

Lower Thames Crossing

6.1 Environmental Statement

Chapter 15 Climate

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Lower Thames Crossing

6.1 Environmental Statement

Chapter 15 Climate

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15 Climate

15.1 Introduction

- 15.1.1 This chapter presents an assessment of the likely significant effects of the A122 Lower Thames Crossing ('the Project') on climate (greenhouse gas (GHG) emissions) and vulnerability of the Project to climate change during construction and operation.
- 15.1.2 The assessment follows the methodology set out in the Design Manual for Roads and Bridges (DMRB) LA 114 Climate (Highway England, 2019a), which requires the assessment, reporting and management of effects of the Project on the climate along with the effects of climate on the Project.
- 15.1.3 This chapter is supported by additional information contained in the following appendices (Application Document 6.3):
- Appendix 15.1: Carbon and Energy Plan (CEP)
 - Appendix 15.2: Climate Resilience Baseline
 - Appendix 15.3: Climate Resilience Impacts and Effects
- 15.1.4 In addition to the supporting appendices, a number of other documents are inherently linked with the climate assessment, namely:
- Chapter 14: Road Drainage and the Water Environment
 - Appendix 14.6: Flood Risk Assessment (FRA) (Application Document 6.3)

15.2 Legislative and policy framework

- 15.2.1 This assessment has been undertaken in accordance with relevant legislation, together with national, regional and local plans and policies. A list of plans is provided within Table 15.3 and further detail can be found in the Planning Statement (Application Document 7.2).

Legislative requirements

- 15.2.2 Relevant climate legislation that has been considered during the assessment is presented in Table 15.1.

Table 15.1 Legislative requirements

| Scale | Description of legislation |
|---------------|--|
| International | <p>The Paris Agreement 2015</p> <p>In December 2015, a global climate agreement – the Paris Agreement – was adopted at the 21st Conference of the Parties. A central aim of the Paris Agreement is to strengthen the global response to climate change by limiting the global temperature increase this century to below 2°C above pre-industrial levels, and to pursue efforts to limit the temperature increase even further to 1.5°C. To achieve this aim, the Paris Agreement additionally sets a target for net zero global carbon emissions in the second half of this century. The Paris Agreement was ratified and entered into force in the UK in November 2016.</p> |

| Scale | Description of legislation |
|----------|--|
| | <p>United Nations Framework Convention on Climate Change (UNFCCC) and Paris Agreement, 1992</p> <p>The UNFCCC is an international environmental treaty adopted on 9 May 1992. The UNFCCC's objective is to '<i>stabilise greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system, in a time frame which allows ecosystems to adapt naturally and enables sustainable development</i>'.</p> |
| National | <p>Planning Act 2008</p> <p>The Planning Act introduced a new system of development consent for Nationally Significant Infrastructure Projects. The system included National Policy Statements which provided the framework within which decisions are to be made.</p> <p>Section 104(3) provides that the Secretary of State must, '<i>decide the application in accordance with any relevant national policy statement, except to the extent that...</i>':</p> <ul style="list-style-type: none"> • it would lead to the United Kingdom being in breach of any of its international obligations; and • it would lead to the Secretary of State being in breach of any duty imposed on it by or under any enactment. <p>Infrastructure Planning (Environmental Impact Assessment) Regulations 2017 (EIA Regulations)</p> <p>These regulations transposed the requirements of the EIA Directive 2014/52/EU into UK law. This introduced climate as a topic for environmental assessment, including a description of the likely significant effects resulting from the impact of the Project on climate (for example the nature and magnitude of GHG emissions) and the vulnerability of the Project to climate change.</p> <p>The Climate Change Act 2008/Climate Change Act (2050 Target Amendment) 2019</p> <p>In June 2019, the Government amended the Climate Change Act 2008 to revise the 2050 GHG target of an 80% reduction of GHG emissions compared to 1990 levels to a 100% reduction carbon target.</p> <p>The Climate Change Act required that the pathway to achieving the previous 2050 carbon target was set out through five-year carbon budgets. The most recent carbon budget is the fifth which sets a cap on carbon emission levels between 2028 and 2032. However, the Committee on Climate Change (CCC) (2019b) has stated:</p> <p><i>'The path to achieving net-zero emissions by 2050 will necessarily entail a steeper reduction in emissions over the intervening three decades ... As the existing carbon budgets were set on a cost-effective path to achieving an 80% reduction in UK greenhouse gas emissions by 2050, a more ambitious long-term target is likely to require outperformance of the carbon budgets legislated to date. The Committee will revise its assessment of the appropriate path for emissions over the period to 2050 as part of its advice next year on the sixth carbon budget (covering 2033-2037).'</i></p> <p><i>'In December, the Committee will publish its recommendation on the level of the sixth carbon budget, the limit on UK emissions for 2033-37. This will present a full pathway to net-zero greenhouse gas emissions by 2050. Government is required to respond to that advice and legislate the new carbon budget by June 2021.'</i> (CCC, 2020)</p> |

| Scale | Description of legislation |
|-------|---|
| | <p>Energy Act 2013</p> <p>This Act introduced Contracts for Difference to incentivise long-term, low carbon energy investments. The Act aimed to help ensure the security of electricity supply in the UK whilst meeting climate and renewables targets and delivering low cost energy to consumers.</p> |
| | <p>Climate Change and Sustainable Energy Act 2006</p> <p>This Act placed an obligation on the Department for Environment, Food and Rural Affairs (Defra) to report to parliament on GHG emissions and on action taken by the Government to reduce these emissions.</p> |

National policy framework

- 15.2.3 The National Policy Statement for National Networks (NPSNN) (Department for Transport, 2014) sets out the Government's policies in relation to the development of Nationally Significant Infrastructure Projects (NSIPs) on the national road and rail networks in England. Major utilities diversions are required as part of the Project, and the National Policy Statements for Energy Networks 1, 4 and 5 sets out the relevant policies for these.
- 15.2.4 NSIPs are determined in accordance with the decision-making framework in the Planning Act 2008 and relevant NPSs for major infrastructure, as well as any other matters that are relevant (which may include the National Planning Policy Framework (NPPF)).
- 15.2.5 The NPPF, published in 2012 and updated in 2019 (Ministry of Housing, Communities and Local Government, 2019), sets out the Government's overarching planning policies for England and how these are expected to be applied. The NPPF confirms (in paragraph 5) that it does not set policy for NSIPs, and that relevant policy is to be found within the NPSs, however, the NPPF may contain guidance considered important by the decision-making authority.
- 15.2.6 The Project is required to be assessed against both the NPSNN as well as the Overarching National Policy Statement for Energy (EN-1), National Policy Statement for Gas Supply Infrastructure and Gas and Oil Pipelines (EN-4) and National Policy Statement for Electricity Infrastructure (EN-5). The NPSNN forms the "case-making" basis for the Project, and the need for nationally significant utilities diversions arises solely from the need for the road element of the Project. Notwithstanding this, the assessment principles in the NPSs have been considered with equal weight. All NPSs are designated utilising and conforming to the same legislative requirements, guidance and international obligations, and accordingly, there is consistency across them. For this reason Table 15.2, below, lists the planning policies at a national level, including those in the NPSNN but does not repeat the same policy requirements that appear in EN-1, EN-4 and EN-5. Instead, cross-references and individual responses (where necessary) to the relevant sections within the suite of Energy National Policy Statements can be seen in Appendix A2 to the Planning Statement (Application Document 7.2).

Table 15.2 National policy framework and the Project response

| Reference | Requirement | Project response |
|---|---|--|
| National Policy Statement for National Networks (NPSNN) (Department for Transport, 2014) | | |
| Paragraph 4.38 | <i>‘Adaptation is therefore necessary to deal with the potential impacts of these changes that are already happening. New development should be planned to avoid increased vulnerability to the range of impacts arising from climate change. When new development is brought forward in areas which are vulnerable, care should be taken to ensure that risks can be managed through suitable adaptation measures, including through the provision of green infrastructure.’</i> | Section 15.3 and Section 15.6 of this chapter demonstrate application of the latest UK climate projections, United Kingdom Climate Projections 2018 (UKCP18), during the estimated lifetime of the Project. Section 15.5 of this chapter presents the measures that have been incorporated to increase the Project capacity to be resilient to the effects of climate change. |
| Paragraph 4.40 | <i>‘The applicant must consider the impacts of climate change when planning location, design, build and operation. Any accompanying environment statement should set out how the proposal will take account of the projected impacts of climate change.’</i> | In accordance with the requirements of the NPSNN, the ES has set out how the Project takes into account of the projected impacts of climate change. Section 15.6 of this chapter provides information on how the Project would account for the projected impacts on climate, whilst Section 15.5 provides details of the measures included within the Project design to increase the Project’s capacity to cope with the effects of climate change. A detailed FRA has been carried out and is presented in ES Appendix 14.6 (Application Document 6.3). This assessment also included allowances for climate change to ensure alleviation and mitigation measures are robust. ES Chapter 14: Road Drainage and the Water Environment summarises the outcomes of the detailed FRA. |
| Paragraph 4.41 | <i>‘Where transport infrastructure has safety-critical elements and the design life of the asset is 60 years or greater, the applicant should apply the United Kingdom Climate Projections 2009 (UKCP09) high emissions scenario (high impact, low likelihood) against the 2080 projections at the 50% probability level.’</i> | New climate projections (UKCP18) have been released since the publication of the NPSNN. Section 15.3 and Section 15.6 of this chapter demonstrate the application of the updated UKCP18 Representative Concentration Pathway (RCP) 8.5 scenario against the 2080 projections at the 50% probability level. RCP8.5 is the most similar to the high emissions scenario in UKCP09. |

| Reference | Requirement | Project response |
|----------------|--|--|
| Paragraph 4.42 | <i>‘The applicant should take into account the potential impacts of climate change using the latest UK Climate Projections available at the time and ensure any environment statement that is prepared identifies appropriate mitigation or adaptation measures. This should cover the estimated lifetime of the new infrastructure. Should a new set of UK Climate Projections become available after the preparation of any environment statement, the Examining Authority should consider whether they need to request additional information from the applicant.’</i> | Section 15.3 and Section 15.6 of this chapter demonstrate application of the latest UK climate projections, UKCP18, during the estimated lifetime of the Project. Section 15.5 presents the measures that have been incorporated to increase the Project capacity to be resilient to the effects of climate change. |
| Paragraph 4.43 | <i>‘The applicant should demonstrate that there are no critical features of the design of new national networks infrastructure 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 (e.g. by referring to additional maximum credible scenarios such as from the Intergovernmental Panel on Climate Change or Environment Agency) 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.’</i> | A detailed assessment of Project critical features is presented in Appendix 15.3 Climate Resilience Impacts and Effects (Application Document 6.3) and summarised in Section 15.6 of this chapter. The assessment has considered any potentially critical features of the design which may be seriously affected by climate change beyond what has been projected in UKCP18. Measures implemented within the design have been identified to increase the Project’s capacity to be resilient to the effects of climate change throughout its design life. Measures were identified through the detailed assessment in Appendix 15.3 Climate Resilience Impacts and Effects (Application Document 6.3) and are presented in Section 15.5 of this chapter, including the details of how they are secured. |
| Paragraph 4.44 | <i>‘Any adaptation measures should be based on the latest 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 environment</i> | Measures to increase the Project’s capacity to be resilient to the effects of climate change were identified and are described within Section 15.5 of this chapter. The embedded adaptation measures have been based on the latest UK Climate Change Risk Assessment (CCRA) (Defra, 2017). Statutory consultation bodies have been consulted by the relevant topic specialists regarding these measures. For example, a meeting was held with the Environment Agency to agree flood modelling climate change scenarios, and to |

| Reference | Requirement | Project response |
|----------------|---|---|
| | <i>statement, which should set out how and where such measures are proposed to be secured.'</i> | discuss strategies for managing residual flood risks. Consultation in relation to climate change allowances for the FRA and hydrogeological modelling are detailed within Chapter 14: Road Drainage and the Water Environment. Details of agreed climate change allowances and strategies for managing residual flood risk are provided in Part 6 of Appendix 14.6: Flood Risk Assessment (Application Document 6.3). |
| Paragraph 4.46 | <i>'Adaptation measures can be required to be implemented at the time of construction where necessary and appropriate to do so.'</i> | A number of embedded, good practice and essential mitigation and adaptation measures to address the potential impacts associated with climate change events have been considered in Appendix 15.3: Climate Resilience Impacts and Effects (Application Document 6.3), many of which have been identified within other topic chapters of this ES and through the development of the Project's design. The Register of Environmental Actions and Commitments (REAC) (Application Document 6.3, Appendix 2.2) secures good practice and essential mitigation and adaptation measures that have been taken into consideration in this table. |
| Paragraph 4.47 | <i>'Where adaptation measures are necessary to deal with the impact of climate change, and that measure would have an adverse effect on other aspects of the project and/or surrounding environment (e.g. coastal processes), the Secretary of State may consider requiring the applicant to ensure that the adaptation measure could be implemented should the need arise, rather than at the outset of the development (e.g. reserving land for future extension, increasing the height of an existing sea wall, or requiring a new sea wall).'</i> | Measures to increase the Project's capacity to be resilient to the effects of climate change were identified and are described within Section 15.5 of this chapter. These measures have been developed to anticipate the adverse effects of climate change and are based on the latest UK CCRA and in consultation with the relevant bodies presented within Chapter 4: EIA Methodology. Where appropriate, measures agreed with the relevant consultation bodies have been embedded within the Project design and are included within Section 15.5. For example, consultation in relation to climate change allowances for the FRA and hydrogeological modelling are detailed within Chapter 14: Road Drainage and the Water Environment. |
| Paragraph 5.17 | <i>'Carbon impacts will be considered as part of the appraisal of Project options (in the business case), prior to the submission of an application for the Development</i> | Section 15.5 of this chapter outlines how measures to avoid/prevent, reduce and remediate the Project's GHG emissions have been |

| Reference | Requirement | Project response |
|----------------|--|--|
| | <i>Consent Order. Where the development is subject to Environmental Impact Assessment (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. It is very unlikely that the impact of a road project will, in isolation, affect the ability of Government to meet its carbon reduction plan targets. However, for road projects applicants should provide evidence of the carbon impact of the project and an assessment against the Government's carbon budgets.'</i> | applied and developed and how they help contribute to the UK's target for reduction in carbon emissions. In addition, Section 15.6 considers the carbon impacts of the Project during construction and operational phases and compares them to the Government's relevant carbon budgets. |
| Paragraph 5.18 | <i>'The Government has an overarching national carbon reduction strategy (as set out in the Carbon Plan 2011) which is a credible plan for meeting carbon budgets. It includes a range of non-planning policies which will, subject to the occurrence of the very unlikely event described above, ensure that any carbon increases from road development do not compromise its overall carbon reduction commitments. The Government is legally required to meet this plan. Therefore, any increase in carbon emissions is not a reason to refuse development consent, unless the increase in carbon emissions resulting from the proposed scheme are so significant that it would have a material impact on the ability of Government to meet its carbon reduction targets.'</i> | Section 15.5 of this chapter outlines how measures to avoid/prevent, reduce and remediate the Project's GHG emissions have been applied and developed and how they help contribute to the UK's target for reduction in carbon emissions. In addition, Section 15.6 considers the carbon impacts of the Project during construction and operational phases and compares them to the Government's relevant carbon budgets. Section 15.5 of this chapter concludes that the Project would not have a material impact on the ability of Government to meet its carbon reduction targets. |
| Paragraph 5.19 | <i>'Evidence of appropriate mitigation measures (incorporating engineering plans on configuration and layout, and use of materials) in both design and construction should be presented. The Secretary of State will consider the effectiveness of such mitigation measures in order to ensure that, in relation to design and construction, the carbon footprint is not</i> | A number of embedded, good practice and essential mitigation and adaptation measures to address the potential impacts associated with climate change events have been considered in Appendix 15.3: Climate Resilience Impacts and Effects (Application Document 6.3), many of which have been identified within other topic chapters of this ES, and through the development of the Project's design. The Register of Environmental Actions and Commitments (REAC) |

| Reference | Requirement | Project response |
|--|--|--|
| | <i>unnecessarily high. The Secretary of State's view of the adequacy of the mitigation measures relating to design and construction will be a material factor in the decision making process.'</i> | (Application Document 6.3, Appendix 2.2) secures the good practice and essential mitigation and adaptation measures that have been taken into consideration in this table. |
| National Planning Policy Framework (NPPF) (Ministry of Housing, Communities and Local Government, 2019) | | |
| Paragraph 150 | <p>The NPPF describes ways in which the challenge of climate change can be met. Chapter 14 of the NPPF highlights that planning plays a key role in mitigation against climate change. The policy also states that '<i>new development should be planned for in ways that:</i></p> <ul style="list-style-type: none"> • <i>avoid increased vulnerability to the range of impacts arising from climate change. When new development is brought forward in areas which are vulnerable, care should be taken to ensure that risks can be managed through suitable adaptation measures, including through the planning of green infrastructure; and</i> • <i>can help to reduce greenhouse gas emissions, such as through its location, orientation and design. Any local requirements for the sustainability of buildings should reflect the Government's policy for national technical standards.'</i> | A risk assessment has been completed and is presented in Appendix 15.3: Climate Resilience Impacts and Effects (Application Document 6.3). A summary of the risk assessment in Section 15.6 of this chapter demonstrates that a full account of the climate change risks has been provided. Section 15.5 presents adaptation measures for climate change and minimising GHG emissions. |
| Paragraph 151 | <p><i>'To help increase the use and supply of renewable and low carbon energy and heat, plans should:</i></p> <ul style="list-style-type: none"> • <i>provide a positive strategy for energy from these sources, that maximises the potential for suitable development, while ensuring that adverse impacts are addressed satisfactorily (including cumulative landscape and visual impacts);</i> | Appendix 15.1: Carbon and Energy Plan (Application Document 6.3) presents the energy strategy for the Project and identifies potential opportunities for the utilisation of renewable energy on the Project. |

| Reference | Requirement | Project response |
|-----------|---|------------------|
| | <ul style="list-style-type: none">• <i>consider identifying suitable areas for renewable and low carbon energy sources, and supporting infrastructure, where this would help secure their development; and</i>• <i>identify opportunities for development to draw its energy supply from decentralised, renewable or low carbon energy supply systems and for co-locating potential heat customers and suppliers.'</i> | |

- 15.2.7 The following plans have also been considered as part of the assessment to inform the identification of receptors and resources and their sensitivity, the assessment methodology, the potential for significant environmental effects and required mitigation:
- Highways England Delivery Plan 2020-2025 (Highways England, 2020b)
 - A Green Future: Our 25 Year Plan to Improve the Environment (HM Government, 2018a)
 - Clean Growth Strategy 2017 (Department for Business, Energy and Industrial Strategy (BEIS), Amended 2018)
 - The Carbon Plan: Delivering Our Low Carbon Future (HM Government, 2011)
 - Decarbonising Transport: Setting the Challenge (Department for Transport, 2020b)

Local policy framework

- 15.2.8 Consideration has been given to local policies relating to climate within the following local authorities: Kent County Council, Essex County Council, Thurrock Council, the Greater London Authority, London Borough of Havering, Medway Council, Dartford Borough Council, Gravesham Borough Council and Brentwood Borough Council. These are outlined in Table 15.3 below.

