Lower Thames Crossing

6.3 Environmental Statement Appendices
Appendix 15.1 Carbon and Energy Plan

APFP Regulation 5(2)(a)

Infrastructure Planning (Applications: Prescribed Forms and Procedure) Regulations 2009

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Lower Thames Crossing

6.3 Environmental Statement Appendices
Appendix 15.1 Carbon and Energy Plan

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1 Appendix 15.1 Carbon and Energy Plan

1.1 Executive summary

1.1.1 The A122 Lower Thames Crossing (the Project) is a proposed new crossing of the River Thames, east of London. The route is approximately 23km long, 4.25km of which is in tunnel.

1.1.2 Carbon emissions from infrastructure account for 53% of the UK's total emissions (Delivering low carbon infrastructure report). As a major infrastructure project, Highways England (the Applicant) needs to ensure the Project contributes to the UK's net zero carbon goal. This plan sets out how the Project will do this by quantifying its likely carbon emissions and setting out methods for reducing them.

1.1.3 Highways England has quantified the Project's emissions covering the construction phase and a sixty-year operational phase using the best available data. Although the design life of the Project is 120 years, the carbon model uses a sixty-year operational phase as this is the timescale set out in the Department for Transport's Transport Appraisal Guidance, a standard industry methodology. The carbon emissions resulting from the construction and operation of the Project are estimated to be 5,272,562 tonnes of carbon dioxide equivalent (tCO_2e).

1.1.4 The key components of the Project's emissions are:

a. Emissions from traffic in the operational phase: 52% of the Project's total emissions.

b. Emissions from the materials used for the construction of the tunnels (the extraction, processing and manufacturing of the construction material and the movement of materials and goods to final factory gate): 13% of total emissions.

c. Emissions from the maintenance, repair and replacement of the Project's assets: 9% of total emissions.

d. Emissions from the materials used for the construction of the highways (the extraction, processing and manufacturing of the construction material and the movement of materials and goods to final factory gate): 7% of total emissions.

e. Emissions from the enabling works: 6% of total emissions.

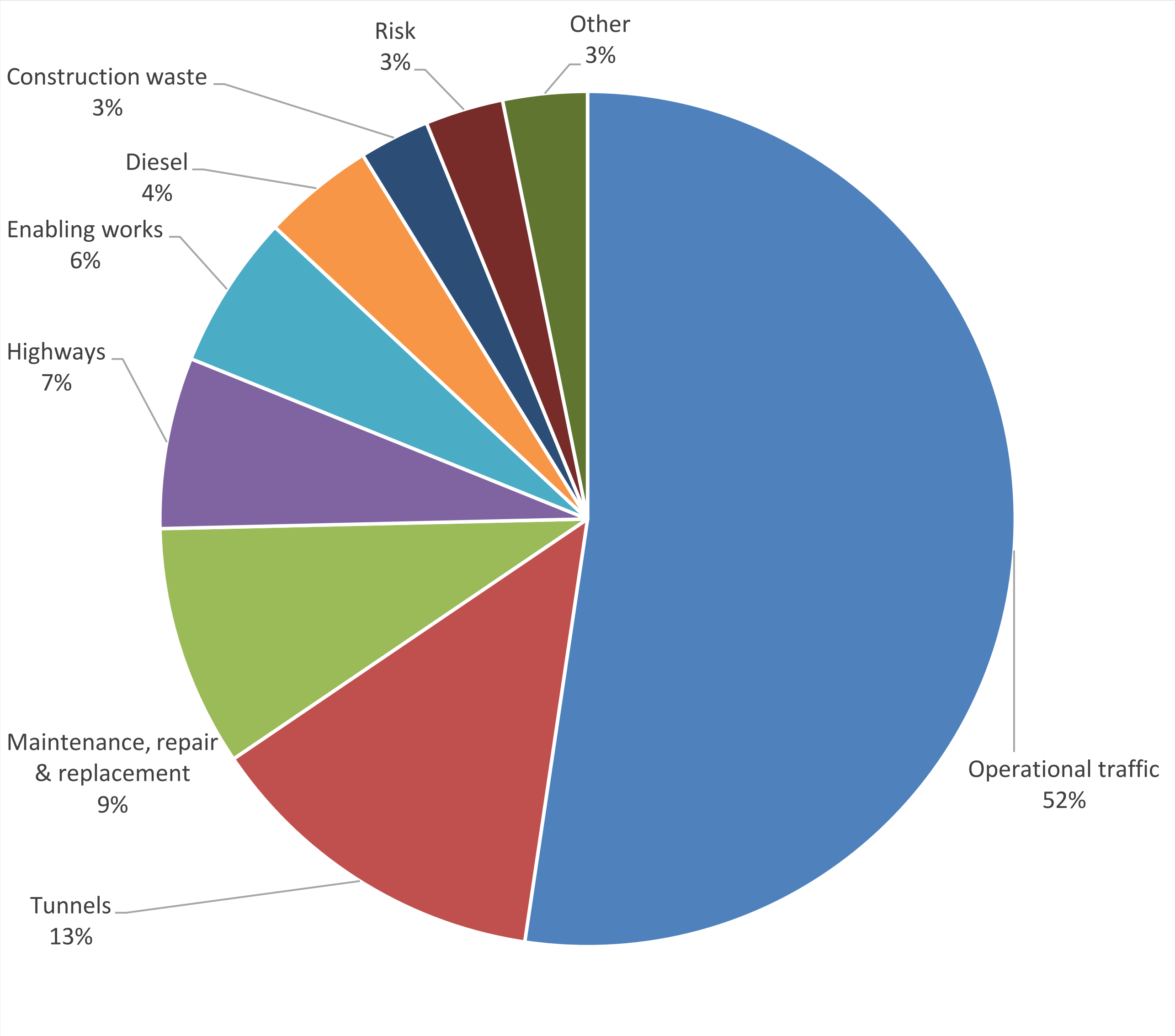
f. Emissions from the consumption of diesel used in the construction of the tunnels and highways: 4% of total emissions.

g. Emissions from construction waste: 3% of total emissions.

h. Emissions associated with risk items: 3% of total emissions. This covers the emissions from scenarios that are uncertain, e.g. the degree of ground improvement that is required for the highways. Although these scenarios may not materialise, we have apportioned carbon emissions to them to provide more thorough estimate of overall emissions.

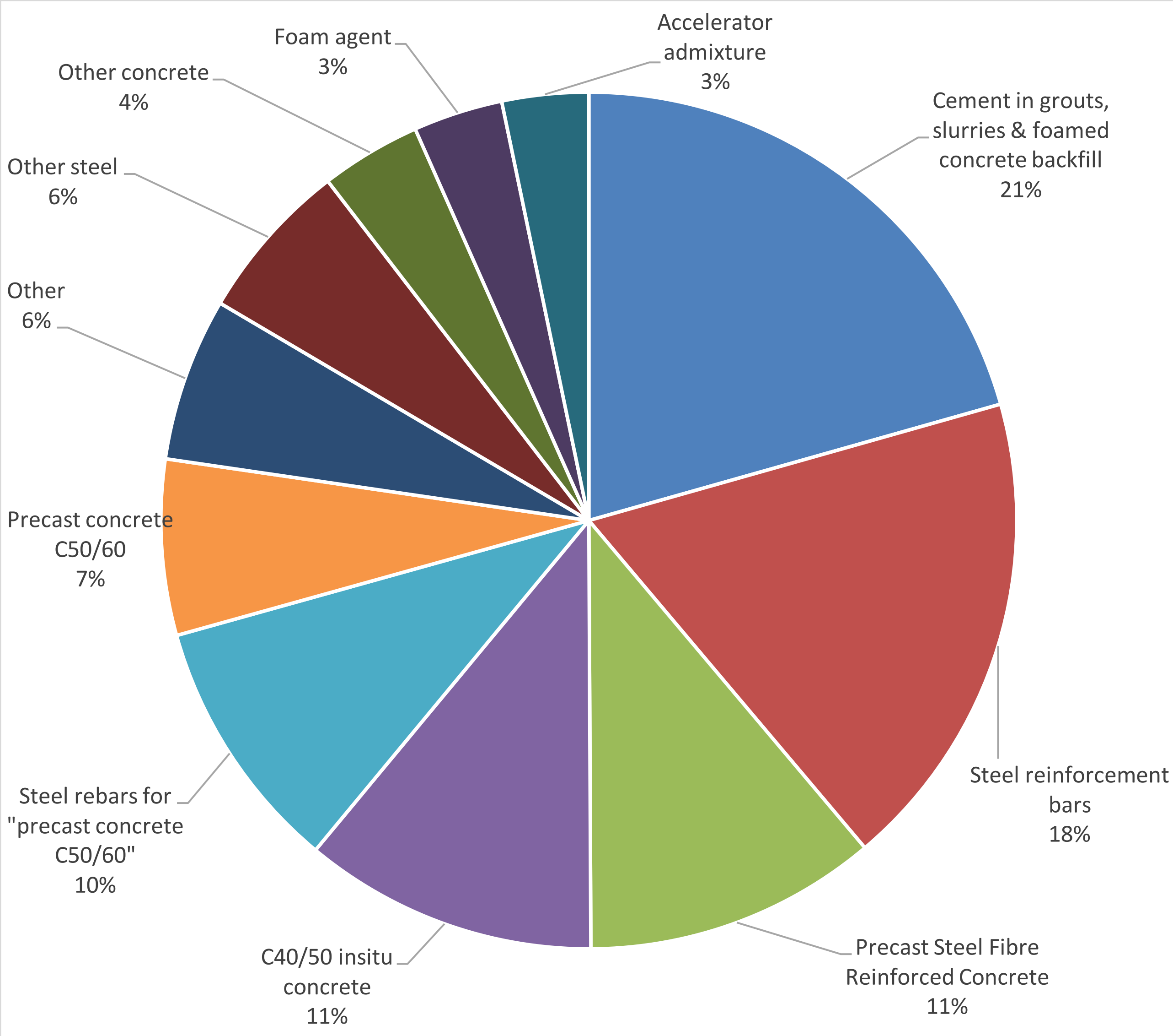
1.1.5 The remaining emission sources account for only 3% of emissions and include construction phase traffic, land use change, soil and fill import and treatment, water consumption and petrol consumption in compounds. Annex A shows tables of emissions data.

