20. Climate

Summary

This chapter considers the effects of the proposed scheme on climate, resulting from estimated changes in emissions of greenhouse gases (GHGs), as well as the potential impacts of future climate change on the proposed scheme. The assessment has been undertaken in accordance with DMRB LA 114 and the Scotland National Application Annex (Highways England et al., 2021).

The proposed scheme is expected to result in an increase to GHG emissions both during its construction and operation phases because of the required consumption of materials, fuel and energy, as well as the disturbance or removal of carbon stores such as soil and vegetation.

The significance of the proposed scheme's potential effects on climate was assessed using professional judgement and based on the perceived likelihood of the scheme affecting either the UK or the Scottish Government's ability to meet their respective carbon emissions reduction targets. Based on a comparison of the estimated change in GHG emission as a result of the proposed scheme with the relevant UK carbon budgets and Scottish carbon reduction targets, the scheme's effect on climate is assessed to be not significant. Despite this conclusion, however, a number of measures are proposed in order to further mitigate the increase in GHG emissions as a result of the proposed scheme going forward.

The scheme will potentially be affected by climate change related impacts during both its construction and operation (e.g. as a result of increased rainfall during winter and more intense rainfall events). Mitigation measures embedded within the scheme design, as well as the application of standard good practice mitigation measures during construction and maintenance operations, are considered likely to reduce the risk of disruption during the construction phase, as well as climate related impacts on the scheme during its operation. With these mitigation measures in place, the effects of these impacts on climate are assessed as not significant.

20.1 Introduction

20.1.1 This chapter presents the results of the DMRB Stage 3 assessment of the effects of the proposed scheme on climate.

20.1.2 The assessment has been produced with reference to DMRB LA 114 Climate (Highways England et al., 2021), which indicates that a climate assessment should consider both:

- the potential effects of the proposed scheme on climate, (i.e. the greenhouse gas (GHG) emissions associated with the construction and operation of the proposed scheme); and

- the vulnerability of the proposed scheme to climate change (i.e. whether anticipated changes to climatic conditions and/or the frequency of extreme weather events are likely to have significant adverse effects on the project (or elements of the project) during construction and/or operation).

20.1.3 The assessment is supported by the following appendices and figures presented in Volume 2 and Volume 3 respectively of this report:

- Appendix A20.1: Vulnerability to Climate Change;
- Appendix A20.2: GHG emissions; and
- Figure 20.1: Road User GHG Study Area.

20.1.4 The assessment of effects from the proposed scheme on climate and vice versa, has been informed by relevant information collated by other environmental factors, notably Chapter 12 (Biodiversity), Chapter 10 (Landscape) and Chapter 14 (Material Assets and Waste), for information relating to GHG emissions and carbon sequestration; and Chapter 13 (Geology and Soils) and Chapter 19 (Road Drainage and the Water Environment) for information relating to the potential vulnerability of the scheme to climate change.

Legislative and Policy Background

20.1.5 The key legislation, policy, plans and statutory guidance influencing the design, construction and assessment of the proposed scheme with regard to climate are identified in this section.

International Level

20.1.6 In December 2015, the Paris Agreement, a global climate agreement, was adopted. The Paris Agreement was ratified and entered into force in November 2016. The central aim of the Paris Agreement is to strengthen the global response to the threat of climate change by keeping the rise in average global temperature this century well below 2 degrees Celsius above pre-industrial levels, and to pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius. The UK was one of the 160 countries who signed the agreement. The UK's response to meeting its commitments under the Paris Agreement resulted in the Climate Change Act 2008 (2050 Target Amendment) Order 2019, which set a 'net zero' carbon emissions target by 2050 and a Nationally Determined Contribution by 2030, as detailed in the following paragraphs.

20.1.7 The Paris Agreement covers seven GHGs that directly contribute to climate change, namely:

- Carbon dioxide (CO_2)
- Methane (CH_4)
- Nitrous oxide (N_2O)
- Hydrofluorocarbons (HFCs)
- Perfluorocarbons (PFCs)
- Nitrogen trifluoride (NF_3)
- Sulphur hexafluoride (SF_6).

20.1.8 As each of these GHGs have a different Global Warming Potential (GWP), emissions of GHGs have been expressed throughout this report as emissions of carbon dioxide equivalent (CO_2e) i.e. the equivalent amount of CO_2 with the same GWP.

National Level

20.1.9 In December 2020, the UK communicated its 2030 Nationally Determined Contribution (NDC) under the Paris Agreement to the United Nations Framework Convention on Climate Change (UNFCCC). The 2030 NDC, which was updated in September 2022, commits the UK to reducing economy-wide GHG emissions by at least 68% by 2030, compared to 1990 levels. In January 2025, the UK communicated its 2035 NDC under the Paris Agreement to the UNFCCC, which commits the UK to reducing economy-wide GHG emissions by at least 81% by 2035, compared to 1990 levels.

20.1.10 Through the Climate Change Act 2008, as amended by the 2050 Target Amendment in June 2019, the UK Government has also committed to:

- reduce GHG emissions by at least 100% of 1990 levels (net zero) by 2050; and
- contribute to global emission reductions, to limit global temperature rise to as little as possible above 2°C.

20.1.11 To meet these targets, the UK Government has set five-yearly carbon budgets, which currently run until 2037. They restrict the amount of GHG the UK can legally emit in a five-year period. The carbon budgets during each period and the corresponding reduction compared to 1990 levels are presented in Table 20.1.

Table 20.1: UK Government Carbon Budgets

Carbon Budget Period	Carbon Budget ($MtCO_2e$)	Reduction below 1990 levels
4th Carbon Budget (2023 to 2027)	1,950	51% by 2025
5th Carbon Budget (2028 to 2032)	1,725	57% by 2030
6th Carbon Budget (2033 to 2037)	965	78% by 2035

20.1.12 In February 2025, the Climate Change Committee advised the UK government to set the 7th Carbon Budget at 535 $MtCO_2e$ for the period 2038-2042, aiming for an 87% reduction in emissions compared to 1990 levels by 2040. Whilst this recommendation has yet to be adopted, and therefore has not been considered within this assessment, the UK government must set the 7th Carbon Budget by June 2026.

20.1.13 The Climate Change (Scotland) Act 2009 established a framework for Scotland to achieve its long-term goals of reducing GHG emissions by at least 80% by 2050. An interim target of a 42% reduction by 2020 was also set. The original 2050 goal was amended through the Climate Change (Emissions Reduction Targets) (Scotland) Act 2019 that was passed in September 2019, which set a 'net-zero emissions target' for all GHG emissions by 2045 (Scottish

Government, 2019b). The interim targets were amended to become 56% by 2020, 75% by 2030 and 90% by 2040.

20.1.14 However, in March 2024, the Climate Change Committee concluded that it was unlikely that the Scottish Government would meet its statutory 2030 goal to reduce emissions by 75%. This conclusion was accepted by the Scottish Government. In response, the Scottish Government intends to bring forward expedited legislation to introduce a target approach based on five-yearly carbon budgets, whilst retaining the 2045 net zero target. Until such time as these carbon budgets are defined and legislated, and for the purposes of this assessment, it is assumed that the interim targets are still applicable.

20.1.15 In the context of the Climate Change (Scotland) Act 2009, Scottish Ministers are obliged to lay a report in Parliament setting out their proposals and policies for meeting annual emissions reduction targets. This Climate Change Plan (CCP) is the Scottish Government's third Report on Proposals and Policies (RPP3) for meeting its climate change targets for the period 2018–2032 (Scottish Government, 2018). In RPP3, special reference is made to Transport Scotland and the related policies and plans.

20.1.16 In December 2020, the Scottish Government released the Climate Change Plan 2018-2032 update, which recognised the enormous challenges caused by the COVID-19 pandemic and the effect these could have on the ability of the Scottish Government to meet its GHG emissions reduction targets. The update makes clear, however, that the Scottish Government remains absolutely committed to ending Scotland's contribution to climate change, despite these challenges. As such, it aims for a 'green recovery' that captures opportunities to transition towards 'net zero' through the creation of green jobs, by developing sustainability skills, improving wellbeing and addressing inequalities (Scottish Government, 2020a).

20.1.17 The CCP update includes commitments to reduce car kilometres by 20% by 2030, to phase out the 'need' for new petrol and diesel cars and vans by 2030 and new petrol and light commercial vehicles within the public sector fleet by 2025. Such activities are likely to result in a substantial reduction in Scottish road traffic related GHG emissions over time.

20.1.18 The CCP update presents proposals and policies to meet Scotland's annual emissions reduction targets to 2032. This is done through a sectoral approach, and each sector has an 'emissions envelope'. The seven sectors for which 'emissions envelopes' have been estimated are: electricity; buildings; transport; industry; waste; land use, land use change and forestry (LULUCF); and agriculture (as illustrated in Diagram 1 below).

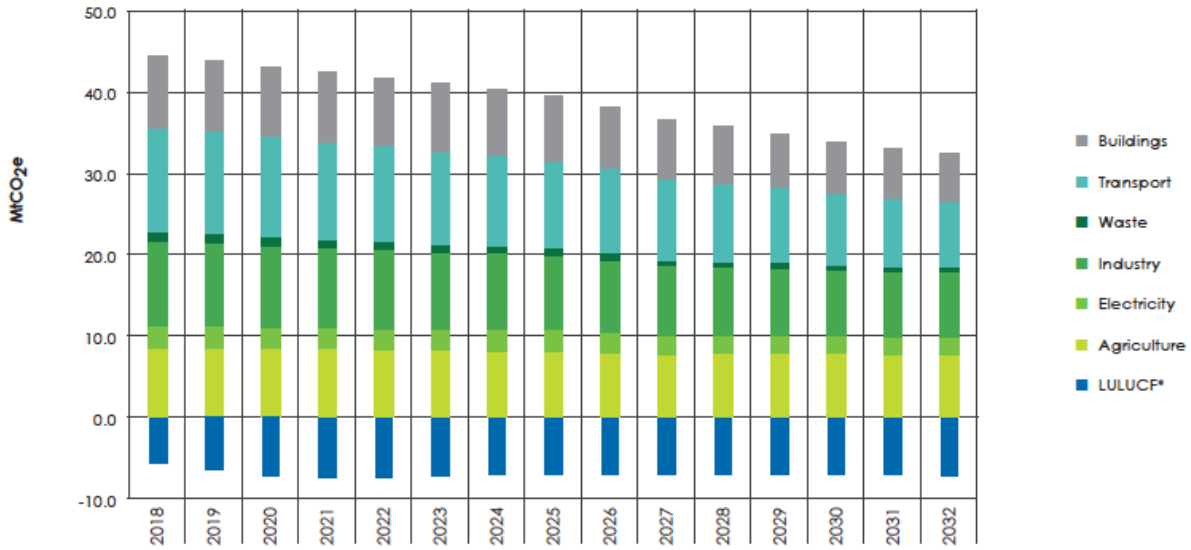

Diagram 1: RPP3 Sectoral Emissions Envelopes (Scottish Government, 2018)

20.1.19 The second Scottish Climate Change Adaptation Programme 2019 – 2024 (SCCAP) (Scottish Government, 2019a) sets out policies and proposals to prepare Scotland for the challenges that will be faced as climate continues to change in the decades ahead. The SCCAP is a requirement of the Climate Change (Scotland) Act 2009 and addresses the risks set out in the UK's second Climate Change Risk Assessment (CCRA2), published under Section 56 of the UK Climate Change Act 2008 (Department for Environment, Food and Rural Affairs (Defra), 2017). A Scottish National Adaptation Plan (2024 – 2029) (Scottish Government, 2024a) has since been produced in response to UK CCRA3 (Defra, 2022), which includes policy proposals for adaptation and resilience to be embedded across trunk road transport networks, supported by the Transport Scotland adaptation strategy (Transport Scotland's Approach to Climate Change Adaptation & Resilience (Transport Scotland, 2023)).