Table 15.3 Local policies for climate

| Strategy/plan | Policy and/or description |
|---|---|
| Kent Environment Strategy (Kent County Council, 2016) | <p>To address national and local drivers and legislation, Kent County Council has committed to:</p> <ul style="list-style-type: none"> Reduce the emissions across the county by 34% by 2020 and 60% by 2030 from a 2005 baseline Generate more than 15% of energy in Kent from renewable sources by 2020 from a 2012 baseline Review climate risk assessment for public sector services Develop resilience plans and risk assessments Report using the Severe Weather Impacts Monitoring System |
| Adapting to climate change – Action Plan (Essex County Council, 2011) | <p>The Action Plan is a living and adaptable document, which highlights the priorities for continuous development on adaptation and reflects the following:</p> <ul style="list-style-type: none"> Continue to understand Essex County Council risk threshold Focus on actions that manage and address risks associated with current climate variability and extremes as a starting point Balance the management of climate and non-climate risks |

| Strategy/plan | Policy and/or description |
|--|--|
| | <ul style="list-style-type: none"> • Ensure climate risk management is integrated into Essex County Council decision making, policies and planning, especially in areas responsible for long-term assets • Avoid actions that stop or limit future adaptation • Review the continued effectiveness of adaptation decisions in light of any climatic and organisational changes • Work in partnership with key stakeholders (internally and externally) |
| Gravesham Local Plan Core Strategy (Gravesham Borough Council, 2014) | CS18: Climate Change, covering flood risk, water quality, sustainable drainage and surface water runoff, water demand management and carbon reduction. |
| Core Strategy and Policies for Management of Development (Thurrock Council, 2015) | CSTP25 – Addressing climate change CSTP26 – Renewable or low-carbon energy generation CSTP27 – Management and reduction of flood risk PMD13 – Decentralised, Renewable and low-carbon energy generation PMD14 – Carbon neutral development |
| Brentwood Replacement Local Plan Saved Policies (Brentwood Borough Council, 2008) | IR5 – Energy and water conservation and the use of renewable sources of energy in new developments. |
| Core Strategy and Development Control Policies Development Plan Document (London Borough of Havering, 2008) | CP15 – Environmental management DC48 – Flood risk DC50 – Renewables energy DC51 – Water supply, drainage and quality |
| Dartford and Gravesham Sustainable Community Strategy (2008 – 2011) (Dartford Borough Council and Gravesham Borough Council, 2008) | ET1 – To reduce carbon emissions ET1 (a) – Ensure all partner agencies reduce their organisational carbon footprint ET1 (b) – Introduce appropriate planning policies and work with developers to reduce energy. |
| Corporate Plan (2017 – 2020) (Dartford Borough Council, 2017) | ET1 – To reduce carbon emissions ET1 (a) – Work with developers, business and the local community to reduce the Borough's Carbon Footprint ET2 – Ensure that development in Dartford is sustainable, with high standards of design, layout and energy efficiency ET2 (a) – Introduce appropriate planning policies and work with developers to reduce energy use and provide high quality living environment |
| The London Plan: The Spatial Development Strategy for London Consolidated with Alterations since 2011 | Policy 5.1 Climate change mitigation Policy 5.2 Minimising carbon dioxide emissions Policy 5.3 Sustainable design and construction Policy 5.5 Decentralised energy networks Policy 5.6 Decentralised energy in development proposals |

| Strategy/plan | Policy and/or description |
|----------------------------------|--|
| (Greater London Authority, 2016) | Policy 5.7 Renewable energy Policy 5.8 Innovative energy technologies Policy 5.9 Overheating and cooling |

15.3 Assessment methodology

Standards and guidance

- 15.3.1 The following standards and guidance documents have been used in devising the methodology for data collection and assessment of climate impacts:
- DMRB LA 114 Climate (Highways England, 2019a)
 - DMRB GG 103 Introduction and General Requirements for Sustainable Development and Design (Highways England, 2019d)
 - Government emissions conversion factors for GHG gas company reporting, (BEIS, 2019a)
 - PAS 2080:2016: Carbon Management in Infrastructure (British Standards Institution, 2016)
 - GHG Protocol (World Resources Institute (WRI) and World Business Council for Sustainable Development (WBCSD), 2015)
 - TAG GHG emissions workbook (Department for Transport, 2019)
 - Appraisal and Modelling Strategy: A route map for updating TAG during uncertain times (Department for Transport, 2020a)
 - Inventory of Carbon and Energy (ICE Database) V3.0 (Circular Ecology, 2019)
 - Net Zero – The UK's contribution to stopping global warming (CCC, 2019a)
 - Infrastructure Carbon Review (HM Treasury, 2013)
 - Construction 2025 – Industrial Strategy: Government and industry in partnership (HM Government, 2013)
 - Climate Adaption Risk Assessment Progress Update (Highways England, 2016)
 - Fifth Assessment Report (Intergovernmental Panel on Climate Change, 2014)
 - The UK CCRA (Defra, 2017)

Scope of the assessment

- 15.3.2 The scope of this chapter is in line with DMRB LA 114 Climate (Highways England, 2019a) and considers the impacts of the Project on climate through its GHG emissions and the vulnerability of the Project to climate change. This comprises two assessments:
- a. Impact of the Project on climate (GHG emissions) – the likely significant effects of the Project on the environment measured through the consideration of changes in GHG emissions arising from the Project's three life cycles presented within Table 15.7 (construction phase, operational phase and opportunities for reduction). The assessment also includes how the Project would affect the ability of the Government to meet its carbon reduction targets.
 - b. Vulnerability of the Project to climate change – the Project's capacity to be resilient to the effects of climate change through the application of adaptation measures within the design.
- 15.3.3 Throughout this chapter, the GHG emissions impact assessment is described first, followed by the vulnerability of the Project to climate change.
- 15.3.4 GHG emissions from the water consumption during the operational phase and other operational processes (management of operational water and waste) have been scoped out of the assessment on the basis that each would be generating less than 1% of total estimated GHG emissions from the Project. This is in line with the Scoping Opinion – see Appendix 4.1: The Inspectorate's Scoping Opinion and Highways England's Responses (Application Document 6.3).
- 15.3.5 In addition, it is very unlikely that the Project would be demolished after its stated design life, as the Project would become an integral part of nationally important infrastructure. GHG emissions from the end of life stage of the permanent works of the Project have been scoped out of the assessment due to the anticipated operational length of the Project. This is in line with the Scoping Opinion – see Appendix 4.1: The Inspectorate's Scoping Opinion and Highways England's Responses (Application Document 6.3). For example, the tunnels are likely to have an operational life well in excess of the 120 years design life, as evidenced by the number of historic tunnels still in use. However, the flexibility of future deconstruction of the highways elements was a key consideration during the Project design and would allow materials to be easily recovered and recycled at the end of first life. The replacement of elements of the Project (e.g. resurfacing, electrical equipment) is included as part of the maintenance life cycle stage of the GHG assessment and has therefore been included within the assessment.
- 15.3.6 This assessment also informs the assessment of Major Accidents and Disasters, summarised in Chapter 4: EIA Methodology and set out in full in Appendix 4.2: Major Accidents and Disasters Long List and 4.3: Major Accidents and Disasters Short List (Application Document 6.3), by providing the likelihood and consequence of potential major climate events.

Scoping Opinion

- 15.3.7 A Scoping Report (Highways England, 2017) was issued to the Planning Inspectorate on 2 November 2017, setting out the proposed approach to this EIA. A Scoping Opinion (Planning Inspectorate, 2017) was received from the Secretary of State on 13 December 2017, which included comments on the scope of assessment from the Planning Inspectorate and statutory environmental bodies. These comments have been taken into account in the preparation of this chapter, and the Project response is set out in Appendix 4.1: The Inspectorate's Scoping Opinion and Highways England's Responses (Application Document 6.3).
- 15.3.8 It should be noted that the climate assessment methodology was updated from that outlined in the Scoping Report, following the issue of DMRB LA 114 Climate (Highways England, 2019a). DMRB LA 114 Climate makes provision for the requirements outlined within EU Directive 2011/92/EU as amended by 2014/52/EU and the Climate Change Act 2008 (as amended) and remains consistent with the Scoping Opinion.
- 15.3.9 The new DMRB standard provides a defined methodology that goes beyond the professional judgement basis of earlier guidance. Implementation of the new standard DMRB LA 114 Climate (Highways England, 2019a) leads to the same outcome of the assessment on likely significant effects presented in the Scoping Report (Highways England, 2017).

Consultation

Project consultation

- 15.3.10 Statutory Consultation under Section 42 of the Planning Act 2008 was undertaken on the Project from 10 October 2018 to 20 December 2018. This provided an opportunity for consultees to comment on the Preliminary Environmental Information Report (PEIR) (Highways England, 2018). A summary of the responses can be found in the Consultation Report (Application Document 5.1). Consultees comprised statutory bodies, local authorities, people with an interest in land affected by the Project and local communities.
- 15.3.11 The Project design continued to be developed and Supplementary Consultation was undertaken from 29 January 2020 to 2 April 2020. A further Design Refinement Consultation was then undertaken from 14 July 2020 to 12 August 2020.
- 15.3.12 The Supplementary Consultation and Design Refinement Consultation both included an environmental assessment of the changes in the context of the PEIR. A summary of the responses to these consultation stages can also be found in the Consultation Report (Application Document 5.1).

Stakeholder engagement

- 15.3.13 A summary of stakeholder engagement specific to climate is shown in Table 15.4. Consultation in relation to climate change allowances for the FRA and hydrogeological modelling are detailed within Chapter 14: Road Drainage and the Water Environment.

Table 15.4 Stakeholder consultation

| Stakeholder | Date of meeting / communication | Summary of discussions |
|----------------------------|---|---|
| Kent County Council | December 2017 and August 2018 – email communication | A request for confirmation on the relevant policies that should be considered as part of the Project climate assessment. The communication also included a request for baseline information relating to GHG emissions and climate change targets. No responses were received from Kent County Council and so the assessment proceeded with publicly available policy information and data. The methodology and data sources to be used in the assessment were presented and discussed in the meeting held on 21 and 22 April 2020. |
| London Borough of Havering | December 2017 and August 2018 – email communication | A request for confirmation on the relevant policies that should be considered as part of the Project climate assessment. The communication also included a request for baseline information relating to GHG emissions and climate change targets. No responses were received from London Borough of Havering and so the assessment proceeded with publicly available policy information and data. The methodology and data sources to be used in the assessment were presented and discussed in the meeting held on 21 and 22 April 2020. |
| Gravesham Borough Council | December 2017 and August 2018 – email communication | A request for confirmation on the relevant policies that should be considered as part of the Project climate assessment. The communication also included a request for baseline information relating to GHG emissions and climate change targets. No responses were received from Gravesham Borough Council and so the assessment proceeded with publicly available policy information and data. The methodology and data sources to be used in the assessment were presented and discussed in the meeting held on the 21 and 22 April 2020. |
| Thurrock Council | December 2017 and August 2018 – email communication | A request for confirmation on the relevant policies that should be considered as part of the Project climate assessment. The communication also included a request for baseline information relating to GHG emissions and climate change targets. No responses were received from Thurrock Council, and so the assessment proceeded with publicly available policy information and data. The methodology and data sources to be used in the assessment were presented and discussed in the meeting held on 21 and 22 April 2020. |

| Stakeholder | Date of meeting / communication | Summary of discussions |
|---|---------------------------------|--|
| Environment Agency | 16 May 2019 | Meeting to agree flood modelling climate change scenarios, and to discuss strategies for managing residual flood risks. Details of agreed climate change allowances and strategies for managing residual flood risk are provided in Part 6 of Appendix 14.6: Flood Risk Assessment (Application Document 6.3). |
| Kent County Council, London Borough of Havering, Gravesham Borough Council and Thurrock Council | 21 and 22 April 2020 | A meeting was held to outline the updated DMRB methodology (Highways England, 2019) to be used in the assessment, data sources and preliminary findings of the environmental assessments. |
| Thurrock Council | 23 September 2020 | Meeting to discuss issues raised by Thurrock within the Statement of Common Ground. Meeting required the presentation of the scope of the climate assessment, study areas and confirmation of the information sources used within the assessment. No objections were raised during the meeting and all issues were closed. |

Study area

GHG emissions impact assessment

Construction phase

- 15.3.14 The study area for GHG emissions impact assessment for the construction phase covers GHG emissions associated with the Project's construction activities and materials usage, included within Table 15.7, within the Order Limits, as well as the emissions associated with their transport from outside of the Order Limits. The traffic model informing the Transport Assessment (Application Document 7.9) and Chapter 5: Air Quality has been used to derive predicted emissions from construction traffic. This study area is appropriate as it captures the emissions from the Project's construction activities and materials usage as well as emissions from staff travel and movements associated with material assets and waste.

Operational phase

- 15.3.15 The study area for GHG emissions impact assessment for the operational phase was the area covered by the Project's traffic model contained within the ComMA (Application Document 7.7). This study area is appropriate as it captures the user emissions from the Project, those arising from the outlying road network, and vehicle movements that have been indirectly influenced by the Project (positively and negatively).
- 15.3.16 In addition, the study area includes the activities, materials and their transport associated with operation and maintenance of the Project.

Vulnerability of the Project to climate change

- 15.3.17 The study area for assessing the vulnerability of the Project to climate change during the construction and operational phases was the Order Limits, which captured all assets, environmental mitigation areas and physical infrastructure associated with the Project (e.g. earthworks, structures, pavement, temporary land take and compounds).

Impact assessment methodology

- 15.3.18 The assessment follows the general approach described in Chapter 4: EIA Methodology; deviations are noted where relevant. This section provides topic-specific information regarding the methodology used for establishing the baseline, and the methods used for the construction and operational phase assessments as well as the criteria for assessing significance.

Method of establishing existing baseline conditions

- 15.3.19 The existing baseline was established using data collection from published sources (refer to Appendices 15.1 and 15.2 for a complete list of sources) and the outputs of traffic modelling completed for the Project.

GHG emissions impact assessment

- 15.3.20 The existing baseline for the GHG emissions impact assessment is a 'Do Minimum' scenario, which presents the GHG emissions of the existing road network without the Project. The 'Do minimum' scenario has been based on information obtained from the Project's traffic model contained within the ComMA (Application Document 7.7).
- 15.3.21 The baseline year for the GHG emissions impact assessment is 2016 in line with the Project's validated traffic model base year (Application Document 7.7, ComMA). Through the traffic model, an estimation of the baseline year GHG emissions (2016) was able to be established.
- 15.3.22 The ComMa presents the results from the Transport Appraisal Guidance (TAG) GHG emissions workbook and Transport Users Benefit Appraisal (TUBA) software program. However, this chapter has only included data from TAG to present the reasonable worst-case scenario estimates of the GHG emissions arising from the operational traffic.
- 15.3.23 The TAG GHG emissions workbook is based on Defra's Emission Factor Toolkit version 9 and includes forecasts of the mix of vehicles (petrol/diesel/electric) in the fleet and engine fuel efficiency up to 2030. This means that it underestimates both the proportion of the vehicle fleet that will be electric in the future and the fuel efficiency of petrol/diesel vehicles. Therefore, the TAG workbook overestimates GHG emissions.
- 15.3.24 The TUBA appraisal software program includes projections of the future fleet vehicle mix and fuel efficiencies that run beyond 2030. However, TUBA is an origin-destination based appraisal tool, as opposed to the link-based approach used in the TAG workbook. Therefore, even for the same forecasts of the future vehicle mix and engine efficiency, the TUBA approach would tend to underestimate carbon emissions.

