BANWELL BYPASS

Environmental Statement

HIF Banwell Bypass and Highways Improvements Project

Environmental Statement Chapter 14- Climate

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Contents

14 Climate

14.1 Introduction

14.1.1 This chapter reports the potential effects from the construction and operation of the proposed Scheme (as detailed in ES Volume 1 - Chapter 2 - Scheme Description) on climate. This chapter and assessment follow the methodology set out in Design Manual for Roads and Bridges (DMRB) *LA 114 Climate*[1].

14.1.2 This chapter details the assessment methodology, summarises the legislative and policy framework related to climate change and describes the existing and projected future local and regional baseline environment in the area surrounding the Scheme. Following this, the design, mitigation and residual effects of the Scheme are discussed, along with any limitations of the assessment.

14.1.3 To align with the requirements of DMRB *LA 114 Climate*, the National Policy Statement for National Networks (NPSNN)[2], the National Planning Policy Framework (NPPF)[3] and The Town and Country Planning (Environmental Impact Assessment) Regulations 2017, the climate assessment includes the following elements:

a) Impact of the Scheme on climate (greenhouse gas emissions (GHG) assessment): the effect on the climate of GHG emissions arising from the Scheme, including how the Scheme would affect the ability of government to meet its carbon reduction plan targets.

b) Vulnerability of the Scheme to climate change (climate change resilience (CCR) assessment): the resilience of the Scheme to climate change, including how the Scheme design has been adapted to take account for the projected impacts of climate change[4].

14.1.4 This chapter also demonstrates how Objective F: Be innovative and efficient in reducing and offsetting carbon from the design and construction of the infrastructure, set out in ES Volume 1 - Chapter 1 - Introduction, has been achieved throughout the

Scheme design evolution.

14.1.5 This chapter also considers the potential impacts of future climate conditions on the environment combined with the impacts of the Scheme. The future projected climate conditions for the area has been considered within relevant topic assessments of likely significant effects. This means that the environmental receptors that are vulnerable to impacts from both the project and climate factors are fully considered within the context of the changing climate. The assessment is presented within each topic chapter and shown in the ICCI assessment, in ES Volume 3 - Appendix 14.F – Carbon Assessment Report

Scheme Overview

14.1.6 The following section provides a brief description and overview of the Banwell Bypass and Highways Improvements Project.

14.1.7 The Scheme comprises the following distinct elements:

a) a bypass of the village of Banwell (referred to as the "Banwell Bypass");

b) a route connecting the A371 at Castle Hill and the A368 at East Street (referred to as the "Southern Link"); and

c) Mitigation and enhancement measures, which broadly consist of the following:

- Environmental mitigation and enhancement measures in connection with the Banwell Bypass and the Southern Link, examples of which include (but are not limited to) flood compensation areas, planting and habitat creation, attenuation basins etc.

- Placemaking improvements within Banwell, comprising mitigation and enhancement measures to the public realm; and

- Traffic mitigation in connection with the Banwell Bypass and the Southern Link, including Improvements to the wider local road network.

14.1.8 Together, these elements comprise the "Scheme". Each element as listed is described in more detail below.

Banwell Bypass

14.1.9 The Banwell Bypass would be located within the administrative area of North Somerset. The village of Banwell is located approximately 8km east of Weston-super-Mare. The Banwell Bypass would primarily consist of:

a) signalisation and capacity improvements to the Summer Lane/ Wells Lane junctions on the A371;

b) a 40mph single carriageway Banwell Bypass, connecting the existing A371 (east of Summer Lane) to A368 (west of Towerhead Farm);

c) a 3 metre wide shared use path provided along the majority of the Banwell Bypass providing a link from Weston-super-Mare to Sandford;

d) Banwell West Junction - a three arm roundabout located east of Knightcott Industrial Estate at the western end of Banwell;

e) Wolvershill Road Junction – a traffic signalised junction, providing access for all users to the west, east, and north. Access to the south would be restricted to public transport and walking, cycling and horse-riders, and limited agricultural access only;

f) Banwell River Bridge – an overbridge across Riverside and the River Banwell. There would not be a direct connection between Riverside and the Banwell Bypass;

g) Moor Road to Riverside Link - a side road connection between Riverside and Moor Road; and

h) Banwell East Junction - A three-arm traffic signalised junction, with dedicated turning lanes from the bypass towards the Southern Link.

Southern Link Road

14.1.10 The Southern Link will provide the new primary route south to Winscombe, as Castle Hill and Dark Lane are proposed to be stopped up. The Southern Link would be a 30mph single carriageway, connecting the A368 (East Street) to the A371 at Castle Hill. The Southern Link would be located within the Mendip Hills AONB. The Southern Link would link into the Banwell Bypass at the Banwell East Junction. A T-junction located along the Southern Link would provide access into the east of Banwell (at East Street).

Mitigation Measures

Environmental mitigation and enhancement measures in connection with the Banwell Bypass and the Southern Link.

14.1.11 The Scheme would include mitigation measures which are provided to offset the impact of the Banwell Bypass proposal. These include (but are not limited to):

a) flood mitigation to ensure that the Banwell Bypass does not increase flood risk for third-party properties;

b) land for essential mitigation, such as ecology and landscape mitigation;

c) sustainable urban drainage systems (e.g. attenuation basins and swales), and additional groundwater mitigation, to prevent adverse water quality impacts (including the Source Protection Zone); and

d) replacement land to mitigate the impact of the scheme on Banwell Football Club.

Placemaking improvements within Banwell

14.1.12 As a result of the Banwell Bypass, there would be a reduction in traffic through Banwell. The reduction in traffic (and resulting reduction in congestion) through the village could result in higher traffic speeds without mitigation.

14.1.13 A reduced 20mph speed limit through Banwell would discourage vehicles from travelling at higher speeds, whilst also discouraging the use of the road as a through route (instead of the Banwell Bypass).

14.1.14 The reduction of traffic through Banwell due to the provision of the Banwell Bypass provides the opportunity to make improvements to the existing road and public spaces within Banwell to enhance the historic and urban setting of the village. These improvements would include, but are not limited to:

a) Alteration to the road and footways including resurfacing, widening, and narrowing (which would encourage drivers to comply with the posted 20mph speed limit);

b) Incorporation of active travel measures;

c) Soft landscaping and ecological improvements; and

d) Street signage improvements.

Improvements to the wider local road network

14.1.15 Improvements to the local road network and junctions including the surrounding villages of Churchill, Sandford and Winscombe are proposed to mitigate increases in traffic as a result of the Banwell Bypass and Southern Link. These mitigation measures would consist of:

a) Lowered speed limits:
   - 20mph: A368 through Churchill, A368 through Sandford, A371 through Winscombe.
   - 30mph: A368 between Churchill and Sandford Villages.

b) Gateway Features when entering and exiting the villages of Sandford, Churchill and Winscombe;

c) Non-physical traffic calming measures through and between villages (e.g. road markings and speed signage);

d) Capacity improvements to the Churchill Junction (A38/ A371);

e) Provision of new/ improvements to existing pedestrian and cycling crossings;

f) Active travel measures along the A368, with improved footway/ cycleway access from Churchill and Langford to Churchill Academy;

g) Improvements to footways, shared pedestrian, and cycleway; and

h) Soft landscaping, native planting, rewilding, and ecological enhancements.

Context

14.1.16 North Somerset Council's (NSC) Housing Infrastructure Fund (HIF) proposal supports potential housing sites (subject to the emerging Local Plan 2038).

14.1.17 A business case was submitted to Homes England to secure funding for a package of infrastructure improvements in February 2019 and a successful funding announcement was made at the end of October 2019.

14.1.18 The Banwell Bypass would provide a highway connection to enable potential housing sites that may be allocated in the emerging Local Plan and alleviate the anticipated impact of

further traffic growth upon the already congested Banwell village.

14.1.19 NSC appointed Alun Griffiths (Contractors) Ltd, with Arup and TACP (the 'AGC Team') as their technical and environmental advisors, to develop a solution including optioneering, design and planning support of the proposed HIF Banwell Bypass and Highways Improvements Project Stage 1 (the "Scheme"). Stage 1 of the project includes: optioneering; preliminary design; Environmental Impact Assessment (EIA); planning permission; Statutory Processes. Stage 2 of the project is the detailed design and construction phase, following planning determination and land acquisition.

Environmental Context

14.1.20 The Scheme crosses the North Somerset Levels which are characterised by flat open landscape of arable land divided by hedgelined ditches and rhynes. These have been inhabited and exploited for thousands of years. Much of the area lies within a designated flood zone.

14.1.21 Banwell lies to the immediate north of the Mendip Hills Area of Outstanding Natural Beauty (AONB). The Southern Link lies within the boundary of the AONB and within a groundwater Source Protection Zone. Whilst the Mendip Hills AONB is not a designated International Dark Sky Reserve (IDSR), it is well known for its dark sky environment.

14.1.22 There are five Scheduled Monuments in the vicinity of the Scheme, the closest of which is a Romano-British villa. There are numerous Grade I, II* and II listed buildings within Banwell and its vicinity. The centre and east of Banwell is designated as a Conservation Area.

14.1.23 The North Somerset and Mendip Bats Special Area of Conservation (SAC), which includes ancient woodland, lies adjacent to the A368 and the eastern junction of the Scheme. The Banwell Ochre Caves and Banwell Caves Sites of Special Scientific Interest (SSSI) are designated for their geology and overlap with the North Somerset and Mendip Bats SAC, providing hibernation sites for Greater Horseshoe bats. The wider area provides habitat for a variety of protected and notable species including dormouse, grass snakes, otter, badger,

kingfisher and several species of bat.

14.1.24 The Scheme is dissected by the River Banwell which flows northwards along Riverside. It is classified as a main river and is the source of the River Banwell Estuary.

14.1.25 There is an extensive Public Right of Way (PRoW) network in and around Banwell which includes well-used bridleways. To the east of Banwell, north of the A368 (Towerhead Road) lies a 7.2 MW photovoltaic power station (Banwell Solar Farm).

Scheme objectives

14.1.26 NSC's overall objectives for the Scheme are to deliver, within cost, quality, and programme targets:

a) Improve the local road network to deal with existing congestion issues.

b) Improve and enhance Banwell's public spaces by reducing traffic severance and improving the public realm.

c) Provide the opportunity to increase active and sustainable travel between local villages and Weston-super-Mare.

d) Deliver infrastructure that enables housing development (subject to Local Plan).

e) Ensure the development respects the local area and minimises visual impact upon the surrounding countryside and Mendip Hills Area of Outstanding Natural Beauty (AONB).

f) Innovative and efficient in reducing and offsetting carbon from the design and construction of the infrastructure.

g) Ensure the development provides the opportunity to increase Biodiversity Net Gain by at least 10%.

h) Proactively engage with stakeholders in a way that is both clear and transparent.

14.2 Competent Expert Evidence

14.2.1 The assessment for this Climate Change Chapter has been undertaken by Damien Canning, a Chartered Environmentalist (CEnv) with a Civil Engineering degree MEng (Hons) and a Doctorate in Environmental Technology (EngD).

14.3 Legislative and Policy Framework

14.3.1 This section provides a review of legislative, policy and strategy positions around climate change and development of highways. They range in relevance from those that are directly applicable to the Scheme and those which provide wider policy context.

Legislation

Climate Change Act

14.3.2 The Climate Change Act 2008[5] committed the UK to its first statutory carbon reduction target to reduce carbon emissions by at least 80% from 1990 levels by 2050. The Climate Change Act 2008 (2050 Target Amendment) Order 2019[6] amended the Climate Change Act 2008 by introducing a target for at least a 100% reduction of GHG emissions (relative to 1990 levels) in the UK by 2050, following advice from the Committee on Climate Change[7]. The 100% reduction is often referred to as 'net zero' GHG emissions.

14.3.3 The Climate Change Act 2008 requires that five-yearly carbon budgets are set and not exceeded to ensure that regular progress is made towards the target. The first three carbon budgets were set in 2009, with the fourth, fifth and sixth following in 2011, 2016 and 2021 respectively, as outlined in Table 14-1.

14.3.4 The third, fourth and fifth carbon budgets, as set out in the Carbon Budgets Order 2009[8], the Carbon Budget Order 2011[9] and the Carbon Budget Order 2016[10], are based on an 80% reduction as legislated by the Climate Change Act 2008. The sixth carbon budget[11] is based on the target for 100% reduction in emissions by 2050. GHG emissions from the Scheme are reported against the latest legislated carbon budgets, in line with the requirements of *DMRB LA 114 Climate.*

Table 14-1 UK third, fourth and fifth carbon budgets (as legislated by the Climate Change Act 2008 and set out in the Carbon Budgets Order 2009, the Carbon Budget Order 2011, the Carbon Budget Order 2016 and the Carbon Budget Order 2021)

Carbon budget	Carbon budget level million tonnes of carbon dioxide equivalents ($MtCO_2e$)
Third carbon budget (2018 - 2022)	2,544 $MtCO_2e$
Fourth carbon budget (2023 - 2027)	1,950 $MtCO_2e$

Fifth carbon budget (2028 - 2032)	1,725 $MtCO_2e$
Sixth carbon budget (2033 - 2037)	965 $MtCO_2e$

14.3.5 The Climate Change Act also established a requirement for UK Government to undertake a Climate Change Risk (CCR) Assessment every five-year period and develop a programme for adaptation action in response to the risks identified. The UK Government's second and third UK CCR Assessment was published in 2017 and 2022 respectively[12,13]. The latest publication considers sixty-one UK-wide climate risks and opportunities cutting across multiple sectors of the economy and prioritises the following eight risk areas for action in the next two years:

a) risks to the viability and diversity of terrestrial and freshwater habitats and species from multiple hazards
b) risks to soil health from increased flooding and drought
c) risks to natural carbon stores and sequestration from multiple hazards
d) risks to crops, livestock and commercial trees from multiple climate hazards
e) risks to supply of food, goods and vital services due to climate-related collapse of supply chains and distribution networks
f) risks to people and the economy from climate-related failure of the power system
g) risks to human health, wellbeing and productivity from increased exposure to heat in homes and other buildings
h) multiple risks to the UK from climate change impacts overseas[14].

14.3.6 The CCR Assessment identifies significant risks to national infrastructure, including transport networks, from embankment and bridge failure, river, surface/ groundwater and coastal flooding, erosion, and increases in the frequency and severity of extreme weather such as high winds, high temperatures, lightening, storms and high waves. It highlights the need for infrastructure to be located, planned and designed and maintained to be resilient to climate change. It also recognises that more action is needed to encourage information sharing between infrastructure operators to improve overall risk management. Section 14.7 Baseline Conditions, Section 14.8 Predicted Environmental Effects and ES Volume 3 - Appendix

14.B - Climate change resilience assessment considers identification and implementation of any adaptation measures.

National policy and strategy

National Planning Policy Framework (NPPF)

14.3.7 The NPPF sets out the UK Government's planning policies for England and how these are expected to be applied and provides a high-level framework within which other development can come forward. The NPPF describes the role of planning policy in meeting the challenges posed by climate change and helping to shape places to secure radical reductions in GHG emissions as well as reducing vulnerability and providing resilience to the impacts of climate change. NPPF 8: the principle of achieving sustainable development includes the overarching environmental objective, which requires a move to a low carbon economy. NPPF 152 requires the planning system to support the transition to a low carbon future in a changing climate, taking full account of flood risk and coastal change. This includes a requirement to help shape places in ways that contribute to radical reductions in GHG emissions, minimise vulnerability and improve resilience; encourage the reuse of existing resources, including the conversion of existing buildings; and support renewable and low carbon energy and associated infrastructure. Section 14.8 Predicted Environmental Effects, Section 14.10 Residual Environmental Effects (Following Mitigation) and ES Volume 3 - Appendix 14.B - Climate change resilience assessment consider identification and implementation of any avoidance and mitigation measures.

National Policy Statement for National Networks (2014)[2]

14.3.8 The National Policy Statement for National Networks (NPSNN) establishes the need for nationally significant infrastructure rail and road projects for England. Although the Scheme is not a nationally significant infrastructure project, due to the nature of the development the assessment of the Scheme should have regard to key policies of the NPSNN in terms of the requirements to take into account climate change.

14.3.9 In relation to carbon[15] reduction for such Schemes, Paragraph 5.16 asserts that the impact of road development on aggregate levels of emissions is likely to be very small (Paragraph 3.8

asserts less than 0.1% of annual carbon budgets) and needs to be seen against significant projected reductions in carbon emissions because of requirements to meet the UK Government's legally binding carbon budgets.

14.3.10 Table 14-2 identifies specific NPSNN requirements relevant to the climate assessment and specifies where in this ES chapter information is provided to address each requirement.