20.1.20 National Planning Framework 4 (NPF4) (Scottish Government, 2023) was published in February 2023 and provides a spatial planning response to the global climate emergency up to 2050. As per the NPF4 document, the proposed key objective of NPF4 is to ensure planning policy results in spatial and land use change that facilitates Scotland's ambition to have 'net-zero' emissions by 2045 and meet other statutory emissions reduction targets, whilst also supporting communities and businesses in making the necessary changes to meet the targets. One of the main issues to be considered is the policy criteria needed to ensure that new development, including transport and infrastructure, contribute as far as possible to meeting emission reduction targets.

20.1.21 NPF4 includes key policies focused on climate. Policy 1 Tackling the climate and nature crisis states:

'When considering all development proposals significant weight will be given to the global climate and nature crises'

20.1.22 Policy 2 Climate mitigation and adaptation states:

(a) 'Development proposals will be sited and designed to minimise lifecycle greenhouse gas emissions as far as possible

(b) Development proposals will be sited and designed to adapt to current and future risks from climate change

(c) Development proposals to retrofit measures to existing developments that reduce emissions or support adaptation to climate change will be supported.'

20.1.23 In February 2020, the Scottish Government released its latest Environment Strategy. In the strategy it is stated that:

'By 2045: By restoring nature and ending Scotland's contribution to climate change, our country is transformed for the better - helping to secure the wellbeing of our people and planet for generations to come' (Scottish Government, 2020b).

Local Level

20.1.24 Perth & Kinross Council (PKC), in line with the Climate Change (Scotland) Act 2009, has undertaken Climate Change commitments by signing Scotland's Climate Change Declaration (SCCD) in 2007. In becoming a signatory of the SCCD, PKC has made a commitment to:

- provide effective leadership, governance and management on climate change;
- reduce the local authority's own 'corporate' greenhouse gas emissions;
- reduce emissions in the local authority area;
- assess and adapt to the risk of climate change impacts; and
- develop effective partnership working and climate change communications, including annual statement of plans, activities and achievements.

20.1.25 PKC's Community Plan 2022 – 2032 (PKC, 2022a), Corporate Plan 2022/23 – 2027/28 (PKC, 2022b) and Local Development Plan (PKC, 2019), all include aspirations to address climate change through mitigation (reducing emissions) and adaptation (improving resilience to the impacts of climate change).

20.1.26 In June 2019, PKC acknowledged its responsibilities relating to climate change by unanimously passing a motion, which committed the Council to lead by example in accelerating the transformational change required to address the climate emergency. The Chief Executive was tasked with setting out a route map to deliver, through co-production with citizens and other stakeholders, a low carbon Perth & Kinross. In December 2021, PKC adopted a Climate Change Strategy & Action Plan, which sets out how Perth and Kinross will reach net zero carbon emissions by 2045 (PKC, 2021).

Transport Scotland

20.1.27 The Road Asset Management Plan for Scottish Trunk Roads - RAMP (Transport Scotland, 2016) identifies Environmental Sustainability as one of its main objectives and specifically commits

'…to protect the environment by minimising carbon emissions and promote the use of sustainable materials used on road maintenance work'. Furthermore, it identifies weather related disruption due to climate change as one of the major risks in network management.

20.1.28 Transport Scotland's Approach to Climate Change Adaptation & Resilience (ACCAR), outlines the key climate risks affecting Scotland's transport system and sets out a Strategic Outcome for '*Trunk Roads which are well adapted and resilient to the current, projected and unexpected impacts of climate change*' (Transport Scotland, 2023).

20.2 Approach and Methods

Scope and Guidance

20.2.1 The Climate effects assessment has been prepared in accordance with DMRB LA 114, and associated Scotland National Application Annex (NAA) (Highways England et al., 2021). This chapter sets out the requirements for assessing and reporting the effect of GHGs from construction, operation and maintenance of motorway and all-purpose trunk road projects on climate, and the effects of climate on highways (climate change resilience and adaptation) during both construction and operation.

GHG emissions

20.2.2 The potential GHG emissions sources scoped in/out of this assessment are summarised in Table 20.2, for each stage of the proposed scheme (i.e. construction, operation and end of life). GHG emission sources have been further broken down by the life-cycle sub-stages defined in PAS 2080:2023 'Carbon Management in Buildings and Infrastructure' (British Standards Institution, 2023). DMRB LA 114 advises that a proportionate approach should be applied to capture the principal contributing factors to the overall GHG emissions associated with a project.

Table 20.2: GHG Emission Sources Included in the Assessment

Project life cycle stage	Life cycle sub-stage	Potential sources of GHG emissions	Scoped in (✓) /out (û)	Rationale for Exclusion (Where Relevant)	Data
Construction	Product stage (A1-A3); comprising raw material supply, transport and manufacturing.	Embodied carbon emissions (i.e. GHG emissions associated with energy consumption and chemical processes during the extraction, transport and/or manufacture of construction materials or products) associated with the required raw materials for the main works of the proposed scheme.	✓	N/A	A Bill of Quantities (BoQ) was provided by the design team for the proposed scheme.
	Construction process stage (A4-A5); comprising transport of materials to/from works site and construction/installation processes.	Fuel, electricity and/or water consumption by: ▪ construction plant and other machinery; ▪ worker accommodation/facilities; and ▪ other on-site construction activities.	×	Information regarding on-site fuel, electricity and/or water consumption are not available.	N/A
		GHG emissions associated with workers commuting to/from the work site.	×	Information regarding the modes or distances over which workers will commute to the construction site are not available.	N/A
		GHG emissions associated with transportation of construction materials to site.	✓	N/A	Quantities of raw materials derived from the BoQ.

Project life cycle stage	Life cycle sub-stage	Potential sources of GHG emissions	Scoped in (✓) /out (û)	Rationale for Exclusion (Where Relevant)	Data
					Assumptions regarding mode of transportation and transportation distances.
		GHG emissions associated with the transportation and treatment of waste materials.	✓	N/A	Estimated quantities of waste materials derived to inform Chapter 14 (Materials Assets and Waste). Assumptions about mode of transportation, transportation distances and treatment methods.
	Land use change	GHG emissions mobilised from vegetation losses and soil disturbance during construction.	✓	N/A	Mapped habitat areas/land uses derived to inform Chapter 12 (Biodiversity). Mapped areas with the potential to be disturbed during construction of the proposed scheme.
Operation	Use of the infrastructure by the operational road users (B8).	Changes in road traffic flows, composition and/or speeds as a result of the proposed scheme.	✓	N/A	Traffic data (i.e. traffic flows, % heavy Duty Vehicles (HDVs), average vehicle speed) under the Do-Minimum and Do-Something scenarios for the study area.

Project life cycle stage	Life cycle sub-stage	Potential sources of GHG emissions	Scoped in (✓) /out (û)	Rationale for Exclusion (Where Relevant)	Data
	Operational maintenance, repair, replacement and refurbishment (B2-B5).	Embodied carbon emissions associated with replacement materials and assets and their transportation to site.	✓	N/A	Assumed replacement frequencies of relevant assets and materials.
		Other maintenance and repair activities.	×	GHG emissions associated with such activities are expected to be minimal.	N/A
		Refurbishment	×	Not relevant to the proposed scheme.	N/A
	Operational energy consumption (B6)	Electricity consumed by proposed scheme lighting.	×	As part of the proposed scheme, there will be street lighting at Dunkeld Junction, the Dunkeld & Birnam Station Replacement Car Park and Pedestrian Underpass. The likely contribution to total GHG emissions associated with electricity consumed by proposed scheme lighting is therefore likely to be minimal, particularly as energy efficient LED lighting will be used and the national grid is expected to continue	N/A

Project life cycle stage	Life cycle sub-stage	Potential sources of GHG emissions	Scoped in (✓) /out (û)	Rationale for Exclusion (Where Relevant)	Data
				to become increasingly decarbonised over time.	
	Changes in land use and forestry	Ongoing land use GHG emissions/sequestration each year.	✓	N/A	Areas of woodland proposed to be lost and planted, respectively. Mapped proposed habitat areas/land uses.
End of life	Demolition and disposal	GHG emissions associated with demolition activities and the transport and treatment of waste.	×	GHG emissions from the decommissioning of the scheme at the end of its life are not considered, in line with DMRB LA 114.	N/A

Managing GHG Emissions

20.2.3 The effective assessment and management of GHG emissions for highway schemes offers the opportunity to reduce the impact of projects on climate by minimising the magnitude of GHG emissions. As per DMRB LA 114, this assessment has been informed by the general principles of PAS 2080:2023 'Carbon Management in Buildings and Infrastructure' (British Standards Institution, 2023) (with the exception of setting project level carbon reduction targets), specifically:

- Relevance - Data and assessment methods relevant to the defined boundary of carbon management and assessment have been selected, documented and used;
- Completeness - All life cycle carbon emissions arising within the defined infrastructure system boundary which provide a material contribution to the management and assessment of carbon emissions have been included;
- Consistency - Consistent methodologies and data sources for carbon management and assessment have been and will be used to allow comparisons of emissions over time. Any changes to methodologies, assumptions or data sources will be transparently documented;
- Accuracy - The quantification of carbon emissions has neither over nor under-estimated actual emissions, as far as can be judged, and uncertainties have been reduced as far as reasonably practicable. A sufficient level of accuracy has been achieved to enable users to make decisions with reasonable assurance as to the integrity of the reported information.
- Transparency - Information has been made available on the methodology and data sources used and any relevant assumptions to allow third parties to make associated decisions with confidence.

Vulnerability

20.2.4 DMRB LA 114 states that where anticipated changing climatic conditions and weather events are likely to have significant adverse effects on a scheme (or elements of a scheme), an assessment of the vulnerability of the scheme to climate change should be undertaken.

20.2.5 Potential climate related impacts during the construction phase are summarised in Table 20.3.

Table 20.3: Potential Climate Related Impacts During Construction

Projected change in climate variable **(See Section 20.4 (Baseline Conditions)).**	**Potential climate related impacts**
Increased temperatures, longer periods of hot weather and reduced precipitation during summer	Health risks to construction workers associated with high temperatures and increased dust emissions due to drier conditions. Effects of high temperatures on performance and operation of mechanical equipment. Costs/delays associated with unsuitable conditions for concrete pours or road surfacing.
Increased precipitation during winter months and more intense periods of rainfall	Damage, delays, health and safety impacts and/or increased costs associated with impacts such as flooding of construction areas and site access roads or increased slope instability.

20.2.6 The climate related impacts identified in Transport Scotland's ACCAR (Transport Scotland, 2023) which are potentially relevant to the operation of the proposed scheme are:

- river, surface water and groundwater flooding, resulting in travel and freight delays, accidents and impacts on emergency services;
- flooding and erosion or bridge scour[1] due to increased rainfall, which can lead to travel disruption, significant repair costs and the potential isolation of remote communities;
- slope and embankment failure associated with increases in heavy rainfall events, which can result in damage to transport infrastructure, travel delays and accidents;
- risks to surface infrastructure from ground subsidence (often due to shrinkage and swelling of clay soils); and
- impacts on transport from high and low temperatures, high winds and lightning.

20.2.7 The potential climate related impacts during operation of the proposed scheme scoped in/out of this assessment are summarised in Table 20.4. These potential impacts have been identified based upon the impacts identified above and projected changes in key climate variables described in Section 20.3 (Baseline Conditions).

[1] Defined as the removal of sediment such as sand and gravel from around bridge abutments or piers. Scour, caused by swiftly moving water, can scoop out scour holes, compromising the integrity of a structure.