- 15.3.25 Consequently, it is likely that emissions arising from the operational traffic would be lower than the emissions estimated in this chapter. Assumptions to the TAG methodology have been presented in the ComMA (Application Document 7.7).

Vulnerability of the Project to climate change

- 15.3.26 To establish the baseline for the vulnerability of the Project to climate change assessment, a review of published current and historical regional weather data in the location of the Project was completed, including Local Climate Impact Profiles (LCIP) and historical flood data – see Appendix 15.2: Climate Resilience Baseline (Application Document 6.3).
- 15.3.27 In addition, a desk-based review of the following data sources was undertaken in Chapter 14: Road Drainage and the Water Environment to determine baseline conditions across the Project study areas and to inform conceptual and numerical models of flooding:
- a. Environment Agency flood data, including hydraulic models, and flood defence asset data (various dates 2018 and 2019)
 - b. Groundwater flood maps from GeoSmart (2019), GW5
- 15.3.28 The stations represent the closest climate stations to the Order Limits and allowed the identification of current climate impacts within the study area.
- 15.3.29 Met Office historic climate data, from the period 1981–2010, were obtained from the following climate stations, which were selected as they were the closest weather stations to the Project:
- a. Stanford-le-Hope – grid reference TQ 687822
 - b. Writtle – grid reference TL 680066
 - c. Gillingham No2 – grid reference TQ 784682
 - d. East Malling – grid reference TQ 709566

Forecasting the future baseline ('Without Scheme' scenario)

GHG emissions impact assessment

- 15.3.30 The future baseline for the GHG emissions impact assessment is also a 'Do Minimum' scenario whereby the Project does not go ahead and provides the basis for comparison against which net changes in GHG emissions can be established. Under this scenario the GHG emissions associated with the future use and maintenance of the existing road networks were estimated, through the validated Project's traffic model contained within the ComMA (Application Document 7.7). The model provided the forecast emissions from the existing road network layout considering predicted increases in traffic and associated congestion, presenting the GHG emissions for the 2027 opening year for the Project and 2042 (design year for the Project). Expected policy impacts (for example the phasing out of vehicles with internal combustion engines and the decarbonisation of the national electricity grid) are also included in this future baseline.

Vulnerability of the Project to climate change

- 15.3.31 UKCP18, developed by the UK Climate Impacts Programme (Environmental Change Institute at the University of Oxford, 1997), was used to provide projections for future climate scenarios and trends in the study area. The UKCP18 data are recognised as a robust source of information on the UK's future climate.
- 15.3.32 UKCP18 provides probabilistic projections of climatic variables (presented below). For the purposes of assessment, and in line with DMRB LA 114 Climate (Highways England, 2019a) requirements, the future baseline for the vulnerability of the Project to climate change assessment covers the timescales for the construction phase and the Project operational life span of 60 years from the opening year. Therefore, the UKCP18 projections for the climate variables listed below were analysed for the selected 20-year time periods of 2020–2039, 2040–2059, 2060–2079, and 2080–2099:
- a. Mean annual temperature
 - b. Mean summer temperature
 - c. Mean winter temperature
 - d. Maximum summer temperature
 - e. Minimum winter temperature
 - f. Mean annual precipitation
 - g. Mean summer precipitation
 - h. Mean winter precipitation
- 15.3.33 The UKCP18 'RCP8.5 scenario' for the 2080 projections at the 50% probability level was used to determine the future baseline for the above climate variables. RCP8.5 is the closest scenario to the high emissions scenario presented in UKCP09 which is the methodology that was presented in the Scoping Report.
- 15.3.34 UKCP18 probabilistic projections for RCP8.5 were analysed for the relevant two 25km² grid squares in which the Project would be located. These figures were expressed as temperature and precipitation anomalies in relation to the 1981–2000 baseline. The 50% probability level has been presented for the appraisal period, assumed 60 years for operational life cycle stage plus the timescales for construction stage.
- 15.3.35 In addition, climate change has the potential to increase peak rainfall intensity. This increased peak rainfall intensity results in a corresponding increase in the rate and volume of runoff being discharged to local watercourses and subsequently creates an escalation in flood risk. Furthermore, sea levels are also projected to increase as a result of climate change.
- 15.3.36 The current Environment Agency guidance on climate change allowances for FRAs was updated in December 2019 to apply UKCP18 sea level rise allowances (and further amended in March 2020 with a minor clarification that

did not change the allowances). Other allowances, including peak rainfall and river flow allowances, were not updated and remain unchanged since before the UKCP18 projections were published.

- 15.3.37 Fluvial and tidal flood risk zones and flood defence assets are illustrated in Appendix 14.6: Flood Risk Assessment (Application Document 6.3).

Method of assessment – construction and operational phases

GHG emissions impact assessment

- 15.3.38 The GHG emissions impact assessment considers the significance of the Project's contribution to UK GHG emissions and the Government's ability to achieve its carbon reduction targets to meet the relevant carbon budgets set by the Climate Change Act 2008 (as amended).
- 15.3.39 The budgets relevant to the GHG emissions impact assessment (for the construction and operational phases), expressed in the form of tonnes of carbon dioxide equivalent (tCO₂e), are detailed in Table 15.5. Reporting GHG emissions from the Project in the form of tCO₂e allowed the emissions of the seven key GHGs from the Kyoto Protocol Reference Manual (UNFCCC, 2008) to be accounted for: carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF₆) and nitrogen trifluoride (NF₃). The Paris Agreement 2015 has superseded the Kyoto Protocol. However, the Kyoto Protocol Reference Manual is still used for background reference on the GHG accounted for in the Paris Agreement.

Table 15.5 UK Carbon Budgets applicable to the GHG emissions assessment

| Budget | Carbon Budget level (million tCO ₂ e) | Reduction below 1990 levels |
|--|---|--------------------------------|
| 3 rd Carbon Budget (2018 to 2022) | 2,544 | 37% by 2020 |
| 4 th Carbon Budget (2023 to 2027) | 1,950 | 51% by 2025 |
| 5 th Carbon Budget (2028 to 2032) | 1,725 | 57% by 2030 |

- 15.3.40 To determine the significance of the Project's contribution to the UK GHG emissions, the assessment compared two scenarios: the 'Do Minimum' scenario (baseline and future baseline); and the 'Do Something' scenario, presented within Table 15.6, against the carbon budgets as set out in Table 15.5. Using these scenarios, an estimation of the net emissions resulting from the Project was determined.

Table 15.6 GHG assessment scenarios

| Scenario | | Description |
|----------------|--|---|
| 'Do Minimum' | Baseline without the Project (2016) Future baseline without the Project (2027 - 2042 Project's design year) | Two do minimum scenarios are presented as follows: Baseline conditions in a business-as-usual scenario. An estimation of the GHG emissions from the traffic model's baseline year of 2016. The future baseline of 2027-2042 which includes an allowance for expected policy (as identified in Table 15.1 and Table 15.3), for example the phasing out of vehicles with internal combustion engines and the decarbonisation of the national electricity grid. The future baseline also included any increase in traffic and associated congestion due to any committed developments within the study area between 2027 and 2042. |
| 'Do Something' | Project goes ahead | The Project with the design measures presented in Appendix 15.1: Carbon and Energy Plan (Application Document 6.3), covering both the construction and the assumed 60 year (from opening) operational phase, as described in Table 15.7. The expected policy impacts of the future baseline and the assumptions presented within the 'assumptions and limitations' in Section 15.3 underpin this scenario. The Project carbon model was developed for the Project and is presented in Appendix 15.1: Carbon and Energy Plan (Application Document 6.3). |

15.3.41 Table 15.7 outlines the Project life cycle stages and the associated sources of GHG emission data that were quantified to develop the 'Do Something' scenario. The two life cycle stages (construction stage and operation 'use' stage) considered the level of certainty of future activity and GHG emissions, and the extent that the predicted GHG emissions would be additional to the existing GHG inventory. Opportunities for reductions during the construction and operational phases were also considered within the assessment. A full description of the opportunities is included within Appendix 15.1: Carbon and Energy Plan (Application Document 6.3) and summarised in Section 15.5.

Table 15.7 Sources and life cycle stages included within the Project GHG emissions assessment

| Main stage of Project life cycle* | Sub-stage of life cycle* | Sources of GHG emissions | Activity data |
|---|---|---|---|
| Construction stage (Construction phase) | Product stage, including raw material supply, transport and manufacture | Embodied GHG emissions associated with the raw material assets required to construct the Project. | <ul style="list-style-type: none"> Estimation of the volume (m³) of material assets including both temporary and permanent works. |

| Main stage of Project life cycle* | Sub-stage of life cycle* | Sources of GHG emissions | Activity data |
|--|---|---|---|
| | Construction process stage, including transport of materials to and from works site | <ul style="list-style-type: none"> • Transport of construction materials assets and equipment from point of purchase to the works site • Transport of workers • Emissions associated with construction and installation processes (including fuel and electricity consumption) of the temporary works, ground works, landscaping and permanent works • Emissions associated with site water demand, including water treatment • Waste management activities (transport, processing, final disposal) associated with waste arising from the Project | <ul style="list-style-type: none"> • Estimation of the volume (m³) of material assets including both temporary and permanent works • Type of material assets required (e.g. concrete) • Transport distances (km) of material assets • Volume (m³) of waste generated (both construction and demolition) • Water usage (m³) • Fuel and energy usage associated with plant, equipment, site operations and processes |
| | Land use change | GHG emissions mobilised from vegetation or soil loss during the construction stage in addition to GHG emissions associated to land use change – representing the influence of land use change through the Project's planting proposals and ongoing sequestration of carbon each year during the construction phase. | <ul style="list-style-type: none"> • Land types areas (m²) |
| Operation 'use stage' (to extend 60 years in line) | Use of the infrastructure by road user | Vehicles using the highways infrastructure. | <ul style="list-style-type: none"> • Transport emissions |

| Main stage of Project life cycle* | Sub-stage of life cycle* | Sources of GHG emissions | Activity data |
|---|--|---|---|
| with appraisal period) (Operational phase) | Operation and maintenance, including repair, replacement and refurbishment | <p>This sub-stage includes the following aspects:</p> <ul style="list-style-type: none"> Energy – represents the GHG emissions resulting from the fuel and electricity used by the Project's infrastructure (e.g. lighting signals, technology, pumps) and activities conducted as part of routine maintenance. Raw materials – represents the GHG emissions resulting from the provision of materials assets required by the Project to enable it to operate and deliver its service, for example material assets used for maintenance and cleaning. | <ul style="list-style-type: none"> Fuel and energy usage associated with the Project's infrastructure Water usage (m³) Estimation of the volume (m³) of material assets required for maintenance and cleaning Volume (m³) of waste generated (both maintenance and cleaning) |
| | Land use and forestry | Land use and forestry – representing the influence of land use change through Project's planting proposals and ongoing sequestration of carbon each year during the operational phase. | <ul style="list-style-type: none"> Land type areas (m²) |

| Main stage of Project life cycle* | Sub-stage of life cycle* | Sources of GHG emissions | Activity data |
|--|---|---|---|
| <p>Opportunities for reduction</p> <p>[Note: for both project life cycles]</p> | <p>GHG emissions potential of recovery including reuse and recycling GHG emissions potential of benefits and loads of additional functions associated with the study system</p> | <p>Opportunities for reductions in GHG emissions were identified for both the construction and operational phases. Examples included:</p> <ul style="list-style-type: none"> Retention and reuse of excavated materials suitable for use as engineered fill and landscaping. Reuse of demolition material. Changes to design – e.g. reducing number of lanes. Use of alternative materials with lower embodied carbon – e.g. ground granulated blast-furnace slag (GGBS). Use of hybrid plant. Use of energy efficient equipment during construction. Procurement of renewable electricity suppliers for the construction compounds and for the operational phase. <p>All construction and operational opportunities for GHG emission reduction, considered within the Project's carbon model, have been described in full within Appendix 15.1: Carbon and Energy Plan.</p> | <ul style="list-style-type: none"> Estimation of material and waste volumes (m³) and recycling and/or reuse fate. Transport distances (km) of material assets and waste. Material emission factors. Fuel and energy usage associated with hybrid plant and renewable electricity. Plant specifications. |

**Main stages and sub-stages of Project life cycle included in Table 3.11.1 Sources and lifecycle stages for project GHG emissions of DMRB LA 114.*

15.3.42 The key assumptions and results of calculations of GHG emissions from each of the sub-stages of the life cycle presented in Table 15.7 have been described further throughout this chapter and are presented in more detail in Appendix 15.1: Carbon and Energy Plan (Application Document 6.3).

15.3.43 Estimated GHG emissions have been assessed using the following equation (aligned with the GHG Protocol principles (WRI and WBCSD, 2015) – relevance, completeness, consistency, transparency and accuracy):

$$\text{Activity data} \times \text{GHG emissions factor} = \text{GHG emissions value}$$

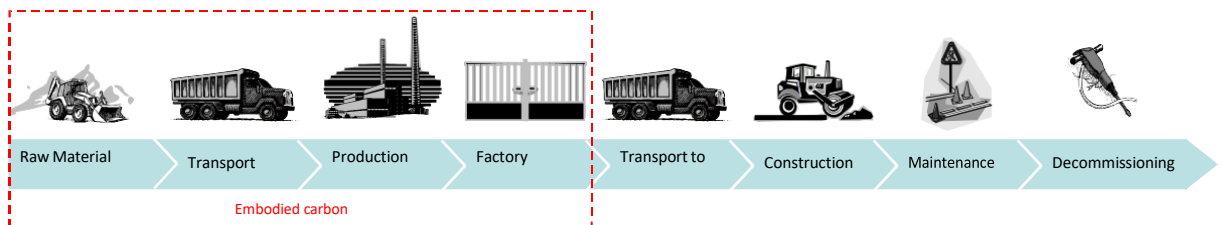
15.3.44 All GHG emissions reported within this assessment are in the form of tCO₂e.

Construction phase

15.3.45 The quantification of GHG emissions arising from the construction stage of the Project, also referred to ‘construction carbon’, was calculated in line with PAS 2080:2016 (British Standards Institution, 2016) and emission factors from the sources presented in Appendix 15.1: Carbon and Energy Plan (Application Document 6.3).

15.3.46 Using the estimated material quantities and types, the embodied carbon of the construction material assets was calculated, giving its contribution to the overall construction carbon. The calculation of embodied carbon allowed the sum of the energy required in resource extraction, and any processing required prior to transport to the Project for use, to be accounted for within the overall carbon baseline. This is illustrated in Plate 15.1.

Plate 15.1 Diagrammatic representation of the measure of embodied carbon in relation to material assets life cycle



15.3.47 In addition to the calculation of embodied carbon, the emissions of construction activities were also considered and quantified. These included emissions associated with waste arisings and their transportation, water use, construction site energy and fuel usage for the duration of the construction phase and land use change.

15.3.48 The excavation and movement of materials both within and outside of the Order Limits were modelled separately and included within the overall Project’s carbon model. This assessment considered volumes of materials reused onsite along with distances travelled and modes of transport. As explained in paragraph 15.3.4, decommissioning was excluded from the GHG emissions impact assessment. The data sources used for key components of activity data have been presented in Appendix 15.1: Carbon and Energy Plan (Application Document 6.3).

Operational phase

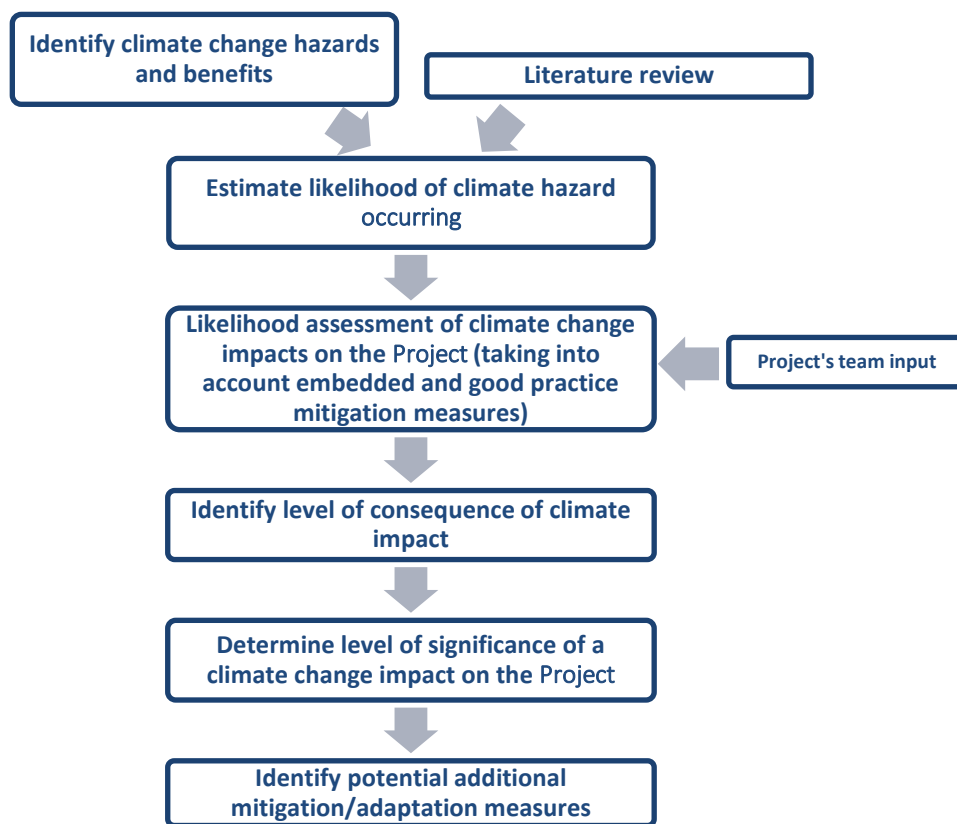
15.3.49 The operation or ‘use’ stage included emissions resulting from maintenance activities, mechanical and electrical energy use (for example tunnel lighting, tunnel service building and ventilation system) as well as the net variation in emissions from vehicle journeys in the validated traffic model study area (also referred to as ‘road user carbon’). As at least part of the GHG emissions associated with the operation of the Project would have been displaced from other parts of the road network (e.g. road users), they are not considered additional to the UK GHG inventory.