Table 14-2: Relevant NPSNN policies for the climate assessment

Relevant NPSNN paragraph reference	Requirement of the NPSNN	Link to where information is provided in this ES chapter to address the requirement
4.3	Paragraph 4.3 specifies that when considering a proposed development and weighing its adverse impacts against its benefits, any cumulative adverse impacts must be taken into account.	Future projected climate conditions for the area have been considered within relevant topic assessments of likely significant effects. This means that environmental receptors that are vulnerable to impacts from both the Scheme and climate factors are fully considered in the context of cumulative impacts from a changing climate. This assessment is presented within each topic chapter. General cumulative impacts with other developments are covered within ES Volume 1 - Chapter 15 - Cumulative Effects.
4.42	Paragraph 4.42 specifies that applicants should consider the potential impacts of climate change using the latest UK Climate Projections and ensure the environmental statement identifies appropriate mitigation or adaptation measures to ensure the long-term resilience of a Scheme.	Section 14.7 Baseline Conditions Baseline Conditions demonstrates application of the latest UK Climate Projections (UKCP18). Section 14.8 Predicted Environmental Effects and ES Volume 3 - Appendix 14.B Climate change resilience assessment considers appropriate mitigation and adaption measures.
4.43	Paragraph 4.43 requires the applicant to demonstrate that there are no critical features of the design which may be seriously affected by more radical changes to the climate beyond that projected in the latest set of UK Climate Projections. Any potential critical features should be assessed taking account of the latest credible scientific evidence on, for example, sea level rise and on the basis that necessary action can be taken to ensure the operation of the infrastructure over its estimated lifetime	ES Volume 3 - Appendix 14.B Climate change resilience assessment considers any potentially critical features of the design which may be seriously affected by climate change as projected in the latest UK climate projections. The safety of the Scheme is assessed against the high emissions Representative Concentration

Relevant NPSNN paragraph reference	Requirement of the NPSNN	Link to where information is provided in this ES chapter to address the requirement
	through potential further mitigation or adaptation.	Pathways RCP8.5[16] global warming scenario. Additionally, a resilience assessment of the safety-critical features of the Scheme against H++ climate scenarios[17] has also been undertaken and is reported in Section 14.7 Baseline Conditions Predicted Environmental Effects.
4.44	Paragraph 4.44 specifies that 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 environmental statement, which should set out how and where such measures are proposed to be secured.	Section 14.8 Predicted Environmental Effects , and ES Volume 3 - Appendix 14.B - Climate change resilience assessment considers identification and implementation of any adaption measures.
5.16	Paragraph 5.16 sets out the framework of legally binding targets (the Climate Change Act 2008) to be delivered through a system of five year carbon budgets.	The carbon budgets are set out in Table 14.1 and will be used to consider adverse effects in Section 14.8 Predicted Environmental Effects .
5.17	Paragraph 5.17 requires that carbon impacts will be considered as part of the appraisal of Scheme options (in the business case), prior to the submission of an application for a DCO. Where the development is subject to EIA, any Environmental Statement will need to describe an assessment of any likely significant climate factors in accordance with the requirements in the EIA Directive. For road projects applicants should provide evidence of the carbon impact of the project and an assessment against the Government's carbon budgets.	Section 14.7 Baseline Conditions Predicted Environmental Effects considers the carbon impacts of the Scheme and reports an assessment of carbon emissions against the UK Government's legislated carbon budgets. Operational and maintenance emissions between 2033 and 2037 (the period for the sixth carbon budget) are provided in Table 14-1.
5.18	Paragraph 5.18 notes that there is a legal requirement for Government to meet the carbon budgets. Any increase in carbon emissions is not a reason to refuse consent, unless the increase in emissions resulting from a Scheme is so significant that it would have a material impact on the ability of the Government to meet its carbon reduction targets.	The carbon budgets will be used to consider adverse effects in this context within Section 14.8 Predicted Environmental Effects .

Third Climate Change Risk Assessment

14.3.11 The Climate Change Act 2008 includes a requirement for UK Government to undertake a CCR Assessment every five year period and to develop a programme for adaptation action in response to identified risks.

14.3.12 The UK CCR Assessment 2022 was published in January 2022. The third CCR Assessment sets out risk areas, including for transport, which should be considered as part of an assessment of the resilience of the Scheme to the effects of climate change.

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

14.3.13 The Climate Change: second national adaptation programme (2018 – 2023) (NAP)[18] was produced by the Department for Environment, Food and Rural Affairs (Defra) and launched in 2018. The plan sets out the UK Government's response to the second CCR Assessment. Section 3.4.4 of the NAP highlights the economic and strategic value of the Strategic Road Network (SRN) in the UK and notes the implications of risks to severance and safety posed by climate change.

Clean Growth Strategy

14.3.14 In 2017, the UK Government published the Clean Growth Strategy, which is a plan for meeting the legislated carbon budgets[19] as set out in the Carbon Budget Order 2016. The strategy includes a key policy to accelerate the shift to low carbon transport, which primarily focuses on a transition to low emission vehicles, investing in new technologies such as autonomous vehicles and low carbon fuels, promoting cycling and walking and shifting freight from road to rail.

Road to Zero Strategy

14.3.15 In October 2018 the UK Government launched the Road to Zero Strategy[20], a policy paper which includes a forward-looking route map to articulate the steps required to decarbonise and electrify road transport in line with their Industrial Strategy[21]. The document outlines key policies to aid in the drive to decarbonise road transport. Its main focuses are on supporting modal shift, reducing emissions from vehicles and investing in electric vehicle infrastructure.

Transport Decarbonisation Plan

14.3.16 The Transport Decarbonisation Plan ("TDP") published on 14 July 2021 sets out the government's commitment and action plan for addressing the topic of decarbonising the UK's transport system[22].

14.3.17 The TDP follows on from the government's previous document, "Setting the Challenge" which set out the challenges the transport network faced which needed to be considered within the TDP.

14.3.18 Various commitments were made within the TDP, including but not limited to:

a) a £2 billion investment over five years into cycling and walking to bolster the uptake of both;

b) delivering the National Bus Strategy including the uptake of zero emissions buses and phase out dates for sale of new non-zero emission buses and coaches;

c) various delivery points on zero emissions cars, vans motorcycles and scooters, including:

d) financial and non-financial incentives to support demand for zero emission vehicles; and

e) ensuring charging infrastructure network is in place to meet user demand.

Local policy

West of England Climate Emergency Action Plan[23]

14.3.19 The Scheme is within the West of England, north of the Mendip Hills AONB. This strategy sets out how the region can take meaningful steps towards a low carbon economy.

14.3.20 Challenge area 1: Low carbon transport system describes targets and work to decarbonise the transport system by reducing car trips, increasing electric vehicle update and increasing cycling and walking and the use of public transport.

14.3.21 Further challenge areas also with the action plan set out actions to protect and enhance the environment through proactive green infrastructure, encouraging consultants to specify lower carbon materials and landscaping proposals that maximise carbon capture.

North Somerset Core Strategy (2017)[24]

14.3.22 The Core Strategy sets out the broad long-term vision, objectives and strategic planning policies for North Somerset up to 2026. Policy CS1 Living within Environmental Limits: sets out a broad policy framework drawing together various themes where development can address climate change issues. Primarily the Core Strategy seeks to address climate change by:

a) Reducing unsustainable carbon emissions,
b) Making all buildings more sustainable,
c) Encouraging sustainable transport patterns, and,
d) Planning for a sustainable distribution of land uses.

14.3.23 Many of the specific themes are dealt with elsewhere in the Core Strategy including green infrastructure (Policy CS9) and sustainable construction and design (Policy CS2) but are included in this more general policy as a means of co-ordinating action to address climate change.

14.3.24 CS2: Delivering sustainable design and construction. This policy sets out a broad aspiration for all new buildings including conversions to be sustainable and to reduce the demand for and use of non-renewable forms of energy. It implements national standards on home sustainability and sets out a trajectory to meeting zero-carbon homes by 2016, gradually increasing standards for small scale residential development, and setting high standards where there are most opportunities to deliver. It also uses the industry standard BREEAM assessment methods to determine the sustainability of non-residential buildings.

14.3.25 CS9: Green infrastructure. Policy CS9 reflects the importance of green infrastructure and its value for health, biodiversity, landscape and climate change. The policy then sets out the green infrastructure priorities for North Somerset although these are not an exhaustive list and may vary over the plan period. Clear priorities will be established through an overarching Green Infrastructure Strategy which will incorporate local open space standards, map green infrastructure and set out principles guiding development and management of green infrastructure.

14.3.26 Development proposals should demonstrate how they contribute to addressing climate change by putting in place the necessary measures to make their development as sustainable as possible.

14.3.27 CS3 Environmental impacts and flood risk management states that new development will need to be mindful of the increased risks of flooding as a result of climate change.

North Somerset Climate Emergency Strategy (2019)[25]

14.3.28 The North Somerset Climate Emergency Strategy is a live document which outlines seven key principles for how North Somerset Council will tackle the causes and consequences of climate change, with the aim to be carbon neutral by 2030:

a) Become a net zero carbon council
b) An energy efficient built environment
c) Renewable energy generation
d) Repair, reuse, reduce and recycle
e) Replenish their carbon stores
f) Reduce emissions from transport
g) Adapting to climate change

14.3.29 For each key principle within this strategy, actions have been identified in an Action Plan that will help to either avoid carbon production (low carbon homes), reduce the amount (renewable electricity), mitigate against production (public transport) or help to store it away (tree planting).

North Somerset Council Climate Emergency - Report on Baseline Emissions[26]

14.3.30 This report contains a comprehensive assessment of greenhouse gas (GHG) emissions from activities within the North Somerset area – a greenhouse gas inventory. As a summary of this inventory, by far the largest sector for North Somerset is Road Transport, with approximately 42% of their emissions – half of which are due to vehicles on the M5. Road transport emissions have also remained relatively static since Local Authority records began in 2005.

14.3.31 The report uses the Tyndall Centre for Climate Change tool which suggests carbon budgets for each local authority across the UK using advisory targets.

14.3.32 The budgets have been allocated using a “grandfathering” sub-national approach. Which means that emissions are allocated to North Somerset, based on its previous share of UK emissions.

The outline recommendations are:

a) Stay within a carbon budget of 6.9 $MtCO_2$ between 2020 to 2100;

b) Initiate an immediate carbon mitigation programme to deliver carbon emissions reductions of -13.9% per year; and

c) Reach zero or near zero carbon no later than 2040.

Joint Local Transport Plan 4 (2020-2036)

14.3.33 The Joint Local Transport Plan 4 sets out how the West of England Combined Authority (WECA), working with Bath & North East Somerset, Bristol, North Somerset and South Gloucestershire councils aim to achieve a well-connected sustainable transport network that works for residents, businesses and visitors across the region; to provide a network that offers greater, realistic travel choices and makes walking, cycling and public transport the natural way to travel.

14.3.34 The plan aims to ensure that transport is carbon neutral by 2030. To do this there has to be a substantial shift towards cleaner and greener and more sustainable forms of transport. There will be a need to maximise every opportunity and work in partnership with sustainable transport organisations, bus and rail operators, to encourage and help people switch from cars to cycling, walking and public transport.

14.3.35 Transport Schemes should be designed from the outset with strong green infrastructure principles including establishment and maintenance considerations and costs have the potential to deliver significant benefits including carbon capture, air quality and wellbeing through improving access to green spaces via shared use path and building resilience to against climate change.

West of England Climate and Ecological Strategy and Action Plan 2022[27]

14.3.36 The West of England Climate and Ecological Strategy and Action Plan was published on the 8th April 2022. The plan sets out the West of England Combined Authority's ambition for the year 2030, in that:

a) the West of England is net zero carbon, and

b) wildlife and the natural environment are in recovery, with their decline halted.

14.3.37 This plan sets out a range of actions that the AGC team will work with our partners on to deliver to help meet this challenge however the one relevant to this chapter is key action 4:

> "Reduce carbon emissions from our transport system and car dependency through better bus service, delivering walking and cycling infrastructure, travel planning and investing £5m to improve the EV charge point infrastructure"

14.3.38 Image 14-1 is taken from the West of England Climate and Ecological Strategy and Action Plan and shows the level of GHG emission reduction required to reach net zero by 2030 and compares this to the current projections of business as usual and the central projection scenario. This image shows that even with mitigation, the expected carbon gap to reach net zero by 2030 is 1.38 Mt CO_2.

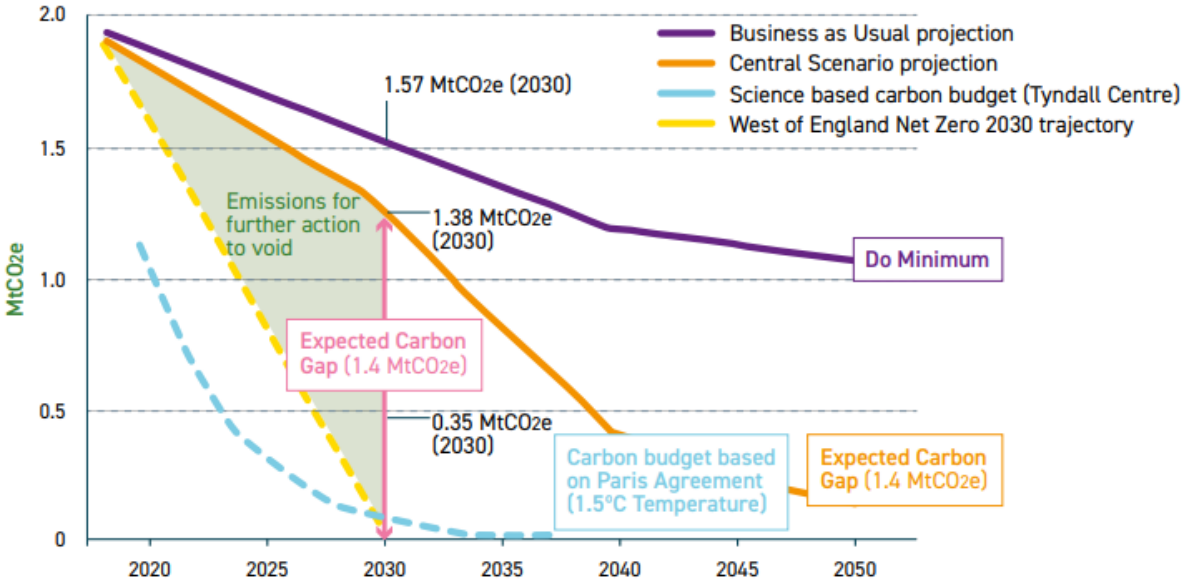

Image 14-1 Emissions cuts which would be required to reach net zero by 2030 from transport (yellow line) compared with baseline following national trends (orange line) (WSP)

Standards and guidance

Impact of the Scheme on climate (GHG emissions assessment)

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

a) DMRB LA 114 Climate, which provides the requirements for assessment and reporting the effect on climate of

greenhouse gas from construction, operation and maintenance of highways projects[28].

b) DMRB LA 105 Air Quality, which provides the calculation method for regional emissions from vehicles that use the road network[29].

c) DMRB GG 103 Introduction and general requirements for sustainable development and design[30].

d) The Publicly Available Specification 2080 (PAS 2080) on carbon management in infrastructure[31], a global standard for managing infrastructure carbon.

e) Royal Institution of Chartered Surveyors (RICS) professional standards and guidance document on Whole life carbon assessment for the built environment (1st edition, 2017)[32].

f) Department for Transport, Transport Analysis Guidance (TAG) Unit A3 Environmental Impact Appraisal, Chapter 4 Greenhouse Gases[33], which provides the methodology for consistent and transparent reporting of GHG emissions, including those resulting from the production of materials used (referred to as embedded or embodied carbon), as well as those resulting from changes to the use of transport fuels.

Vulnerability of the Scheme to climate change (climate change resilience assessment)

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

a) DMRB LA 114 Climate, which provides a methodology for assessment and reporting the effects of climate for highway projects (climate change resilience and adaptation) [34]; and

b) The Association of Directors of Environment, Economy, Planning & Transport (ADEPT) Preparing for a changing climate: Good Practice Guidance for Local Governance[35] on climate change resilience and adaptation. This guide focuses on preparing for the impacts of climate change, a process known as climate change adaptation. The guide is designed to assist local government with its work on climate change adaptation.

14.4 Assessment Methodology

14.4.1 To align with the requirements of the Town and Country Planning (Environmental Impact Assessment) Regulations 2017 (the EIA Regulations) and the NPPF, the climate assessment includes the following elements:

a) Impact of the Scheme on climate (GHG emissions assessment).

b) Vulnerability of the Scheme to climate change (CCR assessment).

14.4.2 The assessment of cumulative effects of this chapter topic both in-combination with other technical assessments on specific receptors and with other relevant developments have been assessed and are reported in the Cumulative Effects chapter, ES Volume 1 Chapter 15.

Impact of the Scheme on climate (GHG emissions assessment)

14.4.3 The assessment of the magnitude of carbon emissions has been undertaken in accordance with DMRB *LA 114 Climate* and the principal steps identified in PAS 2080[36]. The National Highways Carbon emissions calculation tool[37] has been used to calculate product, construction process and maintenance/ refurbishment emissions, except where specified. The National Highways Carbon emissions calculation tool uses carbon benchmarks from the Institute of Civil Engineers for materials such as steel and concrete. It allows the calculation of carbon emissions from every material used on the Scheme.

14.4.4 A 60-year appraisal period is used in line with DMRB *LA 114 Climate,* ensuring consistency which allows stakeholders to compare GHG emissions across Schemes.

14.4.5 Consideration has also been given to Transport Analysis Guidance (TAG) *Unit A3 Environmental Impact Appraisal*, Chapter 4 Greenhouse Gases[38], which provides the methodology for consistent and transparent reporting of GHG emissions, including those resulting from the production of materials used (referred to as embedded or embodied carbon), as well as those resulting from changes to the use of transport fuels.

14.4.6 The goal of the emissions quantification exercise is to calculate the emissions anticipated to be generated or avoided by the Scheme. The purpose of this is to:

a) Determine the magnitude of the Scheme's emissions for the relevant scenarios - 'Do-Something' and 'Do-Minimum' (See scenario descriptions in Table 14-3).

b) Enable comparison of the 'Do-Something' scenario against the 'Do-Minimum' scenario and the UK carbon reduction targets.

c) Enable identification of emissions hot spots within the 'Do-Something' scenario to inform identification and prioritisation of mitigation measures.