Table 20.4: Potential Climate Related Impacts During Operation Included in the Assessment

Projected change in climate variable (See Section 20.3 (Baseline Conditions)).	Potential climate related impact	Scoped in (✓) /out (✗)	Rationale for Exclusion (Where Relevant)
Increased precipitation, particularly during winter	River, surface water and groundwater flooding	✓	N/A
	Flooding and erosion or bridge scour	✓	N/A
	Slope and embankment failure	✓	N/A
Increased precipitation during winter/reduced precipitation during summer	Ground subsidence due to shrink/swell	✗	Based on GeoIndex (British Geological Survey (BGS), 2023), and specifically the GeoClimateUKCP18 dataset, it is considered 'improbable' that foundations will be affected by increased clay shrink-swell due to climate change under 'average' soil humidity conditions in the region of the proposed scheme in the 2080s.
Increased mean winter temperatures/reduced snowfall	Low temperature, snow and ice related impacts	✗	As mean winter temperatures are projected to increase and snowfall decrease, this suggests climate related risks associated with low temperatures (e.g. those associated with snow/ice) are likely to reduce over time. Although this potential beneficial impact has been identified, it is considered unlikely to be significant, and therefore has not been considered further.
Reduced maximum wind gusts	Impacts of high winds on proposed scheme assets and infrastructure	✗	Projections again suggests a potential benefit, however, as the projected change in this climate variable is marginal, it is considered unlikely to be significant and therefore

Projected change in climate variable (See Section 20.3 (Baseline Conditions)).	Potential climate related impact	Scoped in (✓) /out (✗)	Rationale for Exclusion (Where Relevant)
			climate related impacts associated with high winds have also not been considered further in this assessment.
Increased temperatures, particularly during summer	Impacts of high temperature on proposed scheme assets and infrastructure	✓	N/A
Reduced rainfall during summer	Impacts of extended dry periods on proposed scheme assets and infrastructure	✓	N/A

Temporal Scope

20.2.8 The construction of the proposed scheme is expected to occur between 2028 and 2032. Whilst different construction activities will be undertaken at different times over this period, for the purposes of this assessment, GHG emissions associated with construction activities have been assumed to be occur evenly over each year in this period so that emissions can be compared with relevant carbon budgets or targets which are defined over a specific year or years.

20.2.9 Whilst the proposed scheme is expected to be operational by the end of 2032, the operational phase of the proposed scheme has been assessed over a 60-year appraisal period (as required by DMRB LA 114) from 2036 onwards, as this is when the full A9 dualling programme is expected to be complete and after which the greatest changes in road traffic are expected to occur.

Study Area

20.2.10 In line with DMRB LA 114, different study areas are required to be defined for each aspect of a climate assessment. The study areas are defined as follows:

- for GHG emissions resulting from the construction and operation of the proposed scheme, the study area is limited to:
    - GHG emissions associated with carbon embodied in raw materials, the transportation of raw materials, and the transportation and treatment of waste materials, all of which are assumed to occur within Scotland;

- GHG emissions associated with changes in land use and forestry within the CPO boundary;
- GHG emissions resulting from operational road users on roads within 500m of the proposed scheme footprint (see Figure 20.1), in order to avoid double counting changes in road user GHG emissions associated with other sections of the A9 Dualling Programme; and

- for the assessment of the potential vulnerability of the proposed scheme to climate change, the study area comprises the CPO boundary.

Assessment Methodology

GHG emissions

Construction Stage

20.2.11 Transport Scotland has developed the 'Transport Scotland Projects Carbon Calculator and Assessment System – Roads Projects Carbon Tool' (Transport Scotland, 2024) to estimate construction phase GHG emissions associated with Transport Scotland highways projects. It is intended to be used throughout the design process, from outline design to detailed design, allowing for the comparison of different design options, and for contractors to report actual GHG emissions during the construction phase.

20.2.12 Construction related GHG emissions can be estimated for projects based on the embodied carbon associated with the materials used, the transport of materials and the transport and treatment of waste.

20.2.13 For this assessment, entries into the tool were based on the DMRB Stage 3 design information available at the time of the assessment (Interim Design 3). It is noted that elements of the design will continue to be refined throughout the design process, which may result in changes to material quantities to that presented herein. As such, a 15% contingency was applied to all material quantities entered into the tool, in order to provide a more conservative assessment in line with contingency factors suggested by the Royal Institution of Chartered Surveyors (RICS) (RICS, 2024).

20.2.14 Design and waste information that was incorporated into this carbon assessment are presented in Appendix A20.2 (GHG Emissions).

Operational Maintenance

20.2.15 The 'Road Projects Carbon Tool' (Transport Scotland, 2024) was also used for the estimation of GHG emissions from operational replacement activities. In order to do this a design life for each asset/material was entered into the tool to represent the number of likely replacements over a 60-year appraisal period (as required by DMRB LA 114).

20.2.16 The replacement frequencies that were incorporated into this carbon assessment are presented in Appendix A20.2 (GHG Emissions).

Operational Road Users

20.2.17 Operational Road User GHG emissions were calculated in line with DMRB LA 114 for the Do-Minimum and Do-Something scenarios for the opening and design years (2036 and 2051, respectively) using the Emissions Factors Toolkit (EFT) v13 (Defra, 2025). Road User GHG emissions for the interim years between the opening and design years were linearly interpolated, whereas from the design year to the end of the 60-year appraisal period, GHG emissions were assumed to remain constant.

20.2.18 Operational road user GHG emissions were calculated based on Annual Average Daily Traffic (AADT) flows, percentage HDVs and average vehicle speeds, for each road link in the study area. The traffic data used were derived based on the latest available Transport Model for Scotland 2018 (TMfS 2018).

Land Use Change and Forestry

20.2.19 GHG emissions mobilised from vegetation loss and soil disturbance during construction have been estimated based on the area within the CPO boundary over which construction activities are expected to take place, mapped habitat types/land uses within these areas and published vegetation and soil carbon density factors by habitat/land use (Natural England, 2021). It was assumed that within construction areas, 100% of vegetation carbon (due to removal) and 25% of soil carbon (due to disturbance) would be lost to atmosphere. Furthermore, it was assumed that all of this carbon would be released as CO_2.

20.2.20 Over the operational phase, it was assumed that where soil carbon was lost during construction and the overlying habitat/land use (post construction) would result in a higher soil carbon density, soil carbon would gradually be restored or increased to the soil carbon density for the overlying habitat/land use (post construction). However, as this process is likely to happen relatively slowly (for example Table A 5.1.40 of the UK Greenhouse Gas Inventory, 1990 to 2023: Annual Report (Brown *et al.*, 2025) suggests that it could take 74 years to achieve 50% of soil carbon stock gains), only 50% of this increase was allowed for over the 60-year appraisal period .

20.2.21 Where the overlying habitat/land use (post construction) would have a lower soil carbon density than after soil carbon losses during construction had been accounted for, it was assumed the remaining soil carbon would gradually be reduced/lost so as to equal the soil carbon density for the overlying habitat/land use (post construction). As this process is likely to happen relatively quickly (for example Table A 5.1.40 of UK Greenhouse Gas Inventory, 1990 to 2023: Annual Report (Brown *et al.*, 2025) suggests that it could take 52 years to achieve 90% of soil carbon stock losses), 100% of this change was allowed for over the 60 year appraisal period.

20.2.22 Carbon sequestered by areas of woodland within the CPO boundary on an annual basis over the 60 year appraisal period (for both areas of woodland proposed to be lost and created as a result of the proposed scheme) were estimated using the Woodland Carbon Code tool (UK Woodland Carbon Code, 2024). This tool requires areas of different tree species along with tree spacing to be entered into the tool. Whilst this information was known for proposed areas of woodland, various assumptions had to be made for areas of existing woodland by the

biodiversity team (albeit these assumptions were informed by the results of habitat surveys, wherever possible).

20.2.23 The Woodland Carbon Code tool is designed to estimate carbon sequestered by areas of woodland over a 100 year period from when they are planted (with rates of carbon sequestration varying over this period). For proposed areas of woodland, the amount of carbon estimated to sequestered over the first 60 years was used, however, for existing areas of woodland which are proposed to be lost, rates of carbon sequestration over a 60 year period for more mature trees were used (i.e. the amount of carbon estimated to be sequestered by trees between the ages of 40 and 100 years old).

20.2.24 The net change in carbon sequestration caused by changes in forestry as a result of the proposed scheme was then estimated by subtracting the total amount of carbon estimated to be sequestered by lost areas of woodland (over the 60 year appraisal period) from the amount of carbon estimated to be sequestered by proposed areas of woodland (over the 60 year appraisal period).

Vulnerability

20.2.25 In line with DMRB LA 114, current and future projected climate conditions were collated in order to identify potential climate trends for the study area over the lifespan of the proposed scheme. For this purpose, and as stated in DMRB LA 114, the 25km UK Climate Projections 2018 (UKCP18) probabilistic projections dataset was used under the high emissions scenario (i.e. Representative Concentration Pathway - RCP8.5) for the 50% probability level.

20.2.26 The UKCP18 dataset also includes projections at a regional (12km) and local (2.2km) resolution for the high emissions scenario (i.e. RCP8.5). These projections are provided at daily resolution, allowing the identification of potential changes in climate extremes in the study area.

20.2.27 Where possible, historical events as a result of weather patterns and extreme weather events (e.g. landslides after heavy rainfall), were identified in order to provide an indication of past vulnerability. Information was obtained through a desktop review and with reference to the baseline conditions reported in other chapters of this EIAR (e.g. Chapter 13 (Geology and Soils) and Chapter 19 (Road Drainage and the Water Environment)).

20.2.28 Following the identification of past vulnerabilities and potential future trends in climate, scheme-related receptors likely to be vulnerable to these changes during operation of the proposed scheme were identified based on the DMRB Stage 3 Design Fix on which this EIAR is based.

Impact Assessment

GHG emissions

20.2.29 Specific human or natural receptors are not considered in the GHG emissions assessment as the receptor being considered is the global climate. Consequently, the exact location of GHG emissions sources does not alter the potential impact. The global climate receptor is,

however, considered to have a high sensitivity, given the severe consequences of global climate change and the cumulative contributions of all GHG emission sources.

20.2.30 The assessment of the proposed scheme's impacts on climate therefore relies on a comparison of project related GHG emissions against UK Government and Scottish Government carbon budgets and targets (as a proxy for the global climate). Potential impacts and effects are assessed including embedded mitigation (i.e. design measures which are integrated into a project for the purpose of minimising environmental effects).

20.2.31 In line with DMRB LA 114, GHG emissions are reported in metric tonnes of carbon dioxide equivalent (tCO_2e) over the construction period and over the 60-year appraisal period of the project. The magnitude of the impact of the proposed scheme on climate has been assessed based on estimated changes in GHG emissions as tCO_2e.

GHG Emissions Assessment Approach

20.2.32 The following metrics (expressed as tCO_2e) were calculated for the construction and operation phase and compared separately, and in total, against the relevant UK Government carbon budgets:

- estimated total GHG emissions over carbon budget period in Do-Something scenario; and
- net change in GHG emissions over the carbon budget (i.e. difference between Do-Something and Do-Minimum scenarios).

20.2.33 The proposed scheme's carbon emissions have additionally been compared against the Scottish Government interim carbon emissions target for 2030 and 2040. For example, the interim carbon reduction target for 2040 is 90% of 1990 carbon emissions, therefore the proposed scheme's emissions in the year 2040 have been compared with 10% of 1990 emissions for Scotland.

20.2.34 As per S/2 of the SNAA of DMRB LA114, a comparison has also been made of:

- estimated GHG emissions embodied within raw materials against the 'emissions envelope' given for industry in RPP3;
- estimated GHG emissions associated with the treatment of waste materials against the 'emissions envelope' given for waste in RPP3;
- estimated changes in GHG emissions associated with the transport of raw materials and waste against the 'emissions envelope' given for transport in RPP3; and
- estimated changes in GHG emissions as a result of changes in land use and forestry against the 'emissions envelope' given for Land Use Land Use Change and Forestry (LULUCF) in RPP3.

20.2.35 As the sectoral 'emissions envelopes' in RPP3 are only defined for the years 2020 – 2032, it has only been possible to compare GHG emissions associated with the construction of the proposed scheme to these 'emissions envelopes'.

