

A417 Missing Link

Preliminary Environmental Information Report

Chapter 14 Climate

28 September 2020

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14 Climate

14.1 Introduction

- 14.1.1 This chapter provides a preliminary assessment of the potential climate impacts and effects from construction and operation of the A417 Missing Link (the proposed scheme), following the methodology set out in the Design Manual for Roads and Bridges (DMRB) LA 114 Climate¹.
- 14.1.2 This chapter details the methodology followed for the assessment, summarises the legislative and policy framework related to climate change and describes the existing and projected future local and regional baseline environment in the area surrounding the proposed scheme. Following this, the design, mitigation and residual effects of the proposed scheme are discussed, along with any limitations of the assessment.
- 14.1.3 To align with the requirements of DMRB LA 114 Climate, the National Policy Statement for National Networks (NPSNN) and the Infrastructure Planning (Environmental Impact Assessment) Regulations 2017 (the EIA Regulations), this chapter describes the likely significant effects of proposed scheme on the environment resulting from the:
- impact of the proposed scheme on climate (greenhouse gas (GHG) emissions);²
 - vulnerability of the proposed scheme to climate change (adaptation).
- 14.1.4 In addition, to align with the requirements of the EIA Regulations to assess the direct and indirect significant effects of climate relevant to the project, including those caused by climate change, those effects of the proposed scheme identified by an environmental factor that are also affected by climate change is assessed on a case by case basis by the environmental factors. This preliminary in-combination climate change impact (ICCI) assessment is presented in Appendix 14.3 of this Preliminary Environmental Information (PEI) report.

14.2 Competent expert evidence

- 14.2.1 The Climate lead, responsible for this chapter of the PEI report, is a Chartered Environmentalist (CEnv) with a Civil Engineering degree MEng (Hons) and a Doctorate in Environmental Technology (EngD). Further details are provided in Appendix 1.2.

14.3 Legislative and policy framework

- 14.3.1 This section provides a review of legislative, policy and strategy positions around climate change and development of highways. They range in relevance from those that are directly applicable to the proposed scheme and those which provide wider policy context.
- National Policy Statement for National Networks (2014)
- 14.3.2 As discussed in Chapter 1 Introduction, the primary basis for deciding whether to grant a Development Consent Order (DCO) is the *National Policy Statement for National Networks*, (NPSNN), which sets out policies to guide how DCO applications will be decided and how the effects of national networks infrastructure should be considered.
- 14.3.3 The NPSNN establishes the need for nationally significant infrastructure rail and road projects for England and is the primary source of policy guidance relevant to

the proposed scheme. In relation to carbon³ reduction for such proposed schemes, Paragraph 5.16 asserts that the impact of road development on aggregate levels of emissions is likely to be very small (Paragraph 3.8 asserts less than 0.1% of annual carbon budgets) and needs to be seen against significant projected reductions in carbon emissions because of meeting the Government's legally binding carbon budgets. Paragraph 5.18 asserts that an increase in carbon emissions is not a reason to refuse development consent, unless the increase is large enough to have a material impact on the ability of the Government to meet its carbon reduction targets.

- 14.3.4 Table 14-1 identifies specific NPSNN requirements relevant to the climate assessment and specifies where in this PEI report chapter information is provided to address each requirement.

Table 14-1 Relevant NPSNN policies for the climate change assessment

Relevant NPSNN paragraph reference	Requirement of the NPSNN	Link to where information is provided in this PEI report chapter to address the requirement
4.40	Paragraph 4.40 specifies the need for applicants to consider the impacts of climate change when planning location, design, build and operation.	Sections 14.9 Design, mitigation and enhancement measures and 14.10 Assessment of likely significant effects consider how the proposed scheme would account for the projected impacts of climate change.
4.41	Paragraph 4.41 specifies that 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 high emissions scenario (high impact, low likelihood) against the 2080 projections at the 50% probability level.	Section 14.7 Baseline conditions demonstrates application of the latest set of UK Climate Projections (UKCP18) high emissions scenario (high impact, low likelihood) against the 2080 projections at the 50% probability level.
4.42	Paragraph 4.42 specifies that applicants should consider the potential impacts of climate change using the latest UK Climate Projections and ensure the environmental statement identifies appropriate mitigation or adaptation measures to ensure the long-term resilience of a proposed scheme.	Section 14.7 Baseline conditions demonstrates application of the latest UK Climate Projections (UKCP18). Section 14.9 Design, mitigation and enhancement measures and Appendix 14.2 considers appropriate mitigation and adaptation measures.
4.43	Paragraph 4.43 requires the applicant to demonstrate that there are no critical features of the design which may be seriously affected by more radical changes to the climate beyond that projected in the latest set of UK Climate Projections. Any potential critical features should be assessed taking account of the latest credible scientific evidence on, for example, sea level rise and on the basis that necessary action can be taken to ensure the operation of the infrastructure over its estimated lifetime through potential further mitigation or adaptation.	Appendix 14.2 Climate resilience full assessment results considers any potentially critical features of the design which may be seriously affected by climate change beyond that projected in the latest UK climate projections. Additionally, the safety of the proposed scheme is assessed against the high emissions Representative Concentration Pathways RCP8.5 ⁴ global warming scenario. An assessment using H++ climate scenarios has not been undertaken at this stage. Assessment of the safety critical features against H++ scenarios will be undertaken to inform the ES.
4.44	Paragraph 4.44 specifies that adaptation measures should be based on the latest	Section 14.9 Design, mitigation and enhancement measures and Appendix 14.2

Relevant NPSNN paragraph reference	Requirement of the NPSNN	Link to where information is provided in this PEI report chapter to address the requirement
	set of UK Climate Projections, the Government's national Climate Change Risk Assessment and consultation with statutory consultation bodies. Any adaptation measures must themselves also be assessed as part of any environmental impact assessment and included in the environmental statement, which should set out how and where such measures are proposed to be secured.	considers identification and implementation of any adaptation measures.
5.17	Paragraph 5.17 requires that Carbon impacts will be considered as part of the appraisal of scheme options (in the business case), prior to the submission of an application for a DCO. Where the development is subject to EIA, any Environmental Statement will need to describe an assessment of any likely significant climate factors in accordance with the requirements in the EIA Directive. For road projects applicants should provide evidence of the carbon impact of the project and an assessment against the Government's carbon budgets.	Sections 14.4 Assessment methodology and 14.10 Assessment of likely significant effects considers the carbon impacts of the proposed scheme and assesses them against the Government's carbon budgets.

Legislative

EIA Directives 2011/92/EU and 2014/52/EU

- 14.3.5 The *EIA Directive 2011/92/EU*⁵ place a requirement upon projects which have the potential for significant effects on the surrounding environment and communities to make a formal assessment of these effects. The amended Directive *2014/52/EU* identifies the important role that the EIA process can play in assessing climate change impacts. It states that EIAs shall identify, describe and assess the direct and indirect significant effects of climate change relevant to the proposed scheme (i.e. GHG, CCR and in-combination climate change impacts). The regulations implementing this directive were transposed into UK legislation in May 2017 through The Infrastructure Planning (Environmental Impact Assessment) Regulations 2017⁶. This chapter reports the preliminary outcomes of the GHG and CCR assessment, and Appendix 14.3 reports the preliminary in-combination climate change impact assessment, as assessed on a case by case basis by the environmental aspect chapters of this PEI report.

Climate Change Act

- 14.3.6 The *Climate Change Act 2008*⁷ committed the UK to its first statutory carbon reduction target to reduce carbon emissions by at least 80% from 1990 levels by 2050. The Climate Change Act 2008 (2050 Target Amendment) Order 2019⁸ amended the Climate Change Act 2008 by introducing a target for at least a 100% reduction of GHG emissions (relative to 1990 levels) in the UK by 2050, following advice from the Committee on Climate Change⁹. The 100% reduction is often referred to as 'net zero' GHG emissions.

- 14.3.7 The Climate Change Act requires that that five-yearly carbon budgets are set and not exceeded to ensure that regular progress is made towards the target. The first three carbon budgets were set in 2009, with the fourth and fifth following in 2011 and 2016 respectively, as outlined in Table 14-2.
- 14.3.8 The carbon budgets, as set out in the Carbon Budgets Order 2009¹⁰, the Carbon Budget Order 2011¹¹ and the Carbon Budget Order 2016¹², are based on an 80% reduction as legislated by the Climate Change Act 2008. At the time of undertaking this assessment, they have not been updated to reflect the target for 100% reduction in emissions set out in the Climate Change Act 2008 (2050 Target Amendment) Order 2019. GHG emissions from the proposed scheme are reported against the latest legislated carbon budgets, in line with the requirements of DMRB LA 114 and the NPSNN (Paragraph 5.18). The Committee on Climate Change report that to meet future carbon budgets and the 100% reduction target for 2050 it will require the government to apply more challenging measures.

Table 14-2 UK carbon budgets (as legislated by the Climate Change Act 2008 and set out in the Carbon Budgets Order 2009, the Carbon Budget Order 2011 and the Carbon Budget Order 2016)

Carbon budget	Carbon budget level - million tonnes of carbon dioxide equivalents (MtCO ₂ e)
3rd carbon budget (2018 - 2022)	2,544 MtCO ₂ e
4th carbon budget (2023 - 2027)	1,950 MtCO ₂ e
5th carbon budget (2028 - 2032)	1,725 MtCO ₂ e

- 14.3.9 The Climate Change Act also established a requirement for government to undertake a climate change risk assessment (CCRA) every five-year period and develop a programme for adaptation action in response to the risks identified. The UK Government's second UK CCRA was published in 2017^{13,14}. It establishes six priority risk areas for action over the following five years: flooding and coastal change; health and well-being from high temperatures; water shortages; natural capital; food production and trade; and pests and diseases and invasive non-native species. It is based on the independent evidence report published by the Committee on Climate Change¹⁵.
- 14.3.10 The CCRA identifies significant risks to national infrastructure, including transport networks, from embankment and bridge failure, river, surface/groundwater and coastal flooding, erosion, and increases in the frequency and severity of extreme weather such as high winds, high temperatures, lightening, storms and high waves. It highlights the need for infrastructure to be located, planned and designed and maintained to be resilient to climate change, including severe weather events. It also recognises that more action is needed to encourage information sharing between infrastructure operators to improve overall risk management. Section 14.9 Design, mitigation and enhancement measures and Appendix 14.2 of this PEI report chapter considers identification and implementation of any adaptation measures.

National policy

National Planning Policy Framework

- 14.3.11 The *National Planning Policy Framework* (2019) (NPPF)¹⁶ sets out the government's planning policies for England and how these are expected to be applied and provides a high-level framework within which other development can come forward. The NPPF does not contain specific policies for nationally

significant infrastructure projects (including the proposed scheme), which are primarily determined in accordance with the decision-making framework in the Planning Act 2008 (as amended) and the relevant national policy statement (which for the proposed scheme is the NPSNN, as described in section 14.3.2-14.3.4), as well as any other matters that are relevant (which may include the NPPF). The NPPF describes the role of planning policy in meeting the challenges posed by climate change and helping to shape places to secure radical reductions in GHG emissions as well as reducing vulnerability and providing resilience to the impacts of climate change. Section 14 of the NPPF states that developments should avoid increased vulnerability to the range of impacts arising from climate change and should be planned for in ways that can help to reduce GHG emissions, in line with the objectives and provisions of the Climate Change Act 2008. Section 14.9 Design, mitigation and enhancement measures and Appendix 14.2 of this PEI report chapter considers identification and implementation of any avoidance and mitigation measures.