Table 14-3 GHG emissions assessment scenarios

Scenario	Description
Do-minimum	The future baseline with minimal interventions and without the Scheme. The do-minimum scenario accounts for the same level of growth and proposed developments that already have planning permission. The additional housing growth is the same as the Do-Something scenarios however this growth is spread across Somerset.
Do-something without HIF	The Scheme is implemented taking into account embedded GHG mitigation measures. This scenario accounts for housing growth (the same as the Do-minimum) and proposed developments that already have planning permission. The housing growth is spread across Somerset.
Do-something with HIF	The Scheme is implemented with the Housing Investment Fund (HIF) and housing development concentrated adjacent to the Scheme, taking into account embedded GHG mitigation measures. This has only been considered as part of the cumulative impacts assessment.
Do-nothing	The 'Do Nothing' scenario measures the carbon baseline without the Scheme or a connecting road to the proposed housing development. This scenario was only used at the optioneering stage.

14.4.7 Assessment has included the life cycle stages of 'product', 'construction' and 'use' as per PAS 2080, BS EN 15804 and RICS guidance. In line with DMRB LA 114, 'end of life' impacts have not been considered, as it is considered highly unlikely that the Scheme would be decommissioned as the road is likely to have become an integral part of the infrastructure in the area. Decommissioning would not be either feasible or desirable and is therefore not considered further within this ES.

14.4.8 The assessment estimates four sources of carbon emissions during the construction and operation (use) life cycle stages, including:

a) **Construction works and supply chain carbon emissions.** Carbon is assessed, based on information provided by design

teams based on relevant drawings of the design where available. Section 14.5 outlines how assumptions were made. The National Highways Carbon emissions calculation tool[37] is used along with its carbon factors for the calculation, supplemented with other factors where necessary as discussed in Section 14.5.

b) **Operational maintenance-related emissions.** An estimation of carbon emissions associated with maintenance of the road over 60 years of operation (calculated using the same method as the construction works and supply chain carbon emissions).

c) **Operational traffic carbon emissions (user carbon) from vehicle tailpipes**. These are calculated for both the "Do-Minimum" and "Do-Something" scenarios from the traffic model over a 60 year period of operation, with the study area being the same as that of the traffic model. The model years for these scenarios are 2024, opening year and 2039, future year.

d) **Emissions associated with ongoing land use change/ sequestration.** These are calculated over the 60-year operational period for 'habitats lost' and 'habitats gained' as a result of the Scheme.

14.4.9 In line with Paragraph 3.12 of DMRB *LA 114 Climate*, a proportionate approach is taken to calculating and reporting emissions from changes in land use.

14.4.10 Opportunities to mitigate the effects on climate through minimising activities that generate GHG emissions, reusing and adopting low carbon materials are also considered and are outlined in Section 14.8 Predicted Environmental Effects .

14.4.11 Emissions from these sources are compared to a baseline 'Do-Minimum' scenario to quantify the impact of the Scheme, these are summarised in Table 14-3.

14.4.12 GHG emissions in each scenario have been compared in order to assess the contribution of the Scheme to climate change. Values are reported in metric tonnes of carbon dioxide equivalents (tCO_2e). This measure considers the six Kyoto Protocol gases: Carbon dioxide (CO_2); Methane (CH_4); Nitrous oxide (N_2O); Sulphur hexafluoride (SF_6); Hydrofluorocarbons (HFCs); and Perfluorocarbons (PFCs), converted into tCO_2e. This calculation normalizes the global warming potential of the main GHGs into one measure, based on the global warming

potential of CO_2.

14.4.13 In accordance with DMRB *LA 114 Climate*, the third lifecycle stage for a Scheme's GHG emissions (the first and second being construction and operation) comprises opportunities to reduce the production/ use of GHG emissions. The third life cycle stage comprises opportunities to minimise production/ use of GHG emissions i.e. the potential for reduction of GHG emissions through reuse and recycling during the construction of the Scheme. The GHG assessment results and measures to reduce GHG emissions as far as practicable are outlined in Section 14.8.

Vulnerability of the Scheme to climate change (CCR assessment)

14.4.14 The CCR assessment reports a qualitative assessment of the impacts and risks of climate change on the Scheme based on professional expertise and judgement.

14.4.15 In the case of flood risk, detailed planning requirements and design guidance relating to climate change exist. A Flood Risk Assessment (FRA) has been undertaken and reported in ES Volume 3 - Appendix 13.B - Flood Risk Assessment of ES Volume 1 - Chapter 13 - Road drainage and the water environment. This considers current Environment Agency (EA) climate change allowances for increases in peak river flow and rainfall intensity.

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

14.4.17 The following climate change hazards have been considered in the CCR assessment: high temperatures; high precipitation; and low precipitation. These hazards are based on the climate modelling shown later in Table 14-10 and Table 14-11.

14.4.18 H++ scenarios are also used to assess future Scheme vulnerability to climate change, in line with the methodology set out in DMRB *LA 114 Climate* Section 3.30. H++ climate scenarios are required to test the sensitivity of vulnerable safety critical features, to ensure that such features would not be affected by more radical changes to the climate beyond that projected in UKCP18. These are typically high impact, low

likelihood events.

14.4.19 As part of the climate change resilience assessment, the potential likelihood and consequence of climate change hazards occurring during construction and operation of the infrastructure and assets associated with the Scheme are scored using a qualitative five-point scale, based on DMRB *LA 114 Climate*. These are set out in Table 14-4 and

14.4.20 Table 14-5.

Table 14-4 Qualitative five-point scale of likelihood

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

Table 14-5 Qualitative five-point scale of consequences

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

14.4.21 As part of the risk assessment the need for any essential resilience measures to protect against the impacts of climate change have been identified for any effects assessed as significant, as per the significance matrix in Table 14-8.

In-combination climate change impacts (ICCI) assessment

14.4.22 To take account of the potential impacts of future climate conditions on the environment combined with the impacts of the proposed project, the future projected climate conditions for the area has been considered within relevant topic assessments of likely significant effects. This means that environmental receptors that are vulnerable to impacts from both the project and climate factors are fully considered in the context of the changing climate. This assessment is presented within each topic chapter.

14.4.23 Future climate conditions have been reviewed as part of this assessment, including changes to long term seasonal averages and extreme weather events as projected by the UK Climate Projections 2018 and presented within Section 14.7 Baseline Conditions Baseline conditions of this chapter.

Assessment of significance

Impact of the Scheme on climate (GHG emissions assessment)

14.4.1 As set out in PAS2080, the system boundary is the set of criteria specifying the life cycle, spatial and temporal extent of a GHG quantification or management system. The system boundary for this assessment covers construction activities and the use of construction materials for the Scheme, as well as the operational carbon associated with these. Table 14-6 summarises the individual life cycle modules associated with infrastructure GHG emission quantification.

Table 14-6: Summary of Individual PAS 2080 Life Cycle Modules

PAS 2080 Life Cycle Modules	Activities Incorporated
Pre-construction stage (A0)	Preliminary studies and consultations prior to construction. Negligible effect on the total footprint.
Product stage (A1-A3)	Carbon associated with the construction materials. Detailed quantities will be derived from the available information or Preliminary Design
Construction stage - transport to site (A4)	The transportation of all materials required for the permanent assets and construction equipment to site from the point of production.
Construction/ Installation processes (A5)	Construction site works activities including installation of materials and products into the infrastructure asset. Waste management activities associated with waste arising from the construction site.
Use stage - Installed products and materials (B1)	Change in emission rates due to changes in land use.

PAS 2080 Life Cycle Modules	Activities Incorporated
Use stage - Maintenance (B2)	The production, transportation (to and from the site) and end of life processing of all materials required for preventative maintenance.
Use stage – Repair (B3)	The repair of any components during the use stage of the development.
Use stage - Replacement (B4)	The production, transportation (to and from the site) and end of life processing of all materials required to replace any assets or any components within assets that have a design life of less than 120 years.
Use stage - Refurbishment (B5)	The production, transportation (to and from the site) and end of life processing of all materials required for any anticipated refurbishment.
Use stage - operational energy (B6)	The electricity used for road lighting, based on the expected electricity requirements.
Use stage - operational water (B7)	The water required by the asset to enable it to operate and deliver its service, minus any water sourced on site, e.g. rainwater harvesting.
Use stage - other operational processes (B8)	GHG emissions associated with other operational processes.
Use stage - users utilisation (B9)	GHG emissions associated with Users' utilisation of infrastructure and the service it provides during operation. In transport infrastructure this relates to vehicles using the road.
End of life stage (C1-C4)	GHG emissions associated with the end of life stage.
Beyond system boundary (D)	Benefits and loads of additional infrastructure functions beyond the system boundary. GHG emissions associated with the recovery including reuse and recycling.

14.4.2 Due to limitations of current data information, the replacement and refurbishment emissions (B1-B8), End of Life (C1-C4) and Beyond System Boundary (D) will be excluded for the initial baseline. Therefore, the embodied carbon assessment (A1-A3) study period is for the duration of design and construction activities. Embodied carbon calculations also include the embedded mitigation measures within the Scheme design. These design measures are outlined in ES Volume 1 - Chapter 2 - Scheme Description.

14.4.3 Given the project stage and available information, Table 14-7 represents the most comprehensive assessment possible at present.

Table 14-7: Overview of Individual Life Cycle Modules included in this assessment

Product				Construction		Use-stage									End of life	
A0	A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	B8	B9	C1-C4	D
N	Y	Y	Y	N	N	N	Y	Y	Y	Y	N	N	N	Y	N	N

14.4.4 An assessment of significance has been undertaken in accordance with DMRB *LA 114 Climate*. The emissions assessment is based on the National Highways carbon reporting tool and assessment of road user emissions in line with DMRB *LA 105 Air quality*. For the methodology related to quantification of road user emissions (module B9), please refer to ES Volume 1 - Chapter 5 - Air Quality of this ES. The traffic forecasting is in line with the current guidance. Road user emissions are tailpipe emissions from the use of vehicles on the road.

14.4.5 For the calculation of GHG emissions associated with ongoing land use change (module A5), the areas of habitat losses and gains were calculated based on baseline survey information and Scheme plans. This carbon is related to the carbon in habitat sinks, ie. vegetation and soils.

14.4.6 An estimate of the likely magnitude of GHG emissions associated with the Scheme has been assessed against the legislated national UK carbon budgets. The UK Government has currently passed into law carbon budgets up to 2037, as shown in Table 14-1.

14.4.7 In accordance with Para 5.18 NPSNN, a significant effect occurs where the increase in carbon emissions resulting from the Scheme would have a *"material impact on the ability of Government to meet its carbon reduction targets"*.

Vulnerability of the Scheme to climate change (CCR assessment)

14.4.8 The evaluation of significance is a product of the likelihood and consequence of each impact as set out in Table 14-8. Significance conclusions for each impact incorporate confirmed design and mitigation measures.

Table 14-8: Significance matrix

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

Note: NS = Not significant; S = Significant

14.5 Assessment Assumptions and Limitations

GHG emissions assessment assumptions and limitations

14.5.1 The GHG emissions assessment has been undertaken on the basis of the information available at the time of assessment (2021/ 2022). Where assumptions have been made, they have been selected to present the worst-case scenario for the particular item/ factor.

14.5.2 Assumptions/ judgements in each case have been made from either:

a) Emerging design detail.

b) Engineering specialist knowledge.

c) Environmental specialist knowledge, for example Ecology or Landscape Specialists.

d) Climate change/ carbon specialist knowledge.

e) Manufacturer specifications.

f) Proxy engineering data from previous comparable projects.

14.5.3 The materials and quantities listed in ES Volume 3 - Appendix 14-A - Greenhouse gas assessment assumptions, methodology and emissions factors are included in the assessment. This is the list of materials provided by the design team, including any embedded mitigation. A full schedule of assumptions associated with material volumes and quantities is also contained within ES Volume 3 - Appendix 14-A - Greenhouse gas assessment assumptions, methodology and emissions factors.

14.5.4 Table 14-9 provides information on the PAS 2080 life cycle modules that have formed part of the assessment along with

justification where modules have been excluded.

Table 14-9: Justification for inclusion or exclusion of PAS 2080 life cycle stages and individual modules within GHG emissions quantification

Life cycle stage	Boundary stage	Module	Description	Included in scope?[39]	Justification
Before use Stage	Preconstruction	A0	Preliminary studies, consultations	No	Carbon emissions from preliminary studies and works are largely office-based and are assumed to be insignificant.
	Product	A1	Raw material supply	Yes	A1-A3 emissions (i.e. from raw material extraction, product processing, and final product manufacture, its energy use, and waste management within these processes, transportation within the supply chain, and manufacture) is calculated using emissions factors from the National Highways carbon emissions calculation tool, based on information provided by design teams based on relevant drawings of the design where available.
		A2	Transport	Yes	
		A3	Manufacture	Yes	
	Construction process	A4	Transport to works site	Yes	A4 emissions have been calculated using the RICS guidance[32], applying transport conversion factors from Defra[40]. They are calculated using emissions factors from the National Highways carbon emissions calculation tool, based on information provided by design teams based on relevant drawings of the design where available.
		A5	Construction/ installation processes	Yes	A5 emissions have been calculated using emissions factors from the National Highways carbon emissions calculation tool, based on information provided by the contractor. Carbon through habitat loss has been calculated with data from the Biodiversity Net Gain calculation from ES Volume 1 - Chapter 8 - Biodiversity has been used to estimate the carbon stocks within the habitats and soils lost. Carbon storage estimates were calculated using factors for the relevant habitat type from a Natural England Report[41] multiplied by the area of lost habitat.
Use Stage	Installed products and materials	B1	Use	No	Carbon emitted directly from the fabric of products and materials once they have been installed as part of the Scheme, when it is in normal use, are assumed to be insignificant.
		B2	Maintenance	Yes	B2-B5 emissions associated with maintenance and refurbishment assume that the road surface would be replaced once every ten years for the duration of the assumed 60-year design life (calculated using the same method as the construction works and supply chain carbon emissions).
		B3	Repair	Yes	
		B4	Replacement	Yes	
		B5	Refurbishment	Yes	
		B6	Operational energy use	No	There are likely minimal direct emissions associated with operating the Scheme since the Scheme lighting is only proposed at the proposed junctions, with the majority of the Scheme being left unlit. Power

Life cycle stage	Boundary stage	Module	Description	Included in scope?[39]	Justification
					consumption has been assumed as negligible in the context of the Scheme and therefore the associated carbon impact does not form part of the GHG emissions assessment.
		B7	Operational water use	No	Carbon emissions resulting from the consumption of water required by the Scheme to enable it to operate and deliver its service are assumed to be insignificant.
		B8	Other operational processes	No	Other process carbon emissions arising from the Scheme to enable it to operate and deliver its service, such as management of operational waste, are assumed to be insignificant.
		B9	Users utilisation of infrastructure	Yes	The DEFRA Emissions Factor Toolkit (EFT)[42] includes assumptions about the predicted mix of vehicles for operation. It has fleet mix assumptions up to 2050. As this is the latest year the EFT has assumptions for, these assumptions have been used to map the emissions from 2050 to 2083 as seen in ES Volume 3 - Appendix 14.A – Greenhouse Gas Assessment. The latest version of the EFT considers carbon from energy generation. As EV uptake increases, further transport decarbonisation will be in line with energy decarbonisation.
End of life stage		C1	Deconstruction	No	End of life (C1-C4) impacts have not been considered as it is assumed the Scheme will not be decommissioned.
		C2	Transport		
		C3	Waste processing for recovery		
		C4	Disposal		
Supplementary Information beyond the infrastructure life cycle		D	Boundary of benefits and loads beyond the infrastructure life cycle	No	Carbon emissions arising from the Scheme beyond the Affected Road Network and mitigation measures are deemed insignificant.

GHG assessment assumptions

14.5.5 For transport-related emissions (module A4), data on default transport scenarios for UK projects contained within the RICS professional standards and guidance document on whole life carbon assessment for the built environment (2017), were used. For locally manufactured materials and products a transport distance of 31 miles (50 kilometres) by road has been applied. For nationally manufactured materials and products a transport distance of 186 miles (300 kilometres) by road has been applied. Emission factors from the National Highways carbon emissions calculation tool have been used exclusively, with the exception of the product emissions (module A1-A3) relating to bridges, which are derived from peer reviewed research[43]. This is due to the level of design maturity at the time of assessment, resulting in detailed material quantity data not being available.

14.5.6 Module A5 also includes consideration of emissions arising from the installation of materials and products into the infrastructure asset. At the time of assessment there was no accurate construction information available to inform the assessment of emissions from the installation of materials and products. Therefore, this assessment has been undertaken based on an average per kilometre emissions factor for emissions resulting from labour and plant, derived from a sample of comparable highway Schemes (see) and applying this to the length of the Scheme.

14.5.7 To quantify operational emissions (module B2-B5) associated with maintenance of the road surface (in both the 'Do-Minimum' (baseline) and 'Do-Something' (with Scheme) scenarios) it is estimated the road surface would be replaced once every ten years for the duration of the design life. Module B2-B5 emissions are calculated using the same method as the construction works (module A5) and supply chain (module A1-A3) carbon emissions: using emissions factors from the National Highways carbon emissions calculation tool, based on experience provided by design teams for the Scheme.

14.5.8 For the calculation of GHG emissions associated with ongoing land use change/ sequestration (Module B5), the areas of habitat losses and gains were calculated based on baseline survey information and Scheme plans. When calculating emissions

gained from habitats created it has been assumed that these habitats will mature, and this is the carbon stock assumed for the Scheme. This gives an accurate depiction of carbon lost through construction against the carbon stock gained from habitat creation and maturation.

14.5.9 For the calculation of GHG emissions associated user carbon (Module B9), the assessment has used the DMRB Screening Tool for consistency with the air quality assessment. The traffic model data is converted into air quality emissions which includes GHGs using the DEFRA Emissions Factor Toolkit (EFT) V11.0. EFT V11.0 includes data relating to the UK vehicle fleet and associated emissions for the period between 2031 and 2050 inclusive. EFT V11.0 also includes a greater uptake rate of electric vehicles, aligned to electric vehicle penetration rates.