GHG Emissions Significance Criteria

20.2.36 The significance criteria utilised in this chapter for the assessment of GHG emissions resulting from the proposed scheme are in accordance with DMRB LA 114 (paragraphs 3.18 to 3.20) and the Scotland NAA (Section S/2).

20.2.37 Project related GHG emissions have therefore been compared to UK Government carbon budgets and Scottish Government interim carbon reduction and sectoral targets within this assessment. In this context, DMRB LA 114 indicates that significant effects should only be reported where increases in GHG emissions will have a material impact on the ability of Government to meet its carbon reduction targets.

20.2.38 It should be noted that, as stated in DMRB LA 114, it is very unlikely that the impact of a road project will, in isolation, affect the ability of Government to meet its carbon reduction targets.

Benchmarking

20.2.39 To benchmark the performance of a scheme, DMRB LA 114 states that GHG emissions should be compared to other highway projects (with GHG emissions normalised to take account of differences in size and scale). Estimated embodied carbon in raw materials for other A9 Dualling Programme projects have therefore been compiled and normalised by dividing by the length of each scheme, as shown in Table 20.5. This benchmarking does not, however, influence the assessment of significance, but rather allows the relative carbon intensity of different projects to be assessed.

Table 20.5: Benchmarks for other highways projects

Scheme	Scheme Length (km)	Embodied Carbon (tCO_2e) – including 15% contingency	Normalised embodied carbon (tCO_2e/km)
A9 Dualling Programme: Pitlochry to Killiecrankie (Transport Scotland, 2017a)	5.7	42,756	7,501
A9 Dualling Programme: Dalwhinnie to Crubenmore (Transport Scotland, 2017b)	11.0	36,913	3,356
A9 Dualling Programme: Dalraddy to Inverness (Transport Scotland, 2018a)	24.6	155,111	6,305
A9 Dualling Programme: Killiecrankie to Glen Garry	21.6	96,946	4,488

Scheme	Scheme Length (km)	Embodied Carbon (tCO_2e) – including 15% contingency	Normalised embodied carbon (tCO_2e/km)
(Transport Scotland, 2017c)			
A9 Dualling Programme: Crubenmore to Kincraig (Transport Scotland, 2018b)	16.5	35,745	2,166
A9 Dualling Programme: Dalraddy to Inverness (Transport Scotland, 2018c)	9.6	55,278	5,758
A9 Dualling Programme: Tay Crossing to Ballinluig (Transport Scotland, 2018d)	8.2	24,961	3,044
A9 Dualling Programme: Glen Garry to Dalwhinnie (Transport Scotland, 2017d)	10.0	42,121	4,212

Vulnerability

20.2.40 Having obtained information regarding future climate conditions in the vicinity of the proposed scheme, as outlined in Section 20.3, receptors within the study area that were considered vulnerable to the resulting climate change impacts during operation of the proposed scheme were identified. The receptors identified fell into the following categories:

- construction activities, staff and equipment;
- proposed scheme assets (e.g. pavements, structures, earthworks, drainage, technology, etc); and
- end-users (e.g. members of the public, commercial operators etc).

20.2.41 Where a climate change impact on receptors was considered potentially significant, a qualitative risk assessment was undertaken in accordance with DMRB LA 114.

20.2.42 For the construction phase, DMRB LA 114 states that a qualitative description of disruption risk should be reported, while for the operational phase, it states that having identified potential climate change impacts, a qualitative risk assessment should be undertaken and the significance of each impact assessed based on the likelihood (i.e. probability and frequency) of occurrence and the potential consequences (i.e. the extent and duration of disruption).

20.2.43 The likelihood of occurrence and the potential consequences associated with each impact were assessed in accordance with the criteria given in DMRB LA 114 (reproduced in Table 20.6 and Table 20.7, respectively).

Table 20.6: Likelihood Categories

Likelihood	Descriptors
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 20.7: Measure of Consequence

Consequence	Descriptors
Very large adverse	Operation - national level (or greater) disruption to strategic route(s) lasting more than 1 week.
Large adverse	Operation - national level disruption to strategic route(s) lasting more than 1 day but less than 1 week or regional level disruption to strategic route(s) lasting more than 1 week.
Moderate adverse	Operation - regional level disruption to strategic route(s) lasting more than 1 day but less than 1 week.
Minor adverse	Operation - regional level disruption to strategic route(s) lasting less than 1 day.
Negligible	Operation - disruption to an isolated section of a strategic route lasting less than 1 day.

Vulnerability Significance Criteria

20.2.44 The evaluation of the significance of each potential climate change related impact during operation of the proposed scheme was based on its likelihood and consequence (derived using the criteria described in Table 20.6 and Table 20.7) and Table 3.41 of DMRB LA 114, which is reproduced in Table 20.8.

20.2.45 DMRB LA 104 'Environmental assessment and monitoring' (Highways England et al., 2020) requires that the significance of an effect shall be reported with the embedded mitigation measures included. Therefore, the assessment of significance for each impact incorporated embedded mitigation measures.

Table 20.8: Significance Matrix for Vulnerability

Likelihood / Consequence	Very low	Low	Medium	High	Very high
Very Large	Not significant	**Significant**	**Significant**	**Significant**	**Significant**
Large	Not significant	Not significant	**Significant**	**Significant**	**Significant**
Moderate	Not significant	Not significant	**Significant**	**Significant**	**Significant**
Minor	Not significant	Not significant	Not significant	Not significant	Not significant
Negligible	Not significant	Not significant	Not significant	Not significant	Not significant

Cumulative Effects

20.2.46 Potentially significant cumulative effects of the proposed scheme, and those of the proposed scheme in combination with other reasonably foreseeable developments, are assessed in Chapter 21 (Assessment of Cumulative Effects).

Limitations to Assessment

20.2.47 There are a number of limitations to this assessment, as detailed below, the majority of which relate to the assessment being based on design information which is at a relatively early stage or uncertainties inherent in supporting modelling, tools or prediction methods. It is, however, considered that these limitations are acceptable and do not affect the conclusions of likely significant effects presented herein.

Generic

20.2.48 The climate related elements of the proposed scheme (i.e. GHG emissions and vulnerability) can be affected by aspects of the design and other environmental factors, the assessments for which act as a source of information for the climate assessment. Therefore, this chapter is influenced by the limitations detailed in Chapter 13 (Geology and Soils); Chapter 19 (Road Drainage and the Water Environment); Chapter 12 (Biodiversity); Chapter 10 (Landscape); Chapter 14 (Material Assets and Waste); and the Traffic Report.

GHG emissions

Construction, Maintenance and Operation

20.2.49 As the scheme is at the DMRB Stage 3 design stage, there is uncertainty in the material types and quantities which have been used to estimate embodied GHG emissions. As such, and to provide a more conservative assessment, a contingency factor of 15% has been applied to the

material quantities extracted from the detailed Bill of Quantities for the current design (Interim Design 3) in line with contingency factors suggested by RICS (RICS, 2024).

20.2.50 No data are available relating to potential fuel and electricity consumed by on-site plant, equipment and facilities. However, the 'Roads Projects Carbon Tool' (Transport Scotland, 2024) states that '*Plant emissions are not estimated during the design stage due to the lack of data and complexity in modelling this fuel/ electricity consumption*'. Despite not being estimated at this stage, potential mitigation measures to reduce emissions from on-site construction plant will be considered going forwards.

20.2.51 There are no prescribed tools or processes for estimating the impact of changes in land use as a result of infrastructure projects. Tools developed for other purposes (i.e. the Woodland Carbon Code tool) and the results of relevant research have therefore been used to estimate potential changes in GHG emissions/sequestration which may occur as a result of the proposed scheme. Whilst it is recognised that the approach taken is subject to uncertainty, it is considered to be appropriate and proportionate, and suitable for assessing the relative magnitude of the net change in GHG emissions/sequestration which could potentially occur.

20.2.52 In the absence of detailed information regarding material quantities, it has not been possible to estimate operational maintenance GHG emissions in the absence of the Scheme (i.e. in the Do-Minimum scenario) using the 'Roads Projects Carbon Tool' (Transport Scotland, 2024). Instead, potential Do-Minimum operational maintenance GHG emissions have been derived from estimated Do-Something operational maintenance GHG emissions using a ratio of 50%. This ratio was derived based on a simple, high-level comparison of the differences between the proposed scheme and the existing section of the A9 which it would replace (e.g. the number of lanes).

Operational Road Users

20.2.53 While the latest version of Defra's Emission Factors Toolkit (EFTv13) has been used to estimate changes in road user GHG emissions within this assessment, EFTv13 includes a number of assumptions which will have influenced the magnitude of estimated road user GHG emissions presented herein. Of greatest importance are the assumptions made regarding the proportion of electric vehicles in the Scottish vehicle fleet over time. EFTv13, however, includes electric vehicle fleet projections which were derived in 2020/2021, and as such do not reflect the effect of more recent policy commitments (such as the proposed ban on new petrol and diesel cars in 2035).

20.2.54 Furthermore, there is no allowance whatsoever within EFTv13 for the decarbonisation of Heavy Goods Vehicles. In addition, the fleet composition projections within EFTv13 only go as far as 2050, whereas changes in road user GHG emissions have been estimated over the 60 year appraisal period between 2036 and 2095 (with no reduction in road user GHG emissions assumed to occur beyond 2050). As such, the changes in road user GHG emissions presented in this report are considered worst-case, particularly those in later years.

Vulnerability

20.2.55 There is inherent uncertainty in the climate models from where the climate projections used in this assessment were obtained (i.e. climate models utilised in the UKCP18 projections). The use of the UKCP18 High Emissions RCP8.5 projections dataset, is however likely to provide a more conservative estimate of future climate change.

20.2.56 As not all of the meteorological parameters were available from the Met Office for all UKCP18 projections datasets or provided at the same spatial resolution, the most appropriate datasets and spatial resolutions were utilised depending on the required parameter.

20.2.57 For the vulnerability assessment, only one grid cell, for each of the UKCP18 datasets used, was selected to describe the climatic conditions in the study area. It is assumed that the climatic conditions across the study area are spatially stable and adequately described by the selected grid cell, particularly as climate characteristics are not expected to vary substantially over short distances (i.e. the length of the proposed scheme is approximately 8.4km) and that the vast majority of the scheme falls into the grid cells considered.

20.2.58 There is uncertainty with regards to the extent that climate change impacts affect the performance of assets. Therefore, a qualitative approach has been applied, supported by professional judgement.

20.2.59 Where relevant, specific measures to mitigate the vulnerability of the proposed scheme to climate change are detailed in the corresponding chapters. For example, mitigation with regards to increased flood risk as a result of climate change is addressed in Chapter 19 (Road Drainage and Water Environment).

20.2.60 The scheme's vulnerability to climate change was assessed based on the assumption that suitable design standards and robust and good engineering practise are followed and that all relevant design standards are suitable for current and future climate conditions.

20.3 Baseline Conditions

GHG emissions

Existing baseline

20.3.1 The proposed scheme is located within the administrative boundary of PKC. Estimated GHG emissions associated with the PKC administrative area obtained from the most recent UK National Atmospheric Emissions Inventory (NAEI) dataset for local authorities (i.e. for the year 2022) (Department for Energy Security and Net Zero (DESNZ), 2024), are presented in Table 20.9 and compared with relevant emission totals for Scotland as a whole.

20.3.2 The total net council-wide GHG emissions in 2022 are estimated to have been 1,258 kilotonnes of carbon dioxide equivalent (kt CO_2e), which accounts for approximately 3.2% of total net GHG emissions in Scotland (i.e. 38,857kt CO_2e).

20.3.3 Road transport related GHG emissions in the PKC area (i.e. 484kt CO_2e) are estimated to have accounted for 44.2% of total PKC area emissions (excluding LULUCF net emissions, which are negative) and 5.0% of total road transport related GHG emissions in Scotland. 'A' roads, including the A9, are estimated to have contributed 28.7% of total GHG emissions for the PKC area (excluding LULUCF net emissions) and 3.2% of total road transport related GHG emissions in Scotland.