- 15.3.50 The 'road user carbon' emissions were calculated using the outputs from the TAG GHG emissions workbook (Department for Transport, 2019). This covers a 60-year appraisal period from the opening year of the Project.
- 15.3.51 The UK Government Strategy 'Road to Zero' (HM Government, 2018b) sets out a route map for the UK to move towards cleaner road transportation. The long-term aspirations set out in this strategy are that by 2030 between 50% and 70% of new car sales and 40% of van sales will be ultra-low emission vehicles and by 2040 new cars and vans sold will be zero carbon. This is supported by a range of initiatives to increase the supply of low carbon fuels and to grow the EV charging network.
- 15.3.52 In addition, future decarbonisation of the National Grid would have an impact on the GHG emissions associated with the operation of the Project. According to the Updated Energy and Emissions Projections 2017 (BEIS, 2019b), up to 300 terawatt hours (TWh) could be generated by low carbon energy sources (renewables and nuclear) by 2035, with 100TWh generated using natural gas and from imports. The calculation of GHG emissions during the operational phase has taken into account future National Grid decarbonisation by using the predicted grid electricity emission factors modelled by BEIS.
- 15.3.53 All GHG emissions would contribute to global climate change. The UK has legally binding GHG reduction targets, and therefore the assessment considers how the Project would contribute to the national GHG inventory and the UK achieving its reduction targets.

Vulnerability of the Project to climate change assessment

- 15.3.54 The vulnerability of the Project to climate change assessment was carried out in line with the assessment standards of DMRB LA 114 Climate (Highways England, 2019a). The assessment considered the strategic aims and objectives encompassed within government, Highways England and local planning strategy and policy. These have the overarching aim of minimising the adverse impacts of climate change, while requiring new development to take climate change considerations into account within design.
- 15.3.55 The following key terms and definitions relating to the vulnerability of the Project to climate change assessment were used:
- a. Climate hazard – a weather or climate related event which has potential to do harm to environmental or community receptors or assets, for example increased winter precipitation
 - b. Likelihood – probability and frequency of occurrence of the climate hazard
 - c. Climate change impact – an impact from a climate hazard which affects the ability of the receptor or asset to maintain its function or purpose
 - d. Consequence of impact – any effect on the receptor or asset as a result of the climate hazard having an impact
- 15.3.56 Plate 15.2 summarises the methodology and stages for the vulnerability of the Project to climate change assessment.

Plate 15.2 Vulnerability of the Project to climate change



- 15.3.57 The UK CCRA (Defra, 2017) and UKCP18 data outputs (Met Office, 2019) for the location of the Project were used to identify potential climate hazards that may affect the geographical location of the Project.
- 15.3.58 The assessment considered vulnerability against both gradual climate change and the risks associated with an increased frequency of severe weather events as per the UKCP18 climate change projections (Met Office, 2019).
- 15.3.59 A review of the potential climate change impacts was followed by an assessment of their potential consequence and likelihood of occurrence, taking into account the measures incorporated into the design of the Project.
- 15.3.60 The assessment presented in Appendix 15.3 Climate Resilience Impacts and Effects (Application Document 6.3) includes all infrastructure and assets associated with the Project and identifies the Project's receptors within the study area which are vulnerable to future climate change scenarios developed as follows:
- Construction phase receptors (e.g. workforce, plant and equipment)
 - The assets and their operation, maintenance and refurbishment (e.g. pavements, structures, earthworks and drainage, technology assets)

c. End-users (e.g. members of public, commercial operators)

Determining significance of effects

- 15.3.61 To determine the significance of environmental effects on climate, the assessment uses the specific criteria set out within DMRB LA 114 Climate (Highways England, 2019a). The GHG emissions impact assessment and vulnerability of the Project to climate change assessment use separate approaches as described within the sections that follow. The following sections set out the methodology applied as both approaches are different to the approach described in Chapter 4: EIA Methodology.
- 15.3.62 The assessment of significance undertaken in this chapter is with regard to compliance with the EIA Regulations.

GHG emissions

- 15.3.63 GHG emissions from the Project were quantified and expressed as tCO₂e per annum for the 'Do Minimum' and 'Do Something' scenarios. The difference between the two scenarios was calculated to provide the evidence of the carbon impact of the Project from its construction and operational phases.
- 15.3.64 Paragraph 5.17 of the NPSNN (Department for Transport, 2014) requires applicants to provide evidence of carbon impact of their projects and assessment against the Government's carbon budgets. It states that it is very unlikely that the impact of a road project will, in isolation, affect the ability of Government to meet its carbon reduction plan targets. The assessment has shown the carbon impact in comparison to the 3rd, 4th and 5th carbon budgets.

Vulnerability of the Project to climate change assessment

- 15.3.65 The 60-year Project lifetime includes the operational phase from the opening of the Project. The assessment has also accounted for the construction phase in addition to the 60-year Project lifetime. As the construction phase would be much shorter in duration than the operational phase, and is expected to be undertaken within the seven years following the granting of a Development Consent Order (DCO), future climate change is less relevant to the assessment of construction impacts and effects. Accordingly, for the construction assessment, a qualitative description of the disruption risk was reported.
- 15.3.66 For the operational phase of the Project, a risk assessment assessing the likelihood (probability and frequency of occurrence) and measure of consequence of a climate change impact occurring to a receptor (where relevant) was used to determine the significance over the selected future time frame for operation (60 years).
- 15.3.67 The assessment of likelihood and consequences of the potential impacts were undertaken using the framework provided in DMRB LA 114 (Highways England, 2019a) and presented in Table 15.8 and Table 15.9.

Table 15.8 Likelihood categories

| 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 four events. |
| Low | The event occurs during the lifetime of the Project (60 years), e.g. once in 60 years. |
| Very low | The event may occur once during the lifetime of the Project (60 years). |

Table 15.9 Measure of consequence

| 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. |

15.3.68 Using Table 15.10, the likelihood and consequence were combined to determine the significance of each impact.

Table 15.10 Significance measure

| Measure of consequence | Measure of likelihood | | | | |
|-------------------------------|------------------------------|-----------------|-----------------|-----------------|------------------|
| | Very low | Low | Medium | High | Very high |
| Very large | Not significant | Significant | Significant | Significant | Significant |
| Large | Not significant | Not significant | Significant | Significant | Significant |
| Moderate | Not significant | Not significant | Significant | Significant | Significant |
| Minor | Not significant | Not significant | Not significant | Not significant | Not significant |

| Measure of consequence | Measure of likelihood | | | | |
|------------------------|-----------------------|-----------------|-----------------|-----------------|-----------------|
| | Very low | Low | Medium | High | Very high |
| Negligible | Not significant | Not significant | Not significant | Not significant | Not significant |

Assumptions and limitations

GHG emissions

- 15.3.69 The following assumptions and limitations are noted with respect to the GHG emissions assessment and have been utilised to establish the ‘Do Something’ scenario GHG emissions (referred to as the Project’s carbon model in Appendix 15.1: Carbon and Energy Plan (Application Document 6.3)).
- 15.3.70 The DCO application has been developed on the basis of a 2027 opening year. This assumes consent is granted and work commences in 2022. Construction may take up to six years, but as with all large projects there is a level of uncertainty over the construction programme, which will be refined once contractors are appointed and as the detailed design is developed. The anticipated opening date for the Project is in 2027 or 2028. The 2027 opening year has been selected for the basis of the assessments as representative of the reasonable worst case, this has been used consistently across the environmental assessments, transport assessments and the economic appraisal of the Project.
- 15.3.71 While considered sufficient to inform the assessment, quantifications of materials required and waste arisings forecast from the Project have been derived from the emerging design and professional judgement. Therefore, the GHG assessment presented in Section 15.6, and the Project’s carbon model presented within Appendix 15.1: Carbon and Energy Plan (Application Document 6.3), is an estimation. This was calculated using the most representative, accurate and plausible data available. Data sources used for the assessment have been presented within Appendix 15.1: Carbon and Energy Plan (Application Document 6.3).
- 15.3.72 Where possible, emission factors were researched for the exact material/product specified for the Project. Primary sources of emission factors are ICE Database V3.0 (Circular Ecology, 2019) and Ecoinvent databases. In most cases, an exact match could not be identified, and therefore assumptions were made to select a representative material or product from these databases. Emission factors sources have been included within Appendix 15.1: Carbon and Energy Plan (Application Document 6.3).
- 15.3.73 Data collection for GHG calculations was based on the set of standard data quality principles detailed in the GHG Protocol guidelines and summarised in Table 15.11. Applying these principles allowed the results from the GHG assessment to be as representative as possible.

Table 15.11 GHG Protocol principles

| Data quality principle | Application to Project |
|-------------------------------|---|
| Age | The GHG assessment is based on activity data and GHG emissions factors applicable to the study period. The construction year baseline (2022) for the GHG assessment incorporates GHG emissions from fuel use for construction activities along with embodied carbon within material assets used for the construction phase. The assessment has been based on an estimation of the types and quantities of key materials required for the construction and operation of the Project. |
| Geography | The activity data is specific to the Project and emission factors used are representative of the UK construction industry and UK transport sector. |
| Technology | The activity data and emission factors used are representative of the UK construction and transport sectors. |
| Methodology | The activity data is specific to the Project and has been provided by the Project's engineering and design teams. |
| Competency | <p>The activity data is specific to the Project and has been provided by the Project's engineering and design teams.</p> <p>The emission factors used are from published sources. A full list of emission factors used has been presented in Appendix 15.1: Carbon and Energy Plan (Application Document 6.3).</p> <p>Data gaps have been filled using best available data, for example extrapolating existing data or using industry guidance documents.</p> |

- 15.3.74 The design and ground investigation will continue to evolve; however, conservative assumptions were used in estimating material quantities to inform the Project's GHG emissions to cover a reasonable worst case. Therefore, changes that may occur as a result of emerging data would not alter the conclusions of this assessment.
- 15.3.75 It is recognised that many parameters of the 'Do Something' scenario cannot be fully defined at the preliminary design stage and would be the subject of further evaluation during the development of the detailed design. However, for the purposes of quantifying the Project's GHG emissions, a number of design assumptions were built into the Project's carbon model Appendix 15.1: Carbon and Energy Plan (Application Document 6.3) to apply the principles of avoiding/preventing, reducing and remediating GHG emissions in line with the DMRB LA 114 Climate (Highways England, 2019a) standard. These design assumptions have been based on professional judgment and practices on major infrastructure projects.
- 15.3.76 As acknowledged in the Transport Assessment (Application Document 7.9), Highways England have continued to refine the construction planning, including further construction traffic modelling. However, the construction traffic model provides an extensive quantitative assessment of the impact of construction works on the regional road network, using the same traffic baseline. Therefore, it is not anticipated that the ongoing refinements to the construction planning will lead to material changes in the environmental impacts reported in this chapter.

- 15.3.77 The construction traffic represented in the Transport Assessment (Application Document 7.9) and within the assessments presented in this Environmental Statement incorporates the following elements:
- a. Estimated HGV movements associated with the construction of the Project
 - b. Temporary traffic management measures associated with:
 - i. Other modifications of the M25 and A2.
 - ii. Other the construction of the new junctions with the A122 road.
 - iii. Other construction of new structures over existing highways.
 - iv. Other modification of existing side roads.
- 15.3.78 Although all assumptions in this section are considered reasonable to determine the GHG emissions at the preliminary design stage, the assumptions may change during the detailed design. Section 15.5 provides details of the committed mitigation related to the Project's GHG emissions and it would be for the Contractors to determine the best means to achieve a betterment of Project's carbon model GHG emissions, as secured by the REAC Ref. CC002. As conservative assumptions were used to inform the Project's carbon model, the assessment covers a reasonable worst case. Therefore, changes that may occur as a result of emerging data during detailed design would not alter the overall conclusions of this assessment.
- 15.3.79 The Project's carbon model reflects the following assumptions and aspects of design:
- a. Published geology, supported by ground investigation, was reviewed to determine the volume of site-won materials that could be assumed to be utilised by the Project. The advantages and disadvantages of onsite reuse were evaluated by all Project specialists, including a consideration of the savings in embodied carbon emissions as well as the GHG emissions associated with material asset and waste transportation. Examples where embodied carbon emissions were avoided and/or prevented in the Project's carbon model presented within Appendix 15.1: Carbon and Energy Plan (Application Document 6.3) include:
 - i. The Project prioritised reducing the import of fill through the retention and reuse of excavated materials (including uncontaminated minerals) suitable for use as engineered fill and landscaping. For example, it was estimated that 29,000 tCO₂e emissions would be avoided from Heavy Goods Vehicle movements (assuming a travel distance of 20km) by retaining 2 million tonnes of topsoil stripped during the Project.
 - ii. The Project would apply the avoid/prevent principle by maximising the potential for reusing demolition and waste concrete materials as

recycled aggregate onsite. It was estimated 7,013 tonnes of recycled aggregate would be recovered, avoiding material import to the Project.

- iii. GHG emissions associated with the volumes of vegetation and excess excavated material generated were avoided. Approximately 20.4 million tonnes of potential waste and therefore around 654,000 tCO₂e were eliminated through the application of the material assets and waste 'elimination' principle, as presented in Chapter 11: Material Assets and Waste.
- c. Refinements of the design, as quantified within the Project's carbon model Appendix 15.1: Carbon and Energy Plan (Application Document 6.3), provided advantages in GHG emissions. Examples of design refinements that resulted in GHG emissions reduction are included in Section 11.5 of Chapter 11: Materials Assets and Waste. These include:
 - i. Removing the bridge at Hornsby Lane.
 - ii. Reducing the number of lanes on the Project road south of the M25.
 - iii. Widening the existing Rectory Road rather than constructing a new highway.
 - iv. Reducing the span of the Tilbury Viaduct from 1.2km to 600m.
 - v. Removing the A226 junction and removing the A128 junctions with the Project and the A13.
- d. The Project's carbon model included a number of assumptions related to the use of energy efficient equipment during the construction phase resulting in a reduction of GHG emissions. Diesel consumption within the compounds was reduced by assuming the use of the following achievable percentages of hybrid plant:
 - i. 5% of articulated 40 tonne and 55 tonne dump trucks
 - ii. 20% of tracked cranes (55 tonne and 60 tonne)
 - iii. 20% of dumpers (5 tonne and 9 tonne)
 - iv. 50% of excavators
 - v. 50% of dozers
 - vi. 50% of forklifts/telescopic handlers
 - vii. 50% of lorry mounted cranes
 - viii. 50% of telehandlers

- ix. 75% of 4x4 vehicles
- e. Use of energy efficient equipment such as jet fans (incorporating energy saving technologies such as soft start technology, start-stop technology and optidrive variable torque control drive), light emitting diode (LED) lights, active/adaptive lighting, and visibility and air quality sensors. Detailed information about energy efficient equipment has been included within Appendix 15.1: Carbon and Energy Plan (Application Document 6.3).
- f. Procurement of renewable electricity suppliers to cover the consumption from the Project's construction compounds (including the consumption of the tunnel boring machine and concrete batching plant), as secured by the REAC Ref. CC004. Approximately 93,480 tCO₂e will be avoided (5% of total construction emissions).
- g. Design options were also reviewed to substitute material assets for others with lower embodied carbon. Examples where materials assets were substituted have been included in Appendix 15.1: Carbon and Energy Plan (Application Document 6.3). These include:
 - i. Replacement of 65% of the Ordinary Portland Cement with Ground Granulated Blast-furnace Slag for C40/50 in situ concrete in both tunnels and highways and C50/60 precast concrete in tunnels. This reduced the GHG emissions from the tunnel material assets by 119,350 tCO₂e and from the highways' material assets by and 34,240 tCO₂e.
 - ii. Use of steel fibre reinforced concrete for most of the concrete segments in the bored tunnels. This typically results in savings of around 0.2 tCO₂e per m³ of concrete.
- h. GHG emissions associated with risk items were assumed to be 3% of total emissions or 8.05% of the construction emissions. This covers the emissions from scenarios that are uncertain, e.g. the degree of ground improvement that is required for the highways. Although these scenarios may not materialise, GHG emissions have been apportioned to them to provide a more thorough estimate of overall emissions.