14.5.10 The EFT includes assumptions about the predicted mix of vehicles for operation. It has fleet mix assumptions up to 2050. To map the emissions from 2050 to 2083, the 2050 emissions are used as the last available set of factors to represent CO_2e emissions into the future. The traffic model has traffic data for years 2024 and 2039. Post 2039 the traffic model assumes traffic is not increasing. This clearly overestimates the CO_2e emissions in future years because it does not take into account the higher uptake rates of electric vehicles post 2050. This demonstrates the limitations of the traffic model as growth and electric vehicle uptake stagnate in 2039 and 2050 respectively, which may not be a representation of the real-world scenario, meaning the emissions output may be an over estimation.

14.5.11 The methodology used to calculate the UK carbon budgets is different to that used for the calculation of lifecycle emissions from a road Scheme and therefore caution should be taken when making a direct comparison. However, for the purposes of identifying to what extent the Scheme may impact the ability of the UK to meet its carbon budgets it is necessary to make this comparison to put the Scheme into context.

GHG emissions assessment study area

Carbon emissions during construction

14.5.12 For the assessment of carbon emissions associated with construction of the Scheme, the study area takes account of

emissions associated with the extraction, processing and transport of materials from outside of the redline boundary as well as site-based emissions that result from the construction activities within the redline boundary shown in Planning Document - Environmental MasterPlans (EMP) Drawings.

Carbon emissions during operation

14.5.13 For the assessment of carbon emissions associated with maintenance and refurbishment of the Scheme, the study area is defined by the redline boundary and takes account of emissions associated with the extraction, processing and transport of materials as well as site-based emissions that result from the maintenance and refurbishment activities within the redline boundary.

Road user carbon emissions (during operation)

14.5.14 The study area for operational road user carbon is consistent with the Affected Road Network (ARN), as defined by the Scheme's traffic model. The ARN is described in Section 5.8 Operational Effects of ES Volume 1 - Chapter 5 - Air Quality and ES Volume 2 - Figure 5.1 - Operational affected road network.

14.5.15 This includes emissions from vehicles using the Scheme and those in the wider road network which have been positively or negatively influenced by the Scheme. The assessment of road user carbon includes the total emissions across the ARN model, as described in ES Volume 1 - Chapter 5 - Air Quality and shown in ES Volume 2 - Figure 5.12 Affected Road Network. The ARN and the operational traffic study area covers the following areas:

a) The Scheme alignment
b) A371 between Weston-super-Mare and Banwell
c) A371 between Banwell and Winscombe
d) A368 between Banwell and Churchill
e) Wolvershill Road between Banwell and the A370

14.5.16 It should be noted that the traffic model at the optioneering stage used a wider catchment and used different model years, resulting in larger numbers that are not comparable to those modelled in this ES. The results of the user carbon at optioneering were used to compare options to take forward for preliminary design and are shown in Table 14-14. The results of the assessment of the

preliminary design are shown in Table 14-18.

Carbon emissions associated with ongoing land use change/ sequestration

14.5.17 For the calculation of GHG emissions associated with ongoing land use change/ sequestration (module A5/ B5), the study area is defined by the total areas of loss and total areas of gain of habitats within the redline boundary, shown in Planning Document - Environmental MasterPlans (EMP) Drawings. The estimated emissions were calculated based on Natural England carbon stock benchmarks.

Climate change resilience assessment assumptions and limitations

14.5.18 Data on the climate baseline and future projections are based on freely available information from third parties, including the historical meteorological variables recorded by the Meteorological Office (Met Office) and UKCP18 developed by the Met Office. In addition, the assessment has been informed by a selected range of existing climate change research and literature, available at the time of undertaking this assessment.

14.5.19 Climate projections are not predictions or forecasts but simulations of potential scenarios of future climate, under a range of hypothetical emissions scenarios and assumptions. Therefore, the results from running the climate models cannot be treated as exact or factual, but projection options. They represent consistent representations of how the climate may evolve in response to a range of potential forcing scenarios, and their reliability varies between climate variables. Scenarios exclude outlying "surprise" or "disaster" scenarios in the literature, and any scenario includes, out of necessity, subjective elements and is open to various interpretations. In general, global projections are more certain than regional projections, and temperature projections are more certain than those for precipitation. Wind projections have the highest amount of uncertainty associated with them. Furthermore, the degree of uncertainty associated with all climate change projections increases for projections further into the future.

14.5.20 The CCR assessment has been informed by the following assumptions:

a) The assessment has assumed that mitigation measures relevant to different assets would be implemented effectively.

b) The assessment is affected by assumptions associated with climate modelling and climate change projections, incorporated in UKCP18.

14.5.21 The CCR assessment has the following limitations:

a) The assessment is largely qualitative, with the exception of assessments relevant to drainage assets and flood risk, which have been informed by the EA climate change allowances for increases in peak river flow and rainfall intensity.

b) There is limited methodological guidance on CCR assessment in EIA from Government, and other institutions.

c) There is inherent uncertainty in climate change projections. This study has been quantified using UKCP18, the latest set of probabilistic climate projections for the UK.

d) There is often uncertainty in the relationship between changes in climate hazards and the respective response in terms of asset performance. This uncertainty has been assessed qualitatively.

CCR assessment study area

14.5.22 The study area for the CCR assessment is based on the construction footprint and includes temporary and completed works within the redline boundary.

14.5.23 The study area includes all potential climate hazards for infrastructure and assets associated with the Scheme. The assessment of climate effects on the Scheme is assessed over the 60-year operational life cycle in line with the methodology set out in DMRB *LA 114 Climate*.

14.6 Consultation

14.6.1 There are no Statutory Stakeholders for climate change specifically. General consultation with NSC has occurred throughout the Scheme development and is discussed in Chapter 3 - Alternatives.

14.7 Baseline Conditions

GHG emissions baseline

14.7.1 The UK's most recent final GHG emissions national statistics (for 2020)[44], set out the total UK GHG emissions for 2020 at 405.5 million tonnes of carbon dioxide equivalents ($MtCO_2e$). UK total emissions are showing a general downward trend, with 2020 UK total GHG emissions down 9.5% from 447.9 $MtCO_2e$ in 2019. In 2020, the largest emitting sector was transport, accounting for 23% of the UK GHG emissions.

14.7.2 The baseline conditions for the DM scenario were identified based on the modelling volumes of traffic currently on the existing road network, and its predicted use (accounting for increases in traffic and associated congestion) through to year 2039 (the design year for the Scheme). This established the baseline against which the Scheme was subsequently compared, in order to identify any variation in GHG emissions over time.

Vulnerability of the Scheme to climate change (climate change resilience assessment)

14.7.3 This section presents future projected climate conditions and extreme weather events that may impact the Scheme for the time periods, 2020s to 2080s covering the construction period commencing in 2023 and operational period assumed from 2024 to 2085.

14.7.4 Using the historical baseline data, two methods were implemented to establish the future climate baseline:

a) The changes in average climate conditions were obtained from the UKCP18 probabilistic projections of climate change[45].

b) The changes in extreme weather events were obtained using UKCP18 regional projections[46].

14.7.5 Climate change projections for a range of meteorological parameters are presented for different probability levels within the Representative Concentration Pathways 8.5 (RCP8.5) high emission scenario for the near-term and long-term future time

periods. Table 14-10 presents changes in extreme weather events for the 2020 to 2079, such as number of heavy rain days and Table 14-11 presents expected changes in climate conditions, such as mean temperature and precipitation for the 2020s to 2099.

14.7.6 Temperatures in the area are projected to increase in both winter and summer. The largest increase is projected to be in the mean daily maximum temperature in summer, which is expected to increase by 5.6°C to 21.8°C in the time-period 2080-2099, relative to the baseline in the high emissions scenario.

14.7.7 Mean precipitation rates in the region are anticipated to change significantly throughout the century, increasing by 7%-26% in the winter and decreasing by 13%-43% in summer during the time periods 2020-2039 and 2080-2099.

14.7.8 The mean number of hot days, when the maximum temperature in above 25°C, is anticipated to increase from 13.1 to 48.1 days per year in the time-period 2060-2079 for the high emissions scenario. The average number of days in a given year when the mean daily temperature is below 0°C, is anticipated to decrease from 38.6 to 14.5 in the time period 2060-2079 under the high emissions scenario.

Table 14-10: UKCP18 climate change projections for extreme weather events for the local area (12-kilometre grid square) for the time periods; 2020-2049, 2040-2059 and 2050-2079 (under the RCP 8.5 high emission scenario)[47]

Parameter		Baseline (1981-2010)	2020-2049			2040-2059			2050-2079		
			Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.
Temperature	Number of frost days (daily minimum temperature equal or lower than 0°C)	38.6	35.7	26.6	19.8	28.5	20.7	14.1	24.1	14.5	4.2
	Heatwaves (2 days with maximum temperature higher than 29°C and minimum temperature higher than 15°C)	1.2	1.7	3.3	7.6	3.3	5.8	12.5	4	11.4	17.8
	Number of hot days (daily maximum temperature higher than 25°C)	11.8	16.6	24.9	43.6	27.1	37.6	62.3	28.8	59.9	83.2
	Winter mean daily minimum temperature	2.3	2.5	3.4	4.1	3.2	4.2	4.7	4.2	5.3	6.1
	Summer mean daily maximum temperature	20.6	22.1	23.0	24.4	23.7	24.4	26.0	24.6	26.4	27.8
Precipitation	Dry spells (10 days or more with no precipitation)	4.7	4.2	5.1	5.9	5	5.7	6.5	5.5	6.3	7.6
	Annual number of days per year when precipitation is greater than 25mm per day (Met Office definition of ‘heavy rain’)	1.8	1.6	2.3	2.9	1.1	2.3	2.9	2.5	3.2	4.3

Table 14-11: UKCP18 climate change projections for average climate variables for the local area (25km grid square) for the time periods; 2020-2039, 2040-2059, 2060-2079 and 2080-2099 (under the RCP 8.5 high emissions scenario)

Parameter		Baseline (1981 2010)	2020-2039			2040-2059			2060-2079			2080-2099		
			10th percentile	50th percentile	90th percentile	10th percentile	50th percentile	90th percentile	10th percentile	50th percentile	90th percentile	10th percentile	50th percentile	90th percentile
Temperature (°C) (change from baseline)	Mean winter daily temperature	5.2	5.2	6.1	7.0	5.6	6.8	8.1	5.9	7.6	9.3	6.5	8.6	10.8
	Mean summer daily temperature	16.2	16.4	17.4	18.4	16.9	18.5	20.1	17.2	19.8	22.7	18.5	21.8	25.4
Precipitation (% change from baseline)	Winter mean precipitation rate	2.8	2.7	3.0	3.3	2.7	3.1	3.6	2.8	3.3	4.0	2.9	3.5	4.3
	Summer mean precipitation rate	2.1	1.4	1.8	2.3	1.1	1.6	2.1	0.8	1.4	2.0	0.5	1.2	2.0

H++ scenarios

14.7.9 In line with the methodology set out in DMRB *LA 114 Climate* Section 3.30, H++ climate scenarios are required to test the sensitivity of vulnerable safety critical features, to ensure that such features would not be affected by more radical changes to the climate beyond that projected in UKCP18. These are typically high impact, low likelihood events.

14.7.10 H++ scenarios are a set of plausible 'high-end' climate change scenarios which are typically extreme climate change scenarios on the margins or outside of the 10th to 90th percentile range presented in the UK Climate Projections 2009 (UKCP09)[48]. The UKCP18 projections do not include an updated H++ scenario and so the H++ scenario developed from UKCP09 remains current and applicable. The H++ scenarios are shown in Table 14-12 and cover the following climate hazards: heat waves, cold snaps, low and high rainfall, droughts, floods and windstorms.

Table 14-12: The H++ scenarios covering heat waves, cold snaps, low and high rainfall, droughts, floods and windstorms

Hazard	Scenario	Scenario description
Heat waves	H++	Annual average summer maximum temperatures exceeding 30°C over most of the UK and 34°C over much of central and southern England. Hottest days would exceed 40°C in some locations, with 48°C being reached in extreme cases.
Low rainfall	H++	A 6 month duration summer drought with rainfall deficits of up to 60% below the long-term average (1900-1999). Longer dry periods spanning several years with rainfall deficits of up to 20% below the long-term average (1900-1999) across all of England and Wales, similar to the most severe and extensive long droughts in the historical record.
Low river flows	H++	A 40-70% reduction in 'low flows' (Q95) in England and Wales in a single summer. For multi-season droughts, including 2 summers, a 20 to 60% reduction in low flows in England and Wales.
High rainfall	H++	A 70%-100% increase in winter rainfall (Dec to Feb) in a single winter (from a 1961-1990 baseline). An up to five-fold increase in frequency and 60% to 80% increase in heavy daily and sub-daily rainfall depths, for both summer and winter events (all year round).
High river flows	H++	A 60% to 120% increase in peak flows at the 'lower end' of the H++ scenarios for some regions in England and Wales. The upper limit for any region is a 290% increase in peak flows (1961-1990 baseline). The scenarios are based on the average response of "Enhanced-high" catchments, which are particularly sensitive to increases in rainfall.

Hazard	Scenario	Scenario description
Windstorms	H++	A 50-80% increase in the number of days per year with strong winds over the UK (1975-2005 baseline). A strong wind day is defined as one where the daily mean wind speed at 850 hPa, averaged over the UK (8W-2E, 50N-60N), is greater than the 99th percentile of the historical simulations.
Cold snaps	L--*	In the 2020s, UK average winter temperatures (December, January and February) of 0.3°C and for the 2080s, UK average winter temperatures would be around -4°C. In the 2020s, UK average temperatures on the coldest day would be -7oC in some locations. UK average temperature of the coldest day would be around -11°C.
*Note the term L-- is used specifically for the 'cold snap' scenario to emphasise that it is at the opposite end of the scale to the extreme warm summer temperatures in H++ and linked to Low emissions.		

Baseline and assessment scenarios

14.7.11 Assessment scenarios are based on current and future climate baselines, as described in Sections 3.26 – 3.28 of DMRB *LA 114 Climate*. The CCR assessment is based on climate trends associated with the UKCP18[49] high emissions scenario (50% probability) projection. Recent weather patterns and extreme weather events i.e. observed data have been identified and used to provide an indication of how the Scheme would account for climate change in the immediate future i.e. during construction. The time periods for climate projections are selected based on the assumed lifespan and stages of the Scheme (60 years), with construction assumed to commence in early 2023 and operation assumed from 2024 to 2085.

14.7.12 Additionally, DMRB *LA 114 Climate*, Section 3.30, requires that H++ (which are typically extreme) climate scenarios[50] are used to test the sensitivity of vulnerable safety critical features, to ensure that such features would not be affected by more radical changes to the climate beyond that projected in UKCP18. Safety critical features that are vulnerable to climate change have been identified for the Scheme to include:

a) Drainage

b) Earthworks

14.7.13 A high-level sensitivity test using H++ climate scenarios has been undertaken and is presented in Section 14.7 Baseline Conditions.

14.7.14 The integral safety of the Scheme has also been considered

against UKCP18 (and Representative Concentration Pathways 8.5 (RCP8.5)[51] models therein).

14.8 Predicted Environmental Effects

GHG emissions assessment – Embedded mitigation

14.8.1 The baseline scenario is the 'Do-Minimum' approach, which represents continual operation of the existing network without the Scheme. The baseline scenario includes current operational maintenance GHG emissions, operational user GHG emissions and land use change/ sequestration GHG emissions. A 60-year appraisal period has been adopted in line with the methodology set out in DMRB *LA 114 Climate*. The assessment outlined within DMRB LA 114 Climate also aligns with the latest IEMA Guidance Assessing Greenhouse Gas Emissions and Evaluating their Significance (2022). The relevance of the IEMA guidance is discussed further within the Planning Statement.

14.8.2 The assessment scenario is the 'Do-Something' approach, i.e., implementing the Scheme. The assessment scenario includes the construction, operational maintenance, operational user and habitat GHG emissions described in Table 14-3. GHG emissions in this scenario are compared to the baseline in order to assess the net contribution of the Scheme to climate change (in tCO_2e) from construction and operation over the 60-year appraisal period.

14.8.3 Mitigation measures identified are divided into the following hierarchy options:

a) Avoid/ prevent - maximise potential for re-using and/ or refurbishing existing assets to reduce the extent of new construction required, and/ or explore alternative lower carbon options to deliver the Scheme objectives.

b) Reduce - low carbon and/ or reduced resource consumption solutions (including technologies, materials and products) to minimise resource consumption during the construction, operation, and at end of life.

c) Remediate - measures to further reduce carbon through on or off-site offsetting or sequestration.

14.8.4 The following mitigation measures are a summary of the full works throughout the design process. A full description of mitigation measures are outlined in ES Volume 3 - Appendix 14.C - Carbon Baseline Report, ES Volume 3 - Appendix 14.D - Carbon Management Plan, ES Volume 3 - Appendix 14.E - Carbon Options Assessment Report and ES Volume 3 - Appendix 14.F - Carbon Assessment Report. These mitigation measures have been and would continue to be considered to reduce GHG emissions from the Scheme. Key emissions impacts during construction would be from construction activities and embedded/ embodied carbon of the materials.

Early-Stage Carbon Reduction Opportunities

14.8.5 The focus of decarbonisation of embodied carbon efforts were upon assets with the highest carbon impacts. On this Scheme, the highest impact assets/ components, in order of decreasing carbon emissions magnitude, were:

a) Earthworks
b) Structures
c) Pavements
d) Earthworks- Floodplain treatment
e) Drainage and Service Ducts
f) Kerbs, footways, and Paved areas
g) Traffic signs and road marking
h) Road Lighting and CCTV Columns
i) Fencing
j) Road Restraint Systems
k) Electrical work for road lighting and traffic signs
l) Site clearance
m) Accommodation works
n) Landscaping

14.8.6 Consideration was given to minimisation of the volume/ length of these assets, in particular earthworks. Consideration of the impact of vertical and horizontal alignment as well as junction design might have on user carbon was undertaken within the traffic modelling. This was an iterative process (between alignment, carbon modelling and traffic modelling) to achieve the right balance for the Scheme.