Table 20.9: Estimated GHG Emissions associated with the PKC area (2022)

PKC area GHG emissions in 2022 (kt CO_2e)	
Industry Total	49.4
Commercial Total	84.4
Public Sector Total	31.1
Domestic Total	239.9
Road Transport (A roads)	314.6
Road Transport (Motorways)	87.3
Road Transport (Minor roads)	81.8
Diesel Railways	15.4
Transport Other	5.3
Agriculture Total	437.9
Waste Total	73.7
LULUCF Net Emissions	-162.5
Total net emissions	**1,258.2**
PKC area road transport GHG emissions as proportion of total PKC area GHG emissions (excluding LULUCF Net Emissions)	44.2%
PKC area road transport GHG emissions as proportion of total Scotland road transport GHG emissions	5.0%
PKC area A roads GHG emissions as a proportion of total PKC area GHG emissions (excluding LULUCF Net Emissions)	28.7%
PKC area A roads GHG emissions as a proportion of total Scotland road transport GHG emissions	3.2%

20.3.4 At a national level, the latest Scottish Greenhouse Gas Statistics (Scottish Government, 2024b) indicates that GHG emissions in 2022 were down by 50.1% (between the 1990 baseline and 2022), compared to The Climate Change (Emissions Reduction Targets) (Scotland) Act 2019 (Scottish Government, 2019b) specified target of a 53.8% reduction over the same period. Therefore the interim target for 2022 has not been met.

20.3.5 Between 1990 and 2022, domestic transport emissions in Scotland are estimated to have decreased by 15.0% (Scottish Government, 2024b), however, such emissions were the largest source of net emissions in Scotland in 2022 (contributing 28.3%).

Proposed Scheme Baseline

20.3.6 The baseline against which the proposed scheme has been compared is the Do-Minimum scenario. In a Do-Minimum scenario the typical GHG emission sources include maintenance works (e.g. materials embodied emissions), operational electricity use (e.g. lighting) and operational road users (i.e. vehicles' fuel consumption) for the existing road network.

20.3.7 As GHG emissions associated with operational electricity use (e.g. lighting) have been scoped out of the assessment (see Table 20.2), the Do-Minimum scenario for the proposed scheme is based only on the GHG emissions associated with operational road users in the Do-Minimum traffic scenario (based on modelled traffic data) and operational maintenance activities.

20.3.8 Operational road user GHG emissions for the Do-Minimum scenario are presented in Table 20.10 for the base year (2025), the opening year (2036), the design year (2051) and over the 60-year appraisal period (i.e. 2036 - 2095). Emissions in intervening years between 2036 and 2051 were derived by linear interpolation, whilst emissions were assumed to remain constant between 2051 and 2095 (which is a worst-case assumption).

Table 20.10: Road User GHG Emissions (tCO_2e) for the Do-Minimum Scenario

Assessment Year/Period	Operational road user GHG emissions (tCO_2e)
Base Year (2025)	15,916
Opening Year (2036)	13,064
Design Year (2051)	12,560
60 year appraisal period (2036 - 2095)	757,644

20.3.9 As shown in Table 20.10, road user GHG emissions are expected to reduce over time (despite an increase in road traffic flows over the same time period) due to projected improvements in the national vehicle fleet (e.g. increased proportions of electric cars and LGVs).

20.3.10 No data are available regarding existing baseline operational maintenance emissions relevant to the proposed scheme. Estimated operational maintenance GHG emissions for the Do-Minimum scenario are presented in Table 20.11 over the assumed 60-year life span of the proposed scheme (i.e. 2036 - 2095).

Table 20.11: Operational Maintenance Emissions (tCO_2e) for the Do-Minimum Scenario

Assessment Year/Period	Operational maintenance GHG emissions (tCO_2e)
60 year appraisal period (2036 - 2095)	18,437

20.3.11 Operational maintenance GHG emissions are likely to reduce over time as a result of government policies, and other such policies and plans implemented at a local, national and UK level in order to meet net zero emission targets. It should be noted, however, that no allowance for 'decarbonisation' of operational maintenance emissions has been allowed for within this assessment as the rate and extent of any such decarbonisation is uncertain.

Vulnerability

Climate Baseline and Projections

20.3.12 The Met Office has produced the HadUK-Grid Gridded Climate Observations (Met Office et al., 2024), which are observed values for climate variables at a 25km resolution, derived from 1km resolution data, and covering the period 1836–2023. From this dataset, values representing the baseline period 1981–2010 and for the 25km grid square that encompasses the study area have been used in this assessment. The baseline period 1981–2010 and 25km grid resolution allow comparison to the future UK climate projections produced by the Met Office, referred to as the UK Climate Projections 2018 (UKCP18) (Met Office, 2018a). The UKCP18 uses a 30-year baseline period from which potential climatic changes in future years are projected.

20.3.13 UKCP18 uses scenarios for future GHG called representative concentration pathways (RCPs), which cover a range of assumptions around future population, economic development and include the possibility of mitigation of GHG emissions towards international targets. The RCPs are expressed for future radiative forcing targets of 2.6, 4.5, 6.0 and 8.5 watts per square metre (W/m^2) in 2100 (RCP2.6, RCP4.5, RCP6.0 and RCP8.5 pathways). Each pathway drives a different range of projected global mean temperature increases over the 21st century, taking account of uncertainty in aspects such as the transient climate response and rate of ocean heat uptake (Met Office, 2018b).

20.3.14 The RCP pathways lead to a broad range of climate outcomes but are neither forecasts nor policy recommendations. RCP2.6 represents a scenario where there are sizeable reductions in emissions of greenhouse gases. This scenario gives a reasonable chance of limiting global average warming to between 1.5°C and 2°C above pre-industrial levels. RCP8.5 represents a scenario in which global greenhouse gas emissions continue to rise uncontrolled with temperature increases exceeding 4°C by the end of the century.

20.3.15 Current and future climate conditions (i.e. long-term weather conditions) are presented in Table 20.12 in terms of temperature and precipitation, utilising the 25km spatial resolution UKCP18 probabilistic dataset (Met Office Hadley Centre, 2018a) for the grid cell centred at Easting: 312500, Northing: 737500. The current climate conditions (i.e. climate baseline) refer to the most recent historic climate dataset of 1981-2010 (Met Office et al., 2024). The future climate conditions (i.e. climate projections) refer to projections made under the high emissions scenario (i.e. RCP 8.5) with a 50% probability of occurrence (i.e. the 50th percentile value of the dataset) for the 2030s (2020 – 2049), 2060s (2050 – 2079) and 2080s (2070 – 2099), covering successive 30-year periods to include the assumed life span of the proposed scheme.

20.3.16 Under the climate scenario considered, annual accumulated precipitation at the location of the proposed scheme is projected to increase steadily over time, and by the 2080s, is projected to have increased by 3.6% compared to the observed baseline (reaching 932mm). Projected changes in seasonal precipitation by the 2080s, i.e. +26.3% during winter and -29.2% during summer, indicate substantially wetter winters and substantially drier summers have the potential to occur.

20.3.17 All of the temperature related metrics considered indicate a steady increase in temperature has the potential to occur. Specifically, the mean winter minimum, the mean summer maximum and the annual mean temperature, which are projected to increase by 2.9°C, 4.6°C and 3.3°C by the 2080s, respectively, compared to the observed baseline values.

Table 20.12: Current Climate Conditions and Potential Future Changes at the Location of the Proposed Scheme

Climate Metric	Observed Baseline (1981-2010)	Projected Change (UKCP18)		
		RCP8.5 (50% probability) 2030s (2020 – 2049)	RCP8.5 (50% probability) 2060s (2050 – 2079)	RCP8.5 (50% probability) 2080s (2070 – 2099)
Mean Winter Minimum Temperature (°C)	-0.2	+0.9	+2.0	+2.9
Mean Summer Maximum Temperature (°C)	18.2	+1.2	+2.9	+4.6
Annual Mean Temperature (°C)	8.0	+0.9	+2.1	+3.3
Winter Mean Accumulated Precipitation (mm/year and %)	239	+11.8%	+16.1%	+26.3%
Summer Mean Accumulated Precipitation (mm/year and %)	211	-5.1%	-18.3%	-29.2%
Annual Mean Accumulated Precipitation (mm/year and %)	903	+2.6%	+2.8 %	+3.6%

20.3.18 Other climate variables, selected to represent more extreme conditions (i.e. 10th and 90th percentiles of projected values) are presented in Table 20.13, in terms of temperature, precipitation, maximum wind gust and snowfall flux. These variables were determined utilising the regional (12km) (Met Office Hadley Centre, 2018b) and where relevant local (2.2km) (Met Office Hadley Centre, 2018c) spatial resolution UKCP18 high emissions scenario (i.e. RCP 8.5) datasets for the grid cell centred at Easting: 306000, Northing: 738000. The 2.2km spatial resolution UKCP18 dataset (grid cell centred at: Easting: 302500, Northing: 742500) was utilized for the wind gusts and snowfall flux, as there are no equivalent data under the 12km dataset.

20.3.19 Unlike the 25km datasets discussed above, there are no equivalent 'observed' data, so the data presented for both periods are projected values. The ranges provided for each metric

represent the relevant percentiles of projected values from the 12 different ensembles (i.e. model runs) used by the Met Office in the UKCP18.

20.3.20 Daily projections for the period of 2061-2080 were used to estimate more extreme temperature and precipitation events with the potential to occur in a day. The 90th percentile of projected values has been used to represent the value above which any event happening within a day (e.g. precipitation event) is likely to occur less frequently. For instance, for the period 2061-2080, maximum daily precipitation events greater than 11.1 mm are likely to occur relatively infrequently. Similarly, the 10th percentile has been used to represent the value below which any event happening within a day is likely to occur less frequently. The corresponding metrics for the observed baseline period 1981-2000 (which is the baseline for the 12km and 2.2km projection datasets) are also presented for comparison.

20.3.21 The 90th percentile of daily precipitation values is projected to increase from 10.9 mm/day during 1981-2000 to 11.1 mm/day during 2061-2080 (upper limits used), indicating that more extreme precipitation events have the potential to be of similar intensity in the study area. The 10th percentile of minimum daily temperatures is increased from -0.7°C to 1.4°C, indicating that days with more extreme low temperatures have the potential to be warmer. The 90th percentile of maximum daily temperatures is projected to increase from 18.7°C to 24.7°C, indicating that days with more extreme temperatures will potentially be substantially warmer. The intensity of the 90th percentile of maximum wind gusts shows a small decrease from 9.9 m/s to 9.5 m/s, indicating that wind speeds on days with higher winds will potentially be marginally reduced. The intensity of the 90th percentile of daily snowfall flux shows a decrease from 1.1mm/day to 0.2mm/day, indicating that more extreme snowfall events will potentially have less snowfall.

Table 20.13: Current Climate Conditions and Potential Future Climate Conditions at the Location of the Proposed Scheme

Meteorological Parameter	Observed Baseline: 1981-2000		Projected Baseline RCP 8.5 - Period 2061-2080	
	10th Percentile	90th Percentile	10th Percentile	90th Percentile
Minimum Daily Temperature (°C)	-6.1 – -0.7	8.9 – 11.2	-2.1 – 1.4	12.0 – 14.6
Maximum Daily Temperature (°C)	0.5 – 3.8	16.0 – 18.7	2.8 – 6.1	20.6 – 24.7
Daily Temperature (°C)	-1.8 – 1.8	12.3 – 14.7	0.6 – 4.0	16.2 – 19.1
Maximum Daily Wind gusts (m/s)	3.6 – 3.8	9.1 – 9.9	3.5 – 3.7	8.6 – 9.5
Daily Precipitation (mm/day)	0.0 - 0.1	8.7 – 10.9	0.0	8.5 – 11.1
Daily snowfall flux (mm/day)	0.0 - 0.0	0.3 – 1.1	0.0 – 0.0	0.0 – 0.2

Meteorological Parameter	Observed Baseline: 1981-2000		Projected Baseline RCP 8.5 - Period 2061-2080	
	10th Percentile	90th Percentile	10th Percentile	90th Percentile
Note: Ranges are provided for each variable to accommodate the projections of the 12 ensembles included in the UKCP18.				