The Climate Change: second national adaptation programme (2018 – 2023)

- 14.3.12 *The Climate Change: second national adaptation programme (2018 – 2023)* (NAP)¹⁷ was produced by the Department for Environment, Food and Rural Affairs (Defra) and launched in 2018. The plan sets out the Government's response to the second CCRA. It forms part of the five-yearly cycle of requirements laid down by the *Climate Change Act*, with the aim of driving a dynamic and adaptive approach to building the nation's resilience to climate change. Section 3.4.4 of the NAP highlights the economic and strategic value of the Strategic Road Network (SRN) in the UK and notes the implications of risks to severance and safety posed by climate change. It details how Highways England is embedding resilience to climate change, based on the UKCP09 future climate projections, including measures such as safeguarding against flooding, erosion, falling trees, instability and risk of failure across the SRN to increase safety.
- 14.3.13 Highways England is taking action to safeguard against climate risks on the road network through a series of adaptation plans, as set out in Section 8 of their climate change adaptation risk assessment¹⁸. These include adaptation actions related to pavements; drainage; structures; geotechnics; non-motorised users; soft estate; vehicle restraint systems; signs and signals; and road markings. For some risks doing the minimum is appropriate because the rigorous design standards or existing procedures are already sufficient to cope with the predicted impacts of climate change. In other cases, including those relating to drainage, it has been considered necessary to act. For example, updating technical standards through the DMRB or the Manual of Contract Documents for Highway Works (MCHW) to ensure new designs and projects are prepared for the future climate.

Clean Growth Strategy

- 14.3.14 In 2017, the UK Government published the *Clean Growth Strategy*, which is a plan for meeting the legislated carbon budgets¹⁹ as set out in the Carbon Budget Order 2016. The strategy includes a key policy to accelerate the shift to low carbon transport, which primarily focuses on a transition to low emission vehicles, investing in new technologies such as autonomous vehicles and low carbon fuels, promoting cycling and walking and shifting freight from road to rail.

Road to Zero Strategy

- 14.3.15 In July 2018, the UK Government launched the *Road to Zero Strategy*²⁰, a policy paper which includes a forward-looking route map to articulate the steps required

to decarbonise and electrify road transport in line with their Industrial Strategy²¹. The document outlines 46 policy interventions to aid in the drive to decarbonise road transport. Its main focuses are on supporting modal shift, reducing emissions from vehicles and investing in electric vehicle infrastructure.

Local policy

Gloucestershire County Council Local Flood Risk Management Strategy (LFRMS) 2014

14.3.16 The proposed scheme is situated within the Gloucestershire County boundary. The most directly relevant county-level planning policy and infrastructure guidance is the *Gloucestershire County Council Local Flood Risk Management Strategy 2014* (LFRMS)²², which sets out how Gloucestershire County Council and its partner authorities intend to work together to manage flood risk from all sources and is supported by a live action plan which is reported on annually. This LFRMS has been adopted to guide the development of policy and programmes across Gloucestershire County Council's operations and in its work with other organisations, communities and stakeholders. The proposed scheme has been designed to manage flood risk, as set out in Chapter 13 Road drainage and the water environment.

14.3.17 Further policies related to flood risk and water management of relevance to the proposed scheme, including climate change are set out in Chapter 13 Road drainage and the water environment.

Cotswold District Council Local Plan 2011 to 2031

14.3.18 The proposed scheme is situated partly in Cotswold District. The *Cotswold District Council Local Plan*²³ sets out a number of policies with respect to the built, natural and historic environment, placing emphasis on promotion the protection, conservation and enhancement of the natural environment. In line with the NPPF, the local plan asserts that the potential impacts of climate change must be considered in planning for all new development, both in terms of location and design. Plan Objective 6 aims to reduce the environmental impact of development and vulnerability to the impacts of climate change through:

"a. Maximising water and energy efficiency, promoting the use of renewable energy sources and sustainable construction methods, and reducing pollution and waste.

b. Supporting the principle of waste minimisation.

c. Locating development away from areas identified as being at high risk from any form of flooding or from areas where development would increase flood risk to others".

14.3.19 The proposed scheme has been designed to manage flood risk, as set out in Chapter 13 Road drainage and the water environment. Further policies related to flood risk and water management of relevance to the proposed scheme, including climate change, are set out in Chapter 13 Road drainage and the water environment.

Gloucester, Cheltenham and Tewkesbury Joint Core Strategy (JCS) 2011-2031 (adopted December 2017)

14.3.20 The western end of the proposed scheme lies within an area covered by the *Gloucester, Cheltenham and Tewkesbury Joint Core Strategy*²⁴. The Joint Core Strategy is a partnership between Gloucester City Council, Cheltenham Borough

Council and Tewkesbury Borough Council to deliver a co-ordinated strategic development plan. The strategy identifies larger strategic issues which impact all three authorities whilst each authority retains individual local plans which provide planning guidance on smaller and local development issues. Policies of relevance to this chapter include:

- Policy SD3: Sustainable Design and Construction requires that *“All development will be expected to be adaptable to climate change in respect of the design, layout, siting, orientation and function”*;
- Policy INF2: Flood Risk Management requires that climate change is taken into account in minimising the risk of flooding and providing resilience to flooding; and
- Policy INF6: Infrastructure Delivery notes that *“where need for additional infrastructure and services and/or impacts on existing infrastructure and services is expected to arise, the Local Planning Authority will seek to secure appropriate infrastructure which is necessary, directly related, and fairly and reasonably related to the scale and kind of the development proposal, including:… ii. Climate change mitigation/adaptation…”*

14.3.21 Section 14.9 Design, mitigation and enhancement measures and Appendix 14.2 of this PEI report chapter considers identification and implementation of any avoidance and mitigation measures. The proposed scheme has been designed to manage flood risk, as set out in Chapter 13 Road drainage and the water environment.

Pre-submission Tewkesbury Borough Plan 2011-2031 (October 2019)

14.3.22 The proposed scheme is situated partly in Tewkesbury District. One of the stated objectives of the *Pre-submission Tewkesbury Borough Plan*²⁵ is *“Meeting the challenges of climate change and resource conservation (including managing flood risk, energy efficiency, renewable energy and waste minimisation)”*. Specifically of relevance to this chapter is Policy ENV2 Flood Risk and Water Management, which requires that in addition to the requirements of the NPPF and the Gloucester, Cheltenham and Tewkesbury Joint Core Strategy the Council will apply the following principle: *“Proposals (including surface water drainage schemes) should be designed to appropriate, locally specific allowances for climate change for peak river flood flows and rainfall intensity.”*

14.3.23 The proposed scheme has been designed to manage flood risk, as set out in Chapter 13 Road drainage and the water environment.

Cotswolds area of outstanding natural beauty (AONB) Management Plan 2018-2023

14.3.24 The proposed scheme is situated within the Cotswolds AONB. The *Cotswolds AONB Management Plan 2018-2023*²⁶ is a non-statutory plan, which sets out the vision, outcomes and policies for the management of the AONB. It contains seven cross-cutting outcomes and associated policies. Of direct relevance to this chapter is Outcome 3 on climate change and Policy CC7 and Policy CC8, which state that climate change mitigation and adaptation should be a key consideration in all new development, infrastructure and transport provision. Section 14.9 Design, mitigation and enhancement measures and Appendix 14.2 of this PEI report chapter considers identification and implementation of any avoidance and mitigation/adaptation measures.

Climate Change Strategy for the Cotswolds AONB (adopted 2012)

14.3.25 *The Climate Change Strategy for the Cotswolds AONB*²⁷ notes that climate change is likely to significantly affect the special qualities for which the Cotswolds are designated as an AONB. The principal purpose of the strategy is to “*make the Cotswolds more resilient to the impacts of climate change, guiding landscape change in a way that will minimise adverse effects on the inherent character of the area*”, and was used to inform the Cotswolds AONB Management Plan 2018-2023. The strategy’s three key themes are listed below. For each key theme and sub-theme the strategy provides information on the predicted impacts of climate change, along with specific strategies to meet a stated aim:

“1. Climate Change and the Special Qualities of the Cotswold Landscape

- 1a. Landscape*
- 1b. Soil and Water*
- 1c. Biodiversity*
- 1d. Historic Environment*

2. Climate Change and Living and Working in the Cotswolds

- 2a. Farming and Forestry*
- 2b. Energy*
- 2c. Development and Transport*
- 2d. The Cotswolds Economy*
- 2e. Health and Wellbeing*

3. Climate Change and our Understanding and Enjoyment of the Cotswolds

- 3a. Enjoying and Exploring*
- 3b. Awareness and Appreciation”*

14.3.26 The combined effects of the proposed scheme and climate change on environmental receptors, including the Cotswolds AONB, are considered in Appendix 14.3 In-combination climate change impact assessment.

Standards and guidance

Impact of the proposed scheme on climate (GHG emissions assessment)

14.3.27 The following standards and guidance have been used to guide this preliminary assessment:

- DMRB LA 114 Climate, which provides the requirements for assessment and reporting the effect on climate of greenhouse gas from construction, operation and maintenance of Highways England highways projects²⁸;
- DMRB LA 105 Air Quality, which provides the calculation method for regional emissions from vehicles that use the road network²⁹;
- The *Publicly Available Specification 2080 (PAS 2080) on carbon management in infrastructure*³⁰, a global standard for managing infrastructure carbon;
- Royal Institution of Chartered Surveyors (RICS) professional standards and guidance document on Whole life carbon assessment for the built environment (1st edition, 2017)³¹; and
- Department for Transport, *Transport Analysis Guidance (TAG) Unit A3 Environmental Impact Appraisal*, Chapter 4 Greenhouse Gases³², which provides the methodology for consistent and transparent reporting of GHG emissions, including those resulting from the production of materials used (referred to as embedded or embodied carbon), as well as those resulting from changes to the use of transport fuels.

Vulnerability of the proposed scheme to climate change (climate change resilience assessment)

14.3.28 The following standards and guidance have been used to guide this preliminary assessment:

- DMRB LA 114 Climate, which provides the requirements for assessment and reporting the effects of climate on Highways England highways projects (climate change resilience and adaptation)³³; and
- The Institute of Environmental Management and Assessment (IEMA) guidance³⁴ on climate change resilience and adaptation in response to the requirements specified in the amended EIA Directive 2014. This guidance provides an approach to undertaking assessments of climate change resilience within the EIA process in the UK.

14.4 Assessment methodology

Impact of the proposed scheme on climate (GHG emissions assessment)

- 14.4.1 The assessment of the magnitude of carbon emissions has been undertaken in accordance with DMRB LA 114 and the principal steps identified in PAS 2080³⁵ (with the exception of setting project level carbon reduction targets which were not established). The Highways England Carbon emissions calculation tool³⁶ has been used to calculate product, construction process and maintenance/refurbishment emissions, except where specified. Consideration has also been given to Transport Analysis Guidance (TAG) Unit A3 Environmental Impact Appraisal, Chapter 4 Greenhouse Gases³⁷, which provides the methodology for consistent and transparent reporting of GHG emissions, including those resulting from the production of materials used (referred to as embedded or embodied carbon), as well as those resulting from changes to the use of transport fuels.
- 14.4.2 The goal of the emissions quantification exercise is to calculate the emissions anticipated to be generated or avoided by the proposed scheme (according to the draft DCO boundary and emissions scope set out in section 14.6). The purpose of this is to:
- Determine the magnitude of the proposed scheme's emissions for the relevant scenarios - 'Do something' and 'Do minimum';
 - Enable comparison of the 'Do something' scenario against the 'Do minimum' scenario and the UK carbon reduction targets; and
 - Enable identification of emissions hot spots within the 'Do something' scenario to inform identification and prioritisation of mitigation measures.
- 14.4.3 Assessment has included the life cycle stages of 'product', 'construction' and 'use' as per PAS 2080, BS EN 15804 and RICS guidance. In line with DMRB LA 114, 'end of life' impacts have not been considered due to the long design life of the asset and given that emissions associated with end of life are commonly relatively small.
- 14.4.4 The assessment estimates three sources of carbon emissions during the construction and operation (use) life cycle stages, including:
- **Construction works and supply chain carbon emissions.** Carbon is assessed, based on information provided by design teams based on relevant drawings of the preliminary design where available. Section 14.5, outlines

how assumptions were made. The Highways England carbon calculation tool is used along with its carbon factors for the calculation, supplemented with other factors where necessary as discussed in section 14.5.

