbon emissions resulting from the Proposed Scheme can be quantitatively compared with published UK carbon budgets (26% to 2032) as is required by DMRB LA 114 . The remaining 74% of the increase in emissions has no carbon budget for comparison. Future carbon budgets are expected to include less emissions across all sectors, working towards the goal of net zero carbon emissions by 2050.
- 14.10.2. In accordance with DMRB LA 114, this has not precluded efforts to minimise carbon throughout the design and construction of the Proposed Scheme, with regular recalculation of carbon emissions and ongoing review of further opportunities to minimise them. The recent UK government announcement on ending the sales of new petrol and diesel vehicles by 2030 will further reduce the Proposed Scheme's end user carbon emissions.
- 14.10.3. In the context of the vulnerability of the Proposed Scheme to climate change, projected climate change is not anticipated to have a significant effect.

14.11. Monitoring

Effects on climate

14.11.1. The Proposed Scheme will result in an increase in carbon emissions. Monitoring of emissions associated with the construction of the Proposed Scheme will be undertaken as per Highways England requirements to meet their key performance indicator “Carbon dioxide equivalents (or CO₂e) in tonnes associated with the Supply Chain’s activities” (Highways England 2019).

Vulnerability of the Proposed Scheme to climate change

14.11.2. No significant adverse effects as a result of climate have been identified therefore no monitoring is required. However, it is noted that climate change projections are likely to change within the appraisal period of the Proposed Scheme, therefore the vulnerability of the Proposed Scheme to such changes should be reviewed when updated projections become available.

14.12. Summary

14.12.1. This assessment has considered the Proposed Scheme’s effect on climate (i.e. increases in carbon emissions) as well as the potential vulnerability of the Proposed Scheme to climate change (i.e. the resilience of Proposed Scheme assets to projected changes in climate).

14.12.2. In accordance with DMRB LA 114, carbon emissions associated with the Proposed Scheme have been provided in the context of published UK carbon budgets. These budgets currently extend until 2032 and can be compared with 26% of the emissions increase associated with the Proposed Scheme. The remaining 74% of the increase in carbon emissions will occur after 2032 (the end of the last currently published UK carbon budget).

14.12.3. Efforts to minimise carbon emissions throughout the design and construction of the Proposed Scheme at this stage are outlined in accordance with requirements set out in DMRB LA 114. Recommendations to further reduce carbon emissions through design considerations and recalculation of carbon emissions at later stages of the design process have also been made.

14.12.4. The vulnerability of Proposed Scheme assets to projected changes in climate during operation has been assessed, and the Proposed Scheme has been deemed resilient to the current projections. Therefore, no significant effects as a result of climate change are anticipated however this should be reviewed at an appropriate stage once updated projections are published.

14.13. References

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14.14. Glossary

ARN	Affected Road Network
DMRB	Design Manual for Roads and Bridges
GHG	Greenhouse Gases
ICR	Infrastructure Carbon Review
NPS NN	National Networks National Policy Statement
PAS 2080	Publicly Available Specification 2080:2016, Carbon Management in Infrastructure
UKCP18	UK Climate Projections 2018