14.8.7 For retaining structures, the need for retention was questioned by the design teams. Consideration was given to whether they could be replaced with a slope. Designers also rationalised new structures where multiple rights of way were being diverted.

14.8.8 Design teams considered the topography to efficiently achieve onsite/ near site cut and fill balance and, where feasible, avoid unnecessary site transport. Similar considerations were made for all disciplines, namely Drainage, Geotechnics and Transport Planning.

14.8.9 The environmental mitigation was designed to be maintained for minimal carbon impact. There was deliberation of site elements that benefitted carbon such as soil carbon where construction soil management will be key to mitigating this impact. Additional opportunities for carbon sequestration and the creation or restoration of peat bogs/ wetland were also considered.

14.8.10 Design teams reported on project activities, materials/ components, and carbon categories where the greatest emissions occur and indicated where reductions can be made. These potential reductions were recorded as carbon opportunities in a tracker along with key outcomes, recommendations. Each item in the tracker was appraised in terms of carbon emissions. A summary of these recommendations and their carbon reductions are recorded as part of the ES Volume 3 - Appendix 14.A - Greenhouse gas assessment.

Scheme Carbon Hotspots

14.8.11 Carbon hotspots were identified within the carbon workshops. Carbon Hotspots refers to areas with a high carbon impact to identify and compare which design elements have the greatest carbon emissions. The quantification of GHG emissions allowed carbon hotspots to be identified and inform carbon reduction strategies. Design elements which contributed the highest emissions were quickly identified which enabled results to be compared or for variations to be accounted for by highlighting differences in methodologies.

14.8.12 General asset associated hotspots for ordinary highway assets were defined within both ES Volume 3 - Appendix 14.E - Carbon Options Assessment Report and ES Volume 3 - Appendix 14.F -

Carbon Assessment Report. This can be used to identify specific design elements in the Scheme responsible for high levels of carbon which helped to focus efforts to decarbonise through design.

Sustainable Travel

14.8.13 Opportunities for sustainable travel were pursued throughout the design of the Scheme. A walking, cycling and horse-riding assessment was conducted to identify opportunities for potential improvements to be incorporated within the Scheme. These opportunities will continue to be explored/ implemented as the design progressed.

14.8.14 To give the local population the opportunity to travel sustainably, the current design includes a fully separated, traffic-free walking/ cycling route running alongside the Banwell Bypass. The route begins to the west of Banwell, linking with the new route being provided on the A371 as part of the Safer Roads Scheme, this is descripted in ES Volume 1 - Chapter 2 - Scheme Description.

14.8.15 Regular crossings of the Banwell Bypass are also proposed to maintain existing walking, cycling and horse-riding routes, whilst also creating new ones. Some minor diversions to Public Rights of Way (ProW) are proposed to ensure existing footpaths are accessible from the proposed crossings. Dedicated routes for walkers, cyclists and horse-riders are also proposed on roads which will no longer allow through traffic, such as Castle Hill, Eastermead Lane/ and Moor Road.

14.8.16 Within Banwell, a range of improvements are proposed, including improved walking and cycling facilities, created by widening the existing pavement where possible, as well as increased cycle parking. The introduction of a ‘bus gate’ on Wolvershill Road where it crosses the Banwell Bypass would also significantly reduces traffic levels on this southern section of Wolvershill Road into Banwell, providing an improved route for buses, walking and cycling.

14.8.17 On roads where the Scheme has the potential to increase traffic, a range of measures are proposed to support walking and cycling, including new or improved pedestrian crossings in Sandford and Winscombe. There would also be an improved walking and cycling routes to Churchill School. These include

improvements to the existing public footpath between the A368 and Churchill Green, and to the east of Churchill Academy, improvements to surfacing to existing PRoW footpaths towards Langford to make them suitable for cyclists.

14.8.18 Although the carbon impacts of these improvements are not quantifiable (impacts to traffic have not been covered in the traffic model), it is assumed that these impacts will encourage modal shift and reduce overall traffic on the roads and therefore have a benefit to overall carbon.

Target setting

14.8.19 As stated in PAS 2080, during the delivery of assets and programme of work, all value chain members should:

a) Take early action to reduce carbon emissions, where the reduction opportunity is greatest

b) Demonstrate they have investigated alternative solutions for carbon reduction at relevant work stages;

c) Follow the carbon reduction hierarchy (Clause 6.1.4) and select the best collective approach for meeting or exceeding the targets by engaging with other members of the value chain;

d) Communicate and share the proposed carbon reduction actions they have identified with other value chain members;

e) Encourage other value chain members to choose products/ materials and adopt approaches which provide the lowest whole life carbon solution; and

f) Adopt an approach to carbon management that defines and implements measures that achieve whole life carbon reductions against a baseline.

14.8.20 Carbon reduction targets provide clear direction and intent for carbon reduction. Targets have been set against clear baselines so that performance against them can be determined. Each value chain member has fulfilled their roles in accordance with the Target Setting set out in PAS 2080.

Embodied Carbon (A1-A5)

14.8.21 During preliminary design a target of 33% reduction of the overall embodied carbon compared to the baseline (based on end of construction works) was set, whilst aspiring to achieve a 50% reduction. This will be delivered by continued review and

challenge of carbon reduction opportunities through the Carbon Opportunity register, design meetings and monthly carbon workshops.

14.8.22 Carbon impact of all products to be assessed to inform product selection decisions. The lowest whole life carbon material will be considered first and justification provided if this product is not selected.

Operational Carbon (B1-B8)

14.8.23 A target of 10% reduction of the overall operational carbon compared to the baseline has been set (over the 60-year climate change appraisal period from opening year).

14.8.24 The Whole life Carbon impact will be considered when making design decisions for the maintenance requirements of an asset. The lowest whole life carbon asset will be considered first, and justification provided if this solution is not selected.

User Carbon (B9)

14.8.25 At this stage in the design it is difficult to set a realistic target for reducing User Carbon (B9), given that road user carbon is determined by Government Policy (banning the sale of petrol/ diesel car engines in 2030), technology efficiency improvements and market advancements. No target has been set however the design objectives for User Carbon (B9) are listed below:

a) User Carbon (B9) impact will continue to be considered when making all design decisions, whilst balancing all Scheme Objectives eg Highways alignment and Junction layout. Delivered by continued review and challenge of carbon reduction opportunities through the Carbon Opportunity register, all design meetings and monthly Carbon workshops.

b) Design decisions will not increase user Carbon, compared to the baseline, unless it has an overall Scheme benefit, whilst meeting the Scheme Objectives.

c) Reduction in carbon from the Scheme will continue to contribute to NSC target of reduction in Carbon emissions of 13.9% per year in line with NSC's climate emergency report. This will be compared to the Do Minimum (no Banwell Bypass scenario) at the opening year 2024.

d) Further expansion and provision, through design, of alternative means of travel to encourage road users to reduce

car dependency for local journeys. This could be through improved provision of active and sustainable travel.

Impact of the Scheme on climate (GHG emissions assessment)

14.8.26 Prior to the implementation of mitigation, the Scheme has the potential to affect climate during construction and operation, both beneficially and adversely.

14.8.27 During the optioneering stage of design, a baseline carbon assessment was completed for the do minimum scenario and each viable option, making up the potential do something scenarios. This assessment was used to inform the decision-making process for which option to take forward for preliminary design. The findings of this assessment can be found in ES Volume 3 - Appendix 14.E - Carbon Options Assessment Report.

14.8.28 It can be quickly identified from Table 14-13 that the design elements contributing the highest product stage (A1-A3) emissions is both the Earthworks – Imported Fill and the Earthworks Flood Plain – Ground treatment (which is the required ground treatment associated with the lengths traversing the floodplain). These series contribute to 82%, 78% and 75% of the total embodied emissions for routes 1, 2 and 3 respectively.

Table 14-13: The carbon baseline of embodied carbon per option

SHW Series	Item category/ unit	Common Alignment (tCO_2e)	Alignment 1 North (tCO_2e)	Alignment 2 Middle (tCO_2e)	Alignment 3 South (tCO_2e)
300	Fencing - timber rail fence	9.03	29.62	24.85	25.27
400	Barriers - steel RRS	140.88	462.02	387.58	394.10
500	Drainage - Culverts & Headwalls	5.39	80.92	70.13	53.59
500	Highway Drainage	159.03	520.55	436.42	444.26
500	Flood Compensation Area (assume reuse)	-	-	-	-
600	Earthworks - Imported fill	2,821.43	9,476.40	7,893.43	7,651.75
600	Earthworks Flood Plain - Ground treatment	-	4,938.81	3,142.88	1,891.95
600	Earthworks Flood Plain - Landfill piled slab	-	-	443.26	-

SHW Series	Item category/ unit	Common Alignment (tCO_2e)	Alignment 1 North (tCO_2e)	Alignment 2 Middle (tCO_2e)	Alignment 3 South (tCO_2e)
700	Pavement - Carriageway	375.65	1,231.93	1,033.45	1,050.83
1100	Kerbs	22.16	72.66	60.96	61.98
1100	Footways/ Cycleways	66.32	217.48	182.44	185.51
1600	Retaining Wall - sheet pile with capping beam	-	-	-	557.50
1700/ 1800	Bridge		393.77	442.43	442.43
	Total	**3,599.89**	**17,424.17**	**14,117.83**	**12,759.17**

14.8.29 The Common Alignment has been quantified and considered in isolation, with no highway link provided to the east of Wolvershill Road to bypass Banwell. The sole purpose of this route is to provide connectivity to the potential housing that may be identified in the emerging local plan.

14.8.30 Operational user carbon emissions (B9) were estimated in collaboration with the transport planning lead and air quality team to convert tailpipe emission simulations into quantifiable carbon for the Base Model (2018), Opening Year (2026) and Future Year (2038). The Opening Year and Future Year changed post optioneering phase hence the difference with the years assessed in this chapter. The base year model (2018) represents the model without any proposed developments and shows predicted traffic growth over the assessment periods, i.e the increases in emissions from 2018, 2026 and 2038 in the Do-nothing column in Table 14-14. The emissions data from the traffic model are converted into carbon emissions using the DEFRA Emissions Factor Toolkit. The results for operational user emissions are presented in Table 14-14.

Table 14-14: Results for Operational User Carbon (B9) Emissions for all Route Options

	Do-nothing	Route 1 (North)	Route 2 (Middle)	Route 3 (South)
	Average User Carbon per year (tCO_2e/ year)			
Base Model (2018)	1,000,667	N/A	N/A	N/A
Opening Year (2026)	1,032,234	1,032,886	1,031,848	1,031,774

Future Year (2038)	1,074,821	1,086,531	1,085,561	1,086,266
Increase of Future Year from Base Model	7.4%	8.6%	8.5%	8.6%
Cumulative User Carbon (B9) (2026 to 2085)	63,978,226	64,548,134	64,489,128	64,522,072

14.8.31 Note that the Opening Year of Routes 2 and 3 are lower than the Do-Nothing and increase over time. This is because Route's 2 and 3 offer a more efficient route in terms of emissions at current traffic numbers. When the housing development is complete the increase in traffic on Routes 2 and 3 will be greater than the improvements in efficiency, explaining the increases in the Future Year across Routes 1, 2 and 3 compared to the Do-nothing.

14.8.32 Rather than using the do-minimum as a baseline comparison (as done with Embodied carbon), a 'Do-Nothing' scenario was used as a comparison for operational user carbon. The baseline is the scenario for what carbon emissions would have been in the absence of carbon mitigation measures. The 'Do Nothing' scenario measures the carbon baseline without the Scheme or a connecting road to the proposed housing development.

14.8.33 Comparing the 'Do-nothing' opening year values with Route 2 and 3, the annual average operational emissions is higher for the 'Do Nothing' scenario which could be indicative of the predicted congestion in the centre of Banwell without a Banwell Bypass.

14.8.34 For all options, the operational user carbon is similar due to the overall similarity in the route lengths. However, the Future Year from the Base Model is marginally higher for Route 1 and Route 3. Therefore, as Route 2 is the smallest contributor of operational user carbon this option was considered the favoured option, only showing a 1.1% increase from the do-nothing in the Future year scenario; a total increase of 11.7ktCO_2 in 2038.

14.8.35 Comparing both the embodied carbon emissions with the annual average operational user carbon, there is a prominent difference in the values. This cumulative comparison demonstrates that the estimated embodied carbon is a small proportion of the operational user carbon.

Summary of Embedded Mitigation

14.8.36 The Scheme, based on Route 2 described in Tables 14-13 and Table 14-14, has been designed to minimise adverse environmental effects on climate through the process of design development and consideration of good design principles.

14.8.37 By assessing each option's carbon baseline at an early stage, GHG emissions were properly factored into the decision-making process for which option to take forward for detailed design.

14.8.38 By using the carbon hotspots identified above, opportunities for further carbon reduction have been explored and implemented. These include but are not limited to:

a) Carriageway reduced from a dual and 4 lane single carriageway to a 2 lane single carriageway. This decision also removes the need for a central reservation.

b) Lane widths reduced from 3.65m to 3.4m

c) Removal of the hard strip 0.5m either side of north and southbound lanes

d) Foot/ cycleway moved to the bottom of embankment reducing earthworks. The new design now aligns with existing ground level where possible.

e) Foot/ cycleway diverted from bottom of Banwell Bypass before the eastern junction removing the need for lighting at the Eastern Junction.

f) Steel road restraint system reduced from 3460m to 1310m.

g) Traffic flows, earthworks, land requirements and the most effective use of space were all considered when designing junctions. The Eastern junction now a T junction instead of a roundabout requiring less land and earthworks.

h) The Riverside Road Junction removed

i) Wolvershill Road Junction downgraded from 5 lanes to 3 lanes.

j) Minimising the amount of lighting was attempted but wasn't possible due to safety reasons. The overall column height was reduced from 10 to 8m.

k) Speed limit reduced from 50 to 40mph.

Vulnerability of the Scheme to climate change (climate change resilience assessment)

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

14.8.40 During the construction process, receptors may be vulnerable to a range of short-term climate risks, including damage to construction materials, plant and equipment, unsuitable conditions for construction activities, delay, increased costs and health and safety impacts to the workforce during severe weather events.

14.8.41 Once operational, the Scheme has the potential to be impacted upon by a changing climate and more frequent severe weather events in the medium to longer-term. Potential impacts include material and asset deterioration and damage giving rise to health and safety risks to users and increased maintenance requirements.

14.8.42 The potential risks are expected to be largely mitigated through the use of appropriate design standards, delivered through quality construction, as well as appropriate asset management procedures during operation.

GHG emissions

14.8.43 Design decisions summarised in Section 14.8 Predicted Environmental Effects Predicted Environmental Effects reduce the overall materials required to construct the Scheme, reduce maintenance requirements or reduce user carbon, these are shown in Table 14-15. This table shows that the bulk of carbon savings are from reducing emissions from earthworks and pavements. The removal of the Road Restraint System yielded the best improvement by percentage.

14.8.44 Many of these decisions impact multiple carbon streams. Due to the complex interaction of these decisions it has not been possible to quantify every individual decision however the overall measurable reduction is shown in Table 14-15 and Table 14-16.

14.8.45 Note that some decisions cannot be quantified at this stage due to lack of data. For example, it is not yet possible to compare how reducing the speed limit or adding more sustainable transport options has impacted carbon from the baseline design to the preliminary design due to limitations in the traffic model. It is anticipated that these decisions will have a positive impact on overall user carbon.

14.8.46 Table 14-15 shows the overall carbon savings when comparing the tender design undertaken by WSP in August 2020 (as seen in ES Volume 3 - Appendix 14.C - Carbon Baseline Report) to the preliminary design, the latest version.

Table 14-15: Impact of the overall design process on carbon produced at construction

Element	Tender design scheme (tCO_2e)	Preliminary design (tCO_2e)	Savings (tCO_2e)	% Difference
Earthworks	18,113	5,547	-12,565	-69.4%
Pavements	8,508	3,144	-5,364	-63.0%
Earthworks floodplain treatment	2,557	1,753	-804	-31.4%
Drainage and Service Ducts	1,979	759	-1,220	-61.6%
Structures	1,483	5,767	4,284	288.9%
Road Restraint Systems	677	95	-582	-86.0%
Site Clearance	604	236	-368	-60.9%
Traffic Signs and Road Marking	419	158	-261	-62.4%
Kerbs, Footways and Paved Areas	311	463	152	48.9%
Fencing	116	171	54	46.5%
Electrical Work	87	50	-38	-43.0%
Road Lighting and CCTV	59	102	43	73.1%
Temporary Works	34	18	-17	-48.3%
Accommodation Works	0	0	0	0.0%
Total	**34,947**	**18,263**	**-16,684**	**-47.7**

Table 14-16: Impact of the overall design process on carbon produced during operation (B2-B5)

Element	Baseline design (tCO_2e)	Preliminary design (tCO_2e)	Savings (tCO_2e)	% Difference
Pavements	2,834	1,187	-1,647	-58.1%
Traffic Signs and Road Marking	2,264	1,045	-1,219	-53.8%
Drainage and Service Ducts	1,212	143	-1,069	-88.2%
Road Restraint Systems	150	18	-132	-88.2%
Road Lighting and CCTV	90	158	67	74.6%
Fencing	88	100	12	13.3%
Kerbs, Footways and Paved Areas	83	129	46	55.2%
Structures	66	843	777	1176.8%
Landscaping	4	4	0	0.0%
Total	**5,815**	**3,626**	**-2,189**	**-37.60%**

Vulnerability of the Scheme to climate change (climate change resilience assessment)

14.8.47 The Scheme has been designed to improve its resilience to climate change through a range of design and material specification measures including where practicable: the use of construction materials with superior properties (such as increased tolerance to fluctuating temperatures), incorporation of current road design standards and future climate change allowances. Embedded mitigation and adaption measures for all climate risks identified within the CCR assessment are set out in Table 14-22. Additionally, the integral safety of the Scheme has been considered against UKCP18 (and RCP8.5 models therein). A sensitivity test of the safety critical features against H++ scenarios is set out in Table 14-23.