- **Operational maintenance-related emissions.** An estimation of carbon emissions associated with maintenance of the road (calculated using the same method as the construction works and supply chain carbon emissions);
- **Operational traffic carbon emissions (user carbon) from vehicle tailpipes.** These are calculated from the traffic model, with the study area being the same as that of the traffic model.

14.4.5 Emissions from these sources are compared to a baseline 'do minimum' scenario (as described in Table 14-3) to quantify the impact of the proposed scheme. The scenarios used for the GHG emissions assessment of the proposed scheme are summarised in Table 14-3.

Table 14-3 GHG emissions assessment scenarios

Scenario	Description
'Do minimum'	'Business as usual' – the proposed scheme is not implemented.
'Do something'	The proposed scheme is implemented, taking into account embedded GHG mitigation measures.

14.4.6 GHG emissions in each scenario have been compared in order to assess the contribution of the proposed scheme to climate change. Values are reported in metric tonnes of carbon dioxide equivalents (tCO₂e). This measure considers the six Kyoto Protocol gases: Carbon dioxide (CO₂); Methane (CH₄); Nitrous oxide (N₂O); Sulphur hexafluoride (SF₆); Hydrofluorocarbons (HFCs); and Perfluorocarbons (PFCs), converted into tCO₂e. This calculation normalizes the global warming potential of the main GHG into one measure, based on the global warming potential of CO₂.

14.4.7 In accordance with DMRB LA 114, the third lifecycle stage for a project's GHG emissions (the first and second being construction and operation) comprises opportunities to reduce the production/use of GHG emissions. Measures to reduce GHG emissions as far as practicable are considered in section 14.9 Design, mitigation and enhancement measures.

Vulnerability of the proposed scheme to climate change (climate change resilience assessment)

14.4.8 The CCR assessment qualitatively assesses the impacts and risks of climate change on the proposed scheme based on professional expertise and judgement.

14.4.9 In the case of flood risk, detailed planning requirements and design guidance relating to climate change exist. A Flood Risk Assessment (FRA) will be undertaken as part of the EIA and reported in Chapter 13 Road drainage and the water environment of the ES. This considers current Environment Agency (EA) climate change allowances for increases in peak river flow and rainfall intensity.

14.4.10 The climate change resilience assessment is composed of three main parts: the identification of climate hazards and benefits; the assessment of likelihood and consequences; and the evaluation of significance.

14.4.11 The following climate change hazards have been considered in the CCR risk assessment: high temperatures; high precipitation; and low precipitation.

14.4.12 As part of the climate change resilience assessment, the potential likelihood and consequence of climate change risks during construction and operation of the infrastructure and assets associated with the proposed scheme are scored using a qualitative five-point scale, based on DMRB LA 114. These are set out in Table 14-4 and Table 14-5.

Table 14-4 Qualitative five-point scale of likelihood of climate change risks

Likelihood category	Description (probability and frequency of occurrence)
Very High	The event occurs multiple times during the lifetime of the project (60 years) e.g. approximately annually, typically 60 events.
High	The event occurs several times during the lifetime of the project (60 years) e.g. approximately once every five years, typically 12 events.
Medium	The event occurs limited times during the lifetime of the project (60 years) e.g. approximately once every 15 years, typically 4 events.
Low	The event occurs during the lifetime of the project (60 years) e.g. once in 60 years.
Very Low	The event can occur once during the lifetime of the project (60 years).

Table 14-5 Qualitative five-point scale of consequences of climate change risks

Consequence of impact	Description
Very large adverse	Operation - national level (or greater) disruption to strategic route(s) lasting more than one week.
Large adverse	Operation - 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	Operation - regional level disruption to strategic route(s) lasting more than one day but less than one week.
Minor adverse	Operation - regional level disruption to strategic route(s) lasting less than one day.
Negligible	Operation - disruption to an isolated section of a strategic route lasting less than one day.

14.4.13 As part of the risk assessment the need for any essential resilience measures to protect against the impacts of climate change have been identified for any effects assessed as significant, as per the significance matrix in Table 14-6.

Assessment of significance

Impact of the proposed scheme on climate (GHG emissions assessment)

14.4.14 A preliminary assessment of significance has been undertaken in accordance with DMRB LA 114. The emissions assessment is based on the Highways England carbon reporting tool and assessment of road user emissions in line with DMRB LA 105 Air quality.

14.4.15 A preliminary estimate of the likely magnitude of GHG emissions associated with the proposed scheme has been assessed against the national UK carbon budgets. The UK Government has currently passed into law carbon budgets up to 2032:

- 3rd carbon budget period (2018 to 2022) allows the UK to emit 2,544 MtCO₂e;
- 4th carbon budget (2023 to 2027) allows the UK to emit 1,950 MtCO₂e; and
- 5th carbon budget (2028 to 2032) allows the UK to emit 1,725 MtCO₂e.

14.4.16 In accordance with Paragraph 3.20 of DMRB LA 114, a significant effect occurs where the increase in carbon emissions resulting from the proposed scheme would have a 'material impact on the ability of Government to meet its carbon reduction targets'.

Vulnerability of the proposed scheme to climate change (climate change resilience assessment)

14.4.17 The evaluation of significance is a product of the likelihood and consequence of each impact as set out in Table 14-6. Significance conclusions for each impact incorporate confirmed design and mitigation measures.

Table 14-6 Significance matrix

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

Note: NS = Not significant; S = Significant

14.5 Assessment assumptions and limitations

Impact of the proposed scheme on climate (GHG emissions assessment)

- 14.5.1 The preliminary GHG emissions assessment has been undertaken on the basis of the information available at the time of assessment. Where assumptions have been made, they have been selected to present the worst-case scenario for the particular item/factor.
- 14.5.2 Assumptions/judgements in each case have been made from either:
- emerging design detail;
 - engineering specialist knowledge;
 - environmental specialist knowledge;
 - climate change/carbon specialist knowledge;
 - manufacturer specifications; or
 - proxy engineering data from previous comparable projects.
- 14.5.3 The materials and quantities listed in Appendix 14.1 are included in the preliminary assessment. This is the preliminary list of materials provided by the design team, including any embedded mitigation, and will be reviewed and refined prior to submission of the ES. A full schedule of preliminary assumptions associated with material volumes and quantities is also contained within Appendix 14.1.
- 14.5.4 Table 14-7 provides information on the PAS 2080 life cycle modules that have formed part of the assessment along with justification where modules have been excluded.

Table 14-7 Justification for inclusion or exclusion of PAS 2080 life cycle stages and individual modules within GHG emissions quantification

Life cycle stage	Boundary stage	Module	Description	Included in scope?	Justification	
Before use Stage	Preconstruction	A0	Preliminary studies, consultations	✗	Carbon emissions from preliminary studies and works are largely office-based and are assumed to be insignificant.	
		Product	A1	Raw material supply	✓	A1-A3 emissions (i.e. from raw material extraction, product processing, and final product manufacture, its energy use, and waste management within these processes, transportation within the supply chain, and manufacture) is calculated using emissions factors from the Highways England carbon emissions calculation tool, based on information provided by design teams based on relevant drawings of the preliminary design where available.
	A2		Transport	✓		
	A3		Manufacture	✓		
	Construction process	A4	A4	Transport to works site	✓	A4 emissions have been calculated using the RICS guidance ³¹ , applying transport conversion factors from Defra ³⁸ .
			A5	Construction/installation processes	✓	A5 emissions have been calculated using emissions factors from the Highways England carbon emissions calculation tool, based on preliminary information provided by design teams.
Use Stage	Installed products and materials	B1	Use	✗	Carbon emitted directly from the fabric of products and materials once they have been installed as part of the proposed scheme and it is in normal use are assumed to be insignificant.	
			B2	Maintenance	✓	B2-B5 emissions associated with maintenance and refurbishment assume that the road surface would be replaced once every ten years for the duration of the assumed 60-year design life (calculated using the same method as the construction works and supply chain carbon emissions).
	B3		Repair	✓		
	B4		Replacement	✓		
	B5		Refurbishment	✓		
		B6	Operational energy use	✗	The proposed scheme has been designed to reduce the requirement for energy	

Life cycle stage	Boundary stage	Module	Description	Included in scope?	Justification
					consuming operational equipment and therefore associated emissions are assumed to be insignificant.
		B7	Operational water use	✘	Carbon emissions resulting from the consumption of water required by the scheme to enable it to operate and deliver its service are assumed to be insignificant.
		B8	Other operational processes	✘	Other process carbon emissions arising from the proposed scheme to enable it to operate and deliver its service, such as management of operational waste, are assumed to be insignificant.
		B9	Users utilisation of infrastructure	✓	For the methodology related to quantification of user emissions, please refer to Chapter 5 Air quality.
End of life stage		C1	Deconstruction	✘	End of life (C1-C4) impacts have not been considered due to the long design life of the asset and given that emissions associated with end of life are commonly relatively small.
		C2	Transport		
		C3	Waste processing for recovery		
		C4	Disposal		

- 14.5.5 For transport-related emissions (A4), data on default transport scenarios for UK projects contained within the RICS professional standards and guidance document on whole life carbon assessment for the built environment (2017), were used. For locally manufactured materials and products a transport distance of 31 miles (50 kilometres) by road has been applied. For nationally manufactured materials and products a transport distance of 186 miles (300 kilometres) by road has been applied. Emission factors from the Highways England carbon emissions calculation tool have been used exclusively, with the exception of the product emissions (A1-A3) relating to bridges, which are derived from peer reviewed research³⁹. This is due to the design maturity at the time of assessment resulting in material quantity data not being available.
- 14.5.6 GHG emissions related to the construction element of embodied carbon (A5) have been calculated using emissions factors from the Highways England carbon emissions calculation tool, based on preliminary information provided by design teams. For the PEI report, information was available for the earthworks element of construction only. Further information will become available and will be incorporated into the A5 calculation to be reported within the ES.
- 14.5.7 To quantify operational emissions associated with maintenance of the road surface it is estimated the road surface would be replaced once every ten years for the duration of the design life.

- 14.5.8 For the methodology related to quantification of user emissions, please refer to Chapter 5 Air quality of this PEI report. The traffic forecasting is in line with the current guidance.
- 14.5.9 The methodology used to calculate the UK carbon budgets is different to that used for the calculation of lifecycle emissions from a road scheme and therefore caution should be taken when making a direct comparison. However, for the purposes of identifying to what extent the proposed scheme may impact the ability of the UK to meet its carbon budgets it is necessary to make this comparison to put the proposed scheme into context.

Vulnerability of the proposed scheme to climate change (climate change resilience assessment)

- 14.5.10 Data on the climate baseline and future projections are based on freely available information from third parties, including the historical meteorological variables recorded by the Meteorological Office (Met Office) and the UK Climate Projections (UKCP18) developed by the Met Office. In addition, the preliminary assessment has been informed by a selected range of existing climate change research and literature, available at the time of undertaking this assessment.
- 14.5.11 Climate projections are not predictions or forecasts but simulations of potential scenarios of future climate, under a range of hypothetical emissions scenarios and assumptions. Therefore, the results from running the climate models cannot be treated as exact or factual, but projection options. They represent consistent representations of how the climate may evolve in response to a range of potential forcing scenarios, and their reliability varies between climate variables. Scenarios exclude outlying "surprise" or "disaster" scenarios in the literature, and any scenario includes, out of necessity, subjective elements and is open to various interpretations. In general, global projections are more certain than regional projections, and temperature projections are more certain than those for precipitation. Wind projections have the highest amount of uncertainty associated with them. Furthermore, the degree of uncertainty associated with all climate change projections increases for projections further into the future.
- 14.5.12 The preliminary CCR assessment has been informed by the following principle assumptions:
- the assessment has assumed that mitigation measures relevant to different assets would be implemented effectively; and
 - the assessment is affected by assumptions associated with climate modelling and climate change projections, incorporated in UKCP18.
- 14.5.13 The CCR assessment has the following limitations:
- the assessment is largely qualitative, with the exception of assessments relevant to drainage assets and flood risk, which have been informed by the Environment Agency climate change allowances for increases in peak river flow and rainfall intensity;
 - there is limited methodological guidance on climate change resilience assessment in EIA from Government, and other institutions;
 - there is inherent uncertainty in climate change projections. This study has been quantified using UKCP18, the latest set of probabilistic climate projections for the UK;

- there is often uncertainty in the relationship between changes in climate hazards and the respective response in terms of asset performance. This uncertainty has been assessed qualitatively; and
- the evidence relating to climate change impacts for some categories of assets and infrastructure, such as multi-function Gloucestershire Way crossing, is limited at this stage in the design. In these cases, the assessment has been informed by professional judgement.