Plate 1.1 Carbon emissions over construction phase and sixty-year operational phase



1.1.6 The construction of the tunnels accounts for 13% of the total emissions and the key assets that contribute to these emissions are the twin bored tunnels and the North Portal structure, comprising 81% of total tunnel emissions. The key materials which impact on the carbon emissions from tunnels construction are steel, concrete and cement in grouts, slurries and foamed concrete backfill, accounting for 87% of total tunnel emissions.

Plate 1.2 Carbon emissions from the construction of the tunnels, broken down by material



1.1.7 For highways, 55% of the permanent works emissions come from bridges, viaducts and culverts. As for tunnels, concrete and steel are key components of the emissions, representing 76% of highways permanent works emissions.

1.1.8 To comply with LA 114, Highways England has acted to reduce emissions by including mitigation measures embedded in the preliminary design and by embedding carbon reductions in the construction stage through the procurement process to ensure that the Contractors are contractually bound to comply with relevant commitments made as part of this application.

1.1.9 Table 1.1 shows how each opportunity has been implemented either:

a. Assumed in carbon model: These opportunities have been included in the carbon model. If the Contractors choose not to implement them, they will need to implement other carbon reduction opportunities to reduce emissions by an equivalent amount.

b. Mitigation measures set out in the Register of Environmental Actions and Commitments (REAC), (Appendix 2.2, Application Document 6.3). Compliance with the REAC is secured through the Requirements in Part 1 of Schedule 2 of the draft DCO (Application Document 3.1).

c. Contractual requirement: These opportunities will be listed as requirements in the contractual documents.

Table 1.1 Emissions reductions achieved

Opportunity	**Detail**	**Outcome**
Removed some assets and reduced the size of others	Removed bridge at Hornsby Lane Reduced the number of lanes on the Project road south of the M25 Widened the existing Rectory Road rather than constructing a new highway	Assumed in carbon model
Assumed the use of low carbon materials and operations	Electricity used in compounds will be from renewable sources. Using electricity from renewable sources, including procuring it via an electricity supplier, means an emission factor of zero can be used when reporting emissions (market-based).	Appendix 2.2: REAC (Application Document 6.3) lists this commitment [CC004] The use of renewable energy for construction electricity consumption has saved 93,480 tCO_2e.
	Electricity used during the operation of the Project will be from renewable sources	Appendix 2.2: REAC (Application Document 6.3) lists this commitment [CC007] The use of renewable energy for operational electricity consumption has saved 110,722 tCO_2e
	65% ground granulated blast-furnace slag (GGBS) in C40/50 *in situ* and C50/60 precast concrete for tunnels and highways. This goes beyond current typical practice of using approximately 50% GGBS.	Assumed in carbon model Including 65% GGBS in the carbon model has reduced emissions by 118,742 tCO_2e for tunnels and 38,884 tCO_2e for highways.
	Steel fibre reinforced concrete (SFRC) for most of the concrete segments in the bored tunnels which has a	Assumed in carbon model Selecting SFRC has reduced emissions by 31,611 tCO_2e

Opportunity	Detail	Outcome
	lower emission factor than steel bar reinforced concrete.	
	Warm mix asphalt for the base and binder course instead of hot mix asphalt.	Assumed in carbon model Using warm mix asphalt in the carbon model has reduced emissions by 6,315 tCO_2e.
	The use of some hybrid and electric plant in place of diesel plant in construction compounds and work sites.	Assumed in carbon model Including hybrid or electric plant in the carbon model has reduced emissions by 3,009 tCO_2e.
	The use of energy-efficient equipment and lights for the tunnels and highways.	Assumed in carbon model
Assumed the planting of trees and vegetation	The planting of trees and vegetation so that the overall impact of land use change will be to sequester carbon from the atmosphere.	Assumed in carbon model
Contractors to reduce emissions beyond the baseline	Contractors will be required to reduce emissions beyond the baseline presented in this report. Carbon reduction will be one of the criteria used during the selection process and the selected Contractors will develop a carbon reduction target. The target will then become a contractual commitment and failure by the Contractors to provide the works in accordance with its commitment will be treated as a defect in accordance with the contract.	Appendix 2.2: REAC (Application Document 6.3) lists this commitment [CC002]
Contractors to achieve third-party verification with PAS 2080	Contractors will adhere to PAS 2080 and develop a PAS 2080-compliant approach detailing how GHG emissions reductions will be identified, prioritised, implemented and monitored. As taking action early is critical in minimising carbon emissions, the Contractors will submit PAS 2080 compliant carbon management plan to Highways England for approval within three months	Appendix 2.2: REAC (Application Document 6.3) lists this commitment [CC001]

Opportunity	Detail	Outcome
	of appointment and will review it annually. Tier one Contractors will be required to obtain external verification within 12 months of appointment. Where Early Contractor Involvement is used as the procurement model, the tier one Contractor will be required to show substantial progress towards external verification by the end of stage one and to obtain verification within three months of stage two.	
Contractors to quantify & report emissions	Contractors will quantify and report carbon emissions quarterly, both total emissions and asset-level emissions.	Appendix 2.2: REAC (Application Document 6.3) lists this commitment [CC003]
Contractors to provide Environmental Product Declarations	Contractors will identify ten construction products contributing the most to total emissions and provide Environmental Product Declarations to the Project Manager for acceptance.	Contractual requirement
Contractors to include carbon in Building Information Model (BIM)	Contractors will input their revised baseline carbon calculation to BIM within six months of the start date and use BIM to generate quantities data for carbon calculations. This will facilitate the analysis of the emissions impact of design changes and provide a clear audit trail.	Contractual requirement

1.1.10 The actions and commitments outlined above will help the Project reduce its carbon impact and contribute to the UK’s net zero goal.

1.1.11 In addition to the measures set out in Table 1.1, Highways England has identified further measures to reduce emissions. These measures are not assumed in the carbon model so implementing any of them will enable Contractors to reduce emissions beyond what has been assessed in this carbon model and Contractors should take these measures into account when proposing a reduction target. If Contractors choose not to implement any of these measures, they should provide a justification in their PAS 2080 compliant carbon management plan. The key measures are as follows:

a. Reducing the size of assets including tunnel portals, bridges and junctions.

b. Reducing the emissions impact of the concrete used, for example by further increasing the percentage of GGBS in the concrete used, from 65% to 80% and by considering alkali-activated cements.

c. Reducing the emissions impact of the cement used, for example by using GGBS in cement and by investigating the possibility of using non-grout solutions in poor ground conditions.

d. Using steel fibre reinforced concrete in other areas besides the concrete segments in the bored tunnels.

e. Reducing the amount of material used, particularly for materials with a high carbon emission factor, including steel and aluminium.

f. Increasing the percentage of plant that is hybrid or fully electric.

g. Selecting the most energy efficient equipment for tunnels and highways and looking at whole life cost ahead of capital cost.

1.1.12 During the operational phase, the road operator will quantify and report the emissions from the operation and maintenance of the Project annually. The REAC (Appendix 2.2, Application Document 6.3) lists this commitment [CC005]. To reduce emissions associated with maintenance, repair and replacement, Highways England will encourage Contractors to look at whole-life cost and carbon when specifying materials and equipment.

1.2 Introduction

Project description

1.2.1 The Project would provide a connection between the A2 and M2 in Kent, east of Gravesend, crossing under the River Thames through two bored tunnels, before joining the M25 south of junction 29. The Project route is presented in Plate 1.3.

1.2.2 The A122 road would be approximately 23km long, 4.25km of which would be in tunnel. On the south side of the River Thames, the Project route would link the tunnel to the A2 and M2. On the north side, it would link to the A13 and junction 29 of the M25. The tunnel portals would be located to the east of the village of Chalk on the south of the River Thames and to the west of East Tilbury on the north side.

1.2.3 Junctions are proposed at the following locations:

a. New junction with the A2 to the south-east of Gravesend

b. Modified junction with the A13/A1089 in Thurrock

c. New junction with the M25 between junctions 29 and 30

1.2.4 To align with NPSNN policy and to help the Project meet the Scheme Objectives, it is proposed that road user charges will be levied. Vehicles would be charged for using the new Lower Thames Crossing tunnel.