Historical Events

20.3.22 DMRB LA 114 requires that historical events as a result of weather patterns and extreme weather events be identified to provide an indication of past vulnerability. As detailed in Chapter 13 (Geology and Soils), Section 13.4 (Geology), a landslide occurred in August 2004 between approximately ch7900 and ch8200. The contributory cause of the landslide was the drainage system failure of the former A9 (C502 (Dunkeld to Rotmell) Road) which is located approximately 130m east of the existing A9 at ch7900. The damaged part of the slope was remediated (i.e. filled and covered with armour stone), however, it was believed at the time that during rainfall events further slope instabilities could occur between ch7600 and ch8200. Another landslide has occurred since in 2023.

Potential Vulnerabilities

20.3.23 In addition, the Scottish Road Network Landslides Study (Winter et al., 2008) identifies the area from ch7600 to ch8400 as being potentially vulnerable to landslides. Detailed assessment of slope stability will be required during specimen design to determine the appropriate slope angle for cutting and strengthening design taking cognisance of the geotechnical hazard.

20.3.24 As detailed in Appendix 19.2: Flood Risk Assessment, there is a very high risk of fluvial flooding to the existing A9 from the River Tay and River Braan. Along the existing A9 corridor, there is a potential risk of groundwater flooding, which could contribute to, and extend the duration of, other sources of flooding, such as surface water or fluvial flooding in low-lying areas (although this risk is not considered significant). Otherwise, flooding related with surface water or the failure of water retaining infrastructure is considered less likely, as the proposed scheme is located in an area of low risk regarding these aspects.

20.3.25 As both of these potential vulnerabilities are associated with precipitation, the projected future increases in winter precipitation shown in Table 20.12 suggests that the vulnerability of the scheme to both landslides and flooding could increase in the future due to the effects of climate change.

Receptors

20.3.26 Following the identification of climate trends, and considering their potential impact on the most important hazards likely to be experienced by the Scottish road network (i.e. flooding, landslides and bridge scour), the identified receptors during each phase are as follows:

- Construction
    - Machinery & plant;

- Construction activities (e.g. excavations, concrete pours, surfacing, etc.); and
- Construction workforce.

- Operation
  - Road surfaces and pavements;
  - Structures (including embankments, earthworks, bridges)
  - Drainage infrastructure;
  - Road technology and street furniture (including signs, signals, and lighting)
  - Landscaping; and
  - Road users.

20.4 Potential Impacts and Effects

GHG emissions

20.4.1 The assessment of potential impacts on climate through the release of GHG emissions as a result of the proposed scheme during all phases is presented in this section in line with Section 20.2 Approach and Methods.

Construction

20.4.2 Total embodied carbon and transport emissions associated with the construction of the proposed scheme are summarised per construction element in Table 20.14. The full results and the input data to the 'Roads Projects Carbon Tool' (Transport Scotland, 2024) are included in Appendix A20.2 (GHG Emissions). Embodied carbon in bulk materials and civil engineering structures are estimated to make the largest contribution to total embodied carbon and transport emissions, i.e. 46,604 tCO_2e (i.e. 66%) and 10,378 tCO_2e (i.e. 15%), respectively, while the transport of materials to site is estimated to contribute 7,368 tCO_2e (i.e. 11%).

20.4.3 Comparison of estimated embodied carbon emissions on a per km basis (i.e. 7,420 tCO_2e/km, based on a scheme length of 8.4 km) suggests they are comparable to those for other sections of the A9 shown in Table 20.5. Such a simple comparison does not, however, allow for any differences which will influence the magnitude of embodied carbon emissions per km (such as the number and type of structures on different sections of the A9).

Table 20.14: Summary of Total Embodied Carbon and Transport Emissions Associated with the Construction of the Proposed Scheme (15% Contingency included)

Project Element	Materials Embodied (tCO_2e)	Transport (tCO_2e)	Total (tCO_2e)
Civil Engineering Structures	10,378	533	10,911
Bulk Materials	46,604	7,033	53,637
Drainage	1,085	60	1,146
Earthworks	- [a]	- [a]	- [a]

Project Element	Materials Embodied (tCO_2e)	Transport (tCO_2e)	Total (tCO_2e)
Fencing, Barriers & Road Restraint Systems	2,360	31	2,391
Street Furniture & Electrical Equipment	343	5	347
Road Pavement	1,556	296	1,852
Total	**62,326**	**7,958**	**70,284**

[a] The majority of materials which would be used for earthworks are 'site-won' and therefore are assumed to have zero carbon emissions, while a small amount of imported materials which would be used for earthworks are included as 'Fill, aggregate and sand' under 'Bulk Materials'.

20.4.4 The contribution of each material type to total embodied carbon and transport emissions is summarised in Table 20.15. The materials expected to be the most impactful in terms of total embodied carbon and transport emissions are reinforcement steel, asphalt and concrete, accounting for 17,682 tCO_2e (i.e. 28%), 12,225 tCO_2e (i.e. 20%) and 14,468 tCO_2e (i.e. 23%), respectively.

Table 20.15: Summary Total Embodied Carbon and Transport Emissions Associated with Materials Required to Construct the Scheme by Material Type (15% Contingency included)

Material types	Materials embodied (tCO_2e)	Transport (tCO_2e)	Total (tCO_2e)
Civil Engineering Structures			
Bricks and blockwork	89	7	96
Decorative stone	183	28	211
Formwork/Shuttering	414	3	417
Paint	420	4	424
Pre-cast concrete	1,474	309	1,783
Steelwork	7,798	182	7,980
Bulk Materials			
Asphalt	10,039	2,186	12,225
Cement and binders	2,711	14	2,725
Fill, aggregate and sand	2,502	4,034	6,536
Concrete	13,985	483	14,468
Reinforcement steel	17,367	315	17,682
Drainage			
Plastic inspection chambers	2	<1	2

Material types	Materials embodied (tCO_2e)	Transport (tCO_2e)	Total (tCO_2e)
Plastic pipework (HDPE)	892	13	905
Precast concrete circular pipework	191	47	238
Fencing, Barriers & Road Restraint Systems			
Fence	7	<1	7
Road restraint system/ safety barrier	2,343	31	2,374
Paint or timber treatment	10	<1	10
Street Furniture & Electrical Equipment			
Cabinets	7	<1	7
Cable	4	<1	4
Cameras	15	<1	15
Plastic cable ducting	65	1	66
Road lighting and columns	29	<1	29
Road studs	1	<1	1
Traffic signs	212	3	215
Variable Message Signs (VMS)	9	<1	9
Road Pavement			
Bitumen/ surface treatment	1,404	264	1,668
Kerb	117	32	149
Road markings	34	<1	34

20.4.5 Estimated GHG emissions associated with the treatment and transport of waste generated during the construction of the proposed scheme are shown Table 20.16 by waste material type. The majority of these emissions (i.e. 46%) are primarily associated with the transport of surplus excavated materials such as soil, which have been represented using “Aggregates” in the ‘Roads Projects Carbon Tool’ (Transport Scotland, 2024) in the absence of a specific factor for the treatment of waste soil.

Table 20.16: Summary of Waste Treatment and Transport Emissions Associated with Construction of the Scheme (15% Contingency included)

Waste Type	Waste Treatment (tCO_2e)	Transport (tCO_2e)	Total (tCO_2e)
Aggregates	1,205	14,635	15,839
Asphalt	227	2,758	2,985
Concrete/brick	9	107	115.6

Waste Type	Waste Treatment (tCO_2e)	Transport (tCO_2e)	Total (tCO_2e)
Metal	20	11	31
Wood	126	161	163.1
Glass	<1	<1	<1
Plastic	<1	<1	<1
Total	**1,587**	**17,672**	**19,258**

20.4.6 Estimated GHG emissions associated with changes in land use and forestry during the construction of the proposed scheme are shown Table 20.17. The majority of these emissions are associated with the removal of vegetation (primarily woodland), however, it should be noted that they assume that all carbon stored in existing vegetation removed during construction would be converted to CO_2 (i.e. burnt), which is a worst-case assumption. In reality much of this wood is likely to be re-used (e.g. as timber).

Table 20.17: Summary of GHG Emissions Associated with Changes in Land Use and Forestry during Construction of the Scheme

Emission source	Total (tCO_2e)
Vegetation removal	21,660
Soil disturbance	6,649
Carbon sequestered by woodland	2,492 [a]
Total	**30,801**

[a] This number is positive (i.e. an emission) to reflect the fact that a lower amount of carbon would be sequestered by woodland than would otherwise be the case, due to areas of woodland being cleared during the construction process.

Operation

20.4.7 The GHG sources considered for the operation phase are operational road users (i.e. vehicular emissions associated with consumption of fuel and electricity) and the maintenance of the proposed scheme (i.e. emissions associated with the consumption of materials used during maintenance activities and their transportation).

20.4.8 GHG emissions from operational road users were calculated for the Do-Something scenario in the 2036 opening year scenario and 2051 design year scenario. Emissions in intervening years were derived by linear interpolation, whilst emissions were assumed to remain constant between 2051 and 2095, the assumed end of life year of the scheme, i.e. to account for a 60-year appraisal period. The results of these calculations are summarised in Table 20.18 and provided in full in Appendix A20.2 (GHG Emissions).

Table 20.18: Operational Road User GHG Emissions (tCO_2e) for the Do-Something Scenario

Assessment Year/Period	Operational Road User GHG emissions (tCO_2e)
Opening Year (2036)	15,076
Design Year (2051)	14,543
60-year appraisal period (2036-2095)	876,824

20.4.9 The estimated Do-Something GHG emissions decrease by 1.8% between 2036 and 2051 despite total vehicle kilometres increasing by 17.8%, indicating assumed improvements to the vehicle fleet outweigh the increase in traffic flows over the same time period. However, it should be noted that, as detailed in the limitations section of this chapter, the EFTv13 does not currently account for any changes in the vehicle fleet after 2050, nor more recent Government policy, and therefore the positive impact of an increasing proportion of electric cars in future years (e.g. as a result of the future ban on the sale of petrol and diesel cars and LGVs) is not fully reflected in these estimates. Therefore, estimated road user GHG emissions over the 60-year appraisal period can be considered worst-case, particularly in later years.

20.4.10 In Table 20.19, total GHG emissions from maintenance activities during the 60 year appraisal period are summarised per construction element. Bulk materials is the project element with the highest contribution to total maintenance emissions, i.e. 27,434 tCO_2e, accounting for 74% of total maintenance emissions. These bulk materials are primarily associated with asphalt used during planned resurfacing.

Table 20.19: Summary of Total Maintenance Emissions for the Proposed Scheme by Project Element (15% Contingency Included)

Project Element	Maintenance Phase Materials Embodied and Transport (tCO_2e)
Civil Engineering Structures	847
Bulk Materials	27,434
Fencing, Barriers & Road Restraint Systems	2,502
Street Furniture & Electrical Equipment	658
Road Pavement	5,434
Total GHG Emissions from Maintenance Phase	**36,875**

20.4.11 Estimated GHG emissions associated with ongoing changes in land use and forestry during the operation of the proposed scheme are shown Table 20.20. The majority of these changes in emissions are associated with changes in carbon sequestration as a result of the removal and planting of woodland.