14.8.48 All weather and climate-related risks to construction activities are expected to be mitigated through best practice site management, including relevant specific measures which are set out in a register of environmental actions and commitments within the Construction Environmental Management Plan (CEMP). The

best practice site management measures and relevant specific measures would provide a level of resilience to the Scheme throughout construction.

Assessment of likely significant effects

14.8.49 This section presents the assessment of likely significant effects on climate resulting from the construction and operation of the Scheme. The assessment of effects takes into account the potential impacts to each receptor following the implementation of embedded and essential mitigation measures to determine the significance of the residual effects.

Impact of the Scheme on climate (GHG emissions assessment)

14.8.50 This assessment presents a calculation of the emissions calculated for the 'Do-Something' scenario, a comparison against the 'Do-Minimum' (baseline), and assessment against legislated UK Government carbon budgets.

14.8.51 Embedded mitigation measures proposed, as outlined in Section 14.8 Predicted Environmental Effects Predicted Environmental Effects, have already been incorporated into the design and, where possible, the design decisions taken throughout the iterative process have been quantified. In some instances, it has not been possible to complete a quantitative assessment of the impact a design decision has had. It is also anticipated that design mitigation will continue to evolve after this assessment and therefore this is a snapshot of the current design. As the design evolves this will continue to be assessed.

'Do-Something' scenario emissions

Construction

14.8.52 A high-level breakdown of construction phase emissions is displayed in Table 14-17. All assumptions used in the calculations are contained within ES Volume 3 - Appendix 14.A - Greenhouse Gas Assessment and Section 14.5 Assessment Assumptions and Limitations. Emissions from the construction phase are predicted to total in the region of 18,311 tCO_2e.

Table 14-17: Construction stage emissions following mitigation measures

Main stage of project life cycle	Sub-stage of life cycle		Emissions (tCO_2e)	% of total construction emissions*
Construction stage	Product stage; including raw material supply, transport and manufacture (A1-A3)		16,744	91.4
	Construction process stage; including:	Transport to/ from works site (A4)	671	3.7
		Construction/ installation processes (A5)	847	4.6
	Land use change (A5); loss of carbon sinks in habitats vs carbon sinks in habitats created (once mature)		48.5	0.27
	Construction stage total		18,311	100%

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

* Sub-stages of the construction life cycle and modules shown in this table align with PAS 2080 boundary stages and individual modules as shown in Table 14-9.

14.8.53 A more detailed breakdown of the GHG emissions can be found within ES Volume 3 - Appendix 14.F - Carbon Assessment Report.

14.8.54 The largest portion of emissions during construction (85.5%) is likely to arise from the production of materials. Emissions from on-site construction processes equate to 11.2% of the total, and transport of materials totals 3.3% of emissions. Emissions associated with the loss of carbon from habitats vs the amount of carbon gained from planting results in a small net loss of carbon that equates to 0.25% over the 60-year assumed operational period.

Operation

14.8.55 Emissions associated with maintenance and refurbishment assume that the road surface would be replaced once every ten years for the duration of the assumed 60-year design life. Road user GHG emissions are expected to constitute the majority of the whole life GHG emissions of the Scheme. Operational phase emissions for the modelled opening and design years[52] and total over the modelled 60-year operational period are shown in Table 14-18.

Table 14-18: Operational ('use stage') emissions for modelled opening year (2024), design year (2039), and total over the assumed 60-year operational period (2024 – 2083)

Sub-stage of life cycle		Emissions (tCO_2e)	
	Emissions over appraisal period (do-minimum) (tCO_2 e) (2024 to 2083)	Emissions over appraisal period (proposed development) (tCO_2e) (2024 to 2083)	Additional emissions (do-something vs do-minimum) (tCO_2e)
Use of the infrastructure by the end-user (road user emissions) (B9)	15,267,517	15,388,686	121,169
Maintenance and refurbishment (B2-B5)	0	0	3,626
Operation (B2-B9) total			124,795

* Sub-stages of the Operation ('use-stage') life cycle and modules shown in this table align with PAS 2080 boundary stages and individual modules as shown in Table 14-9.

Comparing 'Do-Minimum' and 'Do-Something' scenarios

14.8.56 As GHG emissions associated with construction do not occur in the 'Do-Minimum' scenario, it is shown that the construction stage of the Scheme would have the effect of releasing an additional 18,311 tCO_2e into the atmosphere in the 'Do-Something' scenario.

14.8.57 The calculated annualised operation stage emissions for the Scheme are estimated to lead to an increase of approximately 124,795 tCO_2e during the modelled 60-year operational period (2024 – 2083), relative to the 'Do-Minimum' scenario.

Assessment against legislated UK carbon budgets

14.8.58 Table 14-19 shows the relevant carbon budget periods against which the Scheme would contribute. This approximation assumes an even distribution of emissions across the assumed overall construction period.

14.8.59 If planning permission is granted, construction is expected to start in early 2023 and the Scheme is expected to be open to traffic in 2024. Therefore, the construction period for the Scheme falls wholly within the fourth carbon budget. Operation of the Scheme would commence in 2024 and is assessed against the

fourth, fifth and sixth carbon budgets, up to 2037. Operational and maintenance emissions between 2033 and 2037 (the period for the sixth carbon budget) are provided in Table 14-19.

Table 14-19: Assessment of Scheme net emissions (up to 2037) against UK Government carbon budgets

Project stage	Estimated total (cumulative) GHG emissions over carbon budgets (tCO_2e) ('Do-Something' scenario)	Net (cumulative) Scheme GHG emissions per relevant carbon budget (tCO_2e)			
		Third (2018 2022)	Fourth (2023 2027)	Fifth (2028 2032)	Sixth (2033 2037)
Construction (over a period of 42 months, assumed to commence in early 2023-2024)	18,311	N/A	18,311	N/A	N/A
Operation (modelled from 2024 through to 2039)	124,795	N/A	35,656	44,570	44,570
Total		N/A	53,967	44,570	44,570

Assessment against Regional emissions

14.8.60 As stated in Section 14.3.34, The Joint Local Transport Plan 4 and West of England Climate and Ecological Strategy and Action Plan aims to ensure carbon neutrality by 2030 within the West of England Combined Authority. As shown in ES Volume 3 - Appendix 14.A - Greenhouse Gas Assessment, operational emissions (Module B1 to B8) and user emissions (Module B9) will be produced by the Scheme post 2030.

14.8.61 Operational carbon emissions are predicted to be 60 tCO_2 per year after 2030. User carbon emissions in 2030 are predicted to be predicted to be 320,305 tCO_2 in the Do-something scenario compared to 318,189 tCO_2 in the Do-minimum scenario.

14.8.62 As shown in Image 14-1, the Central Scenario projection, the current gap between reaching net zero by 2030 is 1,380,000 tCO_2 (1.38 $MtCO_2$, decreasing slightly every year. As the Banwell Bypass would increase GHG emissions, from the Do-minimum scenario, by 2,176 tCO_2 in 2030. This equates to increasing the Central Scenario projected overspend by 0.16%.

14.8.63 This increase in projected emissions in 2030 is not considered to

materially impact on WECA's ability to achieve their net zero by 2030 target.

Assessment against Local emissions

14.8.64 As stated in 14.3.32, The North Somerset Climate Emergency Report on Baseline Emissions, NSC's carbon target is 6.9 MtCO2 between 2020 and 2100. Table 14-20 shows how this budget compares with the Scheme's carbon emissions.

Table 14-20: How the Scheme's carbon compares to the NSC carbon target

Project stage	Estimated total (cumulative) GHG emissions over carbon budgets (tCO_2e) ('Do-Something' scenario)	Percentage of NSC carbon target
Construction (over a period of 42 months, assumed to commence in early 2023-2024)	18,311	0.27
Operation B2-B8 (modelled from 2024 through to 2039)	3,626	0.053
User Carbon B9 (modelled from 2024 through to 2039)	124,795	1.8
Total	**156,509**	**2.3%**

14.8.65 The total GHG emissions produced by the Scheme through construction, operation and use is 156,509 tCO_2e. Therefore, Banwell Bypass equates to 2.3% of this budget. As shown, the majority of this percentage (1.8%) is produced by road users which is difficult for NSC to reduce without wider national policy implementation. This is especially true as user emissions consider electric vehicle uptake and emissions from the grid to power them, as shown in Table 14-9. NSC can only have a small influence on the decarbonisation of the National Grid.

Significant effects

14.8.66 The construction and operation phases of the Scheme which fall within legislated carbon budget periods are expected to have an insignificant impact on the ability of the UK Government to meet its carbon budgets. Construction of the Scheme is estimated to contribute approximately 0.0027% of the fourth carbon budget. Operation of the Scheme is estimated to contribute approximately 0.0028% of the fourth carbon budget, 0.0026% of the fifth carbon budget and 0.0046% of the sixth carbon budget.

It is considered that this magnitude of emissions from the Scheme in isolation would not have a material impact on the ability of the UK Government to meet its carbon budgets, and therefore is not anticipated to give rise to a significant effect on climate, in line with the position set out within Section 5.18 of the NPSNN.

Potential design changes

GHG assessment

14.8.67 Ground investigations have identified the presence of artesian ground water in the area. The use of band drains could have a potential adverse impact on the hydrogeology of the area.

14.8.68 Whilst additional ground investigations are undertaken to assess the impact of band drains, an alternative ground improvement solution using Controlled Modulus Columns (CMCs) has been assessed.

14.8.69 Band drains are vertical drains that are pushed into the ground over an area with soft ground and trapped water. A surcharge load is placed on top of the area to consolidate the soil, pushing the trapped water in the soil towards the drains where it can drain to the surface. This allows the soil in the area to consolidate and settle.

14.8.70 CMCs are concrete columns that are poured into the ground to compress the soil. A machine creates a hole in the ground by moving the soil laterally, compressing the area. The hole is then filled with concrete creating the column. A load transfer platform is then placed on top of the columns, the platform is typically made of granular fill or concrete. The CMCs would not require surcharge material, which is required for the band drains option. This would reduce the amount of earthworks required for the Scheme but increase the amount of concrete. Calculations have been carried out to assess the carbon impact of using CMCs instead of band drains.

14.8.71 Detailed calculations are shown within ES Volume 3 - Appendix 14.F - Carbon Assessment Report and show, the embedded (A1-A5) and operational (B2-B8) carbon of the Scheme using band drains would be 21,937 tCO_2e. The embedded (A1-A5) and

operational (B2-B8) carbon of the Scheme using CMCs would be 22,103 tCO_2e. The CMCs option would emit approximately an additional 166 tCO_2e. This option is therefore not deemed to materially change the significant impact of the Scheme.

CCR assessment

14.8.72 Should it be found that CMC are appropriate for the drainage of the Scheme, this would result in a minor impact for climate change resilience against the band drains. As this change only impacts a minor area of the Scheme it is not considered this change would materially change the significant impacts outlined in the CCR assessment and Table 14-22.

Comparison with other Schemes

14.8.73 Construction related emissions are comparable with other projects on a per kilometre basis. Operational and maintenance carbon is expected to be significantly lower than other projects. This is likely due to minimal energy consuming assets within the design. On a per kilometre basis, estimated use phase emissions per annum are notably lower than comparable projects.

Table 14-21: Comparison of the Scheme's carbon with other road infrastructure projects[53]

Carbon footprint lifecycle modules	Project/ length and width component												
	M4 (Welsh Government, 2016)[1]	A14 (Welsh Government, 2016)[2]	A417 (Highways England, 2021)[3]	A428 (Highways England, 2021)[4]	A465 (Welsh Government, 2016)[5]	A47 (Highways England, 2021)[6]	A47 A11 (Highways England, 2021)[7]	M54 to M6 Link Road[8]	A1 Morpeth to Ellingham[9]	M25 Junction 10/ A3 Wisely Interchange[10]	M25 Junction 28[11]	A303 Stonehenge[12]	The Scheme[13]
Capital (embodied) CO_2e (tCO_2e)													
Material	436,600	740,100	40,698	163,230	44,300	25,865	15,235	49,620	15,056	28,195	11,561	267,100	11,197
Labour + plant	42,800	243,800	23,486	51,000	5,800	3,509	1,998	6,670	N/A	34,729	15,872	199,580	847
Earthworks	43,200	N/A			2,500	52,873	13,775	N/A	2,550		N/A	N/A	5,547
Transport								15,940	2,754	29,396	7,762	N/A	671
Land use change								1,880	N/A	N/A	N/A	N/A	48.5

[1] 14.3 miles (23km) new relief road
[2] 23 miles (37km) improvement Scheme
[3] 3.4 miles (5.5km) widening of A road
[4] 10 miles (16km) new dual 2-lane carriageway + 1.8 miles (3km) of tie-in works
[5] 4.8 miles (7.8km) embankment section
[6] 5.6 miles (9km) dualling of A road
[7] 1 mile (1.65km) new slip road
[8] link road between the M54 and M6, providing a link between Junction 1 of the M54, M6 North and the A460 to Cannock
[9] 12.8 miles (20.6km) improvement Scheme
[10] 7.2 miles (11.6km) stretching over the A3 & M25 - improvement Scheme
[11] 3.2 miles (5.14km) alteration of Junction 28 of the M5
[12] 8 miles (13km) of a new two lane dual carriageway between Amesbury and Berwick Down
[13] 2.2 miles (3.5km) Banwell Bypass with junction link

Carbon footprint lifecycle modules	Project/ length and width component												
	M4 (Welsh Government, 2016)[1]	A14 (Welsh Government, 2016)[2]	A417 (Highways England, 2021)[3]	A428 (Highways England, 2021)[4]	A465 (Welsh Government, 2016)[5]	A47 (Highways England, 2021)[6]	A47 A11 (Highways England, 2021)[7]	M54 to M6 Link Road[8]	A1 Morpeth to Ellingham[9]	M25 Junction 10/ A3 Wisely Interchange[10]	M25 Junction 28[11]	A303 Stonehenge[12]	The Scheme[13]
Construction tCO_2e/km	*21,800*	*26,600*	*11,670*	*13,024*	*6,700*	*9,747*	*15,725*	81,890	20,399	92,385	36,954	466,915	8,323
Operational CO_2e (tCO_2e)													
Operation + Maintenance / annum	1,600	2,400	858	N/A	2,600	N/A	N/A			630	240		60
Use/ annum (road users)	2,268,700	4,386,400	209,642	1,835,778	882,000	894,192	894,033	7345560	123,000	218,190	834,367	N/A	2,116

Vulnerability of the Scheme to climate change (climate change resilience assessment)

14.8.74 Climate change risks to infrastructure assets designed and constructed as part of the Scheme have been assessed during construction and operation. Details of the mitigation measures identified to date and the significance assessment are contained in ES Volume 3 - Appendix 14.B - Climate change resilience assessment.

14.8.75 These significant and non-significant climate resilience impacts, identified using criteria set out in the assessment methodology, are detailed in ES Volume 3 - Appendix 14.B - Climate change resilience assessment and summarised in Table 14-22.