1.2.5 The Project road would be three lanes in both directions, except for:

a. link roads

b. stretches of the carriageway through junctions

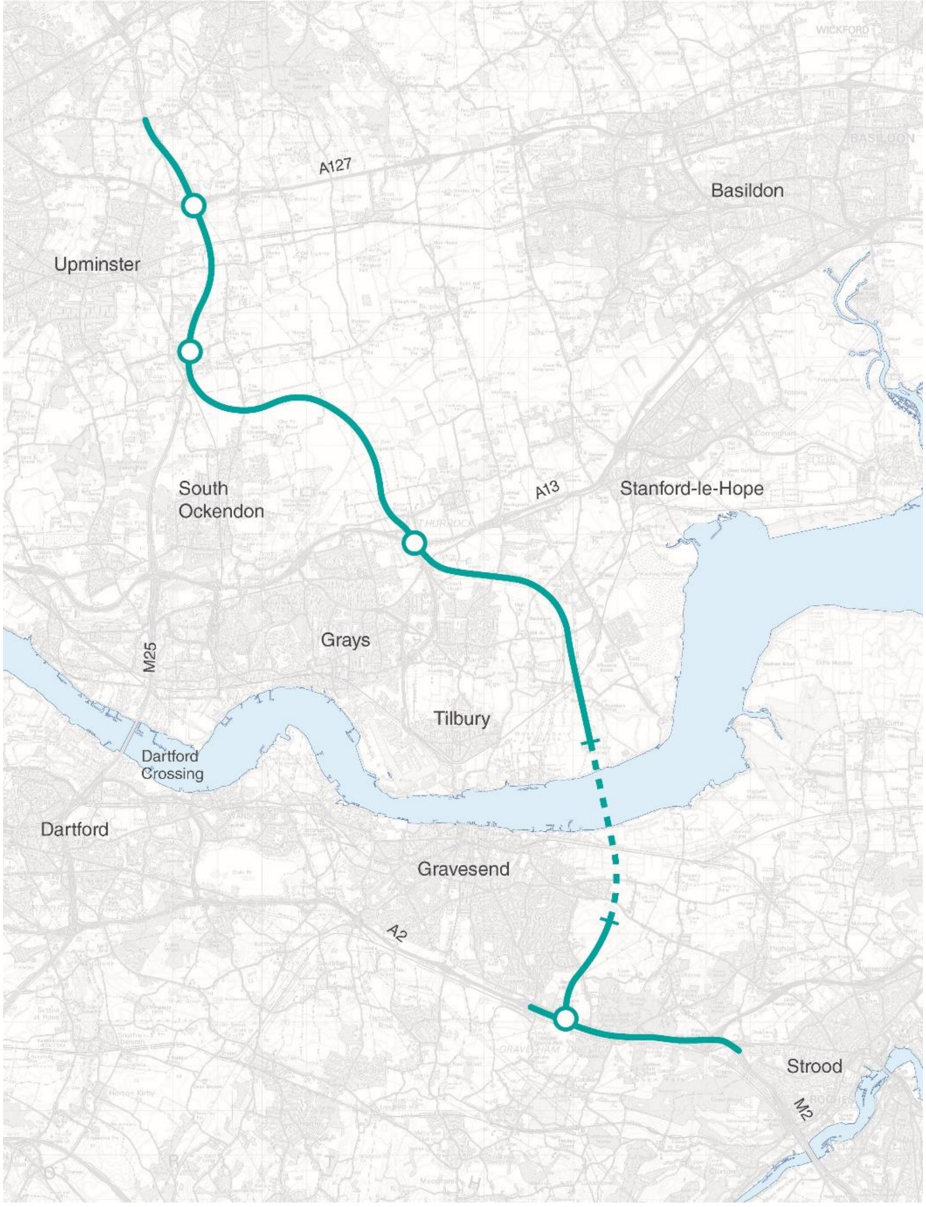
c. the southbound carriageway from the M25 to the junction with the A13/A1089, which would be two lanes

1.2.6 Technology would be provided for lane control and to apply variable speed limits. The A122 road would have hard strips for most of its length, and emergency areas. Modified sections of the M25 and the A2 would have hard shoulders.

1.2.7 The Project road would be an all-purpose trunk road, with green signs, but would have additional vehicle restrictions imposed and managed through signage so that only motorway traffic would be permitted to use the road.

1.2.8 The Project would include adjustment to a number of side roads to accommodate the A122 road and to connect with the Project road at the A13 and A2 junctions. There would also be adjustments to a number of Public Rights of Way, used by walkers, cyclists and horse riders. Construction of the Project would also require the diversion of a number of utilities, including gas pipelines, overhead and underground electricity cables, as well as water supplies and telecommunications assets.

Plate 1.3 Lower Thames Crossing route



Key terms

1.2.9 This section sets out the key terms used in this Carbon and Energy Plan.

Greenhouse gas emissions (GHG)

1.2.10 Greenhouse gases are those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of thermal infrared radiation emitted by the Earth's surface, the atmosphere itself, and by clouds (Intergovernmental Panel on Climate Change).

1.2.11 The United Nations Framework Convention on Climate Change (UNFCC) Kyoto Protocol identifies seven main greenhouse gases:

a. carbon dioxide (CO_2)

b. methane (CH_4)

c. nitrous oxide (N_2O)

d. hydrofluorocarbons (HFCs)

e. perfluorocarbons (PCFs)

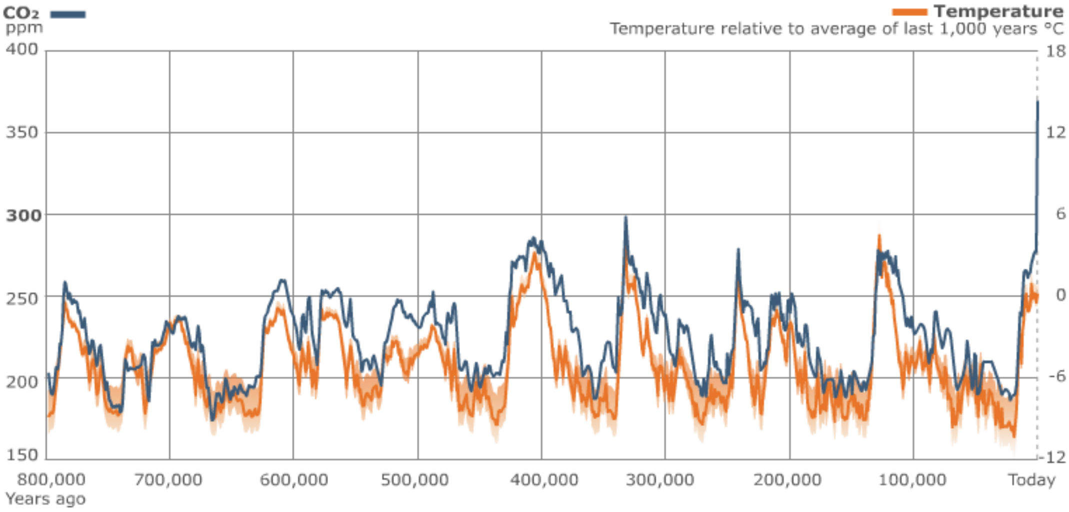
f. sulphur hexafluoride (SF6)

g. nitrogen trifluoride (NF3).

1.2.12 As is common practice, this report uses the term ‘carbon’ as shorthand for the seven main greenhouse gases. The GHG emissions of each gas are converted into tonnes of carbon dioxide equivalent (tCO_2e), considering their different global warming potentials.

1.2.13 The concentration of GHGs has increased significantly in the last 100 years as a result of human activity. Having not been above 300ppm in the last 800,000 years, CO_2 concentrations are now permanently above 400ppm, resulting in climate change across the world.

Plate 1.4 CO_2 concentrations and temperature changes over the last 800,000 years



1.2.14 A carbon footprint is a quantification of the total GHG emissions arising from a project, product or organisation. In this report, we present the carbon footprint for the Project, referred to as the 'carbon model'.

Carbon management

1.2.15 Carbon management is a process through which organisations or projects can reduce their carbon impact, by quantifying emissions and then acting to reduce them.

Net zero

1.2.16 Net zero means balancing the amount of GHG emissions produced and the amount of emissions removed from the atmosphere. Net zero can be achieved by reducing emissions and actively removing GHGs from the atmosphere.

1.2.17 In the context of the UK, net zero means that the UK's total GHG emissions would be equal to or less than the emissions the UK removed from the environment.

Carbon hotspot

1.2.18 A carbon hotspot is a term used to denote and highlight areas or activities which have high carbon emissions.

Purpose of this Carbon and Energy Plan

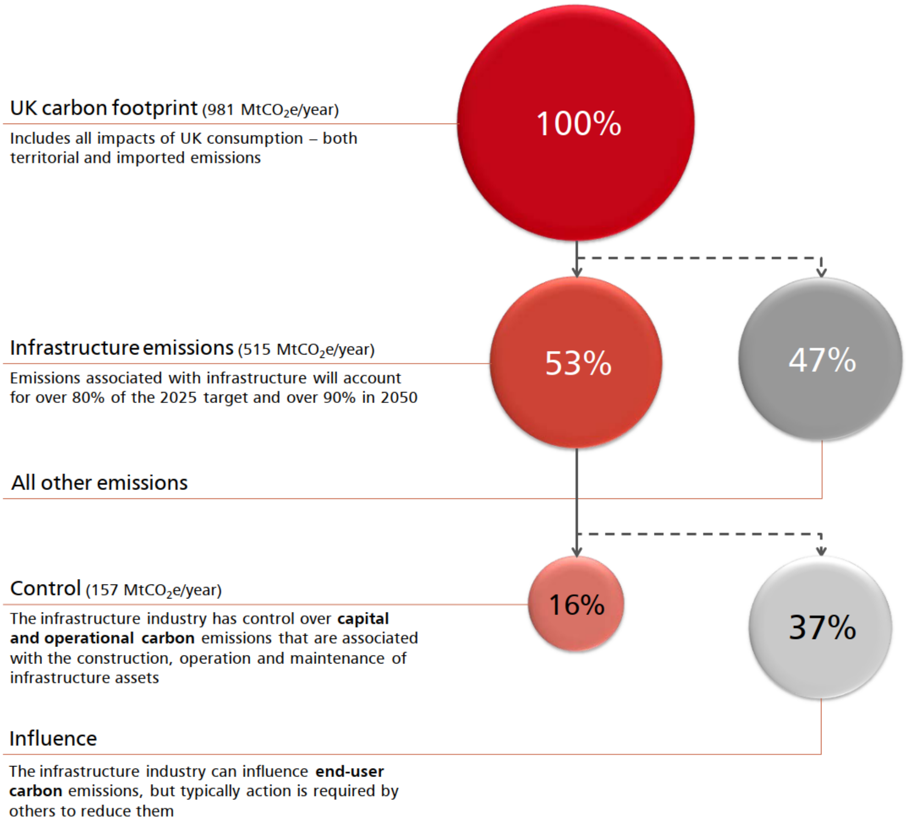
1.2.19 The infrastructure industry has a crucial role to play in helping the UK meet its 2050 net zero emissions target because carbon emissions from infrastructure account for 53% of the UK's total emissions (based on 2010 data, Plate 1.5).