14.6 Study area

Impact of the proposed scheme on climate (GHG emissions assessment)

14.6.1 The assessment of GHG emissions has considered the following emissions sources:

- **Carbon emissions during construction**, i.e. material supply including primary extraction, manufacturing, transportation and construction process and site works associated with the proposed scheme;
- **Carbon emissions during operation**, associated with the maintenance and refurbishment of the proposed scheme; and
- **Road user carbon emissions (during operation)** arising from the use of the asset (vehicle emissions).

14.6.2 In line with DMRB LA 114, carbon emissions arising from decommissioning of the proposed scheme have been excluded from the assessment due to the long design life of the asset and given that emissions associated with end of life are commonly relatively small.

14.6.3 There are also GHG emissions and sequestration associated with land use change throughout construction and operation of the proposed scheme, however, in line with Paragraph 3.12 of DMRB LA 114, a proportionate approach is taken to calculating and reporting emissions from changes in land use. A high-level assessment of CO₂ sequestration rates was undertaken using data from Natural England's research report⁴⁰. It is estimated that an area of between 200-300ha of forest would be required to sequester the embodied carbon⁴¹ impacts of the proposed scheme over its design life. Therefore, an intervention to sequester the carbon impacts of the proposed scheme is not considered feasible and has not formed part of the preliminary GHG emissions assessment.

14.6.4 Opportunities to mitigate the effects on climate through minimising activities that generate GHG emissions, reusing and adopting low carbon materials are also considered and are outlined in section 14.9 Design, mitigation and enhancement measures.

Carbon emissions during construction

14.6.5 For the assessment of carbon emissions associated with construction of the proposed scheme, the study area takes account of emissions associated with the extraction, processing and transport of materials (refer to 14.5.5) from outside of the DCO boundary as well as site-based emissions that result from the construction activities within the DCO boundary.

Carbon emissions during operation

14.6.6 For the assessment of carbon emissions associated with maintenance and refurbishment of the proposed scheme, the study area is defined by the DCO boundary and takes account of emissions associated with the extraction,

processing and transport of materials as well as site-based emissions that result from the maintenance and refurbishment activities within the DCO boundary.

- 14.6.7 There are likely minimal direct emissions associated with operating the proposed scheme since the proposed scheme lighting is minimal. Power consumption has been assumed as negligible in the context of the proposed scheme and therefore the associated carbon impact does not form part of the GHG emissions assessment.

Road user carbon emissions (during operation)

- 14.6.8 The study area for operational road user carbon is consistent with the Affected Road Network (ARN), as defined by the proposed scheme's traffic model. The ARN is described in Chapter 5 Air quality (Section 5.6 Study area) and shown in Figure 5.1 (Affected Road Network). This includes emissions from vehicles using the proposed scheme and those in the wider road network which have been positively or negatively influenced by the proposed scheme. The assessment of road user carbon includes the total emissions across the ARN model, as shown in Chapter 5 Air quality, Figure 5.1 Affected Road Network.

Baseline and assessment scenarios

- 14.6.9 The baseline scenario is the 'do minimum' approach, which represents continual operation of the existing network without the proposed scheme. The baseline scenario includes current operational maintenance GHG emissions and operational user GHG emissions. A 60-year appraisal period has been adopted in line with the methodology set out in DMRB LA 114. The preliminary baseline scenario is set out in section 14.7 Baseline conditions.
- 14.6.10 The assessment scenario is the 'do something' approach, i.e. implementing the proposed scheme. The assessment scenario includes the construction, operational maintenance and operational user GHG emissions described in 14.6.1. GHG emissions in this scenario are compared to the baseline in order to assess the net contribution of the proposed scheme to climate change (in tCO₂e) from construction and operation over the 60-year appraisal period.

Vulnerability of the proposed scheme to climate change (climate change resilience assessment)

- 14.6.11 The study area for the CCR assessment is based on the construction footprint and includes temporary and completed works within the draft DCO boundary.
- 14.6.12 The study includes all potential climate hazards for infrastructure and assets associated with the proposed scheme. The assessment of climate effects on the proposed scheme is assessed over the 60-year operational life cycle in line with the methodology set out in DMRB LA 114.

Baseline and assessment scenarios

- 14.6.13 Assessment scenarios are based on current and future climate baselines, as described in Sections 3.26 – 3.28 of DMRB LA 114. The CCR assessment is based on climate trends associated with the UK Climate Projections 2018⁴² (UKCP18) high emissions scenario (50% probability) projection. Recent weather patterns and extreme weather events i.e. observed data have been identified and used to provide an indication of how the proposed scheme would account for climate change in the immediate future i.e. during construction. The time periods for climate projections are selected based on the assumed lifespan and stages of the proposed scheme (60 years), with construction assumed to commence in early 2023 and operation assumed from 2025 to 2085. For the PEI report, the

traffic models are based on an opening year of 2024 and 2039 (15 years after opening). It is noted that the modelled years do not coincide with the revised opening and design year for the proposed scheme. It is considered that these do not materially affect the results of the assessments undertaken⁴³.

14.6.14 Additionally, DMRB LA 114, Section 3.30, requires that H++ climate scenarios⁴⁴ are used to test the sensitivity of vulnerable safety critical features, to ensure that such features would not be affected by more radical changes to the climate beyond that projected in UKCP18. Safety critical features have been identified as:

- retaining walls;
- bridges and structures;
- pavements;
- road restraint system;
- drainage; and
- earthworks.

14.6.15 An assessment using H++ climate scenarios has not been undertaken at this stage. Assessment of the safety critical features against H++ scenarios will be undertaken to inform the ES.

14.6.16 The integral safety of the proposed scheme has been considered against UKCP18 (and Representative Concentration Pathways 8.5 (RCP8.5)⁴⁵ models therein).

14.7 Baseline conditions

Impact of the proposed scheme on climate (GHG emissions assessment)

Current and future baseline

14.7.1 This section identifies the GHG emissions without implementing the proposed scheme for the current and future baseline (do-minimum scenarios). In these scenarios it is assumed that no construction activity would take place on any of the roads in the area, aside from maintenance, across the study period.

14.7.2 The preliminary estimated baseline GHG emissions for the 'do minimum' scenario in the 2016 baseline year, future baseline years (2024 and 2039) and over the study period (60 years) are summarised in Table 14-8.

Table 14-8 Preliminary estimate of baseline GHG emissions for study area

GHG emissions component	Definition	2016 baseline scenario (historic) (tCO ₂ e)	2024 annualised (modelled opening year) (tCO ₂ e)	2039 annualised design (future) modelled assessment year (tCO ₂ e)	Cumulative estimated GHG emissions over 60-year study period (tCO ₂ e)
Operational maintenance-related GHG emissions	GHG emissions associated with maintenance of the existing road(s) within the study area outlined for the proposed scheme (see section 14.6).	50 (estimated)	50	50	3,000

Operational user GHG emissions	GHG emissions from the tailpipes of vehicles driving in the Affected Road Network (consistent with the study area outlined for the proposed scheme (see section 14.6).	185,000	183,000	208,000	12,278,000
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NOTE: Values which are over 1,000 tCO₂e have been rounded to the nearest 1,000 tCO₂e.

Vulnerability of the proposed scheme to climate change (climate change resilience assessment) - current climate baseline

Historic observed regional weather data

- 14.7.3 The Met Office generates climatologies for different areas of the UK, known as climate districts, including historical regional climate information. The proposed scheme is located within the Midlands climate district⁴⁶. High-level climate observations for the Midlands over a 30-year averaging period between 1981-2010 are presented in Table 14-9.

Table 14-9 High level climate observations for the Midlands district (1981-2010)

Climatic conditions	Climate observations
Temperature	Mean daily temperatures ranged from 0°C to 1.5°C in winter, whilst summer daily maximum temperatures were in the region of 22°C.
Rainfall	Atlantic depressions or convection are the source of the majority of rain in the Midlands, particularly in autumn and winter where Atlantic Lows are more vigorous. Annual rainfall in the Cotswolds averages 800mm. Monthly rainfall is variable but is highest in winter months. The number of days with rainfall greater than 1mm are 30-35 days in winter months, dropping to an average of 20-25 days in summer.
Wind	The Midlands is one of the more sheltered regions of the UK. The strongest winds are associated with the passage of deep areas of low pressure close to or across the UK. The frequency and strength of these depressions is greatest in the winter period, when mean speeds and gusts are strongest at approximately 10 knots.
Sunshine	Average annual sunshine totals were between 1400 and 1600 hours. A mid-century decline in heavy industry across the region has led to an increase in sunshine duration due to reduced industrial pollution.
Air Frost	The average number of days with air frost varies from 40 to 60 days per year.

Recent weather patterns and extreme weather events

- 14.7.4 A Local Climate Impacts Profile (LCLIP) for Wiltshire Council⁴⁷ was developed as part of a larger South West LCLIP (2010)⁴⁸. The Wiltshire LCLIP has been used as a proxy for the current local weather experienced in the neighbouring area of Gloucestershire where the proposed scheme is located, as the Gloucester LCLIP was not available in the preparation of the PEI report. The profile aims to provide an understanding of the nature of past extreme weather events and the impacts they have had on the community, environment and economy. Table 14-10

summarises the primary weather events currently affecting the region and provides a high-level overview of the impacts experienced.

Table 14-10 Local climate impacts profile for Wiltshire Council

Weather event	Impacts
Heavy rain/Flash floods	properties across several Wiltshire towns susceptible to flooding. Health and Safety worries along with significant damage and costs; infrastructure disruption across county (primarily road and rail); and services whose premises of normal operations are affected can only provide normal service with additional resources.
Snow/Frost/Ice	damage to infrastructure; services which involve travel require employment of additional resources to maintain a normal service; and increased maintenance costs for highways.
Heatwave	strains on water and energy utilities; disruption to road and rail infrastructure; significant damage to infrastructure (primarily road and rail); and excess deaths – danger to vulnerable groups is significant.
Wind	property damage; infrastructure disruption; power cuts; and blocked transport routes.

Vulnerability of the proposed scheme to climate change (climate change resilience assessment) - future baseline

- 14.7.5 This section presents future projected climate conditions and extreme weather events for the area encompassing the proposed scheme for the 2020s and 2080s⁴⁹. These time periods cover the assumed construction period (commencing in early 2023 for a period of 36 months) and the assumed 60-year operational life (2025 to 2085⁵⁰).
- 14.7.6 Using the historical baseline data, two methods were implemented to establish the future climate baseline:
- The changes in average climate conditions were obtained from the UKCP18 probabilistic projections of climate change⁵¹; and
 - The changes in extreme weather events were obtained using UKCP18 regional projections⁵².
- 14.7.7 Climate change projections for a range of meteorological parameters are presented for different probability levels within the RCP8.5 high emission scenario for the near-term and long-term future time periods. Table 14-11 presents changes in extreme weather events for the 2020s and 2060s⁵³, such as number of heavy rain days and Table 14-12 presents expected changes in climate conditions, such as mean temperature and precipitation for the 2020s and 2080s.
- 14.7.8 Temperatures in the area are projected to increase in both winter and summer. The largest increase in temperature is projected to be in the mean daily maximum temperature in summer, which is expected to increase by 5.7°C to 26.4°C in the 2080s, relative to the baseline in the high emissions scenario.