Table 20.20: Summary of GHG Emissions Associated with Changes in Land Use and Forestry during Operation of the Scheme

Emission source	Total (tCO_2e)
Soil carbon	3,001
Carbon sequestered by woodland	-3,063 [a]
Total	**-61**

[a] This number is negative (i.e. an increase in carbon sequestration) to reflect the fact that a greater amount of carbon would be sequestered by woodland than would otherwise be the case, due to new areas of woodland being planted during the construction process.

Comparison against carbon budgets and targets

20.4.12 The GHG emissions under the Do-Something scenario from both the construction and operation phase, are summarised in Table 20.21. The table shows the total GHG emissions for each stage over their full periods as well as the split of this total by the relevant UK carbon budget periods. It is apparent that the largest contribution is made over the operation stage of the proposed scheme, which accounts for approximately 90% of the total emissions over the 60-year appraisal period. All construction activities fall into the 5th carbon budget period (2028-2032). The operational phase is from 2036 to 2095, therefore two years, 2036 and 2037, are covered by the 6th carbon budget (2033-2037).

Table 20.21: GHG Emissions Under the Do-Something Scenario – Total Emissions Per Stage and Split Per Budget Period

Project Stage	Total GHG emissions (tCO_2e)	GHG Emissions distributed per UK Carbon Budget (tCO_2e)	
		5th	6th
Construction (2028 – 2032)	120,342	120,342	-
Operation (60 years, i.e. 2036 – 2095)	914,576	-	32,283
Total (Construction and Operation)	1,034,918	120,342	32,283

20.4.13 The net change in GHG emissions between the Do-Something and the Do-Minimum scenario, both from the construction and operation phase, is summarised in Table 20.22, along with a comparison of the net change in GHG emissions against the relevant UK carbon budgets. A comparison against the relevant Scottish interim carbon reduction targets is provided in Table 20.23.

20.4.14 From Table 20.22, the impact of the scheme on the 5th carbon budget (2028-2032) is attributed solely to the construction phase, whereas for the 6th carbon budget (2033-2037) the sole contribution is from the operation stage. The change in GHG emissions estimated to result from the proposed scheme, relative to each carbon budget is estimated to be negligible, accounting for 0.007% of the 5th carbon budget and <0.001% of the 6th carbon budget.

Table 20.22 Net Change in GHG Emissions (Do-Something - Do-Minimum) Compared with Relevant UK Carbon Budgets

Project Stage	Net Change in GHG emissions (tCO_2e)	Net Change in GHG Emissions distributed per Carbon Budget (tCO_2e)		Change as Percentage of Relevant Carbon Budget (%)	
		5th	6th	5th	6th
Construction	120,342	120,342	-	0.007%	-
Operation (60 years)	138,025	-	5,104	-	<0.001%
Total	258,367	120,342	5,104	0.007%	<0.001%

20.4.15 The net changes in GHG emissions for the relevant years that Scottish interim targets have been defined for (i.e. 2030 and 2040), are 30,086 tCO_2e and 2,545 tCO_2e, respectively, as shown in Table 20.23. These changes in emissions are estimated to account for approximately 0.141% and 0.030% of the corresponding targets, which is considered negligible.

Table 20.23 Net Change in GHG Emissions (Do-Something - Do-Minimum) Compared with Scottish Interim Targets

Project Stage	Net Change in GHG Emissions in Interim Target Year (tCO_2e)		Net Change in GHG emissions as Percentage of Scottish Interim Target (%)	
	2030	2040	2030	2040
Construction	30,086	-	0.141%	-
Operation	-	2,545		0.030%

20.4.16 The net changes in GHG emissions for the relevant years and sectors that Scottish emissions envelopes have been defined for are shown in Table 20.24. These GHG emissions, which are associated entirely with the construction phase, are estimated to account for less than 1% of the corresponding sectoral emissions envelopes, which is considered negligible, with the exception of estimated emissions associated with land use change in 2029. As noted previously, however, estimated GHG emissions associated with land use change are considered worst-case as it was assumed that all of the carbon stored in cleared vegetation would be converted to CO_2 (i.e. burnt). In reality, a large proportion of the timber from woodland clearance would be re-used off-site as virgin timber, meaning that this CO_2 would not be released to atmosphere.

Table 20.24 Proposed Scheme GHG Emissions Compared with Sectoral Emissions Envelopes

Sector	Proposed Scheme GHG Emissions (tCO_2e)					Change in GHG emissions as Percentage of Emissions Envelope (%)				
	2028	2029	2030	2031	2032	2028	2029	2030	2031	2032
Industry	12,465	12,465	12,465	12,465	12,465	0.15%	0.16%	0.17%	0.20%	0.23%
Waste	96	96	96	96	96	0.01%	0.01%	0.01%	0.01%	0.01%
Transport	2,717	2,717	2,717	2,717	2,717	0.04%	0.04%	0.04%	0.04%	0.04%
LULUCF	6,160	6,160	6,160	6,160	6,160	1.54%	1.23%	0.34%	0.29%	0.27%

Vulnerability

Construction

20.4.17 Changes in climate over the shorter term (such as the increased likelihood and/or intensity of extreme weather) have the potential to result in the disruption of construction phase activities. For example, extreme weather events such as heatwaves, very high temperatures and heavy rainfall events have the potential to adversely impact construction site workers, equipment and plant and construction processes and activities.

20.4.18 Mitigation measures, including the implementation of good on-site construction practice, are therefore considered necessary to minimise the risk of disruption during the construction phase associated with climate related impacts (see paragraph 20.5.6 and Table 20.25).

Operation

20.4.19 An assessment of the vulnerability of the proposed scheme to climate change is provided in Appendix A20.1: Vulnerability to Climate Change, which sets out for each scheme receptor and potential climate event/impact(s) identified:

- relevant embedded mitigation;
- the likelihood of impact (with embedded mitigation), based on the criteria in Table 20.6;
- the measure of consequence, based on the criteria in Table 20.7;
- the significance of each impact, based on the likelihood and consequence identified and the criteria in Table 20.8.

20.4.20 The environment team has worked in close collaboration with the infrastructure design team to avoid or reduce environmental impacts through the scheme design. Along with compliance with relevant legislation, standards and guidance and good engineering practice, this is referred to as embedded mitigation.

20.4.21 Of particular relevance are allowances made for future climate change in the design of the proposed scheme relating to flood risk and drainage (as set out in Chapter 19 (Road Drainage and the Water Environment)) and to reduce the risk and/or impact of landslides (as set out in Chapter 13 (Geology, Soils, Contaminated Land and Groundwater)).

20.4.22 Along with flood risk and landslides, deformation and cracking of asphalt and soil subsidence and erosion, are some of the other vulnerabilities that have been mitigated against. The highest likelihood rating given was medium (the event occurs limited times during the lifetime of the project) and the highest consequence rating was moderate adverse (regional level disruption to strategic routes lasting more than 1 day but less than 1 week).

20.4.23 Based on the assessment undertaken it is considered that with embedded mitigation measures in place, the potential climate-related hazards and impacts identified during the operational phase are likely to be not significant.

20.5 Mitigation

20.5.1 The embedded mitigation measures, adopted as part of the evolution of the proposed scheme design, are recorded in Chapter 5 (Iterative Design Development), Chapter 6 (The Proposed Scheme) and Appendix A20.1: Vulnerability to Climate Change. These embedded mitigation measures have been allowed for within the assessments described above.

20.5.2 This section identifies the additional 'essential mitigation' measures required to further prevent, reduce and offset the environmental effects for climate identified in Section 20.4 (Potential Impacts and Effects).

20.5.3 Essential mitigation measures for the proposed scheme have been identified through a review of current legislation, policy and guidance, and have been considered in the subsequent identification of likely residual effects in Section 20.6 (Residual Effects). Such measures focus on influencing the project design and construction in order to realise the mitigation purpose/ objectives.

20.5.4 This chapter refers to the overarching standard mitigation measure, **Mitigation Item SMC-S1**, applicable across the A9 Dualling Programme. Project-specific mitigation measures ('P02' mitigation item references) have been identified for the proposed scheme. These measures are also set out in Chapter 22 (Schedule of Environmental Commitments).

20.5.5 The appointed Contractor will be required to develop a management system to structure the implementation of the mitigation measures outlined in this and other chapters of the EIAR. This will include a Construction Environmental Management Plan (CEMP) (see **Mitigation Item SMC-S1**), requirements for which will be established via the Contract Documents.

Standard Mitigation

20.5.6 In order to reduce the vulnerability of construction activities associated with the proposed scheme to climate related impacts, good construction practice (e.g. in accordance with relevant guidance such as the Construction Industry Research and Information Association (CIRIA) Environmental Good Practice on Site Guide (CIRIA, 2015), guidance on Health and Safety in Construction (Health and Safety Executive, 2006) and other relevant guidance) will be implemented and **Mitigation Item SMC-S1**, which involves the preparation of a CEMP, will be applied. This will include determining appropriate locations for site offices and facilities and storage areas for materials.

Specific Mitigation

GHG emissions

20.5.7 While the impact of the proposed scheme on climate through the release of GHG emissions has been assessed as being of negligible magnitude, and therefore not significant, DMRB LA 114 states that projects should seek to minimise GHG emissions in all cases to contribute to the UK's target for a net reduction in carbon emissions. Specific mitigation measures are therefore proposed to reduce GHG emissions associated with the proposed scheme.

Vulnerability

20.5.8 The vulnerability of the scheme has been assessed for current climate trends. Embedded mitigation measures (see Appendix A20.1: Vulnerability to Climate Change) are used to reduce the likelihood and consequence of these climate events to give no significant impacts.

20.5.9 The drainage and geotechnics design will adopt, where appropriate, a conservative approach in order to reduce the risks associated with climate-related hazards, including the use of appropriate landslide protection measures, as set out in **Mitigation Item P02-CC6**.

20.5.10 As set out in **Mitigation Item SMC-W2**, a number of measures will need to be implemented by the contractor to manage flood risk during construction, including the installation of temporary drainage systems and appropriate site management and planning. These measures will be included as part of the Construction Environmental Management Plan (CEMP), as set out in **Mitigation Item SMC-S1**.

Schedule of Environmental Commitments

20.5.11 The essential mitigation measures to be implemented are provided in Table 20.25. These measures shall be secured through contractual responsibilities between Transport Scotland and its Designer and appointed Contractor.