1.2.20 These emissions consist of:

a. End-user carbon emissions (37% of total UK emissions). The infrastructure industry does not control these emissions but may influence them. For this Project, end-user emissions are the emissions from the vehicles using the road.

b. Capital and operational emissions (16% of total UK emissions). These are emissions that the infrastructure sector can control. For this Project, the capital emissions are the emissions from constructing the highways and tunnels and the operational emissions are those from operating the highways and tunnels (e.g. emissions from maintenance, repair and replacement).

Plate 1.5 Carbon emissions in the infrastructure sector (2010), from the Delivering Low Carbon Infrastructure report



1.2.21 Highways England recognises the role it must play in contributing to the UK's effort to tackle climate change. The Government has set a target of achieving and has legislated to achieve net zero carbon emissions by 2050 and Highways England must contribute to this goal by seeking to reduce the emissions resulting from the Project.

1.2.22 As well as helping to tackle climate change, minimising its carbon impact will bring other benefits to the Project including:

a. Reducing cost

b. Promoting innovation

c. Enhancing reputation

1.2.23 Reducing carbon emissions is an important factor for the Department for Transport and as such, the need for carbon reduction is included in Highways

England’s licence (Department for Transport (DfT), 2015). Under Environment (5.23), it states that the Licence holder should:

‘Calculate and consider the carbon impact of road projects and factor carbon into design decisions, and seek to minimise carbon emissions and other greenhouse gases from its operations’

1.2.24 The Road Investment Strategy 2 (DfT, 2020), which includes the Project, also considers carbon. One of the performance indicators, against which the performance of Highways England and the strategic road network is assessed, covers supply chain carbon emissions:

‘Emissions from Highways England’s contractors (including embodied carbon from construction) per million pounds spent’

1.2.25 Carbon is also covered in the Design Manual for Roads and Bridges (DMRB), which is one of the Standards for Highways. The manual contains a section on climate (LA 114 Climate).

1.2.26 LA 114 sets out the method for minimising the carbon impact of highways projects:

a. Avoid/prevent emissions (through reuse or refurbishment of existing assets to reduce the extent of new construction and/or exploration of alternative lower carbon options).

b. Reduce emissions (through low carbon and/or reduced resource consumption solutions during construction, operation and end of life).

c. Remediate (through on or offsite offsetting or sequestration).

1.2.27 Carbon is a key consideration within the transport appraisal process. The Transport Analysis Guidance requires that GHG impact of any proposed scheme is included in the appraisal in a consistent and transparent way.

1.2.28 Therefore, the Project has several different drivers to reduce carbon emissions. This Carbon and Energy Plan demonstrates how the Project will reduce its carbon impact in line with these drivers.

1.2.29 This Carbon and Energy Plan links to other Application Documents including:

a. The Planning Statement and NNNPS Accordance Table, which sets out the policy context and how the Project complies (Application Document 7.2).

b. Environmental Statement (ES) chapter on material assets and waste, which sets out the materials required, and the construction waste generated as a result of the Project (Application Document 6.1, Chapter 11: Material Assets and Waste).

c. ES chapter on climate, which uses the data from the carbon model (presented in this report) for the ‘Do Something’ scenario and which sets out mitigation options aligned to those presented here (Chapter 15: Climate, Application Document 6.1)

d. Register of Environmental Actions and Commitments (REAC) (Appendix 2.2, Application Document 6.3) in which the key carbon commitments presented in this report are listed. Compliance with them is secured through Requirement 4 of the draft DCO (Application Document 3.1).

e. Sustainability Statement which covers the Project's approach to sustainability (Application Document 7.12).

f. Combined Modelling and Appraisal (ComMA) Report which presents the estimates of the GHG emissions arising from operational traffic (Application Document 7.7).

Legal, policy, regulatory and guidance context

1.2.30 The Climate chapter (Application Document 6.1) provides an overview of the national, regional and local policy and guidance relevant to the Project.

1.3 Carbon model for the Project

1.3.1 This section sets out how Highways England has quantified the Project's carbon emissions, following the principles of PAS 2080: 2016 Carbon Management in Infrastructure (Construction Leadership Council, 2016), and presents the results of that quantification.

Goal and scope

1.3.2 The goal in assessing the Project's carbon emissions is to quantify and report predicted emissions, and to identify the main contributors (emissions hotspots) so it can focus its emissions reductions effort effectively.

1.3.3 The scope of the quantification is the whole of the construction phase and a sixty-year operational phase, as this is the timescale set out in the Department for Transport's Transport Appraisal Guidance, a standard industry methodology.

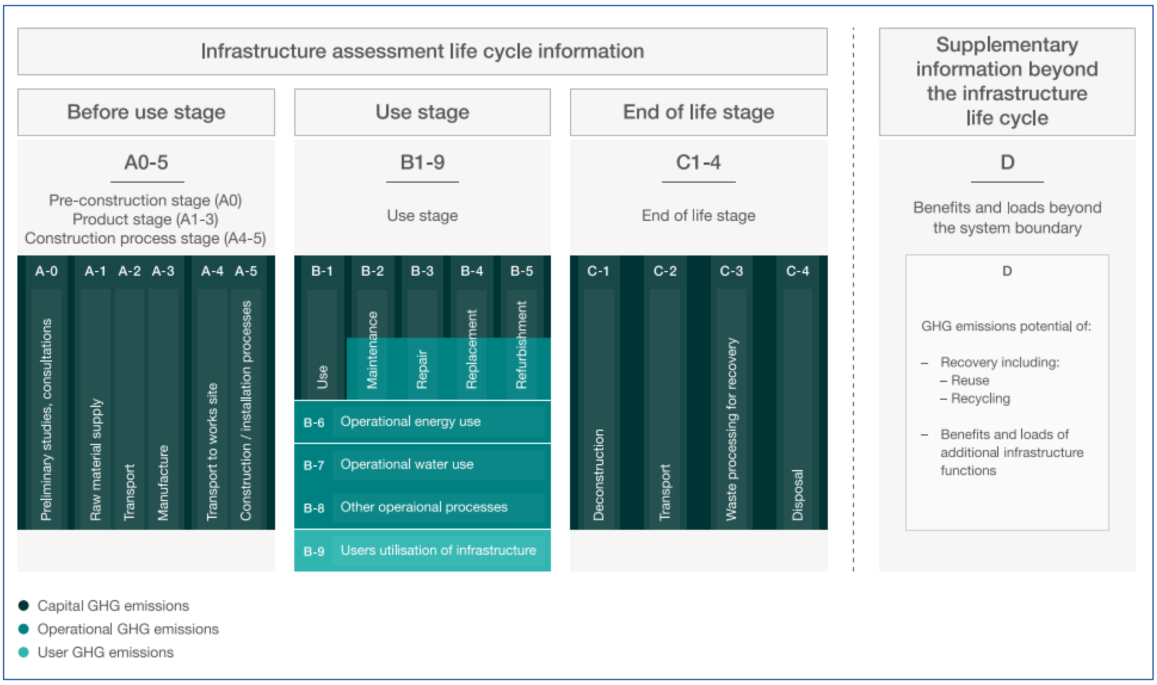
Assessment boundaries

1.3.4 This section outlines the assessment boundaries that have been used for the carbon model.

Lifecycle boundaries

1.3.5 PAS 2080: 2016 divides an infrastructure project into modules, covering the before use stage, use stage and end of life stage, as well as impacts beyond the infrastructure life cycle (Plate 1.6).

Plate 1.6 PAS 2080:2016 Modular Approach (taken from PAS 2080: 2016: Carbon Management in Infrastructure)



1.3.6 As many of these modules as was practically possible, have been included in the carbon model. Table 1.2 shows which ones are included and provides an explanation for those that have been excluded.