- 14.7.9 Mean precipitation rates in the region are anticipated to change significantly throughout the century, increasing by 5%-23% in the winter and decreasing by 6%-37% in summer during the 2020s and 2080s.
- 14.7.10 The mean number of hot days, when the maximum temperature is above 25°C, is anticipated to increase from 11.5 to 60.5 days per year in the 2060s for the high emissions scenario. The average number of days in a given year, when the mean daily temperature is below 0°C, is anticipated to decrease from 45.2 to 17.1 in the 2060s under the high emissions scenario.
- 14.7.11 In the case of extreme precipitation, the number of days with heavy rain (precipitation greater than 25mm/day) in a given year is expected to increase from 1.8 in the baseline period to 2.6 in the 2060s. Similarly, the average annual number of dry spells (periods of at least ten consecutive days with no precipitation) is projected to increase from 4.5 for the baseline period to 5.8 for the 2060s under the high emissions scenario.

Table 14-11 UKCP18 climate change projections for extreme weather events for the local area (12 kilometre grid square) for the 2020s and 2060s (under the RCP 8.5 high emissions scenario)

Parameter		Baseline (1981- 2010)	2020s (2010- 2039)			2060s (2050- 2079)		
			Min. ⁵⁴	Mean	Max.	Min.	Mean	Max.
Temperature	Number of frost days (daily minimum temperature equal or lower than 0°C)	45.2	23.4	33.5	49.4	11.6	17.1	24.8
	Heatwaves (2 days with maximum temperature higher than 29°C and minimum temperature higher than 15°C)	0.4	0.3	1.1	2.9	2.9	7.1	12.9
	Average summer highest daily maximum temperature (°C)	26.9	27.0	29.2	32.1	30.8	33.3	36.2
	Number of hot days (daily maximum temperature higher than 25°C)	11.5	12.2	23.8	45.7	34.3	60.5	86.4
Precipitation	Dry spells (10 days or more with no precipitation)	4.5	3.7	4.7	5.9	4.7	5.8	6.8
	Annual number of days per year when precipitation is greater than 25mm per day (Met Office definition of 'heavy rain')	1.8	1.3	2	2.7	1.6	2.6	3.6
Wind	Wind above 10 metres per second ⁵⁵	1.1	0.2	1.0	2.4	0.2	1.1	2.7

Table 14-12 UKCP18 climate change projections for average climate variables for the local area (25 kilometre grid square) for the 2020s and 2080s (under the RCP 8.5 high emissions scenario)

Parameter		Baseline (1981-2010)	Anomalies from baseline for 2020s (2010-2039)			Anomalies from baseline for 2080s (2070-2099)		
			10 th percentile	50 th percentile	90 th percentile	10 th percentile	50 th percentile	90 th percentile
Temperature (°C) (change from baseline)	Mean winter daily temperature	4.5	-0.1	0.7	1.4	1.1	3	5
	Mean summer daily temperature	16.1	0.2	0.9	1.7	2	4.9	8.1
	Mean daily summer maximum temperature	20.9	0.3	1.2	2.1	2.2	5.7	9.4
	Mean daily winter minimum temperature	1.5	-0.1	0.6	1.4	1	3	5.4
Precipitation (% change from baseline)	Winter mean precipitation rate	2.3mm	-4%	5%	15%	2%	23%	47%
	Summer mean precipitation rate	2mm	-22%	-6%	9%	-65%	-37%	9%

14.8 Potential impacts

Impact of the proposed scheme on climate (GHG emissions assessment)

14.8.1 The proposed scheme would result in GHG emissions during construction as well as changes to emissions during operation.

14.8.2 Sources of potential GHG emissions during construction include:

- Embodied GHG emissions associated with the required raw materials, including raw material supply, transport and manufacture;
- GHG emissions associated with construction processes, including transport to/from works site and construction/installation processes; and
- GHG emissions associated with land use change, for example those mobilised from vegetation or soil loss during construction.

14.8.3 Sources of potential GHG emissions during operation include:

- GHG emissions from vehicles using the highway infrastructure (road users);
- GHG emissions from the maintenance, repair and refurbishment of the proposed scheme, for example emissions associated with raw materials and transport required to replace the road surface; and
- GHG emissions associated with ongoing land use change/sequestration.

14.8.4 Opportunities identified for reduction of GHG emissions and mitigation measures incorporated in the design and construction of the proposed scheme are set out in section 14.9.

Vulnerability of the proposed scheme to climate change (climate change resilience assessment)

14.8.5 Anticipated changing climate conditions and weather events have the potential to have significant adverse effects on the proposed scheme, or on elements of the proposed scheme during construction and operation.

- 14.8.6 During the construction process, receptors may be vulnerable to a range of short-term climate risks, including damage to construction materials, plant and equipment, unsuitable conditions for construction activities, delay, increased costs and health and safety impacts to the workforce during severe weather events.
- 14.8.7 Once operational, the proposed scheme has the potential to be impacted upon by a changing climate and more frequent severe weather events in the medium to longer-term. Potential impacts include material and asset deterioration and damage giving rise to health and safety risks to users and increased maintenance requirements.
- 14.8.8 The potential risks are expected to be largely mitigated through the use of appropriate design standards, delivered through quality construction, as well as appropriate asset management procedures during operation.
- 14.8.9 The A417 provides an important transport link for Gloucester and is a part of the strategic road network in the region. The proposed scheme is expected to increase the resilience of transport systems in the region to a range of hazards, including climatic hazards arising from climate change, and hence provide benefit for the overall resilience of the region.

14.9 Design, mitigation and enhancement measures

Design and construction mitigation

Impact of the proposed scheme on climate (GHG emissions assessment)

- 14.9.1 In accordance with DMRB LA 114, the third lifecycle stage for a project's GHG emissions (the first and second being construction and operation) comprises opportunities to reduce the production/use of GHG emissions.
- 14.9.2 In line with Highways England's Sustainable Development Strategy (2017)⁵⁶ and Action Plan (2018)⁵⁷, which set out Highways England's ambition to reduce carbon emissions, and the UK Government's carbon reduction plan targets, the proposed scheme has sought and would continue to seek to reduce GHG emissions as far as practicable to contribute to the UK's net reduction in carbon emissions and maximise its potential for reducing GHG emissions.
- 14.9.3 The following mitigation measures have been and would continue to be considered to reduce GHG emissions from the proposed scheme. Key emissions impacts during construction would be from construction activities and embedded/embody carbon of the materials. Mitigation measures identified in Table 14-13 are divided into the following hierarchy options:
- avoid/prevent - maximise potential for re-using and/or refurbishing existing assets to reduce the extent of new construction required, and/or explore alternative lower carbon options to deliver the proposed scheme objectives;
 - reduce - low carbon and/or reduced resource consumption solutions (including technologies, materials and products) to minimise resource consumption during the construction, operation, and at end of life; and
 - remediate - measures to further reduce carbon through on or off-site offsetting or sequestration.

Table 14-13 GHG mitigation measures during design and construction

Mitigation measure	Delivery mechanism	Embedded/ Essential	Method of reduction
The proposed scheme looked at a variety of alternative options to solve the identified capacity problem on the existing A417 before defining and refining the preferred option (the proposed scheme). As set out in Chapter 3 Assessment of alternatives, the initial options included tunnel options as well as surface options. A road in a tunnel has a substantially higher carbon footprint than a road at grade, both during its construction and during the operation of its systems through its design life. By taking forward a surface option, substantial carbon emissions associated with tunnelling have been avoided.	Proposed scheme design	Embedded	Avoid/prevent
The current gradient of Crickley Hill is 10%, which results in problems caused by slow-moving vehicles. To address this, the proposed scheme would reduce the gradient and provide two lanes in each direction, with a climbing lane for slow-moving vehicles from Brockworth heading eastwards towards Cowley. This would assist in reducing the operational carbon footprint from road users due to free-flowing traffic and shallower gradients.	Proposed scheme design	Embedded	Avoid/prevent
The proposed scheme has been designed to minimise the requirement for energy consuming operational equipment such as street lighting or intelligent transport systems wherever possible. Where lighting may be potentially required, for example at Grove Farm underpass, low lux demand sensitive lighting is proposed to reduce GHG emissions associated with operating the proposed scheme.	Proposed scheme design	Embedded	Avoid/prevent Reduce
The construction contractor will develop and implement a plan to reduce energy consumption and associated carbon emissions. This could include the consideration of renewable and/or low or zero carbon energy sources and recording the savings implemented. Highways England is committed to reducing carbon emissions and works closely with suppliers to reduce emissions from network related activity. Energy consumption and materials use will be recorded and reported on an ongoing basis during the construction phase of the proposed scheme using the Highways England Carbon Reporting Tool.	Environmental management plan (EMP)	Embedded	Reduce
Where practicable, measures will be implemented to manage material resource use during construction including:	EMP	Embedded	Reduce

Mitigation measure	Delivery mechanism	Embedded/ Essential	Method of reduction
<ul style="list-style-type: none"> • using materials with lower embedded GHG emissions and water consumption; • using sustainably sourced materials; and • using recycled or secondary materials. 			
Material excavated during construction will be processed for use in the works wherever possible to reduce the amount of material disposed of offsite as well as imported from other sources, and associated GHG emissions. Possible uses include General Fill and other graded materials. Processing of material will take place on-site.	EMP	Essential	Reduce
Existing pavements on the A417 will be retained wherever possible within the proposed scheme to reduce the requirement for additional materials and construction.	EMP	Embedded	Avoid/prevent
The proposed scheme design has carefully considered the use of appropriate tree and shrub species and low maintenance wildflower grassland (calcareous grassland) to reduce associated maintenance operations. Calcareous grassland, which has been used throughout the proposed scheme, only requires cutting once a year (reducing maintenance-related emissions) and can be seeded directly on to subsoil, which would remove the requirement to import topsoil during construction.	Proposed scheme design	Embedded	Reduce

Vulnerability of the proposed scheme to climate change (climate change resilience assessment)

- 14.9.4 The proposed scheme has been designed to improve its resilience to climate change through a range of design and material specification measures including where practicable: the use of construction materials with superior properties (such as increased tolerance to fluctuating temperatures), incorporation of current road design standards and future climate change allowances. Embedded mitigation and adaption measures for all climate risks identified within the CCRA are set out in Table 14-19 within section 14.10. Additionally, the integral safety of the proposed scheme has been considered against UKCP18 (and RCP8.5 models therein). Assessment of the safety critical features against H++ scenarios will be undertaken to inform the ES.
- 14.9.5 All weather and climate-related risks to construction activities are expected to be mitigated through best practice site management, including relevant specific measures which will be set out in a register of environmental actions and commitments within an Environmental Management Plan (EMP), which will be submitted with the DCO application. The best practice site management measures and relevant specific measures would provide a level of resilience to the proposed scheme throughout construction. Taking this mitigation into consideration, vulnerability of the proposed scheme to impacts from climate

change during construction has been scoped out of the assessment in line with The Planning Inspectorate's Scoping Opinion on the proposed scheme⁵⁸.

Operational mitigation

Impact of the proposed scheme on climate (GHG emissions assessment)

- 14.9.6 No operational mitigation measures have been proposed. It is not practical to monitor GHG emissions from road users during the operational phase of the proposed scheme as Highways England does not have direct control over road user emissions.