Vulnerability of the Project to climate change assessment

- 15.3.80 The following assumption and limitation is noted with respect to the vulnerability of the Project to climate change assessment:
- a. Climate change, by its very nature, is associated with a range of assumptions and limitations. To overcome these issues, current climate change data and science have been incorporated into the assessment, and proven effective approaches undertaken for similar project types were replicated. Limitations associated with the approach taken for the vulnerability of the Project to climate change assessment relate to

uncertainties inherent within UK climate projections (UKCP18 data). The UKCP18 project currently provides the leading climate change projections for the UK.

- b. In the absence of climate change allowances for rainfall in 2127, the Environment Agency's climate change uplifts to rainfall and flow for 2115 were adopted for the purposes of this assessment. This approach is consistent with the Environment Agency's (2016) climate change guidance for appraisal of flood defence schemes. Sea level rise beyond 2125 were extrapolated by assuming the same rate of rise (mm/year) as specified for 2125 continues beyond 2125.

15.4 Baseline conditions

Existing baseline

GHG emissions impact assessment

- 15.4.1 The existing baseline presents the GHG emissions estimated on the existing road network for the baseline year of 2016, which is defined as the base year for the Project's validated traffic model.
- 15.4.2 GHG emissions calculated through the traffic model (Application Document 7.7, ComMA) estimated approximately 8,860,919 tCO₂e were emitted on the existing road network.

Vulnerability of the Project to climate change assessment

- 15.4.3 A review of relevant information sources has been undertaken to establish existing and future baseline data and current understanding with regards to climate and extreme weather impacts. A summary is provided below, with more detailed information in Appendix 15.2: Climate Resilience Baseline (Application Document 6.3).
- 15.4.4 The Project sits within the Met Office 'South East and Central Southern' district region. Climate observations for this region, presented as 10-year averages between 1970 and 2019, identify gradual warming, with an increase of 1.17°C in mean maximum annual temperatures between the periods 1970-1979 and 2010-2019. Mean annual rainfall has decreased by 4.09% between the same periods.
- 15.4.5 Local Climate Impact Profiles (LCIP) have been developed to assess the vulnerability of local authorities' services to severe weather events for Kent County Council, Essex County Council, Thurrock Council and the London Borough of Havering. Medway, Gravesham and Brentwood local authorities have not produced separate LCIPs but have contributed towards their respective county profiles. All four LCIPs show a pattern with regards to frequency and severity of extreme weather events and highlight the impacts these have on services, including spending pressures, across the counties. A summary of the key findings from the LCIPs for Kent, Essex, Thurrock and Havering is provided in Table 1.1 of Appendix 15.2: Climate Resilience Baseline (Application Document 6.3).

- 15.4.6 The Project is primarily in Flood Zone 1 but includes three sections that would cross Flood Zones 2, 3a and 3b. Highways Agency Drainage Data Management System (HADDMS) indicates that there have been the following historical flooding incidents:
- a. Several surface water flooding incidents along the A2/M2 corridor. Highways England has already addressed some of these flooding issues. The remainder fall in areas where new drainage provisions would be included as part of the Project and it is assumed that any legacy flooding issues at the incident locations would be resolved.
 - b. One surface water flooding incident at the A13 Interchange. It is assumed that any legacy issues at the incident location would be addressed by the new drainage provisions.
 - c. Two flooding incidents on the section of the M25 that would be upgraded as part of the Project. The first of these events occurred in November 2009 at a location approximately 900m south of M25 J29 and was of low severity. The second occurred in May 2010 at a location approximately 2.5km south M25 J29 and was of moderate severity.
- 15.4.7 Fluvial and tidal flood risk zones and flood defence assets are illustrated in Appendix 14.6: Flood Risk Assessment (Application Document 6.3).

Future baseline ('Without Scheme' scenario)

- 15.4.8 The future baseline identifies any anticipated changes to the existing baseline over time in the absence of the Project, and is used as a basis against which to robustly predict the potential impacts of the Project.

GHG emissions impact assessment

- 15.4.9 The future baseline conditions for the 'Without Scheme' ('Do Minimum') scenario have been identified based on the modelling volumes of traffic currently on the existing network, and its predicted use (accounting for increases in traffic and associated congestion) from year 2027 through to year 2042. This established the baseline against which the Project has been subsequently compared, to identify any variation in GHG over time.
- 15.4.10 Under this scenario, GHG emissions associated with the use and maintenance of the road network ('Do Minimum' scenario) in the opening year of 2027 were estimated to be around 9,082,290 tCO₂e and 10,027,120 tCO₂e for the 2042 design year.
- 15.4.11 The estimations for the future baseline years demonstrate that there is expected to be reduction in the GHG emissions associated with road network when compared the existing emissions taken from the base year of the traffic model. Comparisons between the baseline year (2016) and year 2027 future baseline show a 2,322,620 tCO₂e reduction, whilst the design year 2042 indicates a reduction of 3,779,800 tCO₂e compared to the baseline.

Vulnerability of the Project to climate change assessment

- 15.4.12 A review of relevant information sources has been undertaken to establish existing and future baseline data and current understanding with regards to climate and extreme weather impacts. A summary is provided in the following paragraphs, with more detailed information in Appendix 15.2: Climate Resilience Baseline (Application Document 6.3).
- 15.4.13 The UKCP18 for the two 25km² grid square within which the Project would be located suggests an increase in mean summer and winter air temperatures, while precipitation rates are expected to become more seasonal, with increased precipitation expected in winter and decreased precipitation in summer.

Construction year (2022)

- 15.4.14 Between 2020 and 2039, annual average daily temperatures are projected to be 1°C higher than the 1981–2000 baseline average. For the same future time period, annual mean daily precipitation levels are projected to be 1% higher, with a 6% increase projected for winter, and a 1% increase projected for summer (when compared to the 1981–2000 baseline average).
- 15.4.15 UKCP18 projections for changes to the frequency of severe weather events (under the high emissions scenario, 50% probability level), have been assessed for the Project's location. These projections indicate that there is likely to be an increase in the average annual frequency of heatwaves, days when the temperature exceeds 28°C, prolonged periods with no rainfall (10+ days) and days when precipitation is greater than 25mm per day. These projections are against a baseline average for 1981–2000.
- 15.4.16 In addition, climate change has the potential to increase peak rainfall intensity. This increased peak rainfall intensity results in a corresponding increase in the rate and volume of runoff being discharged to local watercourses and subsequently create an escalation in flood risk. Furthermore, sea levels are also projected to increase as a result of climate change.

Opening year (2027)

- 15.4.17 The opening year baseline would be much the same as the construction year as 2027 still falls within the 2020–2039 climate projection period. It is, however, likely to be slightly warmer than in 2022 as the average temperature moves towards those projected within the 2040–2059 period.

Design year (2042)

- 15.4.18 Between 2040 and 2059, annual average daily temperatures are projected to be 1.7°C higher than the 1981–2000 baseline average. For the same future time period, annual mean daily precipitation levels are projected to be 0.6% lower, with a 9.5% increase projected for winter, and a 20.2% decrease projected for summer (when compared to the 1981–2000 baseline average).
- 15.4.19 The projections for changes to the frequency of severe weather events indicate that there is likely to be an increase in the average annual frequency of heatwaves, prolonged periods with no rainfall and days when precipitation is greater than 25mm per day. These projections are against a baseline average for 1981–2000.

Design life (2086)

- 15.4.20 Between 2080 and 2099, annual average daily temperatures are projected to be 3.7°C higher than the 1981–2000 baseline average. For the same future time period, annual mean daily precipitation levels are projected to be 3.7% lower, with a 20.8% increase projected for winter, and a 35.9% decrease projected for summer (when compared to the 1981–2000 baseline average).
- 15.4.21 The projections for changes to the frequency of severe weather events indicate that there is likely to be an increase in the average annual frequency of heatwaves, prolonged periods with no rainfall and days when precipitation is greater than 25mm per day. These projections are against a baseline average for 1981–2000.
- 15.4.22 Severe storms or other extreme weather conditions combined with high tides can cause sea levels to rise above normal levels. This can cause flooding along undefended tidal rivers.
- 15.4.23 As the Project is considered to be Essential Infrastructure and has a protracted operational life, the upper end and central rainfall intensity allowances of 40% and 20% respectively have been used for the purposes of Appendix 14.6: Flood Risk Assessment (Application Document 6.3).
- 15.4.24 Outputs of the current UK Climate Projections (UKCP18) were published in November 2018 through a web-based user interface, providing climate projections for user-selected locations. The current Environment Agency guidance on climate change allowances for FRAs was updated in December 2019 to apply UKCP18 sea level rise allowances (and further amended in March 2020 with a minor clarification that did not change the allowances). Other allowances, including peak rainfall and river flow allowances, were not updated and remain unchanged since before the UKCP18 projections were published.
- 15.4.25 The Project is due to become operational in 2027 and the working life will run to at least 2127. The impacts of climate change are therefore assessed up to 2127. The Environment Agency's guidance on climate change allowances provides uplifts for rainfall and flow for the period covering 2015 to 2115, and sea level rise for the period covering 2000 to 2125.
- 15.4.26 In the absence of climate change allowances for 2127, the Environment Agency's climate change uplifts to rainfall and flow for 2115 will be adopted for the purposes of this assessment. This approach is consistent with the Environment Agency's climate change guidance for appraisal of flood defence schemes. Sea level rise beyond 2125 will be extrapolated by assuming the same rate of rise (mm/year) as specified for 2125 continues beyond 2125.
- 15.4.27 The Project design and assessment has applied the climate change allowances specified in the Environment Agency's guidance. In addition, sensitivity testing will be undertaken to consider the potential impacts on the Project of the H++ climate change scenario (Met Office, University of Reading and Centre for Ecology and Hydrology, 2015). H++ climate change assessment allowances are provided in the Environment Agency's climate change guidance for appraisal of flood defence schemes.
- 15.4.28 The H++ scenario flow uplifts for the Thames River Basin District is 80% for the 2080s (2070-2115). This uplift would be simulated as a sensitivity test to

consider the potential impact of the H++ climate change scenario on the Project.

- 15.4.29 H++ sea level rise allowances are specified as annual rates of rise up to 2115. Extrapolating these rates to 2127 gives a H++ sea level rise of 2.63m at Southend relative to 2017.

15.5 Project design and mitigation

- 15.5.1 Environmental considerations have influenced the Project throughout the design development process, from early route options assessment through to refinement of the Project's design. An iterative process has facilitated design updates and improvements, informed by environmental assessment and input from the Project engineering teams, stakeholders and public consultation.
- 15.5.2 The DCO application for the Project includes a range of environmental commitments. Commitments of relevance to climate are set out in this section under the following categories:
- a. Embedded mitigation: measures that form part of the engineering design, developed through the iterative design process summarised above.
 - b. Good practice: standard approaches and actions commonly used on infrastructure development projects to avoid or reduce environmental impacts, typically applicable across the whole Project.
 - c. Essential mitigation: any additional Project-specific measures needed to avoid, reduce or offset potential impacts that could otherwise result in effects considered to be significant in the context of the EIA Regulations. Essential mitigation has been identified by environmental topic specialists, taking into account the embedded mitigation and good practice commitments.
- 15.5.3 Embedded mitigation is included within the Design Principles (Application Document 7.5) or as features presented on Figure 2.4: Environmental Masterplan (Application Document 6.2). Design Principles relevant to mitigation of effects on climate are described below, each with an alpha-numerical reference code (e.g. LSP. XX). Good practice and essential mitigation are included in Appendix 2.2: Register of Environmental Actions and Commitments (REAC) (Application Document 6.3). The REAC would form part of the Code of Construction Practice (CoCP) (Application Document 7.11) if the DCO is granted. Each entry in the REAC has an alpha-numerical reference code (e.g. CC0XX) to provide cross reference to the secured commitment. Relevant good practice and essential mitigation to reduce climate effects are identified below.

GHG emissions impact assessment

- 15.5.4 Through the application of the DMRB LA 114 Climate (Highways England, 2019a), the Applicant is committed to reducing GHG emissions from the activities by implementing the following hierarchy for GHG emissions:
- a. **Avoid and/or prevent** – measures that maximise potential for reusing and/or refurbishing existing assets.

- b. **Reduce** – measures that apply low carbon solutions, including technologies, materials and products, to minimise resource consumption.
- c. **Remediate** – after addressing a) and b) measures to further reduce carbon through on or offsite offsetting or sequestration.

15.5.5 This hierarchy was applied throughout the design process and has informed the assumptions used to develop the ‘Do Something’ scenario. These are presented within the ‘assumptions and limitations’ section in Section 15.3. Further measures required to mitigate the effects of the Project are described below, along with the principles from the hierarchy set out above and in DMRB LA 114 Climate (Highways England, 2019a).

Embedded mitigation

Construction phase

15.5.6 No construction phase embedded mitigation is presented for GHG emissions.

Operational phase

15.5.7 **Remediate** – Trees, shrubs and hedgerows planted as part of the landscape design would offset around 8,930 tCO₂e of the GHG emissions associated with land use change and subsequent loss of carbon sink. The Project landscape and planting designs are presented in Figure 2.4: Environmental Masterplan (Application Document 6.2).

15.5.8 **Reduce** – The Project design includes the creation of green bridges at the following locations: Brewers Road, North Road, Muckingford Road, Holford Road, Green Lane and two at Thong Lane (one over the Project and one over the A2). The purpose of the green bridges is to maintain and enhance connectivity for walkers, cyclists and horse riders (WCH), to allow for a better and more pleasant environment for those using, crossing and living in the vicinity of the Project. This will have a beneficial impact in reducing GHG emissions associated to the Project as it gives the road users alternatives to the use of vehicles.

15.5.9 **Reduce** – All severed Public Rights of Ways (PRoWs), bridleways and cycle routes would be re-linked across the Project unless better quality routes can be provided in the vicinity, the route can be rationalised to better link communities with the places they want to go, or realigned routes provide better connectivity into the existing WCH network. Consideration has been given to repairing existing PRoW severance, in addition to maintaining and, where practicable, improving existing access. Through the creation of a new horse rider standard bridge and by forming missing connections, the Project aims to create opportunities for people to gain access to the countryside to the east of the M25 by foot, bicycle and horse. In addition, PRoWs impacted by the Project would be upgraded and re-designated as bridleways where practicable, to enhance and improve off-road provision for WCH. This will also have a beneficial impact in reducing GHG emissions associated to the Project as it gives the road users alternatives to the use of vehicles.

15.5.10 **Reduce** – The Project design incorporates provision of new routes for WCH, designed to improve access to the existing network, to increase access for

users (including those with limited mobility) while considering and mitigating potential impacts from misuse and anti-social behaviour through good design. Total additional and improved provision equates to approximately 37km of routes, summarised in Chapter 13: Population and Human Health.

Good practice

Construction phase

- 15.5.11 Good practice mitigation measures to mitigate the GHG emissions impacts during the construction stage are summarised below – these are also included in the REAC, compliance with which is secured through the requirements in Part 1 of Schedule 2 of the draft DCO (Application Document 3.1).
- a. **Avoid and/or prevent** – embodied carbon emissions of material assets and GHG emissions associated with their transportation would be avoided and/or prevented by managing excavated material (and all wastes) in line with the waste hierarchy. Preference is given to appropriate reuse, where feasible and permitted by the design. This would be secured by:
 - i. Inclusion within all relevant procurement documentation and in line with DMRB LA 110 Material Assets and Waste (Highways England, 2019c), a target for 70% recycling and reuse onsite of suitable, uncontaminated concrete from demolition activities to substitute use of primary material. Suitable uncontaminated concrete from demolition and construction activities would be processed to achieve non waste status e.g. in accordance with the Aggregates from Inert Waste Quality Protocol (Waste and Resources Action Programme, 2013) (REAC Ref. MW001). This commitment would avoid GHG emissions associated with the use and transport of new material assets.
 - ii. Undertaking pre-demolition surveys of any structures and buildings. Demolition materials would be identified and quantified including potential sources of recycled aggregate to be reused on site, as well as hazardous materials such as asbestos (REAC Ref. MW005). This commitment would avoid GHG emissions associated with the transport of waste and use and transport of new material assets.
 - b. **Reduce** – priority would be given to sourcing primary, secondary and recycled aggregates from Kent, Essex and Greater London whenever the design specification permits, and supply is available to embody the proximity principle (REAC Ref. MW002). This commitment would reduce GHG emissions associated with the transport of material assets.

Operational phase

- 15.5.12 Good practice mitigation measures to mitigate the GHG emissions impacts during the operation phase are described below – these are also included in the REAC, compliance with which is secured through the requirements in Part 1 of Schedule 2 of the draft DCO (Application Document 3.1).

- a. Electricity used for operation of the Project would be procured from renewable electricity suppliers (REAC Ref. CC007).
- b. Low energy light sources (for example Light-emitting diode (LED) or equivalent technology) would be used within the Project lighting systems (subject to emergency lighting requirements) to reduce energy consumption during the operation of the Project and offer a more readily recyclable product at the end of life, compared to traditional light source lamps and luminaires (REAC Ref. CC008). Lighting systems will include, but not be limited to, information and communication systems, traffic signs and lighting columns.