Table 1.2 PAS 2080:2016 modules in the carbon model

Modules	Scope	Status
A: Before Use Stage (Construction)		
A0: Pre-construction	• Preliminary studies and works such as strategy and brief development, architecture, design efforts, EIA and cost planning. These functions are largely office-based.	• Enabling works have been included • Other aspects have been excluded as no sources of carbon emissions more than 1% of total can be identified from this module, based on professional judgement, and data is not available to quantify this module further.
A1 – A3: Product stage	• Emissions associated with the extraction, processing and manufacturing of the construction material. It includes energy consumption and waste management within these processes. • Emissions associated with the movement of materials and goods within the supply chain up to the point of final factory gate.	• Included
A4: Construction process stage: Transport to works sites	• Transport emissions associated with the delivery of construction material, construction equipment and construction workers to works sites.	• Included
A5: Construction process stage: On site stage	• Enabling works and ground works • Materials storage and any energy or otherwise needed to maintain necessary environmental conditions • Transport of materials and equipment on site • Installation of materials and products into the infrastructure asset • Emissions associated with site water demand • Waste management activities (transport, processing, final disposal)	• Included

Modules	Scope	Status
	associated with waste arising from the construction site • Production, transportation, and waste management of materials/products lost during works • Carbon emissions associated with land use change	
B: Use Stage		
B1: Use	• Carbon emitted directly from the fabric of products and materials once they have been installed as part of the infrastructure.	• Carbon sequestration from planting of trees and vegetation included in land use change part of A5. • No other relevant emissions identified.
B2 – B5: Maintenance, repair, replacement and refurbishment	• Works activities and new materials for the maintenance, repair, replacement and refurbishment of the infrastructure during the use stage.	• Maintenance: The emissions associated with the day-to-day upkeep of the Project have been included. Maintenance includes plant equipment, materials and transport activities. • Repair: The repair of any fixed infrastructure assets is excluded as it is assumed the assets would be maintained to prevent failure. Any preventable failures are not included within scope as it cannot be anticipated and therefore assessed. • Replacement: A number of assets will require replacement over the sixty-year timescale of the carbon model and replacement has been included in the model. • Refurbishment: This has been excluded, as the only potential source of emissions identified was associated with the refurbishment of portal buildings and as it is expected that this would be far less than 1% of total carbon emissions, based on professional judgement, it is not considered

Modules	Scope	Status
		necessary to include. The replacement of the portal buildings has been included.
B6: Operational Energy	• Emissions resulting from the energy used by infrastructure-integrated technical systems to enable it to deliver its service during operation. This might be to provide heating and cooling, ventilation, lighting, auxiliary energy for pumps, control and automation.	• Included
B7: Operational Water	• Emissions resulting from the consumption of water required by the infrastructure to enable it to operate and deliver its service. It includes all water used and its treatment (pre- and post-use) during the normal operation of the infrastructure.	• Excluded as the carbon emissions of water during operation are expected to be low (less than 1%), based on professional judgement. The main use would be by staff at the portal buildings, fire incident response and tunnel washing.
B8: Other Operational Processes	• Other process emissions arising from the infrastructure to enable it to operate and deliver its service including management of operational waste.	• Excluded as this module is expected to contribute less than 1% of total emissions based on professional judgement due to low annual tonnages and high diversion from landfill.
B9: User's Utilisation	• Activities associated with the user's utilisation of the infrastructure during the use stage included.	• Included. This is the emissions from the traffic generated by the Project.
C: End of life stage		
C1: Deconstruction	• Onsite activities of deconstructing, dismantling and demolishing the infrastructure.	• Excluded as the Project has no planned end of life and infrastructure assets are rarely decommissioned.
C2: Transport	• Emissions due to the transport to disposal and/or until the end-of-waste state of waste materials.	• Excluded as above
C3: Waste Processing for Recovery	• Emissions due to the treatment and processing for recovery, reuse and recycling of waste materials	• Excluded as above

Modules	Scope	Status
	arising from the infrastructure.	
C4: Disposal	• Emissions resulting from final disposal of demolition materials (neutralisation, incineration with or without utilisation of energy, landfilling with or without utilisation of landfill gases, etc.).	• Excluded as above

Spatial boundaries

1.3.7 The carbon model includes the emissions outlined in Table 1.2 irrespective of the geographic location in which they occur.

Temporal boundaries

1.3.8 The temporal scope for the carbon model covers:

a. The construction phase.

b. The operational phase. The carbon model uses a sixty-year operational phase as this is the timescale set out in the Department for Transport's Transport Appraisal Guidance. The design life of the Project is 120 years.

Data

Data quality principles

1.3.9 Highways England has assessed the Project's emissions on a life cycle basis following the principles of PAS 2080.

1.3.10 It has used the best available data in line with the PAS 2080 data quality principles:

Table 1.3 PAS 2080 data quality principles

Data quality principle	Application to the Project
Age	The activity data and carbon emission factors used are applicable to the time period for construction or operation.
Geography	The activity data is specific to the Project and emission factors used are applicable to the UK.
Technology	The activity data and emission factors used are representative of the UK construction and transport sectors.
Methodology	The activity data is specific to the Project and has been provided by the Project's engineering and design teams.
Competency	The activity data is specific to the Project and has been provided by the Project's engineering and design teams. The emission factors used are from published sources. Data gaps have been filled using best available data, for example extrapolating existing data or using industry guidance documents.

Activity data

1.3.11 The data sources used for key components of activity data are shown in Table 1.4. Key components are those that account for >1% of total emissions. Module A4 is not considered key by this definition and module B1 is included as part of A5 (as explained in Table 1.2).

Table 1.4 Data sources

Module	Key activity data	Data source
A1 – A3: Product stage	Highways and structures	Bill of Quantities for permanent assets. Professional judgement used for temporary assets that have not yet been designed in detail.
	Tunnels	Building Information Model (BIM model) and design drawings where available. Professional judgement used for assets that have not yet been designed in detail. Third-party data for tunnel boring machine and mechanical and ventilation plant in tunnel.
	Enabling works	Design drawings, information provided by statutory utility companies and needs assessments.
	Soil & fill import	Cut and fill balance associated with the earthworks.
A4: Construction process stage: Transport to works sites	Construction traffic	Department for Transport (2019) TAG greenhouse gas emissions workbook Construction traffic model based on impact of construction works on regional road network
A5: Construction process stage: On site stage	Construction waste	Bill of Quantities
	Electricity consumption	Maximum demand models for compounds. For enabling works, actual consumption data, where available, proportioned up to cover assumed full length of programme.
	Diesel consumption	Construction plant schedule for compounds and work sites. Needs assessments for enabling works and actual consumption data where available, proportioned up to cover assumed full length of programme.
	Land use change	Phase 1 survey and landscape drawings
	Carbon associated with risk	Risk registers Project-specific estimate of emissions to cost ratio
B2 – B5: Maintenance, repair, replacement and refurbishment	Capital carbon	Renewal frequencies schedules.
B6: Operational Energy	Electricity consumption	Estimated energy demand loads.
B9: User's Utilisation	Emissions from traffic during the operational phase	TAG greenhouse gas emissions workbook. The assumptions and method used to calculate the operational traffic emissions is set out in the Combined Modelling and Appraisal Report which presents the estimates of the GHG emissions arising from operational traffic (Application Document 7.7).

1.3.12 The activity data is based on early design information and generally uses forecast data rather than actual data because there is no actual data available at this stage. The exception is for some aspects of the enabling works where actual data was available. Over time, the design will develop and evolve, and Highways England will update the carbon model to reflect this.

1.3.13 In some instances, assumptions based on professional judgement have been made, where necessary, and these are set out in 0.

1.3.14 The carbon model is therefore a best estimate, calculated using the most representative, accurate and plausible data available.

Emission factors

1.3.15 The following sources have been used for emission factors:

a. Highways England Carbon Tool v2.2

b. Inventory of Carbon and Energy (ICE) v3.0

c. ICE Cement, Mortar and Concrete Model - V1.1 Beta

d. Department for Business, Energy & Industrial Strategy (BEIS) Carbon Factors 2019

e. BEIS Electricity emissions factors to 2100 (in kgCO_2e/kWh), last updated March 2019 (for future emission factors for grid electricity)

f. National Atmospheric Emissions Inventory

g. Other third-party data sources: a limited number of emission factors were not available from the above sources so have been obtained from other sources, including the Carbon Trust

1.3.16 Where no emission factor was available for the exact material, the closest match has been used. Annex B lists the emission factor used.

Method

1.3.17 Carbon emissions have been assessed using a calculation-based methodology based on the equation below:

activity data x carbon emissions factor = carbon emissions value

Results

Emissions

1.3.18 The carbon emissions resulting from the construction and operation of the Project are estimated to be 5,272,562 tonnes of carbon dioxide equivalent (tCO_2e). Annex A shows tables of emissions data.

Breakdown of emissions

1.3.19 Fifty-two percent of the Project's emissions are emissions from traffic in the operational phase, over which the design of the Project has no influence. These emissions need to be tackled through the decarbonisation of road transport which can only be dealt with at a society-wide level.