Vulnerability of the proposed scheme to climate change (climate change resilience assessment)

- 14.9.7 A number of preliminary general mitigation and adaptation measures to address the potential impacts associated with climate change events have been considered, many of which have been identified within the other aspect chapters of the PEI report and through the proposed scheme design. The assessment identifies and takes into account existing resilience measures for each climate variable and associated impacts either already in place, or in development, for infrastructure and assets.
- 14.9.8 Most weather and climate-related resilience effects during operation are expected to be mitigated through measures embedded in the design of the proposed scheme, providing a level of resilience throughout operation. Embedded mitigation and adaptation measures for all climate risks identified within the CCRA are set out in Table 14-19 within section 14.10.
- 14.9.9 The preliminary CCR assessment results which identify relevant mitigation measures and management practices are summarised in section 14.10, with detailed results presented in Appendix 14.2.

14.10 Assessment of likely significant effects

Impact of the proposed scheme on climate (GHG emissions assessment)

- 14.10.1 This preliminary assessment presents a preliminary calculation of the emissions calculated for the 'Do Something' scenario, a comparison against the 'Do Minimum' baseline, and assessment against UK Government carbon budgets. The numbers in this section are a high level indication only and will be updated and refined for the ES as the proposed scheme design develops and updated traffic and air quality modelling are available. The numbers indicated in this section of the PEI report should be used only to indicate the potential magnitude of emissions.
- 14.10.2 Due to the embedded nature of the mitigation measures proposed, as outlined in section 14.9, some of which have already been incorporated into the design and some of which are yet to be incorporated, it is not practicable to complete a quantitative assessment of 'before' and 'after' mitigation. Rather, the assessment shows a snapshot of the current design.

'Do Something' scenario emissions

Construction

- 14.10.3 A high-level preliminary breakdown of construction phase emissions is displayed in Table 14-14. All preliminary assumptions used in the calculations are contained within Appendix 14.1 and section 14.5. Emissions from the construction phase are predicted to total in the region of 47,000tCO₂e.

Table 14-14 Preliminary construction stage emissions

Main stage of project life cycle	Sub-stage of life cycle		Emissions (tCO ₂ e)	% of total construction emissions*
Construction stage	Product stage; including raw material supply, transport and manufacture (A1-A3)		38,700	82%
	Construction process stage; including:	Transport to/from works site (A4)	2,700	6%
		Construction/installation processes (A5)	5,600	12%
	Construction stage total		47,000	100%

NOTE: Values which are over 1,000 tCO₂e have been rounded to the nearest 1,000 tCO₂e.

* Due to rounding, percentages may not always appear to add up to 100%

* Sub-stages of the construction life cycle and modules shown in this table align with PAS 2080 life boundary stages and individual modules as shown in Table 14-7.

- 14.10.4 The largest magnitude of emissions during construction (82%) is likely to arise from the production of materials. Emissions from on-site construction processes, particularly from fuel used in construction plant equate to 12% of the total, and transport of materials totals 6% of emissions. At the time of writing, information to calculate construction/installation process emissions (A5) was available for the earthworks element of construction only. Further information will become available and will be incorporated into the A5 calculation to be reported within the ES. This will increase the total A5 emissions.

Operation

- 14.10.5 As noted in the study area section, there are likely minimal direct emissions associated with operating the proposed scheme since the proposed scheme lighting is minimal. Power consumption has been assumed as negligible in the context of the proposed scheme and therefore does not form part of the GHG emissions assessment.
- 14.10.6 Emissions associated with maintenance and refurbishment assume that the road surface would be replaced once every ten years for the duration of the assumed 60-year design life. Road user GHG emissions are expected to constitute the majority of the whole life GHG emissions of the proposed scheme. Operational phase emissions for the modelled opening and design years⁵⁹ and total over the modelled 60-year operational period are shown in Table 14-15.

Table 14-15 Preliminary operation ('use stage') emissions for modelled opening year (2024), design year (2039) and total over the assumed 60-year operational period (2024 – 2084)

Main stage of project life cycle	Sub-stage of life cycle	Emissions (tCO ₂ e)		
		2024 annualised (modelled opening year)	2039 annualised design (future) modelled assessment year	Total (cumulative) over modelled 60-year operation (2024 – 2084)
Operation ('use-stage')	Use of the infrastructure by the end-user (road user emissions) (B9)	193,000	225,000	13,240,000
	Maintenance and refurbishment (B2-B5)	125	125	7,500
	Operation ('use-stage') total	193,000	225,000	13,248,000

NOTE: Values which are over 1,000 tCO₂e have been rounded to the nearest 1,000 tCO₂e.

* Sub-stages of the Operation ('use-stage') life cycle and modules shown in this table align with PAS 2080 boundary stages and individual modules as shown in Table 14-7.

Comparing 'do minimum' and 'do something' scenarios

- 14.10.7 As GHG emissions associated with construction do not occur in the 'Do minimum' scenario, it can be considered that the construction stage of the proposed scheme would have the effect of releasing in the region of an additional 47,000 tCO₂e into the atmosphere in the 'Do something' scenario.
- 14.10.8 The calculated annualised operation stage emissions for the modelled 2024 and 2039 'Do minimum' and 'Do something' scenarios and the cumulative operation stage emissions over the 60-year operation for the 'Do minimum' and 'Do something' scenarios are compared in Table 14-16.

Table 14-16 Preliminary 'do something' and 'do minimum' operation ('use stage') emissions comparison for modelled opening year (2024), design year (2039) and total over the assumed 60-year operational period (2024 – 2084)

Main stage of project life cycle	Emissions (tCO _{2e})								
	2024 (annualised) do minimum	2024 (annualised) do something	Difference	2039 (annualised) do minimum	2039 (annualised) do something	Difference	Total (cumulative) over 60-year operation (2024 – 2084) Do minimum	Total (cumulative) over 60-year operation (2024 – 2084) Do something	Difference
Total operational 'use stage' emissions (maintenance and road user)	183,000	193,000	10,000	208,000	225,000	17,000	12,281,000	13,248,000	967,000

NOTE: Values which are over 1,000 tCO_{2e} have been rounded to the nearest 1,000 tCO_{2e}.

14.10.9 The proposed scheme is provisionally estimated to lead to an increase of approximately 1 million tCO_{2e} during the modelled 60-year operational period (2024 – 2084), relative to the 'do minimum' scenario.

Assessment against total UK carbon budgets

14.10.10 Table 14-17 shows the relevant carbon budgets against which the proposed scheme would contribute. This approximation assumes an even distribution of emissions across the assumed overall construction period.

14.10.11 If the DCO is granted, construction is planned to start in early 2023 and the proposed scheme is due to open to traffic in 2025⁴³. Therefore, the construction period for the proposed scheme falls wholly within the 4th carbon budget. Operation of the proposed scheme would commence in 2025 (however 2024 is currently assumed in the traffic model) and is assessed against the 4th and 5th carbon budgets, up to 2032. Operational and maintenance emissions after 2032 are not assessed since no carbon budget has yet been set after this date.

Table 14-17 Preliminary assessment of proposed scheme net emissions (up to 2032) against UK Government carbon budgets

Project stage	Estimated total (cumulative) GHG emissions over carbon budgets (tCO _{2e}) ('Do something' scenario)	Net (cumulative) GHG emissions over carbon budgets (tCO _{2e}) ('Do something' - 'Do minimum')	Net (cumulative) proposed scheme GHG emissions per relevant carbon budget (tCO _{2e})		
			3 rd (2018 - 2022)	4 th (2023 - 2027)	5 th (2028 - 2032)
Construction (2023-2025)	47,000	47,000	n/a	47,000	n/a
Operation (modelled from 2024 through to 2032)	1,816,000	110,000	n/a	45,000	65,000
Total	1,863,000	157,000	n/a	92,000	65,000

NOTE: Values which are over 1,000 tCO_{2e} have been rounded to the nearest 1,000 tCO_{2e}.

Significant effects

- 14.10.12 The construction and operation phases of the proposed scheme which fall within legislated carbon budget periods are expected to have an insignificant impact on the ability of the government to meet its carbon budgets. Construction of the proposed scheme is estimated to contribute approximately 0.0024% of the 4th carbon budget. Operation of the proposed scheme is provisionally estimated to contribute approximately 0.0023% of the 4th carbon budget and 0.0038% of the 5th carbon budget. It is considered that this magnitude of emissions from the proposed scheme in isolation would not have a material impact on the ability of the government to meet its carbon budgets, and therefore is not anticipated to give rise to a significant effect on climate, in line with the position set out within Section 5.18 of the NPSNN.
- 14.10.13 Further information on construction process emissions will become available and will be incorporated into the final GHG calculation to be published in the ES. This will increase the total estimated construction emissions however it is not expected to change the conclusion that the proposed scheme will not have a significant impact on the ability of the government to meet its carbon budgets.

Comparison with other schemes

- 14.10.14 Table 14-18 compares the preliminary estimated GHG emissions performance of the proposed scheme against other comparable highway projects, normalised to take account of differences in size and scale.

Table 14-18 Comparison of the proposed scheme's carbon with other road infrastructure projects⁶⁰

Carbon footprint life cycle modules	Project/length and width component								
	M4 corridor Around Newport	A14	A465	HA Project A	HA Project B	HA Project C	HA Project D	HA Project E	The proposed scheme
	23km New relief road	37km improvement scheme	7.8km embankment section	26.6km widening of A road	6.5km single to 2 lane dual carriageway	4km upgrade of existing junction	0.7km Refurbished existing viaduct	22.1km Upgrade from dual to 3 lanes	5.5km widening of A road
Capital (embodied) CO₂e (tCO₂e)									
Material	436,600	740,100	44,300	74,500	77,300	36,100	5,800	213,700	38,700
Labour + plant	42,800	243,800	5,800	38,500	27,500	8,200	4,000	20,900	8,300
Earthworks	43,200	n/a	2,500	n/a	n/a	n/a	n/a	n/a	
<i>Construction tCO₂e/km</i>	<i>21,800</i>	<i>26,600</i>	<i>6,700</i>	<i>4,300</i>	<i>16,100</i>	<i>11,100</i>	<i>13,900</i>	<i>10,600</i>	<i>8,500</i>
Operational CO₂e (tCO₂e)									
Operation + Maintenance/ annum	1,600	2,400	2,600	n/a	n/a	n/a	n/a	n/a	125
Use Phase CO₂e (tCO₂e)									
Use/annum	2,268,700	4,386,400	882,000	n/a	n/a	n/a	n/a	n/a	221,000

Table Source: Welsh Government (2016). M4 Corridor around Newport, Environmental Statement: Volume 3, Appendix 2.4 Carbon Report

- 14.10.15 Construction related emissions are provisional at this stage and will increase once additional design and construction information is available, particularly for labour and plant (construction process stage). The revised calculation will be reported in the ES and a comparison drawn with comparable highway projects. Operational and maintenance carbon is expected to be significantly lower than other projects. This is likely due to minimal energy consuming assets within the design. On a per kilometre basis, estimated operational use phase emissions per annum are lower than comparable projects.

Vulnerability of the proposed scheme to climate change (climate change resilience assessment)

Construction

- 14.10.16 Climate resilience impacts on the proposed scheme during the construction phase are not expected to be significant due to the duration and nature of the construction activities. Therefore, these impacts have not been assessed any further.

Operation

- 14.10.17 Climate change risks to infrastructure assets designed and constructed as part of the proposed scheme have been assessed during operation. The preliminary assessment finds all climate change risks to assets during the operation of the proposed scheme to be 'not significant' because of mitigation measures already built into the design and assumed management practices. Details of the mitigation measures identified to date and the significance assessment are contained in Appendix 14.2 Climate resilience full assessment results.
- 14.10.18 These non-significant climate resilience impacts, identified using criteria set out in the assessment methodology, are detailed in Appendix 14.2 Climate resilience full assessment results and summarised in Table 14-19.