Essential mitigation

Potentially significant effects

- 15.5.13 An iterative appraisal of the Project design taking into account the design principles and good practice was undertaken to identify any potentially significant effects that would require essential mitigation. GHG effects that could be significant and therefore required further consideration for essential mitigation were identified below:

- a. Potential for GHG emissions associated with the construction and operational phase to contribute to the UK not meeting the relevant carbon budgets.

Construction phase

- 15.5.14 Construction phase essential mitigation of relevance to GHG emissions is as follows:

- a. Avoid and/or prevent:
 - i. A ground investigation would be undertaken to identify material that would be excavated onsite that could be used as class I-IV fill materials or construction aggregate to reduce the need to import equivalent materials (REAC Ref. MW008).
 - ii. The main tunnels would be constructed so that the crown of the tunnel is a sufficient depth below the bed of the River Thames to avoid the need for any works within the river to provide tunnel scour protection (REAC Ref. RDWE041). This will avoid the need for material assets reducing the GHG emissions from material import and transportation.
 - iii. The main works contractor will adhere to PAS 2080 throughout the works and develop a compliant approach detailing how GHG emissions reductions will be identified, prioritised, implemented and monitored. The main works contractors will be required to submit their PAS 2080 approach to Highways England for acceptance within 3 months of appointment. The main works contractors will be required to obtain

certification/verification by an accredited organisation that verifies PAS 2080 within 12 months of appointment (REAC Ref. CC001).

c. Reduce:

- iv. Included within relevant procurement documentation would be a commitment to reduce GHG emissions from the Project's carbon model presented within Appendix 15.1: Carbon and Energy Plan (Application Document 6.3). Contractors would reduce GHG emissions below the baseline emissions presented in the Project's carbon model within Appendix 15.1: Carbon and Energy Plan (Application Document 6.3). The Contractor would develop and achieve a carbon reduction target to be agreed by Highways England (REAC Ref. CC002).
- v. The Contractors would procure renewable electricity suppliers to cover the consumption from the Project's construction compounds (including the consumption of the tunnel boring machine and concrete batching plant) (REAC Ref. CC004).

Operational phase

- 15.5.15 The Road Operator would provide quarterly GHG emissions returns and analysis from the operation and maintenance of the Project to Highways England during the operational phase in accordance with the requirements of DMRB LA 114 Climate (Highways England 2019a). This information would be evaluated by Highways England and used to inform assessment of future projects (REAC Ref. CC005).

Vulnerability of the Project to climate change assessment

- 15.5.16 A number of measures to increase the Project's capacity to be resilient to the effects of climate change are described below. The assessment of the Project's critical feature has been carried out in line with the UKCP18 RCP8.5 scenario for the 2080 projections at the 50% probability level to provide sufficient resilience against a reasonable worst case in terms of climate change.

Embedded mitigation

Construction phase

- 15.5.17 No construction phase embedded mitigation is presented for vulnerability of the Project to climate change.

Operational phase

- 15.5.18 Operational phase embedded mitigation of relevance to the vulnerability of the Project to climate change is as follows:
- a. To define future baseline flood risk to the Project, climate change allowances have been selected in consultation with the Environment Agency. Further details are provided in Appendix 14.6: Flood Risk

Assessment (Application Document 6.3). The latest climate change allowances (UKCP18) have been applied to the FRA.

- b. Through undertaking the FRA (Application Document 6.3, Appendix 14.6), the vertical alignment of the carriageway, the design of watercourse crossings and protection measures for the tunnel portals all include appropriate allowance for climate change effects on river flows and water levels in the Thames Estuary. Climate change effects on groundwater resources have also been considered in the design of the Project. These measures to increase the Project's capacity to cope with future flood risk is considered embedded within the design.
- c. The Project design and assessment has applied the climate change allowances specified in the Environment Agency's guidance. In addition, sensitivity testing has been undertaken to consider the potential impacts on the Project of the H++ climate change scenario. H++ climate change assessment allowances are provided in the Environment Agency's (2016) climate change guidance for appraisal of flood defence schemes.
- d. The design of all the elements of the Project has built-in climate change resilience for the working life of the Project (2027–2127) in several ways. For example, the operational drainage design has included an allowance for the predicted changes to rainfall intensity and the implications for operational road drainage volumes and rates. The findings of the FRA presented in Appendix 14.6 (Application Document 6.3) have informed the Project design to ensure its resilience to predicted climate change effects on river flows and water levels in the Thames Estuary. Key elements of the design that deliver this resilience are the vertical alignment of the main road, the drainage design, design of watercourse crossings and additional protection measures for the tunnel portals. Climate change effects on groundwater resources have also been considered in the design of the Project. Further details are provided in the future baseline subsection of Section 14.4 of Chapter 14: Road Drainage and the Water Environment, Appendix 14.5: Hydrogeological Risk Assessment and Appendix 14.6: Flood Risk Assessment (Application Document 6.3).
- e. The drainage design reduces the risk of causing flooding elsewhere by using attenuation features as presented on Figure 2.4: Environmental Masterplan (Application Document 6.2). Runoff from areas of new development would be attenuated to rates in line with the policy requirements of the relevant Lead Local Flood Authorities (LLFAs). This attenuation would protect receiving watercourse flow regimes as well as prevent the potential for increased scour local to drainage outfalls and changes to sediment deposition/accretion in downstream reaches (LSP.16).

Good practice

Construction phase

- 15.5.19 Construction phase good practice measures of relevance to the vulnerability of the Project to climate change are as follows:
- a. The Contractor(s) would design the permanent works in accordance with the Highways England DMRB standards identified in Table 2.1 and Table 2.2 in Appendix 15.3 (Application Document 6.3) and use construction materials that would be resilient to the effects of projected future climate change in line with UKCP18 (REAC Ref. CC006). This commitment includes:
 - i. The use of short-mid-term weather forecasting to plan key construction activities
 - ii. Design work site drainage to include allowances for a 20% increase in peak rainfall intensities
 - iii. The management of material stockpiles and the management of geotechnical risks in light of expected climate changes
 - iv. Selection of construction materials in line with forecasted climate set out in UKCP18 or as updated.

Operational phase

- 15.5.20 Operational phase good practice mitigation of relevance to the vulnerability of the Project to climate change is as follows:
- a. The Contractors would design the permanent works in accordance with the Highways England DMRB standards identified in Table 2.1 and Table 2.2 in Appendix 15.3 (Application Document 6.3) and use construction materials and products that would be resilient to the effects of projected future climate change in line with UKCP18 (REAC Ref. CC006). This commitment includes:
 - i. The design criteria for all drainage pipe networks have been that there should be no surcharge for the 1 in 1-year storm and no flooding for the 1 in 5-year storm, including an uplift of 20% in the peak rainfall intensity as an allowance for climate change.
 - ii. Storage volumes for balancing ponds and infiltration basins have been based on the worst 1 in 100-year storm event. To account for the effects of climate change, pond sizes and basins have been determined on the basis that there is a 20% increase in peak rainfall intensity with a further check to ensure no flooding occurs for a 40% increase in peak rainfall intensity. Full details of the surface water drainage proposals for the Project are dealt with in Part 7 of the Appendix 14.6 (Application Document 6.3).

- iii. Implementation of current standards for maintenance of critical Project assets such as pavements, bridge structures and the tunnels to ensure deterioration and/or defects are identified and managed.
- iv. Implementation of effective standard operating procedures and severe weather emergency planning in the event of necessary road closure or traffic diversions. The Contractors will pay due consideration to the impacts of potential extreme weather events and related conditions during construction. The Contractors will use a short to medium range weather forecasting service from the Met Office or other approved meteorological data and weather forecast provider as well as tidal information from the Port of London Authority to inform short to medium-term programme management, environmental controls and impact mitigation measures. In addition, the Contractors will ensure that the relevant measures within the CoCP (Application Document 7.11) are implemented and, as appropriate, consider additional measures to ensure the resilience of the proposed mitigation of impacts during extreme weather events. As appropriate, method statements will also consider extreme weather events where risks have been identified.

Essential mitigation

Potentially significant effects

- 15.5.21 A review of the Project design taking into account the embedded mitigation and good practice was undertaken to identify any potentially significant effects that would require essential mitigation. Climate effects that could be significant and therefore required further consideration for essential mitigation were identified for the construction and operational phases:

Construction phase

- 15.5.22 Construction phase essential mitigation of relevance to the vulnerability of the Project to climate change is as follows:
- a. In accordance with the requirements of the NPPF regarding development and flood risk (Ministry of Housing, Communities and Local Government, 2019), construction compounds CA5, CA5A and CA11 to the north of the River Thames and CA3 and CA3A south of the River Thames which are partially sited within Flood Zones 2 and 3, would be laid out in accordance with a site-specific FRA following the Sequential Test, where facilities at highest vulnerability to flooding, e.g. sleeping accommodation, medical and welfare and principal office facilities, are located in the lowest flood risk zone (Zone 1). Only low vulnerability and water compatible uses should be situated in the high-risk Flood Zone 3 (REAC Ref. RDWE022). Construction compounds are presented in Figure 2.2 (Application Document 6.2). It is acknowledged that the Secretary of State will use the NPS as the primary basis for making decisions on the Project consent application. However,

whilst the Project has been delivered in accordance with the NPS, FRA should also meet the requirement set up within NPPF.

Operational phase

15.5.23 Operational phase essential mitigation of relevance to the vulnerability of the Project to climate change is as follows:

- a. Where the Project ties in with the existing A2/M2 and M25 highways, the existing drainage infrastructure would be upgraded to accommodate the discharge from catchments affected by the Project in accordance with current design guidance, with appropriate allowances for climate change as detailed in DMRB CG 501 Design of Highway Drainage Systems (Highways England, 2020a), and in line with LLFA requirements. The existing discharge rates are not exceeded by the modified catchments but it was agreed with the LLFA that the upgrade of existing M25 drainage infrastructure affected by the Project, as illustrated on Figure 2.4: Environmental Masterplan (Application Document 6.2), would achieve a reduction in existing discharge rates of approximately 50% by providing additional storage capacity giving a high degree of resilience to climate change. New drainage infrastructure, also illustrated on Figure 2.4: Environmental Masterplan (Application Document 6.2), would serve the remainder of the Project and would provide storage to achieve discharges to surface watercourses at greenfield rates plus additional allowances for climate change REAC Ref. RDWE035).
- b. Incorporation of a suite of flood alleviation measures such as altering road geometry to set the vertical alignment of carriageways above the design flood level, inclusive of freeboard and allowance for climate change resilience, including provision for flood bunds or walls to protect areas where the vertical alignment of the road is lower than the design flood level, to make the development safe from flooding over its design lifetime in line with the requirements of DMRB LA 113 (REAC Ref. RDWE029).

15.6 Assessment of likely significant effects

15.6.1 This section presents the assessment of likely significant effects on climate resulting from GHG emissions arising from the construction and operational phases of the Project. It also presents the assessment of the Project's vulnerability to climate change. These are based on the design of the Project and take into account the mitigation as presented in Section 15.5 of this chapter.

GHG emissions impact assessment

Construction phase

15.6.2 Within the sub-stages of life cycle addressed in the construction phase GHG emissions assessment (Table 15.7), the embodied carbon associated with the use of materials is the biggest contributor to the carbon model of the Project. Material assets such as steel, concrete and bitumen can have high embodied

carbon contents (depending on the specifications and energy used in their production). The assessment has reviewed the materials proposed to be used (refer to Chapter 11: Material Assets and Waste) and calculated the associated embodied carbon emissions from their production, as well as their transport to site (refer to Appendix 15.1: Carbon and Energy Plan (Application Document 6.3)).

- 15.6.3 Construction activities would also contribute to GHG emissions due to associated plant and equipment use, which requires electricity and fuel consumption. The treatment, disposal and associated transportation of waste material from the construction sites also has the potential to contribute to the total GHG emissions from the construction phase due to the combustion of hydrocarbons in transport and energy production.
- 15.6.4 Land use change would not increase the construction phase GHG emissions. Site clearance, for example the removal of vegetation for replacement with another land use, would result in losses of carbon sinks, i.e. removal of a natural environment that has the ability to absorb GHG emissions. With landscape planting in place, the loss of carbon sinks associated with site clearance would be balanced out by the carbon sink gain from such landscape planting.
- 15.6.5 Table 15.12 contains the breakdown and comparison of emissions from each assessed activity during the construction phase of the Project.

Table 15.12 Approximate GHG emissions breakdown by construction activity

| Reporting category | Reporting sub-category | Estimated emissions (tCO ₂ e)* | Construction phase emissions (%)** |
|---|------------------------|---|------------------------------------|
| Embodied carbon in raw materials | Tunnels | 694,550 | 37.03% |
| | Highways | 341,190 | 18.19% |
| | Enabling works | 308,000 | 16.42% |
| | Soil and fill import | 64,920 | 3.46% |
| Water demand | | 2,680 | 0.14% |
| Construction phase traffic (including transport of material assets, waste and workers) | | 108,860 | 5.80% |
| Plant and equipment (fuel and electricity used on site) | Diesel | 223,550 | 11.92% |
| | Petrol | 570 | 0.03% |
| | Electricity | 60 | 0.00% |
| Disposal of waste | | 140,210 | 7.48% |
| Land clearance (loss of carbon sink) | | -8,930 | -0.48% |
| Risk | | 155,940 | 8.31% |
| Total | | 2,028,230 | 100% |
| * For the purpose of this assessment the estimated GHG emissions presented in Table 15.12 were rounded to the nearest 10 tCO ₂ e | | | |
| ** Construction phase percentages have been rounded to two decimal places | | | |

- 15.6.6 A construction emissions benchmark has been created based on the highways schemes, included in Table 15.13, normalised by road length, which gives a range of 22,720 tCO_{2e} to 109,490 tCO_{2e} per kilometre of Project. Construction emissions associated with the Project fall within this range at 65,540 tCO_{2e}/km.
- 15.6.7 Furthermore, two additional construction emissions benchmarks have been created based on whether or not the projects within Table 15.13 contain tunnel structures. These give ranges of 22,720 tCO_{2e} to 70,670 tCO_{2e} and 35,920 tCO_{2e} to 109,490 tCO_{2e} per kilometre of project respectively. Therefore, construction emissions associated with the Project also fall within these ranges.

Table 15.13 Estimated construction emissions benchmark

| Project | Project length (km) | Estimated construction emissions (tCO _{2e} /km) |
|--------------------------------|---------------------|--|
| M4 Corridor around Newport | 23 | 22,720 |
| A14 | 37 | 26,590 |
| M54 | 2.5 | 32,760 |
| A303 Amesbury to Berwick Down* | 13 | 35,920 |
| Lower Thames Crossing* | 31 | 65,540 |
| M42 Junction 6 Improvement | 2.5 | 70,670 |
| Silvertown Tunnel* | 1.4 | 109,490 |

* Projects with tunnel structures

Operational phase

- 15.6.8 The total GHG emissions over the operational life cycle of the Project (60 years operational stage from opening) is estimated as 3,240,956 tCO_{2e}.
- 15.6.9 A comparison of operational road user GHG emissions between the 'Do Minimum' and 'Do Something' scenarios for the 2027 opening year and the 2042 design year is presented in Table 15.14.

Table 15.14 Approximate comparison of road user emissions – DM vs DS scenarios

| Reporting category | 2027 opening year (tCO _{2e})* | 2042 design year (tCO _{2e})* |
|---|---|--|
| 'Do Minimum' | 9,082,290 | 10,027,120 |
| 'Do Something' | 9,118,370 | 10,074,650 |
| Variation ('Do Something' - 'Do Minimum') | 36,070 | 47,530 |

* For the purposes of this assessment the 'Do Minimum' and 'Do Something' scenario and the Variation GHG emissions presented in Table 15.14 were rounded to the nearest 10 tCO_{2e}

- 15.6.10 Table 15.14 indicates that in the year of Project opening (2027), GHG emissions would be approximately 36,080 tCO_{2e} higher in the 'Do Something' scenario than the 'Do Minimum' scenario, while for the 2042 design year, GHG emissions with the Project would be approximately 47,530 tCO_{2e} higher in the 'Do Something' scenario than the 'Do Minimum' scenario. The predicted increase in emissions is due to the increase in vehicle kilometres travelled as a result of the Project.

- 15.6.11 The extent of the projected uptake of lower carbon fuels, EVs and improved vehicle technology since the UK Government published the 'Road to Zero' Strategy (HM Government, 2018) is not currently fully captured in the modelling scenarios of future road traffic emissions used for this assessment. The new strategy sets out aspirations that by 2030 between 50% and 70% of new car sales and 40% of van sales will be ultra-low emission vehicles and by 2040 all new cars and vans sold will be zero carbon.
- 15.6.12 The TAG GHG emissions workbook used for the modelling is based on Defra's Emission Factor Toolkit version 9 and includes forecasts of the mix of vehicles (petrol/diesel/electric) in the fleet and engine fuel efficiency up to 2030. This means that it underestimates both the proportion of the vehicle fleet that will be electric in the future and the fuel efficiency of petrol/diesel vehicles. Consequently, the TAG workbook overestimates GHG emissions.
- 15.6.13 In addition, future decarbonisation of the grid would reduce the GHG emissions associated with the operation of the Project. Therefore, emissions data relating to electricity production and decarbonisation of the National Grid were considered in Appendix 15.1: Carbon and Energy Plan (Application Document 6.3), by using the predicted National Grid electricity emission factors modelled by BEIS, to estimate the operational GHG emissions.