1.3.20 The top five carbon hotspots where the Applicant has control or influence over emissions are:

a. Tunnels construction

b. Maintenance, repair and replacement

c. Highways construction

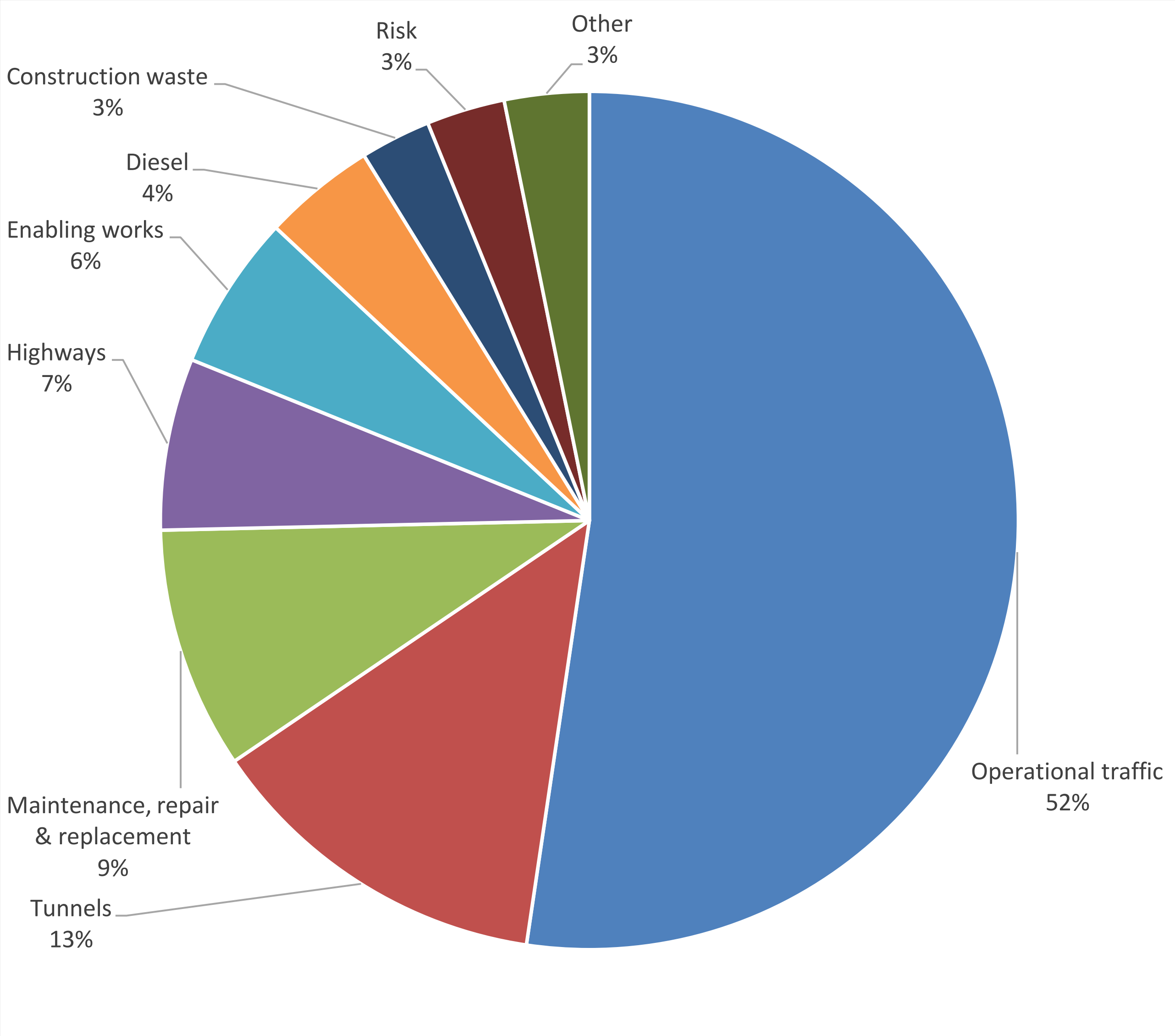
d. Enabling works

e. Diesel consumption

1.3.21 Together these five components account for almost 40% of total emissions.

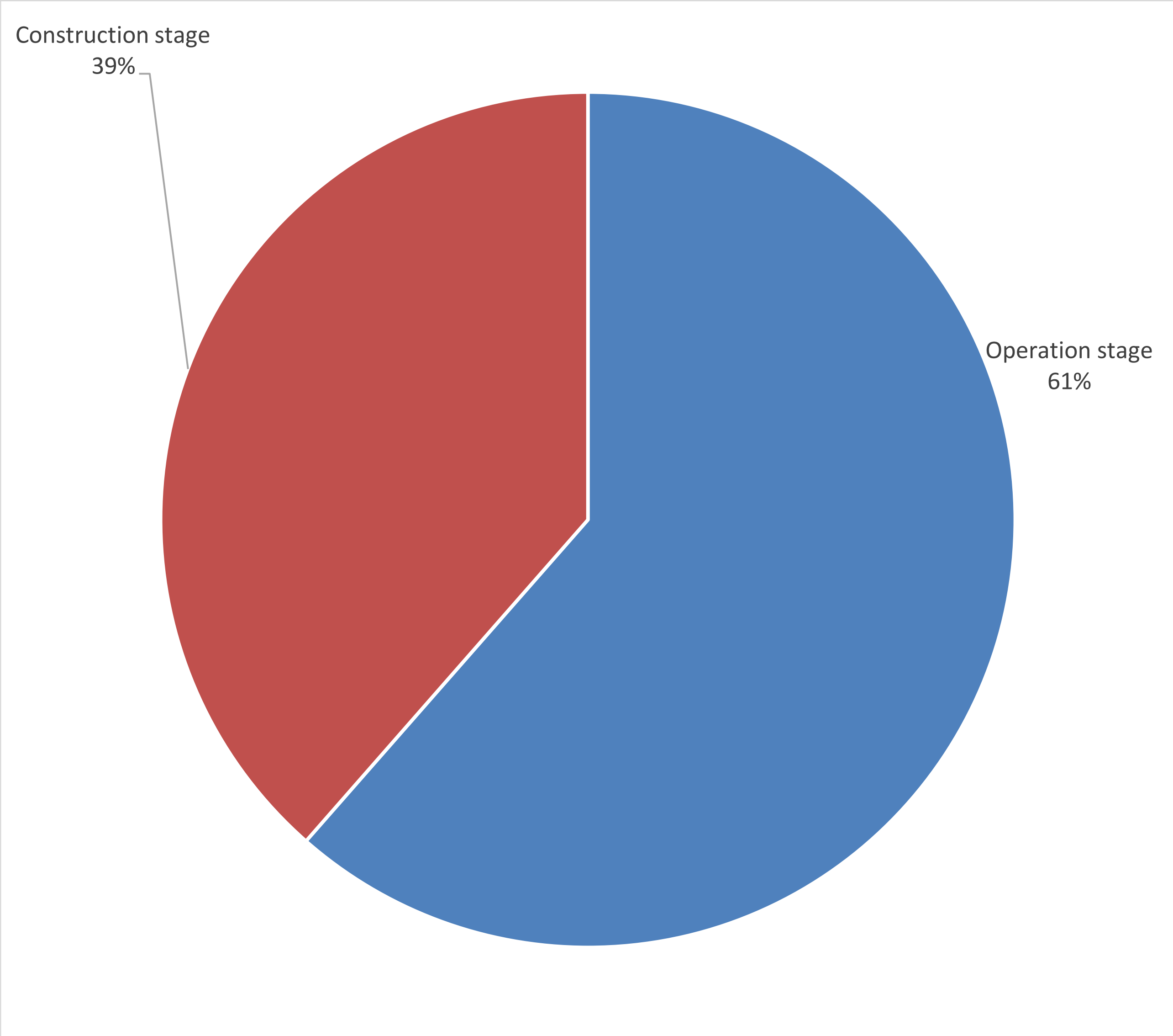
1.3.22 Sections 1.3.26 to 1.3.40 look at each hotspot in more detail.

Plate 1.7 Carbon emissions by category over construction phase and sixty-year operational phase



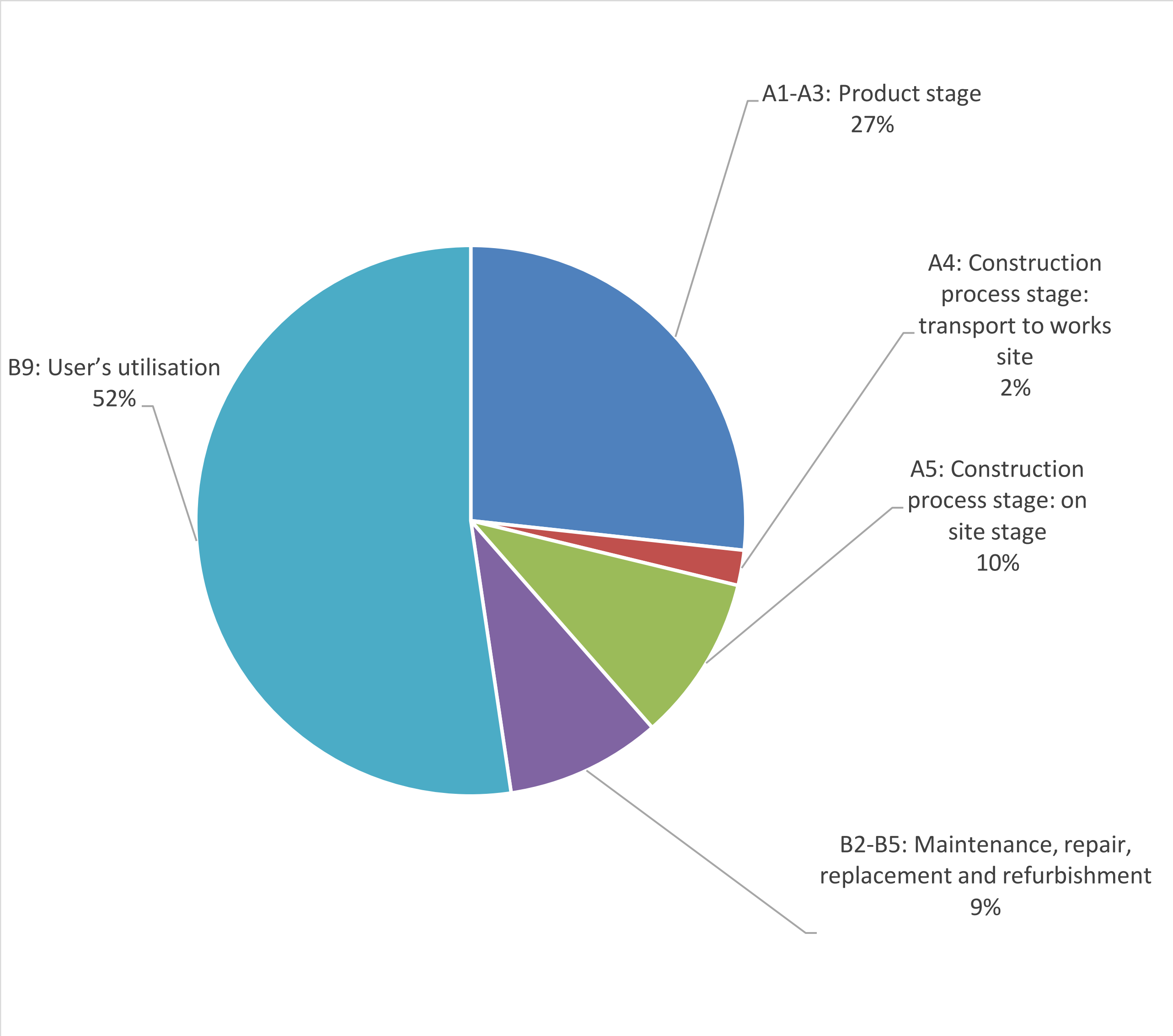
1.3.23 Thirty-nine percent of the emissions occur in the construction phase and the remaining 61% in the sixty-year operational phase. As the main component of the operational phase emissions is operational traffic, which is outside of the influence of the Project's design, reducing construction emissions during design will be the main focus of this report.