Table 14-19 Non-significant climate resilience impacts, existing or embedded mitigation measures and likelihood and consequence (extract from Appendix 14.2 Climate Change Resilience Assessment)

Risk ID	Potential climate change risk to proposed scheme	Existing or embedded mitigation measure	Likelihood of hazard impact	Consequence of hazard impact (should the impact occur)	Evaluation of significance
1	Increased heat stress for staff, particularly for outdoor construction and maintenance workers.	To be incorporated within proposed maintenance regimes. These can be reviewed regularly to ensure health and safety requirements within Highways England are met.	Low	Minor adverse	Not significant
2	Extended periods of hot, dry weather may lead to a risk of spontaneous grassland fires in vicinity of the route, affecting safety on the road.	Risk to be sufficiently mitigated through standard emergency procedures. Additionally, the road would act as a firebreak, providing a gap in combustible material that would act as a barrier to slow or prevent the progress of a wildfire from one side to the other.	Low	Moderate adverse	Not significant
3	Asphalt surface may exhibit permanent deformation in long periods of hot, sunny conditions.	This risk would be managed through the selection of suitable road surface material as well as through the proposed maintenance regimes for road surface.	High	Minor adverse	Not significant
4	High temperatures increase the risk of surfacing rutting leading to water ponding in the ruts. Higher temperatures also increase the risk of reduced skid resistance due to fatting and chipping embedment. This would increase the risk of vehicle incidents.	This risk would be managed through the selection of suitable road surface material as well as through the proposed maintenance regimes for road surface.	Low	Moderate adverse	Not significant

Risk ID	Potential climate change risk to proposed scheme	Existing or embedded mitigation measure	Likelihood of hazard impact	Consequence of hazard impact (should the impact occur)	Evaluation of significance
5	Inability to flex under traffic loads. Increased risk of road surface cracking and fretting with age.	This risk would be managed through the proposed maintenance regimes.	Medium	Minor adverse	Not significant
6	Risk of being unable to lay road surface layers in hot weather.	Risk to be mitigated by following procedures to be detailed in an Environmental Management Plan (EMP).	Low	Minor adverse	Not significant
7	Decreased viscosity in heat leads to greater spreading of diesel in a smaller timeframe. Higher temperatures and increased number of hot, dry days increase the likelihood of ignition of this diesel leading to road and forest fires.	Risk to be sufficiently mitigated through proposed maintenance procedures.	Low	Moderate adverse	Not significant
8	Flooding of road surface.	Attenuation ponds designed for 1/100 year event +20% for climate change (check performed for 40% increase). Climate change allowance in critical drainage areas increased to +40%.	Very low	Moderate adverse	Not significant
9	Flooding of access roads and/or road infrastructure.	Attenuation ponds designed for 1/100 year event +20% for climate change (check performed for 40% increase). Climate change allowance in critical drainage areas increased to +40%.	Very low	Moderate adverse	Not significant
10	Increase risk of sewage overflow in floodwater causing damage and impacting health of maintenance workers.	Attenuation ponds designed for 1/100 year event +20% for climate change (check performed for 40% increase). Climate change allowance in critical drainage areas increased to +40%.	Very low	Moderate adverse	Not significant
11	Increased risk of scouring of culverts.	Attenuation ponds designed for 1/100 year event +20% for climate change (check performed for 40% increase). Climate change allowance in critical drainage areas increased to +40%.	Low	Minor adverse	Not significant

Risk ID	Potential climate change risk to proposed scheme	Existing or embedded mitigation measure	Likelihood of hazard impact	Consequence of hazard impact (should the impact occur)	Evaluation of significance
12	Flooding causing damage to fibre optic cables running near to site.	Attenuation ponds designed for 1/100 year event +20% for climate change (check performed for 40% increase). Climate change allowance in critical drainage areas increased to +40%.	Very low	Negligible	Not significant
13	Increased pore water pressure in embankments/cuttings.	To be mitigated through drainage design. Risk likely to be absorbed by conservative assumptions made during design.	Very low	Large adverse	Not significant
14	Increased erosion at toe of embankment.	To be mitigated through drainage design. Risk likely to be absorbed by conservative assumptions made during design.	Low	Large adverse	Not significant
15	Water ingress to critical construction equipment.	Drainage on site to be suitably managed, to be specified within the EMP.	Very low	Minor adverse	Not significant
16	Water ingress to signalling, lighting and other operational electrical equipment.	Watertight cables housed in plastic ducts. No water ingress to underground cables.	Very low	Minor adverse	Not significant
17	Change in ground water level affecting earth pressures and foundation settlement causing possible large ground movement.	To be mitigated through drainage design. Risk likely to be absorbed by conservative assumptions made during design.	Very low	Large adverse	Not significant
18	Increased risk of debris deposit from water seeping up to the surface through the pavement e.g. calcium sulphate leading to reduced skid resistance.	Weather and weather effects on traffic considered within pavement design.	Low	Moderate adverse	Not significant
19	Construction site flooding during construction phase, excavations flooded and site roads impassable. Safety risk of slips, trips and falls to construction workers.	Drainage on site to be suitably managed, to be specified within the EMP. Health and safety procedures to be further specified within the EMP.	Low	Moderate adverse	Not significant
20	Increased ground water level in winter may lead	To be mitigated through drainage design.	Low	Minor adverse	Not significant

Risk ID	Potential climate change risk to proposed scheme	Existing or embedded mitigation measure	Likelihood of hazard impact	Consequence of hazard impact (should the impact occur)	Evaluation of significance
	to flooding of underpasses.				
21	Increased risk of earthworks failure and landslides. Exacerbated by variance between high and low precipitation events and soil moisture levels.	To be mitigated through geotechnical and drainage design. Risk likely to be absorbed by conservative assumptions made during design.	Low	Large adverse	Not significant
22	Reduced capacity of attenuation ponds due to sediment build-up.	Risk to be mitigated through the monitoring and maintenance procedures specified for the relevant attenuation ponds.	Medium	Minor adverse	Not significant
23	Increased risk of debris washing into drainage gullies, blocking them. A blockage may result in flooding and resulting effects.	Mitigated through drainage design and monitoring and maintenance procedures proposed for drainage systems.	Low	Moderate adverse	Not significant
24	Increase stripping rate of the road surfaces.	This risk would be managed through the proposed maintenance regimes for road surface.	Low	Minor adverse	Not significant
25	Wetter surface may lead to reduced skid resistance.	This risk would be managed through the selection of suitable road surface material as well as through the proposed maintenance regimes for road surface.	Low	Moderate adverse	Not significant
26	Increased likelihood of potholing, rutting and cracking from moisture entering and remaining in road surfaces.	This risk would be managed through the proposed maintenance regimes for road surface.	High	Minor adverse	Not significant
27	Increased flow of groundwater causing accelerated weathering effects, weakening the embankment.	Risk likely to be absorbed by conservative assumptions made during design.	Very low	Large adverse	Not significant
28	Potential risk of soil shrinkage impacting foundations, including bridges and other structures. Possible ground movement (check differential settlement due to different types of foundations).	To be confirmed. Risk likely to be absorbed by conservative assumptions made during design.	Very low	Large adverse	Not significant

Risk ID	Potential climate change risk to proposed scheme	Existing or embedded mitigation measure	Likelihood of hazard impact	Consequence of hazard impact (should the impact occur)	Evaluation of significance
29	Reduced slope stability and potential earthworks failure during or immediately after summer storm events falling on desiccated soils.	To be confirmed. Risk likely to be absorbed by conservative assumptions made during design.	Low	Large adverse	Not significant
30	Anaerobic conditions may occur, risking die back of sediment collecting species, reducing attenuation pools functional capacity.	Risk to be mitigated through the monitoring and maintenance procedures specified for the relevant attenuation ponds.	Medium	Minor adverse	Not significant

14.10.19 The A417 provides an important transport link for Gloucester and is a part of the strategic road network in the region. The proposed scheme is expected to increase the resilience of transport systems in the region to a range of hazards, including climatic hazards and climate change, and hence provide benefit for the overall resilience of the region.

14.11 Monitoring

Impact of the proposed scheme on climate (GHG emissions assessment)

- 14.11.1 As no preliminary significant effects have been identified for the GHG emissions assessment, no monitoring of significant effects is expected to be required.
- 14.11.2 In line with the monitoring requirements set out in DMRB LA 114 Climate, and to be secured through an EMP, quarterly GHG emission returns during construction and operation shall be reported in accordance with Highways England's requirements. Data provided for the GHG returns shall be evaluated to inform any ongoing monitoring of GHG emissions and feed back into future assessment of projects during design development and planning approval.
- 14.11.3 Highways England is committed to reducing carbon emissions and working closely with suppliers to reduce emissions from network related activity. An EMP, will be prepared and submitted with the DCO application, which would require energy consumption and materials use to be recorded and reported on an ongoing basis during the construction phase of the proposed scheme using the Highways England Carbon Reporting Tool. It is not considered practical to monitor GHG emissions from road users during the operational phase of the proposed scheme.

Vulnerability of the proposed scheme to climate change (climate change resilience assessment)

- 14.11.4 As no preliminary likely significant effects have been identified within the climate change resilience assessment, no monitoring of significant effects is expected to be required.

- 14.11.5 The EMP will set out monitoring to be undertaken during the construction stage to ensure that the mitigation measures embedded in the proposed scheme design are appropriately implemented.
- 14.11.6 In line with the monitoring requirements set out in DMRB LA 114 Climate, and to be secured through the EMP, once operational, asset data would be managed, maintained and monitored to ensure the proposed scheme design is operating as intended. Asset management measures would evolve once the proposed scheme is operational and to respond appropriately to climate impacts. Where a design issue is identified, an assessment shall be made to determine if corrective action is required.

14.12 Summary

- 14.12.1 The climate change chapter in this PEI report describes two separate preliminary assessments: the GHG emissions assessment and the climate change resilience (CCR) assessment.
- 14.12.2 The proposed scheme would result in GHG emissions due to construction materials and activities during the construction phase, maintenance and refurbishment during the operation phase and vehicles using the road during the operation phase.
- 14.12.3 Assets and infrastructure designed as part of the proposed scheme are likely to be affected by climate change. A number of potential risks have been identified and assessed; these would be mitigated by applying robust design standards or relevant mitigation measures or would be incorporated in the relevant asset management processes.
- 14.12.4 The preliminary assessment of proposed scheme impacts is considered to be not significant based on evidence that in isolation the proposed scheme would not have a material impact on the ability of Government to meet its carbon reduction targets. Therefore, the following preliminary conclusions can be made.

Preliminary construction assessment

- Impact of the proposed scheme on climate: no significant effect.
- Vulnerability of the proposed scheme to climate change: no significant effects.

Preliminary operation assessment

- Impact of the proposed scheme on climate: no significant effect.
- Vulnerability of the proposed scheme to climate change: no significant effects.

Further work

- 14.12.5 The following will be carried out for the EIA:
- Revision of the construction-related emissions quantification based on additional information on construction process stage becoming available and any revisions to the design of the proposed scheme. An assessment will be made against the latest carbon budgets, which may be updated in line with the revised Climate Change Act 2008 (2050 Target Amendment) Order 2019;
 - Revision of the traffic model to ensure traffic data used in the GHG assessment is consistent with the design of the proposed scheme;

- Consultation with local authorities and other relevant stakeholders;
- Revision of the CCR assessment to reflect any revisions to the design of the proposed scheme;
- Use of the H++ climate scenarios to test the sensitivity of vulnerable safety critical features (identified in paragraph 14.6.14); and
- Any further project-specific mitigation measures and monitoring requirements during construction and operation will be considered and addressed in the ES.

End Notes & References

¹ Highways England, Transport Scotland, Welsh Government, and Department for Infrastructure, “Design Manual for Roads and Bridges Sustainability and Environment Appraisal LA 114 Climate Revision 0,” 2019

² GHG emissions are reported in this chapter in tonnes of carbon dioxide equivalents (tCO₂e). This measure considers the six Kyoto Protocol gases: Carbon dioxide (CO₂); Methane (CH₄); Nitrous oxide (N₂O); Sulphur hexafluoride (SF₆); Hydrofluorocarbons (HFCs); and Perfluorocarbons (PFCs).