Comparison against relevant UK carbon budget

- 15.6.14 The total GHG emissions over the life cycle of the Project (construction stage plus 60 years operational stage from opening) is estimated as 5,269,187 tCO_{2e}.
- 15.6.15 In line with DMRB LA 114 Climate (Highways England, 2019a) and the requirement of the NPSNN (Department for Transport, 2014), Table 15.15 provides an assessment of the Project's GHG emissions impact against the UK Government's five-year carbon budgets.
- 15.6.16 The 6th carbon budget will be legislated by June 2021, and may be more onerous to reflect the recent commitment to a net zero carbon economy by 2050, and the CCC has indicated that the trajectory could be steeper over time (CCC, 2019b). Therefore, it is the later carbon budgets rather than near-term ones which will see a greater impact. It is not expected that the near-term carbon budgets will be significantly different to those currently published.
- 15.6.17 The carbon assessment has considered emissions from the Project in two separate phases: emissions during construction and emissions during operation. The construction of the Project would be a short-term activity that runs from 2022 to 2027. Emissions from construction would therefore fall within the third and fourth carbon budgets. Emissions from the operation of the Project would fall into the fourth, fifth and subsequent future budgets once set through to 2050. Table 15.15 presents the net tCO_{2e} associated with the construction and operation of the Project during each of these carbon budget periods.

Table 15.15 Approximate construction and operational phases emissions in comparison to relevant carbon budgets

| Project phase | Estimated total GHG emissions over relevant carbon budgets (tCO ₂ e) (DS scenario)* | Net Project GHG emissions over relevant carbon budgets (tCO ₂ e) (DS - DM)* | Net Project GHG emissions per relevant carbon budget (tCO ₂ e)* | | |
|---------------|--|--|--|-----------------------------------|-----------------------------------|
| | | | 3 rd (2018 to 2022) | 4 th (2023 to 2027) | 5 th (2028 to 2032) |
| Construction | 1,937,870 | 1,937,870 | 322,980 | 1,614,890 | N/A |
| Operation | 55,714,570 | 275,980 | N/A | 44,090 | 231,890 |
| Total | 57,652,440 | 2,213,850 | 296,990 | 1,658,980 | 231,890 |

* For the purposes of this assessment, the estimated GHG emissions presented in Table 15.15 were rounded to the nearest 10 tCO₂e

- 15.6.18 Operational emissions calculated for the years within each carbon budget period include the vehicle use emissions for each specific year, plus the average annual GHG emissions associated with maintenance and operational energy use.
- 15.6.19 This assessment has established that during the period when GHG emissions from the Project would be at their highest level (short- and near-term construction activity and the first year of operation), the Project would contribute to 0.013% of the UK's carbon budget for the third carbon budget of 2,544m tCO₂e between 2018 and 2022). The Project GHG emissions would equate to 0.089% of the UK's fourth carbon budget of 1,950m tCO₂e during the period 2023 to 2027 and 0.013% of the UK's fifth carbon budget of 1,725m tCO₂e between 2028 and 2032.
- 15.6.20 The method to calculate the UK carbon budgets (presented in Table 15.5) varies to that used for the calculation of life cycle emissions from a road scheme and therefore some caution must be taken when making a direct comparison. However, for the purposes of identifying to what extent the Project may impact the ability of the UK to meet its carbon budgets, it is necessary to make this comparison to put the Project into context.
- 15.6.21 The NPSNN (Department for Transport, 2014) states that it is very unlikely that the impacts of a road project would, in isolation, affect the ability of the government to meet its carbon reduction plans. Indeed, emissions arising as a result of the Project represent less than 0.1% of total emissions in any five-year carbon budget during which they arise.
- 15.6.22 In this context, it is concluded that the GHG impact of the Project would not have a material impact on carbon reduction targets as set by the UK government, and therefore it is considered unlikely that the Project would in isolation cause significant effects on climate.

Vulnerability of the Project to climate change

- 15.6.23 A summary of the forecasted future baseline for climate is provided in Section 15.4, with further detail provided in Appendix 15.2: Climate Resilience Baseline (Application Document 6.3). An assessment of the climate resilience impacts and effects, using the criteria set out in Section 15.3, are presented in Appendix

15.3: Climate Resilience Impacts and Effects (Application Document 6.3). A summary of the climate resilience impacts considered is provided in the following paragraphs.

Construction phase

- 15.6.24 Climate resilience impacts identified and assessed for the construction phase within Appendix 15.3: Climate Resilience Impacts and Effects (Application Document 6.3) are summarised below.

Increased average summer temperatures and increased frequency of extreme temperatures

- 15.6.25 An increase in average summer temperatures and increased frequency of extreme temperatures may lead to more rapid degradation of materials on existing surfaces and structures as well as making materials difficult to work (for example asphalt). This in turn could lead to construction programme delays. A number of measures would be in place to minimise the consequence of these effects including the use of short to medium-term weather forecasting in planning construction activities, environmental controls and impact mitigation measures and the selection of materials appropriate for the projected climate scenarios detailed within UKCP18. Following an assessment of the likelihood and consequence of these events occurring (Appendix 15.3, Application Document 6.3) it is demonstrated that all effects relating to increased temperatures were **not significant**.

Decreased annual mean daily precipitation levels and increased frequency of extreme precipitation events

- 15.6.26 Increases in the frequency of extreme rainfall events have the potential to change the surface and groundwater regime leading to potential impacts on the design and settlement of foundations and site drainage as well effects to earthworks and stockpile construction related to increased erosion and potential for ground movement. The Project would be designed in line with the latest engineering standards as set out within DMRB, some of which include necessary allowances to increase resilience to climate change. For example, the Project has been designed to DMRB CG 501 Design of highway drainage systems (Highways England 2020). To manage the increased frequency of extreme precipitation events and the risk of localised flash flooding, work site drainage systems would be inspected and maintained regularly to ensure they continue to operate to their design standard, safeguarding surface and groundwater quality and can cope with allowances for a 20% increase in peak rainfall intensities.
- 15.6.27 In addition, the Project has been designed to DMRB CD 622 Managing geotechnical risk (Highways England 2019), which requires earthworks, slopes and foundations to be subject to short-, medium- and long-term engineering risk assessment considering groundwater conditions. Measures have also been included within the REAC (Appendix 2.2, Application Document 6.3) and secured through the DCO to ensure the safe management of material stockpiles and handling during the construction phase to reduce the risk of ground movements.

- 15.6.28 Following an assessment of the likelihood and consequence of these events occurring (Appendix 15.3, Application Document 6.3) it is demonstrated that all effects relating to increased intensities of rainfall were **not significant**.

Operational phase

- 15.6.29 Climate resilience impacts identified and assessed for the operational phase within Appendix 15.3 Climate Resilience Impacts and Effects (Application Document 6.3) are summarised below.

Increased average summer temperatures and increased frequency of extreme temperatures

- 15.6.30 An increase in mean summer temperatures and frequency of extreme temperatures has the potential to lead to the effects summarised below. A number of the effects identified within the risk assessment would be managed through the application of the current design standards set within DMRB, which include allowances for future climate change (REAC Ref. CC006).
- a. Thermal contraction and expansion of pavement and structure surfaces as well as joints and bearings leading to an increased rate of deterioration of materials and assets. The likelihood of effects related to the deterioration of materials and Project assets would be reduced through the application of the latest DMRB standards (refer to Appendix 15.3, Application Document 6.3) within the design of structures, pavements and other critical features. Additionally, the implementation of regular inspections and maintenance of assets in line with the Highways England Routine and Winter Service Code (RWSC) and the Network Management Manual (NMM) would eliminate the risk of adverse effects. Therefore, the assessment presented in Appendix 15.3 (Application Document 6.3) determines the effects to be **not significant**.
 - b. Alteration of growing characteristics such as longer vegetation growing seasons and changing soil properties affecting the landscape planting strategy, increasing risks of tree falls and maintenance/management requirements. During detailed design further detail would be provided within the Environmental Management Plan (EMP) iteration 2. The purpose of the EMP iteration 2 would be to provide information relating to existing and future landscape and environmental commitments that would need to be delivered to achieve the intended environmental function and objective. This would include detailed requirements concerning the medium to long-term maintenance and management of all soft landscaping incorporated into the Project and the responsibility of Highways England. This would be developed in accordance with the Manual of Contract Documents for Highway Works (MCDHW) Volume 1, Series 3000 Landscape and Ecology (Highways Agency, 2001). Additionally, measures related to the handling and reinstatement of soils within the Order Limits have been secured through the DCO. These measures would aim to avoid a reduction in soil

function. The detailed assessment presented in Appendix 15.3 (Application Document 6.3) determined the effects to be **not significant**.

- c. Overheating of tunnel and electrical equipment located within the tunnel support buildings, such as information and communication systems, leading to a potential fire risk. This risk is limited to areas closer to the tunnel portals due to the ground cover acting as insulation. The tunnel would be operated in accordance with Highways England RWSC (Highways England, 2009b) and the NMM (Highways England, 2009a). In addition, adequate space within the tunnels for ventilation to account for anticipated cooling and ventilation requirements would be provided. The detailed assessment presented in Appendix 15.3 (Application Document 6.3) determined the effects to be **not significant**.
- d. Increased risk of road user accidents resulting from road user vehicle overheating/fires and smoke drift from wildfires. The likelihood and consequence of this effect would be reduced through the implementation of emergency response and contingency plans and establishing standard operating procedures for use in the event of necessary road closure and/or traffic diversion. In addition, incidents will be managed in accordance with DMRB GM 703 Operational Requirements for Incident Management (Highways England, 2020d). The detailed assessment presented in Appendix 15.3 (Application Document 6.3) determined the effects to be **not significant**.

Decreased mean daily precipitation levels and increased frequency of extreme precipitation events

- 15.6.31 A decrease in mean daily precipitation levels and increased frequency of extreme precipitation has the potential to lead to the effects summarised below. Effects identified within the risk assessment, and related to decreased mean daily precipitation levels and increased frequency of extreme precipitation, would be managed through the application of the current design standards set within DMRB, which include allowances for future climate (REAC Ref. CC006).
- a. An increased frequency of intense rainfall has the potential to increase the Project risk to flooding leading to a reduction in reduced safety, road closures and disruption to the local area. A number of measures have been identified to reduce the consequence of this climate event to an acceptable level including the setting of the vertical alignment of the road to above the design flood level with inclusions for freeboard and climate change allowances, increasing the Project resilience to flooding. Additionally, flood alleviation measures have been designed to include allowances for climate change for the assumed 100 year operational life from the opening year. These include provision of compensation storage for any permanent losses of floodplain storage volume associated with the Tilbury Main, Mardyke and Mardyke West tributary, whilst flood relief culverts would be provided to

maintain floodplain connectivity and prevent embankments forming continuous barriers to floodplain flow conveyance at Tilbury and west of the proposed viaduct spanning the Mardyke and Golden Bridge Sewer. The detailed assessment presented in Appendix 15.3 (Application Document 6.3) has concluded that, following the implementation of the measures to increase the resilience of the Project to future flood risk, the effects are **not significant**.

- d. Changes in rainfall patterns have the potential to alter the moisture content of soils and the overall hydrology of the study area. Consequently, this may lead to increased risk of ground movements affecting the foundations and substructures of Project structures, pavement and earthworks and potentially lead to collapse/failure. As demonstrated by commitment CC006, the engineering design and maintenance regime would accord with the current design standards set out within DMRB taking into account the projected future climate. In accordance with DMRB CG 501 (Highways England, 2020a), storage volumes for balancing ponds and infiltration will be based on the worst 1 in 100-year storm event. To account for the effects of climate change, and as agreed with the Environment Agency, storage volumes should be calculated on the basis that there is a 20% increase in peak rainfall intensity. In addition, to account for the effects of climate change, pond sizes and basins have been determined on the basis that there is a 20% increase in peak rainfall intensity with a further check to ensure no flooding occurs for a 40% increase in peak rainfall intensity. This would help increase the Project's capacity to deal with intense downpours and ensure excess water is channelled away from the live carriageways. Owing to the measures described to reduce the likelihood and consequence of intense rainfall events, the effect was assessed as **not significant**.
- e. 'Summer ice' can occur after a prolonged period of no rain when dirt and oil residue build up on the road. When the first rain event occurs, this material becomes incredibly slippery and dangerous (similar to ice on the road). The risk of 'summer ice' occurring may increase due to the increased frequency of intense rainfall events. The Project's drainage will be designed in accordance with DMRB CG 501 (Highways England, 2020a) and would include provision for pollution treatment systems. The drainage would be inspected and maintained regularly in accordance with Highways England's GS 801 Asset Delivery Asset Inspection Requirements (Highways England, 2020e) and GM 701: Asset Delivery Asset Maintenance Requirements (Highways England, 2020c), as applicable, to ensure they continue to operate to their design standard and to ensure dirt and oil continues to be removed from the road surface. Following the assessment included within Appendix 15.3 (Application Document 6.3), the effect was identified as **not significant**.

- f. Higher frequencies of intense rainfall events may lead to an increase in sediment transport entering the drainage system. Sediment overloading and failure of drainage systems could potentially lead to localised flooding. Drainage infrastructure and treatment systems would be inspected and maintained regularly in accordance with Highways England's GS 801 Asset Delivery Asset Inspection Requirements (Highways England, 2020e) and GM 701 Asset Delivery Asset Maintenance Requirements (Highways England, 2020c), as applicable, to ensure they continue to operate to their design standard. Owing to the assumed measures described to reduce the likelihood and consequence of the impacts, it is assessed as **not significant**.

15.7 Cumulative effects

GHG emissions impact assessment

Intra-project effects

- 15.7.1 Cumulative effects of the Project can occur as a result of interrelationships between different environmental topics, which are referred to as 'intra-project effects'. For climate, interrelationships are identified with Chapter 7: Landscape and visual, Chapter 11: Material assets and waste and Chapter 13: Population and human health. However, these interrelationships do not result in a cumulative effect for the GHG emissions impact assessment as the effects of all GHG emissions presented within this assessment are essentially cumulative.

Inter-project effects

- 15.7.2 In addition to intra-project effects, cumulative impacts can also occur due to the Project in combination with other existing and/or approved development. The effects of all GHG emissions are essentially cumulative. The excess of emissions from human activities contributes to the overall effect on climate in the UK, not only local emissions. For this reason, the impact of the Project has been considered in the context of overall GHG emissions from the UK, rather than in combination with other local developments, by comparing the estimated Project's GHG emissions with UK carbon budgets.
- 15.7.3 It should also be noted that the traffic data (contained within the ComMA (Application Document 7.7)) used in the assessment of GHG emissions already account for traffic generated by other planned or reasonably foreseeable major local developments. In accordance with the Planning Inspectorate's (2019) Advice Note Seventeen: Cumulative Effects Assessment, no additional cumulative assessment of these aspects is required.

Vulnerability of the Project to climate change

Intra-project effects

- 15.7.4 For vulnerability of the Project to climate change, interrelationships are identified with Chapter 5: Air Quality, Chapter 7: Landscape and Visual, Chapter 10: Geology and Soils, Chapter 12: Noise and Vibration, Chapter 13: Population

and Human Health and Chapter 14: Road Drainage and the Water Environment and include combined effects from climate change projections of:

- a. Increased intense rainfall event although drier winters
- b. Drier summers and hotter summers
- c. Warmer winters and reduced snow

15.7.5 Climate change intra-project effects are summarised below and presented in more detail within Appendix 15.3: Climate Resilience Impacts and Effects (Application Document 6.3):

- a. Chapter 5: Air Quality – increased number of hot days may adversely affect magnitude of construction dust due to extended dry spells, however, this would be unlikely to be expected to result in a cumulative effect due to the timescales for the construction of the Project.
- b. Chapter 7: Landscape and Visual – increased occurrence of heatwaves and droughts may adversely affect the growth rates of landscape planting and/or increase the likelihood of plant failure.
- c. Chapter 10: Geology and Soils – increased frequency and severity of drought and high temperatures may adversely affect soil quality.
- d. Chapter 12: Noise and Vibration – increased number of heatwaves may exacerbate noise effects on communities in terms of individual dwellings on a wider community. This is caused by the need for occupants to open windows for ventilation during a heatwave.
- e. Chapter 13: Population and Human Health – increased frequency and severity of drought events may adversely affect magnitude and duration of dust and vapours, and migration through groundwater during the construction phase.
- f. Chapter 14: Road Drainage and the Water Environment – increased frequency and severity of short periods of high rainfall may adversely affect drainage control measures embedded within the Project design. In addition, increased heavier precipitation events may lead to risk of flooding and potential for impacts to surface water and groundwater quality.

Inter-project effects

15.7.6 There are no inter-project cumulative effects identified for climate vulnerability.

15.8 Monitoring

15.8.1 No likely significant adverse residual effects have been identified, and no specific monitoring is required for climate receptors.