Plate 1.8 Carbon emissions by Project phase over 60 years



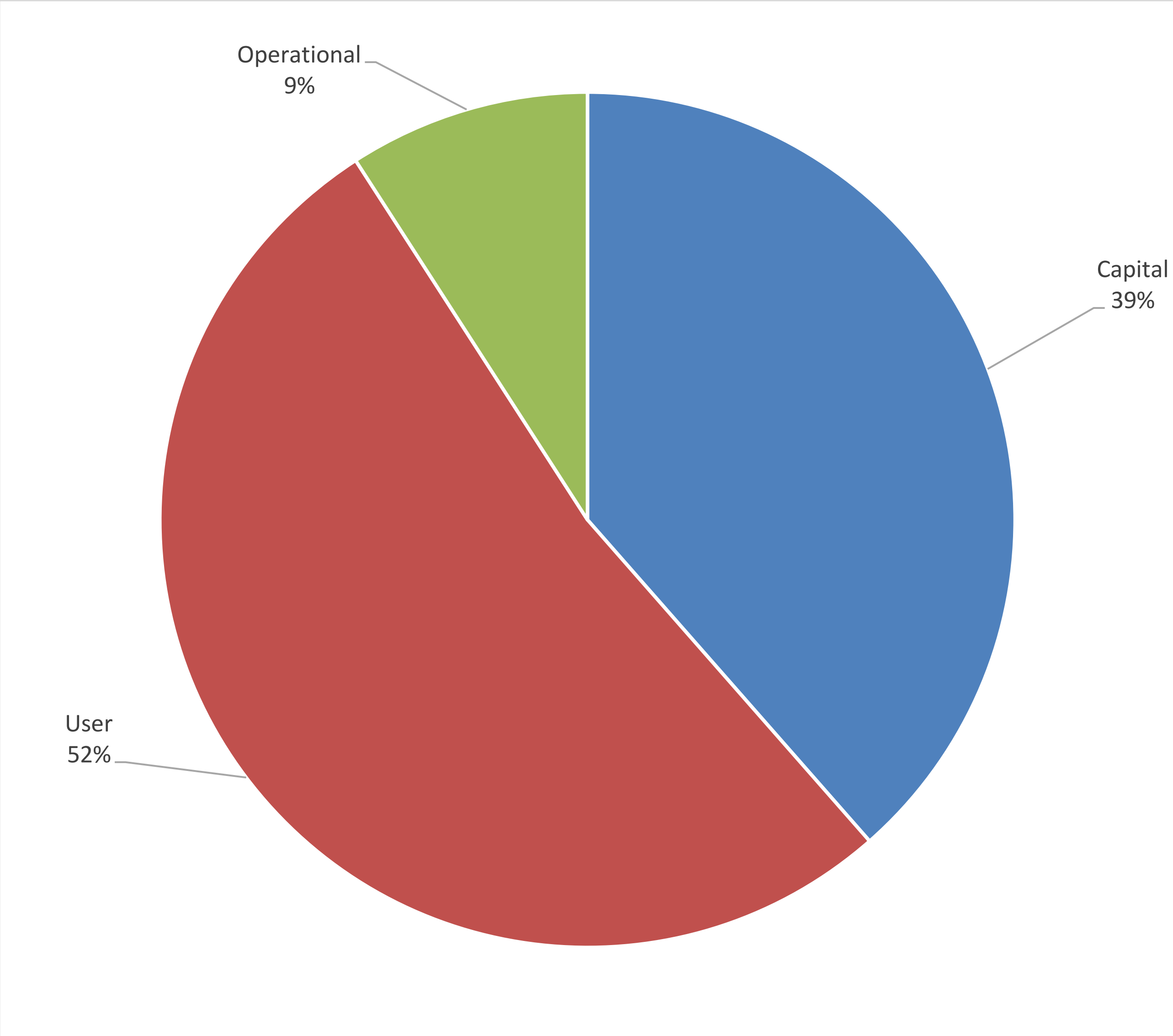
1.3.24 The PAS 2080 module that accounts for most of the carbon emissions is B9 (user's utilisation, i.e. operational traffic), followed by emissions from A1-A3 (product stage, i.e.), accounting for 52% and 27% of total emissions respectively. Product stage emissions result from the extraction, processing and manufacturing of the construction material and the transport of it to the final factory gate. This highlights the importance of selecting construction materials which have a low carbon impact.

Plate 1.9 Carbon emissions by PAS 2080 module over 60 years



1.3.25 Capital carbon emissions represent 39% of total emissions, followed by user emission at 52% and operational emissions at 9%. Highways England has very limited influence on user emissions so has focussed on opportunities for emissions reductions in capital carbon and operational carbon.

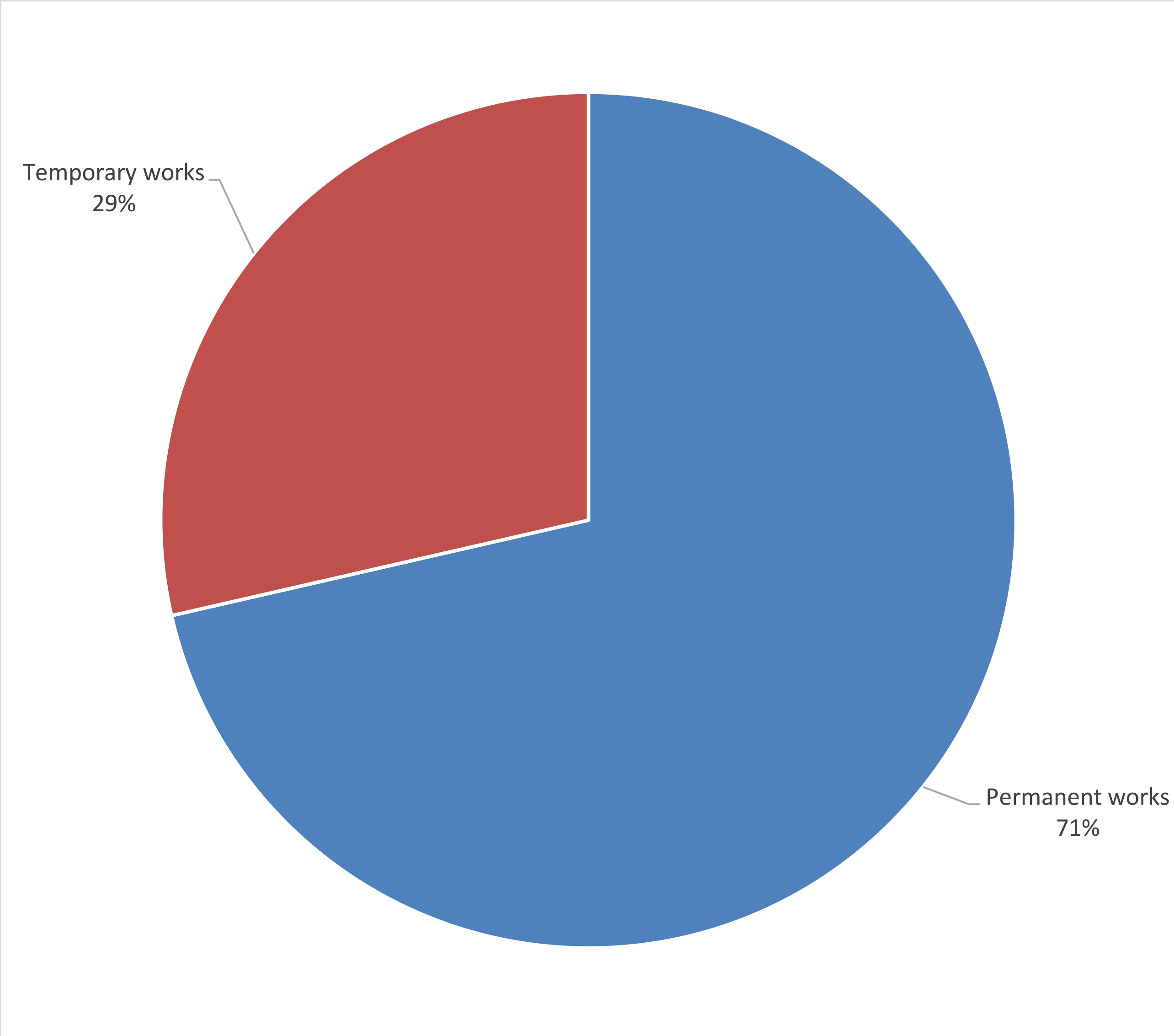
Plate 1.10 Carbon emissions by type over 60 years