Table 20.25: Mitigation items for Climate

Mitigation Item	Approximate Chainage/ Location	Timing of Measure	Responsible Party	Description	Mitigation Purpose/ Objective	Specific Consultation or Approval Required	Monitoring Measures
SMC-S1	Throughout proposed scheme	Pre-construction	Main Contractor	The appointed Contractor is required to develop a management system to structure the implementation of the mitigation measures outlined in this and other chapters of the EIAR. This will include a Construction Environmental Management Plan (CEMP), requirements for which will be established via the Contract Documents.	To manage environmental impacts during construction	Transport Scotland	Review of CEMP
P02-CC1	Throughout proposed scheme	Pre-construction; Construction	Designer and Main Contractor	**Implement avoid/reduce principles in the use of GHG intensive materials and processes** The Contractor shall aim to reduce or avoid where practicable, the use of carbon intensive materials (e.g. steel and concrete). The contractor shall be required to develop and implement a Carbon Management Plan which is aligned with the principles of PAS 2080:2023 in order to inform this process throughout the detailed design, procurement and construction stages.	To minimize materials embodied carbon	Transport Scotland	Review of Carbon Management Plan Quarterly Carbon Emissions Reporting (see **Mitigation Item P02-CC5**)
P02-CC2	Throughout proposed scheme	Pre-construction	Main Contractor	**Substitute/replace GHG intensive materials** As part of the Carbon Management Plan (see **Mitigation Item P02-CC1**), and where it would not significantly impact upon engineering, safety and maintenance characteristics, lower carbon alternatives for materials are to be considered by the Contractor. For example: ▪ the use of ground granulated blast-furnace slag (GGBFS) or pulverized fuel ash (PFA) could be specified for structural members (e.g. to contain 50% GGBFS addition). The addition of this recycled material is more sustainable than CEM1 concrete and would reduce peak temperatures during curing which reduces the effect of early thermal cracking, and hence reduces the volume of steel reinforcement required. It is expected that for every tonne of CEM1 substituted with GGBFS, an avoidance of emitting up to approximately 0.8 tonnes of CO_2e may be accomplished; and/or ▪ use of recycled plastic as a replacement for typical pavement materials. It is expected that for every tonne of bitumen substituted with recycled plastic, an avoidance of emitting up to approximately 3 tonnes of CO_2e may be accomplished.	To minimize materials embodied carbon	Transport Scotland	Review of Carbon Management Plan (see **Mitigation Item P02-CC1**) Quarterly Carbon Emissions Reporting (see **Mitigation Item P02-CC5**)

Mitigation Item	Approximate Chainage/ Location	Timing of Measure	Responsible Party	Description	Mitigation Purpose/ Objective	Specific Consultation or Approval Required	Monitoring Measures
P02-CC3	Throughout proposed scheme	Pre-construction	Main Contractor	**Avoid/Reduce GHG Emissions from Processes** As part of the CEMP (see **Mitigation Item SMC-01**), the Contractor will prepare a Travel Management Plan (TMP) to capture the proposed travelling of staff required for the construction of the proposed scheme and measures to optimise journeys and demonstrate how the TMP has contributed to reduced GHG emissions. It should be noted that maximising the amount of local labour would also reduce GHG emissions from construction workers traveling to and from the site. As part of the Carbon Management Plan (see **Mitigation Item P02-CC1**), the Contractor will prefer, where possible, the sourcing of materials from local suppliers in order to reduce the travel distance of materials. Also, the contractor will optimize the transport of materials on site and include the appropriate plans and actions in the TMP. As part of the Carbon Management Plan (see **Mitigation Item P02-CC1**), the Contractor will investigate the potential of using electric construction equipment instead of conventionally powered construction plant. Also, the Contractor will investigate the potential of on-site renewable energy generation/storage to replace diesel generators and reduce grid power for plant operation. As covered by **Mitigation Items SMC-M1 to SMC-M7**, the Contractor should seek to reduce the quantities of waste materials that are generated as a result of the proposed scheme and that are required to be transported and treated off-site.	Reduce GHG emissions associated with construction activities	Transport Scotland	Review of Travel Management Plan Quarterly Carbon Emissions Reporting (see **Mitigation Item P02-CC5**)
P02-CC4	Throughout proposed scheme	Operation	Main Contractor/ Road Operating Company	**Substitute/Replace GHG Intensive Materials and Processes in Maintenance:** The embodied emissions from the materials needed for the maintenance of the proposed scheme during its whole life cycle comprise 38% of total embodied emissions (i.e. accumulated embodied emissions from construction and maintenance). A large part of the maintenance embodied emissions originates from road pavement resurfacing, including the surface course, sub-base and base course. Investigation of either a more hard-wearing material for the road surface course or a material with lower embodied emissions (e.g. recycled plastic) should be considered in order either to reduce the maintenance frequency or the total emissions per maintenance phase, respectively. This process should be undertaken before the commencement of any large maintenance works to encompass any future technological developments in the pavements and materials domain.	To minimize maintenance materials embodied carbon	Transport Scotland	Quarterly Carbon Emissions Reporting (see **Mitigation Item P02-CC5**)
P02-CC5	Throughout proposed scheme	Construction; operation	Main Contractor	Quarterly Carbon Emissions Reporting during the construction phase is required to be undertaken by the Contractor for the proposed scheme in line with the Overseeing Organisation's requirements (i.e. DMRB LA 114 and the Scottish NAA) using the 'Roads Projects Carbon Tool' (Transport Scotland, 2024). QCER during the operation phase will be required in line with the Overseeing Organisation's requirements (i.e. DMRB LA 114 and the Scottish NAA) using the 'Roads Projects Carbon Tool' (Transport Scotland, 2024). These reports will be informed with actual materials and fuel/energy consumption data.	To monitor and report actual carbon emissions.	Transport Scotland	Review of Quarterly Carbon Emissions Reports

Mitigation Item	Approximate Chainage/ Location	Timing of Measure	Responsible Party	Description	Mitigation Purpose/ Objective	Specific Consultation or Approval Required	Monitoring Measures
P02-CC6	Throughout proposed scheme	Pre-construction; construction; operation	Designer/ Main Contractor/ Road Operating Company	**Design and mitigation measures to minimise vulnerability to climate change:** The designer, contractor and operator of the network shall ensure that, as a minimum, the embedded mitigation measures described in Appendix A20.1: Vulnerability to Climate Change are implemented.	To minimize the vulnerability of the proposed to climate change	Transport Scotland	N/A
P02-CC7	Throughout proposed scheme	Pre-construction	Designer	**Drainage and Landslide Conservative Approach – Good engineering practice:** The drainage and geotechnics design will adopt, where appropriate, a conservative approach in order to reduce the risks associated with climate-related hazards, including the use of appropriate landslide protection measures.	To minimize flooding and landslide vulnerability	Transport Scotland	N/A
P02-CC8	Throughout proposed scheme	Construction	Main Contractor	**CEMP – Weather Forecasts:** In order to reduce the risk of disruption to construction activities as a result of climate related impacts, the contractor will ensure that the CEMP is implemented, along with good construction practice, and that weather forecasts are taken into consideration in the planning of day to day works. The contractor will receive weather forecast information on a daily basis and subsequently confirm weather conditions are suitable for specific tasks to be undertaken, amending the schedule of works accordingly where required. This may, for example, include amending the extent, location and/or schedule of earthworks (e.g. excavations, soil piling), with reference to storm predictions from the National Severe Weather Warning Service or other construction-focused MetOffice services (e.g. VisualEyes) to avoid impacts associated with the flooding of excavations or the stability of earthworks. Appropriate action plans developed by the Contractor will be in place, including personnel training, to address extreme weather events and the subsequent hazards.	To minimize construction sites' vulnerability	Transport Scotland	Review of CEMP to ensure appropriate plans are in place to identify and mitigate potential impacts of adverse weather conditions during the construction phase, and minimise the risk of disruption.

Mitigation Item	Approximate Chainage/ Location	Timing of Measure	Responsible Party	Description	Mitigation Purpose/ Objective	Specific Consultation or Approval Required	Monitoring Measures
P02-CC9	Throughout proposed scheme	Operation	Main Contractor/ Road Operating Company	**Appropriate Asset Management during Operation** The operator of the scheme shall have in place appropriate asset management procedures to maintain the resilience of the scheme to climate related impacts in line with DMRB requirements. These asset management measures should evolve once the asset is operational in response to changes in climate and associated impacts. For example, where a design issue is identified, an assessment should be made to determine if corrective action is required, e.g. drainage amendments to rectify a flooding hotspot that was not anticipated at the design stage. Furthermore, a procedure will be developed (and added as part of the maintenance plan) to establish communication with the operator of the former A9 (C502 (Dunkeld to Rotmell) Road) in order to confirm the maintenance of the road drainage is satisfactorily carried out. It should be noted that the 2004 landslide was exacerbated by the former A9 (C502 (Dunkeld to Rotmell) Road) drainage infrastructure failure, whereas ch7600 to ch8400 is identified as a landslide vulnerable area. The operator will include in their maintenance plans the visual inspection of the proposed scheme's assets to ensure that, if and where required, appropriate maintenance and repair activities are undertaken in response to climate related impacts, in addition to predefined maintenance intervals. The inspections will include one-off inspections after certain precipitation events e.g. intense storm events, longer persistent wet periods, or extended periods with very high temperatures.	To maintain the proposed schemes resilience	Transport Scotland	Review of proposed assessment procedures and reports on maintenance and inspection activities.

20.6 Residual Effects

GHG emissions

20.6.1 GHG emissions during both the construction and operation stage of the proposed scheme are likely to have an adverse impact on climate. However, in line with DMRB LA 114, and based on professional judgement, the magnitudes of these changes in GHG emissions are predicted to be negligible when compared with UK carbon budgets and the Scottish Government interim targets. Therefore, it is not expected the proposed scheme will materially hinder the Scottish or UK Governments from meeting their legislated carbon reduction targets. As such no significant residual effects are identified.

20.6.2 It is also noted that operational road user GHG emissions are estimated to contribute the majority (i.e. approximately 95%) of the estimated increase in GHG emissions beyond 2036. As noted in paragraph 20.4.9, the estimated road user GHG emissions presented within this assessment are likely to be conservative as they do not account for more recent government policy aimed at reducing road user GHG emissions (e.g. future bans on the sale of petrol and diesel cars and vans). Such government policies, and other such policies and plans implemented at a national and UK level in order to meet net zero emission targets, will result in a more substantial reduction in road user GHG emissions in future years compared to that presented within this assessment. It is these national and UK level policies, which will ultimately determine whether carbon budgets are achieved in future years, rather than the impact of an individual highway scheme. That said, mitigation measures have still been proposed to minimise GHG emissions going forwards, where possible.

Vulnerability

20.6.3 While future changes in climate have the potential to have an adverse impact on certain elements of the proposed scheme during both its construction and operation, no significant residual effects are identified following the implementation of the standard, embedded and specific mitigation measures identified.

20.7 Compliance Against Plans and Policy

20.7.1 DMRB LA104, Environmental Assessment and Monitoring, states that environmental assessment, reporting and monitoring shall meet the requirements of the national planning policy for each relevant Overseeing Organisation.

20.7.2 Appendix A3.1 (Assessment of Policy Compliance) provides a review of national and local policy documents which are of relevance to the assessment undertaken and reported in this chapter in accordance with DMRB guidance. The compliance assessment undertaken in Appendix A3.1 focuses principally on the long-term effects of the proposed scheme rather than the short term, temporary effects from construction.

20.7.3 National policy objectives of relevance to this assessment are provided in the National Planning Framework 4, Policies 1 and 2 (Scottish Government, 2023), Climate Change Plan:

The Third Report on Proposals and Polices 2018-2032 (Scottish Government, 2018) and the Update to the Climate Change Plan 2018 – 2032 (Scottish Government, 2020a) and Environment Strategy for Scotland (Scottish Government, 2020b). Climate Ready Scotland: Second Scottish Climate Change Adaptation Programme 2019-2024 (Scottish Government, 2019a), Scottish National Adaptation Plan 2024-2029 (Scottish Government, 2024) and Transport Scotland's Approach to Climate Change Adaptation & Resilience (Transport Scotland, 2023) also provide relevant guidance. In addition, the Perth and Kinross Local Development Plan 2 (Perth and Kinross Council, 2019) Policy 1 (Placemaking) is of relevance.

Summary of Policy Compliance

20.7.4 Overall, the design and assessment of the proposed scheme has had regard to policy objectives to reduce climate change effects. Although increases in GHG emissions have been identified during both construction and operation, these emissions are unlikely to have a material impact on the ability of the UK or Scottish Government to meet respective climate change targets (see Table 20.22, Table 20.23 and Table 20.24). The proposed scheme will therefore not result in non-compliance with national policy. A full assessment of policy compliance can be found in Table A3.1-13 of Appendix A3.1 (Assessment of Policy Compliance).

20.7.5 Furthermore, by including mitigation measures to reduce GHG emissions associated with the construction and operation of the proposed scheme and to reduce the proposed scheme's vulnerability to potential future changes in climate, the proposed scheme is considered to comply with policy aimed at minimising GHG emissions associated with new development and improving the resilience of infrastructure to climate change.

20.8 Statement of Significance

20.8.1 As the results of this assessment suggest increases in GHG emissions due to the proposed scheme are unlikely to have a material impact on the ability of the UK or Scottish Governments to meet their respective carbon reduction targets, the impact of the proposed scheme on climate is considered not significant.

20.8.2 The results of this assessment also suggest that it is unlikely the climate related hazards identified will result in significant impacts, either during construction or operation of the proposed scheme.

20.9 References

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