15.8.2 The CoCP (Application Document 7.11) sets out details of the monitoring to be undertaken during the Project's construction and operational phases to

determine whether the mitigation measures embedded in the Project design are being appropriately implemented. Highways England is committed to reducing carbon emissions and working closely with suppliers to reduce emissions from network related activity.

- 15.8.3 As a requirement of the REAC (Appendix 2.2, Application Document 6.3) which will form part of the CoCP (Application Document 7.11) post DCO grant, the Contractor(s) would quantify and report GHG emissions quarterly to Highways England in line with the requirements of DMRB LA 114 Climate (Highways England, 2019a). This information would be evaluated by Highways England and used to inform assessment of future projects (REAC Ref. CC003).
- 15.8.4 As a requirement of the REAC (Appendix 2.2, Application Document 6.3) (REAC Ref. CC005) which will form part of the CoCP (Application Document 7.11), the road operator would provide quarterly GHG emissions returns and analysis to Highways England during the operational phase in accordance with the requirements of DMRB LA 114 Climate (Highways England, 2019a, or as updated). This information would be evaluated by Highways England and used to inform assessment of future projects.

15.9 Summary

- 15.9.1 The assessment of effects on climate considered effects on climate from GHG emissions and the vulnerability of the Project to climate change during the construction and operational phases. Assessments were undertaken in accordance with DMRB LA 114 (Highways England, 2019a).

GHG emissions impact assessment

- 15.9.2 The GHG emissions impacts assessment considered the potential for effects of the Project on climate by quantifying likely emissions of GHG to the earth's atmosphere, both during the construction and operation phases of the Project.
- 15.9.3 Through the application of the DMRB LA 114 Climate standard (Highways England, 2019a), the Project is committed to reducing GHG emissions from Project activities by implementing the hierarchy for GHG emissions (avoid and/or prevent, reduce, remediate). The 'Do Something' scenario would generate the following change in emissions over the 'Do Minimum' scenario:
- a. Construction: 1,937,870 tCO₂e
 - c. 2027 opening year: 44,090 tCO₂e
 - d. 2042 design year: 55,540 tCO₂e
- 15.9.4 Highways England is committed to reducing emissions wherever practicable and supporting the UK Government in meeting its carbon reduction targets. Paragraph 5.17 of the NPSNN (Department for Transport, 2014) states that '*It is very unlikely that the impact of a road project will, in isolation, affect the ability of Government to meet its carbon reduction plan targets*'.
- 15.9.5 Indeed, emissions arising as a result of the Project represent less than 0.09% of total emissions in any five-year carbon budget during which they arise.

- 15.9.6 In this context, it is concluded that the GHG impact of the Project would not have a material impact on carbon reduction targets as set by the UK Government.
- 15.9.7 Table 15.16 summarises the predicted impact of the Project on the ability of Government to meet the UK'S carbon budgets. There is currently no budget for the period covering from 2033 up to 2086 (to extend the operational phase 60 years in line with the appraisal period). However, the CCC will publish its recommendation on the level for the 6th carbon budget in December 2020. Government is required to respond to that advice and legislate the new carbon budget by June 2021. The 6th carbon budget, required under the Climate Change Act, will provide advice on the volume of GHG the UK can emit during the period 2033-2037. This table takes into consideration the mitigation measures proposed in Section 15.5.

Table 15.16 GHG emissions impact table

| Impact description | Contribution to the UK's carbon budget | Significance |
|---|--|-----------------|
| Ability of Government to meet the UK 3 rd carbon budget (2018 to 2022) | 0.013% | Not significant |
| Ability of Government to meet the UK 4th carbon budget (2023 to 2027) | 0.089% | Not significant |
| Ability of Government to meet the UK 5th carbon budget (2028 to 2032) | 0.013% | Not significant |

Vulnerability of the Project to climate change

- 15.9.8 Climate in the study area is projected to change in the future. The assessment has also considered the vulnerability of the Project to this climate change.
- 15.9.9 The assessment of the vulnerability of the Project to climate change began with a review of the potential impacts and was followed by an assessment of their potential consequence and likelihood of occurrence, taking into account the measures incorporated into the design of the Project.
- 15.9.10 The assessment included all infrastructure and assets associated with the Project and identified the Project's receptors within the study area which are vulnerable to future climate change scenarios developed.
- 15.9.11 Table 15.17 includes a summary of the vulnerability of the Project to climate change impacts assessment presented within Appendix 15.3: Climate Resilience Impacts and Effects (Application Document 6.3) which details sources, pathways and receptors approach. Table 15.17 confirms no likely significant effects of climate change on the Project's receptors, presented in Appendix 15.3: Climate Resilience Impacts and Effects (Application Document 6.3).
- 15.9.12 Likelihood categories and consequences of impact have been defined in accordance with the definitions provided in Table 15.8. A number of mitigation and adaptation measures to address the potential impacts associated with climate change events have been considered in Appendix 15.3: Climate Resilience Impacts and Effects (Application Document 6.3), many of which have

been identified within other topic chapters within this ES, and through the development of the Project's design.

- 15.9.13 Appendix 2.2: REAC (Application Document 6.3) secures these mitigation and adaptation measures, which have been taken into consideration in this table. Consequences of impacts have been measured following the implementation of mitigation measures and in accordance with the descriptions included within Table 15.9.

Table 15.17 Vulnerability of the Project to climate change impacts (Summary)

| Potential effect to Project (Impact) | Likelihood of impact (post mitigation) | Consequence of impact | Significance (including mitigation) |
|--|--|-----------------------|-------------------------------------|
| Construction phase (UKCP18 time period of 2020s) | | | |
| Pavement - Increased winter precipitation and decreased summer precipitation leading to changes in groundwater level and soil moisture. This has the potential to affect the foundation settlement, generate larger ground movement and heave. | Very low | Moderate adverse | Not significant |
| Pavement - Increased extreme temperatures leading to a risk of surface failure or deterioration. For example, curling or warping, sometimes called hogging of concrete pavements and slabs. These can be compounded by loading from passing traffic. Thermal contraction and expansion of the slabs can generate unacceptably large longitudinal internal stresses and excessive movements at joints. | Medium | Minor adverse | Not significant |
| Pavement - Extended periods of hot and sunny conditions which could result in asphalt remaining workable for a considerable time, making it difficult to maintain profile during compaction. | Medium | Minor adverse | Not significant |
| Structures - Increased extreme temperatures resulting in the deterioration of joints and bearings leading to unacceptable movement in the structure. | Very low | Moderate adverse | Not significant |
| Structures - Increased wind speed resulting in minor structures potentially having to withstand larger wind loads. The effect on the bridges should be minimal, as wind is rarely a dominant load. There is an increased risk of disruption to construction work (unable to operate in high winds). | Very low | Moderate adverse | Not significant |
| Structures - Increased mean temperatures and extreme temperatures may lead to the requirement for stronger fill material and therefore increasing the quantities of excavated material becoming waste. | Very low | Minor adverse | Not significant |

| Potential effect to Project (Impact) | Likelihood of impact (post mitigation) | Consequence of impact | Significance (including mitigation) |
|---|--|-----------------------|-------------------------------------|
| Structures - Increased winter precipitation and decreased summer precipitation causing a change in the groundwater level. This could lead to ground movement and heave, requiring more robust foundations. | Very low | Minor adverse | Not significant |
| Structures - Increased extreme precipitation leading to increased scour risk for foundations. | Very low | Minor adverse | Not significant |
| Structures - Increased extreme temperatures leading to a requirement for larger bearings. | Very low | Large adverse | Not significant |
| Drainage - Increased extreme precipitation leading to additional drainage, larger components and more extensive works. | Very low | Minor adverse | Not significant |
| Drainage - Increased risk of flooding during the construction of the Project drainage assets may lead to congestion and reduce their efficiency during operation. This may lead to reduced safety. | Very low | Minor adverse | Not significant |
| Geotechnics - Increased precipitation leading to an increase in erosion of stockpiled site-won materials and cut earthworks. | Very low | Moderate adverse | Not significant |
| Geotechnics - Increased precipitation reducing earthwork stability and leading to the requirement for new / acceptable fill to be imported. | Very low | Moderate adverse | Not significant |
| Geotechnics - Increased extreme temperature and a decreased summer precipitation reducing soil moisture and leading to the need for greater compactive effort. This may require increased costs and construction delays. | Very low | Moderate adverse | Not significant |
| Geotechnics - Increased winter precipitation and extreme precipitation leading to a change in the groundwater level. This could result in ground movement in areas of historic landfill and around the A2. | Very low | Minor adverse | Not significant |
| Signs and signals - Increased extreme precipitation and wind speed increasing loading risks for the construction of signs and signals. | Very low | Moderate adverse | Not significant |
| Technology - Increased wind speed will lead to elevated structures being exposed to high winds. | Very low | Moderate adverse | Not significant |

| Potential effect to Project (Impact) | Likelihood of impact (post mitigation) | Consequence of impact | Significance (including mitigation) |
|--|--|-----------------------|-------------------------------------|
| WCH facilities - Increased projected mean daily rainfall, especially in winter months could lead to safety risks of slips, trips and falls to construction workers. | Very low | Minor adverse | Not significant |
| WCH facilities - Increased summer temperatures, humidity and frequency of hot days and heatwaves leading to stress/heat exhaustion for workers. | Very low | Minor adverse | Not significant |
| WCH facilities - Increased projected mean daily rainfall, especially in winter months could cause excavations to flood. Site roads may also become impassable through flooding. | Very low | Minor adverse | Not significant |
| WCH facilities - Increased projected mean daily rainfall, especially in winter months Water ingress to critical equipment, including traction power distribution sites, leading to signalling or other electronic equipment failures, requiring switch off or, possibly causing damage. | Very low | Minor adverse | Not significant |
| Operational phase (UKCP18 time period of 2080s) | | | |
| Pavement - Increased mean daily rainfall leading to the moisture content of soils being altered. This could cause ground movements, soil settlement as well as expansion and contraction. This could also cause the Project pavements and foundations to heave. | Very low | Moderate adverse | Not significant |
| Pavement - Large changes in temperature causing thermal contraction and expansion of the slabs. This could generate unacceptably large longitudinal internal stresses and excessive movements at joints. | Very low | Minor adverse | Not significant |
| Pavement - Maintained high temperatures leading to excessive rutting of newly laid surfacing layers and the rapid embedment of any chippings, with the latter again causing a reduction of texture depth. | Very low | Minor adverse | Not significant |
| Pavement - An increase in frequency of heavy rainfall, an increase of average temperatures and an increase in frequency of hot days and heatwaves leading to a reduced pavement friction coefficient. | Low | Minor adverse | Not significant |
| Pavement - Changes in mean temperatures and daily rainfall leading to the reduced need for snow clearing. | Low | Negligible | Not significant |

| Potential effect to Project (Impact) | Likelihood of impact (post mitigation) | Consequence of impact | Significance (including mitigation) |
|---|--|-----------------------|-------------------------------------|
| Structures - Increased mean temperature and increased frequency of hot days and heatwaves leading to the potential risk of thermal actions (loads) applied to structure (e.g. leading to joint and bearing failure). Some structures have the potential to fail to operate within original design parameters. This could induce failures meaning additional works would then be required to strengthen them. | Very low | Minor Adverse | Not significant |
| Structures - Increased mean daily rainfall causing premature deterioration rates for joints, bearings and surfaces. This would lead to increased traffic disruption. | Low | Minor adverse | Not significant |
| Structures - Increased frequency and intensity of storms increasing loads on structures, overhead lines which could lead to collapse. | Low | Minor adverse | Not significant |
| Structures - Increased heavy rainfall causing flooding and deterring users from their journey. | Low | Minor adverse | Not significant |
| Structures - Increased mean temperature and increased frequency of hot days and heatwaves resulting in the overheating of the tunnel portal areas and a potential fire risk. | Low | Minor adverse | Not significant |
| Structures – Increased heavy rainfall resulting in tunnel flooding, deterring users from their journey. | Low | Moderate adverse | Not significant |
| Structures - Increased mean daily rainfall causing changes in groundwater levels. This could lead to ground movements and soil settlement causing damage to foundations and substructure. | Low | Moderate adverse | Not significant |
| Drainage - Increased frequency and intensity of heavy rainfall, flooding and storm events could lead to an overwhelming of the drainage system and inundation of the road. | Low | Minor adverse | Not significant |
| Drainage - Increased mean daily rainfall could lead to increased risk of pollution mobilisation from accidental spillages with contaminants entering the water environment. | Low | Minor adverse | Not significant |
| Earthworks - Increased winter precipitation and extreme precipitation causing instability of embankments and cuttings. | Very low | Large adverse | Not significant |

| Potential effect to Project (Impact) | Likelihood of impact (post mitigation) | Consequence of impact | Significance (including mitigation) |
|---|--|-----------------------|-------------------------------------|
| Earthworks - Increased frequency and intensity of heavy rainfall, flooding and storm events resulting in road network becoming inaccessible due to submergence in flood water. | Low | Large adverse | Not significant |
| Soils - Changes in mean temperatures and daily rainfall impacting the soils reinstated by the Project for agricultural use. This may alter the productivity of the land. | Low | Negligible | Not significant |
| Signs, signals, lighting and fencing - Increased frequency and intensity of storms resulting in the reduction of the design life of a number of key assets such as signage, lighting, road surface and road markings. This would lead to an increase in maintenance costs over the lifespan of the road. | Low | Minor adverse | Not significant |
| Signs and signals - Increased mean temperature and daily rainfall could increase the deterioration rate of road markings reducing road user safety. | Low | Minor adverse | Not significant |
| Signs, signals, lighting and fencing - Increased wind speed and frequency of extreme wind events impacting the design life. | Low | Minor adverse | Not significant |
| Signs, signals, lighting and fencing - Increased wind speed and frequency of extreme wind events impacting the stability of signals, signs and lighting columns due to increased wind loads. | Low | Minor adverse | Not significant |
| Signs and signals - Increased extreme weather events may damage and disrupt the power supply and other linked infrastructure. | Low | Moderate adverse | Not significant |
| Signs and signals - Increased mean temperature and frequency of hot days and heatwaves could cause the overheating of electrical equipment leading to failure and/or fire. | Medium | Minor adverse | Not significant |
| Soft Estate - Decreased mean rainfall may lead to drought tolerant trees becoming more prevalent. This may cause a change in the landscape character of the area and would likely affect biodiversity. | Medium | Negligible | Not significant |

| Potential effect to Project (Impact) | Likelihood of impact (post mitigation) | Consequence of impact | Significance (including mitigation) |
|---|--|-----------------------|-------------------------------------|
| Soft Estate - Increased mean temperature and daily rainfall may alter the growing characteristics such as soil properties and length of growing season. This may impact the species identified as part of the landscape planting and change the character of the landscape. This could also lead to tree fall and increased maintenance and management requirements. | Medium | Negligible | Not significant |
| Soft Estate - Increased wind speed and frequency of extreme wind events leading to increased tree/habitat loss, habitat fragmentation and reduction in woodland blocks. | Medium | Negligible | Not significant |
| Soft Estate - Increased wind speed and frequency of extreme wind events, dry spells and heavy rain potentially resulting in a loss of valued landscape features, opening up new views of the Project that were previously shielded. | Medium | Negligible | Not significant |
| Soft Estate - Increased mean daily rainfall changing the hydrology which could lead to the landscape planting failing. | Low | Negligible | Not significant |
| Vehicle Restraint Systems - More frequent extreme weather, changes in temperature and rainfall could increase the rate of deterioration of vehicle restraint systems. | Low | Minor adverse | Not significant |
| End-users (members of public, commercial operators, etc.) - Increased extreme weather events could lead to an increase in the rate of deterioration of assets. This could increase the frequency of maintenance workers and traffic officers working within the carriageway. | Medium | Minor adverse | Not significant |
| End-users - Increased frequency and intensity of storms may discourage the use of WCH facilities to complete journeys. This may lead to more users of the road. | Medium | Negligible | Not significant |
| End-users - Increased heavy rainfall and flooding causing closures and diversions of WCH facilities. | Medium | Negligible | Not significant |
| End-users - Increased frequency and intensity of heavy rainfall, flooding and storm events resulting in the potential for higher rates of vehicle collisions, severe disruption to the highway, harm to road users and adjacent receptors. | Medium | Minor adverse | Not significant |

| Potential effect to Project (Impact) | Likelihood of impact (post mitigation) | Consequence of impact | Significance (including mitigation) |
|--|--|-----------------------|-------------------------------------|
| End-users - Increased mean temperature and frequency of hot days and heatwaves could increase the risk of incidents due to vehicles breakdown, a higher frequency of vehicle fires, smoke drifting across carriageways from wildfires and Heavy Goods Vehicle blow-overs and flying debris. | Medium | Minor adverse | Not significant |
| End-users - Increased frequency of dry spells and heavy rainfall allowing 'Summer ice' to occur. | Medium | Minor adverse | Not significant |
| End-users - Increased frequency and intensity of heavy rainfall, flooding and storm events leading to reduced safety and visibility as a result of standing water. | Medium | Minor adverse | Not significant |
| End-users - Increased mean temperature and frequency of hot days and heatwaves may lead to an increase in stress for road users and maintenance workers. | Medium | Minor adverse | Not significant |

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