Table 14-22: Climate resilience impacts, embedded or essential mitigation measures and likelihood and consequence of hazard impact (extract from ES Volume 3 - Appendix 14.B - Climate change resilience assessment)

Risk ID	Climate hazard	Potential climate change risk to Scheme	Embedded or essential mitigation measure	Likelihood of hazard impact	Consequence of hazard impact (should the impact occur)	Evaluation of significance
1	High temperatures	Increased heat stress for staff, particularly for outdoor construction and maintenance workers.	To be incorporated within proposed maintenance regimes. These can be reviewed regularly to ensure H&S requirements are met	Unlikely	Minor	Very Low
2	High temperatures	Increased risk of thermal expansion joints being pushed beyond their design capability, presenting a direct risk of damage to structures and assets (e.g. concrete joints).	Culverts are buried structures which regulate surrounding temperatures and insulated from climatic temperature changes. Structure design is based on maximum / minimum temperatures rather than mean temperatures, therefore risk mitigated through design. River Banwell underbridge is an integral bridge and does not have thermal expansion joints included in proposed design.	Very unlikely	Major	Low
3	High temperatures	Extended periods of hot, dry weather may lead to a risk of spontaneous grassland fires in vicinity of the route, affecting safety on the road.	Risk to be sufficiently mitigated through standard emergency procedures	Unlikely	Moderate	Low

Risk ID	Climate hazard	Potential climate change risk to Scheme	Embedded or essential mitigation measure	Likelihood of hazard impact	Consequence of hazard impact (should the impact occur)	Evaluation of significance
4	High temperatures	Asphalt surface may exhibit permanent deformation in long periods of hot, sunny conditions.	This risk will be managed through the selection of suitable road surface material as well as through the proposed maintenance regimes for road surface.	As likely as not	Minor	Low
5	High temperatures	High temperatures increase the risk of surfacing rutting leading to water ponding in the ruts. Higher temperatures also increase the risk of reduced skid resistance due to fatting and chipping embedment. This increase the risk of vehicle accidents.	This risk will be managed through the selection of suitable road surface material as well as through the proposed maintenance regimes for road surface.	Unlikely	Moderate	Low
6	High temperatures	Inability to flex under traffic loads. Increased risk of road surface cracking and fretting with age.	This risk will be managed through the proposed maintenance regimes.	As likely as not	Minor	Low
7	High temperatures	Risk of being unable to lay road surface layers in hot weather.	Risk to be mitigated by following procedures detailed in the outline EMP	Unlikely	Minor	Very Low
8	High temperatures	Decreased viscosity in head leads to greater spreading of diesel in a smaller timeframe. Higher temperatures and increased number of hot, dry days increase the likelihood of ignition of this diesel leading to road and forest fires.	Risk to be sufficiently mitigated through proposed maintenance procedures	Unlikely	Major	**Medium**

Risk ID	Climate hazard	Potential climate change risk to Scheme	Embedded or essential mitigation measure	Likelihood of hazard impact	Consequence of hazard impact (should the impact occur)	Evaluation of significance
9	High temperatures	Reduced efficiency and lifespan of LED luminaires.	The impacts associated with increased ambient temperature to be absorbed within current maintenance procedures. Design life 100,000hours (~25 years).	As likely as not	Minor	Low
10	Low temperatures	Change of risk of freeze-thaw occurring to road infrastructure and structures. (The mark against noise barriers is only applicable if not in the form of bunds- still not decided)	To be mitigated by an appropriate choice of concrete mix.	As likely as not	Minor	Low
11	Low temperatures	Possible negative health implications for staff.	For construction: to be mitigated as described in the outline EMP. For operation: To be incorporated within proposed maintenance regimes. These can be reviewed regularly to ensure H&S requirements are met	Very unlikely	Minor	Very Low
12	Low temperatures	Opportunity: Reduced risk of impacts to electrical cabinets / equipment	Number of frost days is projected to decrease. However, cold spells are expected to be more severe and so it is recommended that preparedness levels remain unchanged	N/A	N/A	N/A
13	Low temperatures	Opportunity: Reduced grit/ salt used during winter, reducing deterioration of pavement.	Number of frost days is projected to decrease. However, cold spells are expected to be more severe and so it is recommended that preparedness levels remain unchanged	N/A	N/A	N/A

Risk ID	Climate hazard	Potential climate change risk to Scheme	Embedded or essential mitigation measure	Likelihood of hazard impact	Consequence of hazard impact (should the impact occur)	Evaluation of significance
14	Low temperatures	Increased risk of skidding for road users due to ice/ snow on road - safety concerns + damage to road infrastructure.	It is recommended that preparedness levels remain unchanged.	Very unlikely	Major	Low
15	Low temperatures	Increase in slips trips and falls and construction/ maintenance worker injury.	For construction: to be mitigated as described in the outline EMP. For operation: To be incorporated within proposed maintenance regimes. These can be reviewed regularly to ensure H&S requirements are met	Very unlikely	Minor	Very Low
16	High precipitation	Flooding of road surface.	Attenuation basins currently designed for 1/100 year event +40% for climate change. Highway drainage infrastructure sized to ensure no flooding of the highway for 1/5 year event + 40% climate change, in accordance with DMRB. Critical drainage areas to be assessed independently.	Unlikely	Moderate	Low
17	High precipitation	Flooding of access roads and/ or road infrastructure.	Attenuation basins currently designed for 1/100 year event +40% for climate change. Highway drainage infrastructure sized to ensure no flooding of the highway for 1/5 year event + 40% climate change, in accordance with DMRB. Critical drainage areas to be assessed independently.	As likely as not	Minor	Low

Risk ID	Climate hazard	Potential climate change risk to Scheme	Embedded or essential mitigation measure	Likelihood of hazard impact	Consequence of hazard impact (should the impact occur)	Evaluation of significance
18	High precipitation	Increased risk of scouring of culverts.	To be mitigated through drainage design Risk likely to be absorbed by conservative assumptions made during design	Unlikely	Minor	Very Low
19	High precipitation	Flooding causing damage to fibre optic cables running near to site.	Not currently aware of any utility cables running close to site, however risk should be reassessed at detailed design once surveys have been carried out.	Very unlikely	Minimal	Very Low
20	High precipitation	Increased pore water pressure in embankments/ cuttings.	To be mitigated through drainage design Risk likely to be absorbed by conservative assumptions made during design	Very unlikely	Catastrophic	**Medium**
21	High precipitation	Increased erosion at toe of embankment.	To be mitigated through drainage design Risk likely to be absorbed by conservative assumptions made during design	Unlikely	Catastrophic	**Medium**
22	High precipitation	Water ingress to critical construction equipment.	Drainage on site to be suitably managed, as specified within the outline EMP	Very unlikely	Minor	Very Low

Risk ID	Climate hazard	Potential climate change risk to Scheme	Embedded or essential mitigation measure	Likelihood of hazard impact	Consequence of hazard impact (should the impact occur)	Evaluation of significance
23	High precipitation	Water ingress to signalling, lighting and other operational electrical equipment.	Water tight cables housed in plastic ducts. No water ingress to underground cables.	Very unlikely	Minor	Very Low
24	High precipitation	Change in ground water level affecting earth pressures and foundation settlement causing possible large ground movement.	To be mitigated through drainage design and ground improvement. Risk likely to be absorbed by conservative assumptions made during design Construction phasing to be considered to mitigate effects of potential settlement on drainage assets i.e., cut-off ditches at embankment toes could be constructed after the settlement period has elapsed.	Very unlikely	Catastrophic	**Medium**
25	High precipitation	Increased risk of debris deposit from water seeping up to the surface through the pavement e.g. calcium sulphate leading to reduced skid resistance.	Weather and weather effects on traffic considered within pavement design	Unlikely	Moderate	Low
26	High precipitation	Construction site flooding during construction phase, excavations flooded and site roads impassable. Safety risk of slips,	Drainage on site to be suitably managed, as specified within the outline EMP. H&S procedures to be further specified within the outline EMP	Unlikely	Moderate	Low

Risk ID	Climate hazard	Potential climate change risk to Scheme	Embedded or essential mitigation measure	Likelihood of hazard impact	Consequence of hazard impact (should the impact occur)	Evaluation of significance
		trips and falls to construction workers.				
27	High precipitation	Increased ground water level in winter may lead to flooding of underpasses.	To be mitigated through drainage design	Unlikely	Minor	Very Low
28	High precipitation	Increased risk of earthworks failure and landslides. Exacerbated by variance between high and low precipitation events and soil moisture levels. (The mark against noise barriers assumes that they are in the form of bunds).	To be mitigated through geotechnical and drainage design Risk likely to be absorbed by conservative assumptions made during design	Unlikely	Catastrophic	**Medium**
29	High precipitation	Reduced capacity of attenuation basins due to sediment build-up.	Risk to be mitigated through the monitoring and maintenance procedures specified for the relevant attenuation basins. Potential use of forebays to trap sediment is to be explored in line with water quality assessment.	As likely as not	Minor	Low
30	High precipitation	Increased risk of debris washing into kerb drainage and/ or swales, blocking them. A blockage may result in flooding and resulting effects.	Mitigated through drainage design and monitoring and maintenance procedures proposed for drainage systems	Unlikely	Moderate	Low

Risk ID	Climate hazard	Potential climate change risk to Scheme	Embedded or essential mitigation measure	Likelihood of hazard impact	Consequence of hazard impact (should the impact occur)	Evaluation of significance
31	High precipitation	Increase stripping rate of the road surfaces	This risk will be managed through the proposed maintenance regimes for road surface.	Unlikely	Minor	Very Low
32	High precipitation	Wetter surface may lead to reduced skid resistance	This risk will be managed through the selection of suitable road surface material as well as through the proposed maintenance regimes for road surface.	Unlikely	Major	**Medium**
33	High precipitation	Increased likelihood of potholing, rutting and cracking from moisture entering and remaining in road surfaces.	This risk will be managed through the proposed maintenance regimes for road surface.	Likely	Minor	**Medium**
34	High precipitation	Increased flow of groundwater causing accelerated weathering effects, weakening the embankment	Risk likely to be absorbed by conservative assumptions made during design	Very unlikely	Major	Low
35	Low precipitation	Potential risk of soil shrinkage impacting foundations, including signal gantries, lighting pylons, bridges, other structures. Possible ground movement (check differential settlement due to different types of foundations)	Ground investigation has been done to understand the existing ground conditions. Mitigation has been designed using this understanding.	Very unlikely	Major	Low
36	Low precipitation	Reduced slope stability and potential earthworks failure during or immediately after summer storm events falling on	Ground investigation has been done to understand the existing ground conditions. Mitigation has been designed using this understanding.	Very unlikely	Catastrophic	**Medium**

Risk ID	Climate hazard	Potential climate change risk to Scheme	Embedded or essential mitigation measure	Likelihood of hazard impact	Consequence of hazard impact (should the impact occur)	Evaluation of significance
		desiccated soils. (The mark against noise barriers assumes that they are in the form of bunds).				
37	Low precipitation	Earthing and thermal/ electrical conductivity issues for high voltage or dynamically loaded cables - in typical ground conditions (i.e. near surface geology and subsoil), ground resistance and electrical and thermal conductivity of earthing arrays and high voltage cables are controlled by a range of factors including the presence of moisture (% water saturation) and temperature. As ground moisture decreases, conductivity also decreases and ground 'resistance' therefore increases.	High voltage cables largely overhead - suspended on pylon.	Very unlikely	Minor	Very Low
38	Low precipitation	Anaerobic conditions may occur, risking die back of sediment collecting species, reducing attenuation basins functional capacity.	Risk to be mitigated through the monitoring and maintenance procedures specified for the relevant attenuation basins.	As likely as not	Minor	Low
39	Extreme winds	Possible blockage of drainage systems due to obstructions and	Mitigated through drainage design and monitoring and maintenance	Very unlikely	Minor	Very Low

Risk ID	Climate hazard	Potential climate change risk to Scheme	Embedded or essential mitigation measure	Likelihood of hazard impact	Consequence of hazard impact (should the impact occur)	Evaluation of significance
		debris from domestic or third party objects.	procedures proposed for drainage systems			
40	Extreme winds	Increased risk of wind-blown debris on the road, affecting road safety.	To be mitigated through appropriate design for barriers (incl. noise barriers), lighting columns and landscape	Unlikely	Major	**Medium**
41	Extreme winds	Increase risk of wind interference with construction equipment and workers, particularly with temporary equipment.	This risk will be mitigated as described in the outline EMP.	Unlikely	Major	**Medium**
42	Extreme winds	Failure of or damage to assets as a result of changes in extreme winds.	Risk sufficiently mitigated within current design standards (structures, lighting columns, noise barriers)	Unlikely	Major	**Medium**
43	Extreme winds	Failure of or damage to assets as a result of changes in extreme winds.	Risk sufficiently mitigated within current design standards	Unlikely	Moderate	Low
44	Lightning	Indirect/ direct damage to roadside equipment lightning strikes damaging trees and vehicles.	Surge protection only available for the LED luminaires locally, no plan for surge protection to the main electrical installation.	Unlikely	Moderate	Low
45	Lightning	Safety risk to construction equipment and workers.	To be mitigated as described in the outline CEMP.	Very unlikely	Major	Low
46	Humidity	Risk of accelerated stripping process.	This risk will be managed through the proposed maintenance regimes for road surface.	Unlikely	Minor	Very Low

Risk ID	Climate hazard	Potential climate change risk to Scheme	Embedded or essential mitigation measure	Likelihood of hazard impact	Consequence of hazard impact (should the impact occur)	Evaluation of significance
47	Humidity	Increase in growing season for weeds- causing damage to road infrastructure.	This risk will be managed through the proposed maintenance regimes.	Very unlikely	Minor	Very Low
48	Insolation	Risk of increased road surface temperatures, causing and increased likelihood of cracking and surfacing rutting.	This risk will be managed through the proposed maintenance regimes for road surface.	Likely	Minor	**Medium**

14.8.76 The following climate change risks are considered moderate and therefore have a significant effect:

a) Decreased viscosity in head leads to greater spreading of diesel in a smaller timeframe. Higher temperatures and increased number of hot, dry days increase the likelihood of ignition of this diesel leading to road and forest fires.

b) Increased pore water pressure in embankments/ cuttings.

c) Increased erosion at toe of embankment.

d) Change in ground water level affecting earth pressures and foundation settlement causing possible large ground movement.

e) Increased risk of earthworks failure and landslides. Exacerbated by variance between high and low precipitation events and soil moisture levels. (The mark against noise barriers assumes that they are in the form of bunds).

f) Wetter surface may lead to reduced skid resistance

g) Increased likelihood of potholing, rutting and cracking from moisture entering and remaining in road surfaces.

h) Reduced slope stability and potential earthworks failure during or immediately after summer storm events falling on desiccated soils. (The mark against noise barriers assumes that they are in the form of bunds).

i) Increased risk of wind-blown debris on the road, affecting road safety.

j) Increase risk of wind interference with construction equipment and workers, particularly with temporary equipment.

k) Failure of or damage to assets as a result of changes in extreme winds.

l) Risk of increased road surface temperatures, causing and increased likelihood of cracking and surfacing rutting.

14.8.77 These climate risks will be taken forward into detailed design in order to reduce their likelihood or consequence rating, reducing their risk rating to below medium.

Sensitivity test of the Scheme's vulnerable safety critical features against H++ climate scenarios

14.8.78 This section reports a sensitivity test of the vulnerable safety critical features of the Scheme against the H++ climate scenarios[54] to assess the extent to which such features would be

affected by more radical changes to the climate beyond that projected in UKCP18. Safety critical features that are vulnerable to climate change have been identified for the Scheme to include:

a) Drainage
b) Earthworks

Table 14-23: Sensitivity test of the Scheme's vulnerable safety critical features against the H++ climate scenarios

Hazard (and scenario)	H++ (or L--)[55] future climate scenario description	Banwell Bypass vulnerable safety critical feature	
		Drainage	Earthworks
Heat waves (H++)	Annual average summer maximum temperatures exceeding 30°C over most of the UK and 34°C over much of central and southern England. Hottest days would exceed 40°C in some locations, with 48°C being reached in extreme cases.	**Risks/ Consequences** No vulnerable features identified **Adaptation measures** N/A	**Risks/ Consequences** An increase in average summer maximum temperatures would result in an increased frequency of soils and sub soil desiccation, leading to surface erosion if followed by increases in extreme precipitation. **Adaptation measures** The increase in average maximum temperatures would need to be considered for soil slopes as part the detailed design.
Low rainfall (H++)	A 6-month duration summer drought with rainfall deficits of up to 60% below the long-term average (1900-1999). Longer dry periods spanning several years with rainfall deficits of up to 20% below the long-term average (1900-1999) across all of England and Wales, similar to the most severe and extensive long droughts in the historical record.	**Risks/ Consequences** No vulnerable features identified **Adaptation measures** N/A	**Risks/ Consequences** Extensive drought conditions could impact on the growth of vegetation on soil slopes, which would otherwise provide erosion protection. This combined with soil and sub soil desiccation could lead to surface erosion over time. **Adaptation measures** Erosion management would need to be considered as part of the design and maintenance of the Scheme.
Low river flows (H++)	A 40-70% reduction in 'low flows' (Q95) in England and Wales in a single summer. For multi-season droughts, including 2 summers, a 20 to 60% reduction in low flows in England and Wales.	**Risks** Highway assets: low Operation: low **Consequences**	**Risks/ Consequences** No vulnerable features identified **Adaptation measures** N/A

Hazard (and scenario)	H++ (or L--)[55] future climate scenario description	Banwell Bypass vulnerable safety critical feature	
		Drainage	**Earthworks**
		Pollution - With a reduction in mean precipitation, drainage dilution levels would be more concentrated due to receiving water courses carrying less water. However, this category and the projections apply to Main River basins and large catchments. This is not applicable to the Scheme where there are none. **Adaptation measures** N/A	
High rainfall (H++)	A 70%-100% increase in winter rainfall (Dec to Feb) in a single winter (from a 1961-1990 baseline). An up to five-fold increase in frequency and 60% to 80% increase in heavy daily and sub-daily rainfall depths, for both summer and winter events (all year round).	**Risks affect:** • Maintenance, operation and management of existing assets • Design and Construction of new and replacement assets **Consequences** • Congestion and accidents - An increased risk of flooding within the highway would impact the performance of the network, including congestion and incidents (safety). • Third party flooding - There are risks associated with flooding of third party land from the network. • Cross asset deterioration - Flooding increases the rate of deterioration of other assets. In particular geotechnical assets and pavement assets. **Adaptation measures** • The drainage design considers events beyond	**Risks/ Consequences** • An increase in winter precipitation could adversely impact the stability of any proposed earthworks, including cutting slopes and embankments, through increased groundwater levels and porewater pressures. • Increased rainfall would also impact the stability of existing engineered and natural slopes (e.g. slopes to the north and south of the alignment along Crickley Hill) that could impact the Scheme. • Increased rainfall would also result in increased groundwater flows emerging from springs. This could result in internal erosion of earthwork embankments. **Adaptation measures** • Earthworks stability would need to be considered at the detailed design stage through incorporation of appropriate measures.

Hazard (and scenario)	H++ (or L--)[55] future climate scenario description	Banwell Bypass vulnerable safety critical feature	
		Drainage	Earthworks
		the performance required by standards - this is done explicitly for events up to Q100+40%cc. However adaptation measures for the H++ scenarios would not form part of the Scheme design. • Carriageway collection systems and water levels in drainage systems are designed for synthetic design storms of Q5+20%cc – this is the designed level of service for operations. If the +70% cc factor is applied these interruptions would be more frequent than the specified level of service. The design already includes the facility to passively manage the exceedance events >Q5+20% so that the duration of closures is minimised. However, adaptation to attain the same level of service for operations would require a change to the design of the physical infrastructure – circa 15-20% larger swales, pipes, more outlets etc. This could be implemented at initial construction (precautionary) or retrofitted at a later time if required. • There will always be operational interruptions due to unplanned events such as blockages. Potential adaptations could involve enhanced maintenance and inspection regimes, enhanced response planning and monitoring (enabled by new technology), so that resultant closures are minimised. Adaptation might also include additional redundancies in the physical infrastructure, either at construction	• The stability of existing slopes, particularly where existing landslips have been identified, would need to be considered as part of the detailed design, with appropriate measures adopted taking into account any climate change aspects. • Internal erosion of earthwork embankments would need to be considered as part of the earthworks and drainage design at detailed design stage.