³ This chapter refers to ‘carbon’ as including all main greenhouse gases, as covered by the Kyoto Protocol. GHG emissions are converted into tonnes of carbon dioxide equivalent (tCO₂e), a calculation which normalizes the global warming potential of the main GHG into one measure, based on the global warming potential of CO₂.

⁴ The RCP8.5 global warming scenario represents a very high baseline emission scenario, representing the 90th percentile of no-policy baseline scenarios available at the time. ‘8.5’ represents 8.5 watts per metre squared, which is a measure of the end-of-century radiative forcing increase relative to pre-industrial conditions. The four RCP scenarios include “one mitigation scenario leading to a very low forcing level (RCP2.6), two medium stabilisation scenarios (RCP4.5/RCP6.0) and one very high baseline emission scenarios (RCP8.5)”. The high emissions baseline scenario is representative of the trajectory that global emissions have been on.

⁵ Council of The European Union and European Parliament, “DIRECTIVE 2011/92/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 13 December 2011 on the assessment of the effects of certain public and private projects on the environment,” 2011

⁶ Highways England, “A417 Missing Link Environmental Impact Assessment Scoping Report,” 2019

⁷ UK Government, *Climate Change Act 2008*. Statute Law Database, 2008

⁸ UK Government, *The Climate Change Act 2008 (2050 Target Amendment) Order 2019*. Queen’s Printer of Acts of Parliament, 2019

⁹ Committee on Climate Change, “Net Zero - The UK’s contribution to stopping global warming,” 2019. [Online]. Available: <https://www.theccc.org.uk/publication/net-zero-the-uks-contribution-to-stopping-global-warming/>

¹⁰ UK Government, *The Carbon Budgets Order 2009*. Queen’s Printer of Acts of Parliament, 2009

¹¹ UK Government, *The Carbon Budget Order 2011*. Queen’s Printer of Acts of Parliament, 2011

¹² UK Government, *The Carbon Budget Order 2016*. Queen’s Printer of Acts of Parliament, 2016

¹³ UK Government, “UK Climate Change Risk Assessment 2017 (Policy Paper) Presented to Parliament pursuant to Section 56 of the Climate Change Act 2008,” 2017

¹⁴ The third UK Climate Change Risk Assessment is due in 2022

¹⁵ Committee on Climate Change, “UK Climate Change Risk Assessment 2017. Synthesis Report,” pp. 1–86, 2016

¹⁶ Ministry of Housing Communities and Local Government, “National Planning Policy Framework,” 2019

¹⁷ Department for Environment Food and Rural Affairs, “The National Adaptation Programme and the Third Strategy for Climate Adaptation Reporting Making the country resilient to a changing climate,” 2018

¹⁸ Highways England (2017), Climate Adaptation Risk Assessment Progress Update 2016. Available online:

https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/596812/climate-adrep-highways-england.pdf

¹⁹ UK Government, “The Clean Growth Strategy Leading the way to a low carbon future,” 2017

²⁰ Department for Transport, “The Road to Zero Next steps towards cleaner road transport and delivering our Industrial Strategy,” 2018

- ²¹ UK Government (2017) *Industrial Strategy: building a Britain fit for the future* (Policy paper) 27 November 2017. Available online: <https://www.gov.uk/government/publications/industrial-strategy-building-a-britain-fit-for-the-future>
- ²² Gloucestershire County Council Local Flood Risk Management Strategy (LFRMS). Available online: <https://www.gloucestershire.gov.uk/your-community/emergencies-and-your-safety/flooding-and-drainage/gloucestershire-county-councils-local-flood-risk-management-strategy-lfrms/>
- ²³ Cotswold District Local Plan 2011-2031 (Adopted 3 August 2018). Available online at: <https://www.cotswold.gov.uk/residents/planning-building/planning-policy/local-plan-2011-2031/local-plan-examination/>
- ²⁴ Gloucester, Cheltenham and Tewkesbury Joint Core Strategy (JCS) 2011-2031 (adopted December 2017). Available online: <https://www.jointcorestrategy.org/>
- ²⁵ Tewkesbury Borough Council (2019) Pre-submission Tewkesbury Borough Plan 2011-2031. Available online: <https://www.tewkesbury.gov.uk/pre-submission-tewkesbury-borough-plan#the-pre-submission-plan>
- ²⁶ Cotswolds Conservation Board, "Cotswolds Area of Outstanding Natural Beauty Management Plan 2018-2023" 2018
- ²⁷ Cotswolds Conservation Board (2012) *Climate Change Strategy for the Cotswolds Area of Outstanding Natural Beauty*. Available online at: <https://www.cotswoldsaonb.org.uk/wp-content/uploads/2020/02/Climate-Change-Strategy-adopted-June-2012.pdf>
- ²⁸ Highways England, Transport Scotland, Welsh Government, and Department for Infrastructure, "Design Manual for Roads and Bridges Sustainability and Environment Appraisal LA 114 Climate Revision 0" 2019
- ²⁹ Highways England, Transport Scotland, Welsh Government, and Department for Infrastructure, "Design Manual for Roads and Bridges LA 105 Air quality" 2019
- ³⁰ British Standards Institution, "PAS 2080:2016 Carbon Management in Infrastructure," 2016
- ³¹ RICS (2017) *RICS professional standards and guidance, UK: Whole life carbon assessment for the built environment*. Available online: <https://www.rics.org/globalassets/rics-website/media/upholding-professional-standards/sector-standards/building-surveying/whole-life-carbon-assessment-for-the-built-environment-1st-edition-rics.pdf>
- ³² UK Government, "TAG unit A3 environmental impact appraisal," 2019. [Online]. Available online: <https://www.gov.uk/government/publications/tag-unit-a3-environmental-impact-appraisal>.
- ³³ Highways England, Transport Scotland, Welsh Government, and Department for Infrastructure, "Design Manual for Roads and Bridges Sustainability and Environment Appraisal LA 114 Climate Revision 0," 2019
- ³⁴ The Institute of Environmental Management and Assessment (IEMA), "IEMA Environmental Impact Assessment Guide To: Climate Change Resilience And Adaptation," 2020
- ³⁵ Publicly Available Specification (PAS) 2080 Carbon management in Infrastructure provides a common framework for all infrastructure sectors on how to manage and reduce whole life carbon when delivering infrastructure assets and programmes of work.
- ³⁶ Highways England (2015) *Carbon emissions calculation tool: Highways England*. Available online: <https://www.gov.uk/government/publications/carbon-tool>
- ³⁷ UK Government, "TAG unit A3 environmental impact appraisal," 2019. [Online]. Available: <https://www.gov.uk/government/publications/tag-unit-a3-environmental-impact-appraisal>
- ³⁸ Greenhouse gas reporting: conversion factors 2019. Available online: <https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2019>
- ³⁹ D. Collings (2006) *An environmental comparison of bridge forms*, Proceedings of the Institution of Civil Engineers - Bridge Engineering, Volume 159, Issue 4.
- ⁴⁰ Natural England (2012) *Carbon storage by habitat: Review of the evidence of the impacts of management decisions and condition of carbon stores and sources (NERR043)*. Available online: <http://publications.naturalengland.org.uk/publication/1412347>
- ⁴¹ Embodied carbon includes GHG emissions associated with energy consumption and chemical processes during the extraction, transport and/or manufacture of construction materials or products.

⁴² The Met Office provides information on observed and future climate change relative to the baseline period of 1961-1990, based on the latest scientific understanding UKCP18. UKCP provides probabilistic projections for the whole of the UK, at regional level and at local level.

⁴³ The start date for the construction phase would depend upon a number of factors including the grant of a development consent order. It is currently anticipated that the construction activities for the proposed scheme would commence in early 2023 and be ongoing until the opening year in 2025. The construction programme would be finalised by the contractor in advance of the works.

⁴⁴ H++ scenarios are a set of plausible 'high-end' climate change scenarios which are typically extreme climate change scenarios on the margins or outside of the 10th to 90th percentile range presented in the UK Climate Projections 2009 (UKCP09). They cover the following climate hazards: heat waves, cold snaps, low and high rainfall, droughts, floods and windstorms. Note: the UKCP18 project will not be producing an updated H++ scenario and so the H++ scenario developed from UKCP09 remains current and applicable. The H++ scenarios are available online: <https://www.theccc.org.uk/publication/met-office-for-the-asc-developing-h-climate-change-scenarios/>

⁴⁵ The RCP8.5 global warming scenario represents a very high baseline emission scenario, representing the 90th percentile of no-policy baseline scenarios available at the time. '8.5' represents 8.5 watts per metre squared, which is a measure of the end-of-century radiative forcing increase relative to pre-industrial conditions. The four RCP scenarios include "one mitigation scenario leading to a very low forcing level (RCP2.6), two medium stabilisation scenarios (RCP4.5/RCP6.0) and one very high baseline emission scenarios (RCP8.5)". The high emissions baseline scenario is representative of the trajectory that global emissions have been on.

⁴⁶ The Met Office generates climatologies based on standard areas (UK climate districts) of the UK. The proposed scheme is within the Midlands district as shown on the UK climate districts map. Available online: <https://www.metoffice.gov.uk/research/climate/maps-and-data/about/districts-map>

⁴⁷ Wiltshire Council, "Local Climate Impacts Profile Summary Report," 2010.

⁴⁸ A. Cunningham *et al.*, "South West Local Climate Impacts Profile (LCLIP) Final Report," 2011

⁴⁹ The time periods for climate projections are selected based on the lifespan and stages of the proposed scheme (60 years).

⁵⁰ For the PEI report, the traffic models are based on an opening year of 2024 and 2039 (15 years after opening). It is noted that the modelled years do not coincide with the revised opening and design year for the proposed scheme. It is considered that these do not materially affect the results of the assessments undertaken.

⁵¹ Met Office, "UK Climate Projections (UKCP) - Met Office," 2018. Available online:

<https://www.metoffice.gov.uk/research/approach/collaboration/ukcp/index>

⁵² The Regional (12km) projections are downscaled versions of the Global (60km) projections providing information on local climate effects.

⁵³ Regional projections are only available up to 2079.

⁵⁴ 12 regional models are used in UKCP18 to project the variables for extreme weather events. The min. (minimum) and max. (maximum) values shown here are the minimum projection from the 12 models and maximum projection from the 12 models for the given parameter.

⁵⁵ There is no observational baseline available for wind, therefore values are presented without bias correction.

⁵⁶ Highways England (2017) Sustainable development strategy – Our Approach. Available online at:

https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/605079/Sustainable_Development_Strategy_6.pdf

⁵⁷ Highways England (2018) Sustainable Development and Environment Action Plan: Roads Period 1. Available online at:

https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/763125/Sustainable_Development_and_Environment_Action_Plan_final.pdf

⁵⁸ The Planning Inspectorate (2019) Scoping Opinion for A417 Missing Link Case Reference: TR010056 (June 2019). Section 4.10 Climate. Available online:

<https://infrastructure.planninginspectorate.gov.uk/wp->

[content/ipc/uploads/projects/TR010056/TR010056-000046-TR010056%20-%20Scoping%20Opinion.pdf](#)

⁵⁹ 2025 represents the opening year (first year of operation) and 2040 represents the design (future) assessment year, 15 years after opening. For the PEI report, the traffic models are based on an opening year of 2024 and 2039 (15 years after opening). It is noted that the modelled years do not coincide with the revised opening and design year for the proposed scheme. It is considered that these do not materially affect the results of the assessments undertaken.

⁶⁰ Highways England (2019) M2 Junction 5 Improvements Environmental Statement Volume 1 – Main Report. Available online at: <http://assets.highwaysengland.co.uk/roads/road-projects/M2+Junction+5/Environmental/Volume+1+Environmental+Statement+Main+Text.pdf>