Hazard (and scenario)	H++ (or L--)[55] future climate scenario description	Banwell Bypass vulnerable safety critical feature	
		Drainage	Earthworks
		(precautionary) or retrofitted at a later time if required.	
High river flows (H++)	A 60% to 120% increase in peak flows at the 'lower end' of the H++ scenarios for some regions in England and Wales. The upper limit for any region is a 290% increase in peak flows (1961-1990 baseline). The scenarios are based on the average response of "Enhanced-high" catchments, which are particularly sensitive to increases in rainfall.	**Risks** Watercourses affected by the Scheme are serving relatively small catchments so direct rainfall allowances apply (see "High Rainfall"). **Consequences** Cross asset deterioration - Higher flows in watercourse may accelerate erosion/scour and impact on structures adjacent to watercourses. However, this category and the projections apply to Main River basins and large catchments. This is not applicable to the Scheme as there are no Main Rivers. **Adaptation measures** N/A	**Risks/ Consequences** The realigned tributary of Norman's Brook is positioned along the southern toe of the proposed earthworks embankment on Crickley Hill. Increased river flows, resulting in flooding, could lead to erosion of the earthworks embankment. **Adaptation measures** This would need to be considered as part of the detailed design.
Windstorms (H++)	A 50-80% increase in the number of days per year with strong winds over the UK (1975-2005 baseline). A strong wind day is defined as one where the daily mean wind speed at 850 hPa, averaged over the UK (8W-2E, 50N-60N), is greater than the 99th percentile of the historical simulations.	**Risks/ Consequences** N/A - No vulnerable features identified. **Adaptation measures** N/A	**Risks/ Consequences** No vulnerable features identified. **Adaptation measures** N/A
Cold snaps (L--)	In the 2020s, UK average winter temperatures (December, January and February) of 0.3°C and for the 2080s, UK average winter temperatures would be around -4°C.	**Risks** N/A - No vulnerable features identified.	**Risks/ Consequences** The reduction in average winter temperatures could impact on the local stability of rock slopes through increased freeze-thaw action resulting in increased rock fall events.

Hazard (and scenario)	H++ (or L--)[55] future climate scenario description	Banwell Bypass vulnerable safety critical feature	
		Drainage	Earthworks
	In the 2020s, UK average temperatures on the coldest day would be -7oC in some locations. UK average temperature of the coldest day would be around -11°C.	**Adaptation measures** N/A	**Adaptation measures** This would need to be considered as part of the detailed design and maintenance of the Scheme.

14.8.79 The sensitivity test of the vulnerable safety critical features against the H++ climate scenarios at this stage in the design indicate that such features would be significantly affected by more radical changes to the climate beyond that projected in UKCP18. The extreme climate scenarios will be considered through detailed design and maintenance to ensure the Scheme is designed with resilience to climate change, turning this significance of effect to insignificant.

14.9 Proposed Mitigation and Enhancement Measures

GHG emissions

14.9.1 No further GHG emission mitigation is proposed. It is anticipated that design mitigation will continue to evolve after this assessment as the design evolves and national policy matures.

Climate Change Resilience

14.9.2 No further climate change resilience mitigation is proposed. As significant impacts remain, these will be addressed at the next stage of detailed design.

14.10 Residual Environmental Effects (Following Mitigation)

14.10.1 The Scheme would result in an increase of GHG emissions during both the construction phase and operational phase. Emissions from construction are mostly associated with the embodied carbon within construction materials, and emissions from operation are for the most part are associated with traffic. It is considered that these emissions would not result in a significant residual effect.

14.10.2 The Scheme and the mitigation measures associated with GHG emissions outlined in this chapter are based upon the current regulatory framework and technological readiness. It should also be noted that the emissions from operational traffic are a conservative estimate, which cannot account for changes in

technology or electric vehicle uptake past 2050 due to the limitations of the traffic model used. As such, it is expected that the emissions from traffic over the operational phase would reduce as the EV and technology context continues to improve carbon from vehicles.

14.10.3 This is further supported by the Government's Transport Decarbonisation Plan objectives outlined in Section 14.3.18 and WECA's objectives within the Climate and Ecological Strategy and Action Plan:

a) Reducing the number of car trips and freight journeys, promoting mode shift to sustainable alternatives
b) Increasing cycling and walking
c) Increasing uptake of low carbon vehicles including electric vehicles
d) Increasing the uptake of public transport

14.10.4 Actions outlined in this strategy include:

a) Electrification and decarbonisation of their fleet vehicles
b) Delivery of liveable neighbourhoods
c) Implementing clean air zones e.g. Bath and Bristol
d) Delivery of local walking, wheeling & cycling programmes

14.10.5 Although these targets are outside the scope of this ES chapter, it indicates that the emissions recorded for the Scheme will be an overestimation should WECA implement measures to achieve these targets across the strategic road network.

14.10.6 The CCR assessment has concluded that there are residual effects following embedded and essential mitigation, and following the H++ assessment, there remains some risk that will need to be addressed in detailed design.

14.11 Monitoring

GHG emissions

14.11.1 In line with the methodology in DMRB LA 114, quarterly GHG emission returns required on projects during the construction and operation stages shall be reported in accordance with the Overseeing Organisation's requirements. The methodology for

collecting and recording this data is outlined in ES Volume 3 - Appendix 14.D - Carbon Management Plan. Actual data provided for the GHG returns shall be evaluated to inform any ongoing monitoring of GHG emissions and also feed back into future assessment of projects during design development and planning approval.

14.11.2 The Carbon Management Workshops will continue throughout detailed design, striving to reduce carbon emissions further. The design decisions explored and implemented from these workshops will be recorded and monitored.

Climate Change Resilience

14.11.3 Once the Scheme is operational, asset data shall be managed, maintained and monitored to ensure the project design is operating as intended. Asset management measures can evolve (adaptive management) once the asset is operational as an appropriate response to climate impacts.

14.11.4 Where a design issue is identified, an assessment should be made to determine if corrective action is required, i.e. drainage amendments to rectify a flooding hotspot that was not anticipated at design stage.

14.12 Summary and Conclusions

GHG assessment

14.12.1 The Scheme is compliant with all relevant legislation and policy for climate change outlined in Section 14.3 Legislative and Policy Framework. The GHG emissions caused by the Scheme have been assessed against the ability of the UK Government to meet its legislated carbon budgets and the effect is considered to be not significant. The assessment is inherently cumulative and so the Scheme, together with other committed development that has been included within the traffic model on which this assessment is based, also does not result in a significant effect. In addition to assessing the impacts of the Scheme against national statutory targets, it is noted that there are local and regional aspirations for transport to be carbon neutral by 2030. Whilst it is not a statutory requirement to consider the impact of the Scheme against these local and regional aspirations, these

aspirations have been considered within this chapter. It has been concluded that the Scheme is unlikely to have a material impact on the ability of WECA and NSC to meet their regional and local aims, when considered alongside wider initiatives that are required to be brought forward in order to reduce user carbon emissions more generally.

14.12.2 The Transport Decarbonisation Plan includes a range of non-planning policies which will help to reduce carbon emissions over the transport network as a whole over time (including polices to decarbonise vehicles and radically reduce vehicle emissions) and help to ensure that carbon reduction commitments are met. Beyond transport, Government's wider policies around net zero such as 'The Net Zero Strategy: Build Back Greener' ("Net Zero Strategy"), published by Government in sets out policies and proposals for decarbonising all sectors of the UK economy to meet the net zero target by 2050. Interventions within these documents have not been considered. The Scheme's carbon impact outlined in this ES chapter is therefore a conservative estimate which should improve as Government policy takes effect.

CCR Assessment

14.12.3 It is considered that at this stage, there remains medium climate change risks to the Scheme, as seen in Section 14.8 Predicted Environmental Effects .76 and 14.8.78, resulting in a significant effect.

14.13 References

14.1.1 [1] Highways England, Transport Scotland, Welsh Government, and Department for Infrastructure, "Design Manual for Roads and Bridges Sustainability and Environment Appraisal LA 114 Climate Revision 0," 2019

14.1.2 [2] Department of Transport (2014) National Policy Statement for National Networks. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/387222/npsnn-print.pdf

14.1.3 [3] UK Government (2021) National Planning Policy Framework. Available at: https://www.gov.uk/government/publications/national-planning-policy-framework--2

14.1.4 [4] GHG emissions are reported in this chapter in tonnes of carbon dioxide equivalents (tCO_2e). This measure considers the six Kyoto Protocol gases: Carbon dioxide (CO_2); Methane (CH_4); Nitrous oxide (N_2O); Sulphur hexafluoride (SF_6); Hydrofluorocarbons (HFCs); and Perfluorocarbons (PFCs).

14.1.5 [5] UK Government, Climate Change Act 2008. Statute Law Database, 2008

14.1.6 [6] UK Government, The Climate Change Act 2008 (2050 Target Amendment) Order 2019. Queen's Printer of Acts of Parliament, 2019

14.1.7 [7] Committee on Climate Change, "Net Zero - The UK's contribution to stopping global warming," 2019. [Online]. Available: https://www.theccc.org.uk/publication/net-zero-the-uks-contribution-to-stopping-global-warming/

14.1.8 [8] UK Government, The Carbon Budgets Order 2009. Queen's Printer of Acts of Parliament, 2009

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14.1.10 [10] UK Government, The Carbon Budget Order 2016. Queen's Printer of Acts of Parliament, 2016

14.1.11 [11] UK Government, The Carbon Budget Order 2021. Queen's Printer of Acts of Parliament, 2021

14.1.12 [12] UK Government, "UK Climate Change Risk Assessment 2017 (Policy Paper) Presented to Parliament pursuant to Section 56 of the Climate Change Act 2008," 2017

14.1.13 [13] The third UK Climate Change Risk Assessment is due in 2022

14.1.14 [14] Committee on Climate Change, "UK Climate Change Risk Assessment 2017. Synthesis Report," pp. 1–86, 2016

14.1.15 [15] *This chapter refers to 'carbon' as including all main greenhouse gases, as covered* by the Kyoto Protocol. GHG emissions are converted into tonnes of carbon dioxide equivalent (tCO_2e), a calculation which normalizes the global warming potential of the main GHG into one measure, based on the global warming potential of CO_2.

14.1.16 [16] The RCP8.5 global warming scenario represents a very high baseline emission scenario, representing the 90th percentile of no-policy baseline scenarios available at the time. '8.5' represents 8.5 watts per metre squared, which is a measure of the end-of-century radiative forcing increase relative to pre-industrial conditions. The four RCP scenarios include "one mitigation scenario leading to a very low forcing level (RCP2.6), two medium stabilisation scenarios (RCP4.5/RCP6.0) and one very high baseline emission scenarios (RCP8.5)". The high emissions baseline scenario is representative of the trajectory that global emissions have been on.

14.1.17 [17] H++ scenarios are a set of plausible 'high-end' climate change scenarios which are typically extreme climate change scenarios on the margins or outside of the 10th to 90th percentile range presented in the UK Climate Projections 2009 (UKCP09). They cover the following climate hazards: heat waves, cold snaps, low and high rainfall, droughts, floods and windstorms. Note: the UKCP18 project will not be producing an updated H++ scenario and so the H++ scenario developed from UKCP09 remains current and applicable. The H++ scenarios are available online: https://www.theccc.org.uk/publication/met-office-for-the-asc-developing-h-climate-change-scenarios/

14.1.18 [18] Department for Environment Food and Rural Affairs, “The National Adaptation Programme and the Third Strategy for Climate Adaptation Reporting Making the country resilient to a changing climate,” 2018

14.1.19 [19] UK Government, “The Clean Growth Strategy Leading the way to a low carbon future,” 2017

14.1.20 [20] Department for Business, Energy & Industrial Strategy, “Net Zero Strategy: Build Back Greener,” 2018

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14.1.24 [24] North Somerset Council (2017) Core Strategy (https://www.n-somerset.gov.uk/sites/default/files/2020-07/core%20strategy.pdf)

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14.1.26 [26] North Somerset Council (2020) Climate change emergency – Baseline emissions report. Abilable at: https://www.n-somerset.gov.uk/sites/default/files/2020-11/Climate%20Emergency%20Baseline%20Report%20-%20July2020_0.pdf

14.1.27 [27] West of England (202) Climate and Ecological Strategy and Action Plan. Available at: https://westofengland-ca.moderngov.co.uk/documents/s4584/CEAP.pdf

14.1.28 [28] Highways England, Transport Scotland, Welsh Government, and Department for Infrastructure, “Design Manual for Roads and Bridges Sustainability and Environment Appraisal LA 114 Climate Revision 0” 2019

14.1.29 [29] Highways England, Transport Scotland, Welsh Government, and Department for Infrastructure, “Design Manual for Roads and Bridges LA 105 Air quality” 2019

14.1.30 [30] Highways England, Transport Scotland, Welsh Government, and Department for Infrastructure, “Design Manual for Roads and Bridges “GG 103 Introduction and general requirements for sustainable development and design”,2019

14.1.31 [31] British Standards Institution, “PAS 2080:2016 Carbon Management in Infrastructure,” 2016

14.1.32 [32] RICS (2017) *RICS professional standards and guidance, UK: Whole life carbon assessment for the built environment*. Available online: https://www.rics.org/globalassets/rics-website/media/upholding-professional-standards/sector-standards/building-surveying/whole-life-carbon-assessment-for-the-built-environment-1st-edition-rics.pdf

14.1.33 [33] UK Government, “TAG unit A3 environmental impact appraisal,” 2019. [Online]. Available online: https://www.gov.uk/government/publications/tag-unit-a3-environmental-impact-appraisal.

14.1.34 [34] Highways England, Transport Scotland, Welsh Government, and Department for Infrastructure, “Design Manual for Roads and Bridges Sustainability and Environment Appraisal LA 114 Climate Revision 0,” 2019

14.1.35 [35] The Association of Directors of Environment, Economy, Planning & Transport (ADEPT) Preparing for a changing climate: Good Practice Guidance for Local Governance 2019

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[39] Sources are scoped out by following the DMRB guidance: "are construction GHG emissions (or GHG-emitting activity), compared to the baseline scenario (i.e. when compared to GHG emissions and energy use associated with existing maintenance activities), increasing by >1%?". As these emission sources were not considered to increase the carbon from the Do-minimum by more than 1%, they have been scoped out.

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14.1.44 [45] The Met Office provides information on observed and future climate change relative to the baseline period of 1961-1990, based on the latest scientific understanding UKCP18. UKCP provides probabilistic projections for the whole of the UK, at

regional level and at local level.

14.1.45 [46] The Regional (12 kilometre) projections are downscaled versions of the Global (60 kilometre) projections providing information on local climate effects.

14.1.46 [47] 12 regional models are used in UKCP18 to project the variables for extreme weather events. The min. (minimum) and max. (maximum) values shown here are the minimum projection from the 12 models and maximum projection from the 12 models for the given parameter.

14.1.47 [48] H++ scenarios are a set of plausible 'high-end' climate change scenarios which are typically extreme climate change scenarios on the margins or outside of the 10th to 90th percentile range presented in the UK Climate Projections 2009 (UKCP09). They cover the following climate hazards: heat waves, cold snaps, low and high rainfall, droughts, floods and windstorms. Note: the UKCP18 project will not be producing an updated H++ scenario and so the H++ scenario developed from UKCP09 remains current and applicable. The H++ scenarios are available online: https://www.theccc.org.uk/publication/met-office-for-the-asc-developing-h-climate-change-scenarios/

14.1.48 49 The Met Office provides information on observed and future climate change relative to the baseline period of 1961-1990, based on the latest scientific understanding UKCP18. UKCP provides probabilistic projections for the whole of the UK, at regional level and at local level.

14.1.49 [50] H++ scenarios are a set of plausible 'high-end' climate change scenarios which are typically extreme climate change scenarios on the margins or outside of the 10th to 90th percentile range presented in the UK Climate Projections 2009 (UKCP09). They cover the following climate hazards: heat waves, cold snaps, low and high rainfall, droughts, floods and windstorms. Note: the UKCP18 project will not be producing an updated H++ scenario and so the H++ scenario developed from UKCP09 remains current and applicable. The H++ scenarios are available online: https://www.theccc.org.uk/publication/met-office-for-the-asc-developing-h-climate-change-scenarios/

14.1.50 [51] The RCP8.5 global warming scenario represents a very high

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

14.1.51 [52] 2024 represents the opening year (first year of operation) and 2039 represents the design (future) assessment year, 15 years after opening. For the ES, the traffic models are based on an opening year of 2024 and design (future) assessment year of 2039 (15 years after opening).

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14.1.53 [54] H++ scenarios are a set of plausible 'high-end' climate change scenarios which are typically extreme climate change scenarios on the margins or outside of the 10th to 90th percentile range presented in the UK Climate Projections 2009 (UKCP09). They cover the following climate hazards: heat waves, cold snaps, low and high rainfall, droughts, floods and windstorms. Note: the UKCP18 project will not be producing an updated H++ scenario and so the H++ scenario developed from UKCP09 remains current and applicable. The H++ scenarios are available online: https://www.theccc.org.uk/publication/met-office-for-the-asc-developing-h-climate-change-scenarios/

14.1.54 [55] Note the term L-- is used specifically for the 'cold snap' scenario to emphasise that it is at the opposite end of the scale to the extreme warm summer temperatures in H++ and linked to Low emissions.