Carbon hotspots

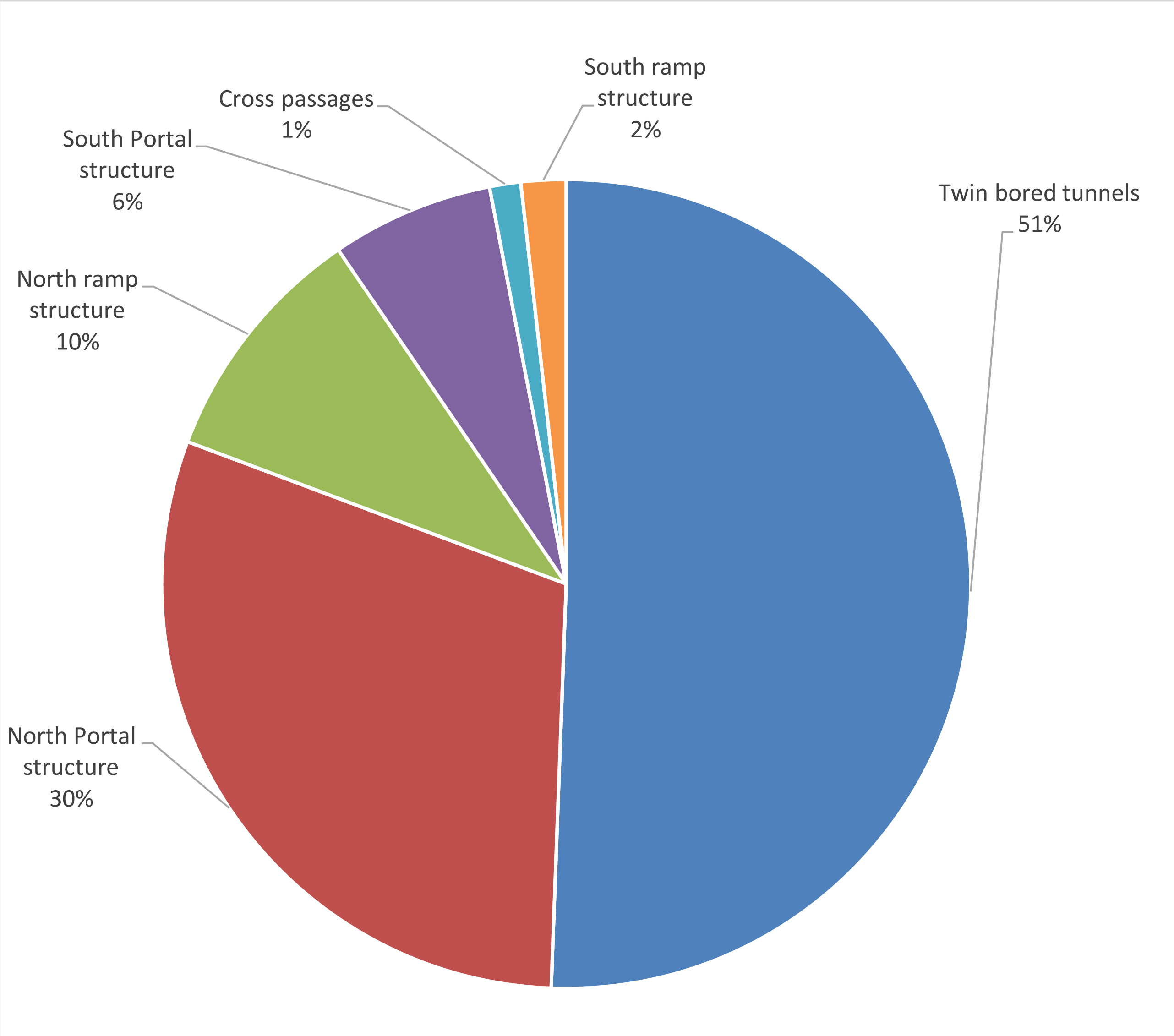
1.3.26 **Tunnels**: The main contributor to the tunnels emissions is the permanent works. Therefore, this hotspot analysis focuses on the emissions arising from the permanent works. The temporary works category covers the embodied carbon in temporary construction structures and activities. The most carbon-intensive ones are the concrete and steel required for foundations at the segment factory, slurry treatment plant and batching plant.

Plate 1.11 Tunnel carbon emissions by construction category



1.3.27 The key assets that contribute to the tunnels' permanent works emissions are the twin bored tunnels and the North Portal structure, accounting for 81% of these emissions.

Plate 1.12 Tunnel carbon emissions by asset



1.3.28 The main materials that contribute to the tunnel emissions are:

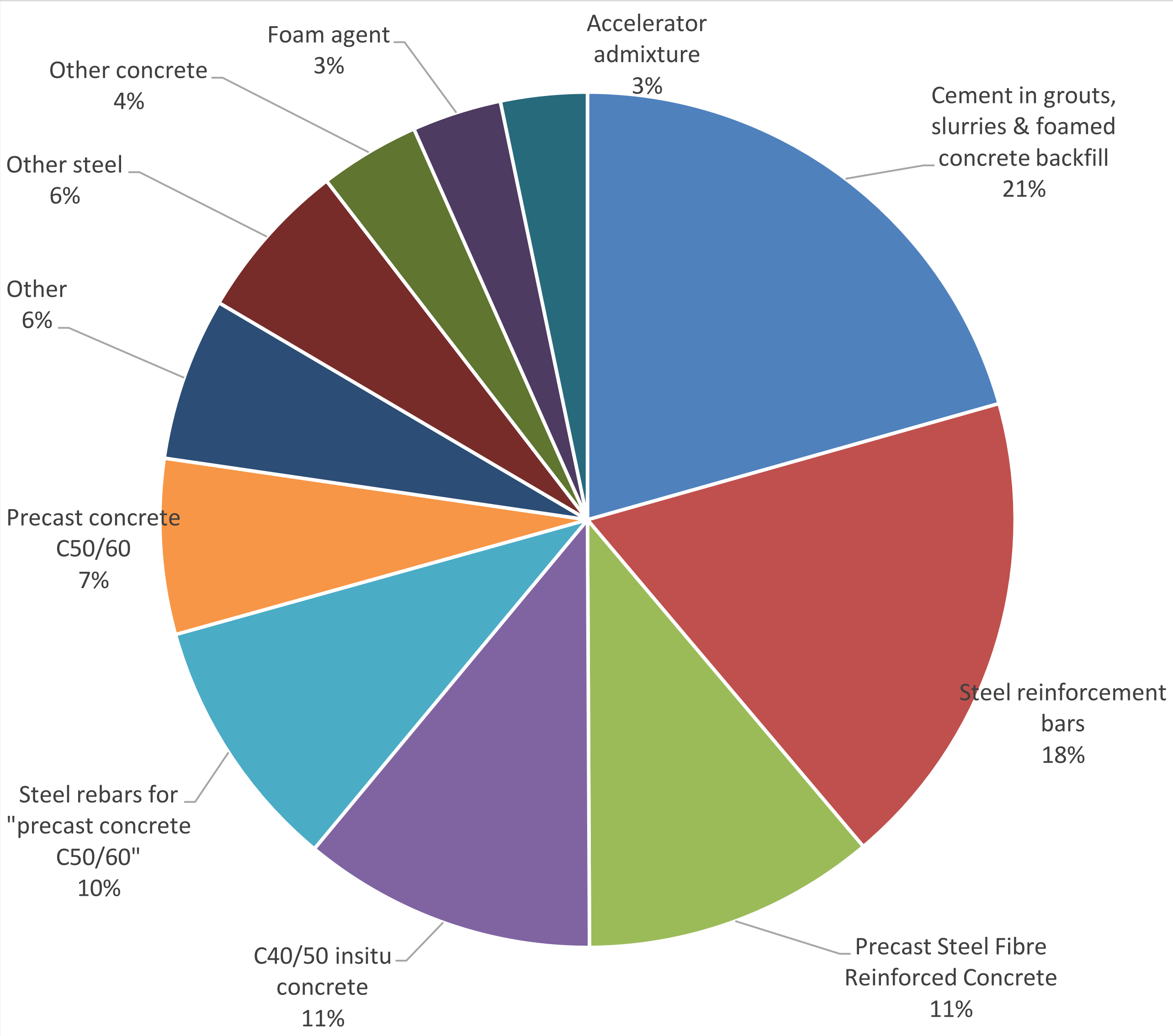
a. Cement in grouts, slurries and foamed concrete backfill

b. Steel reinforcement bars

c. Precast steel fibre reinforced concrete

d. C40/50 *in situ* concrete

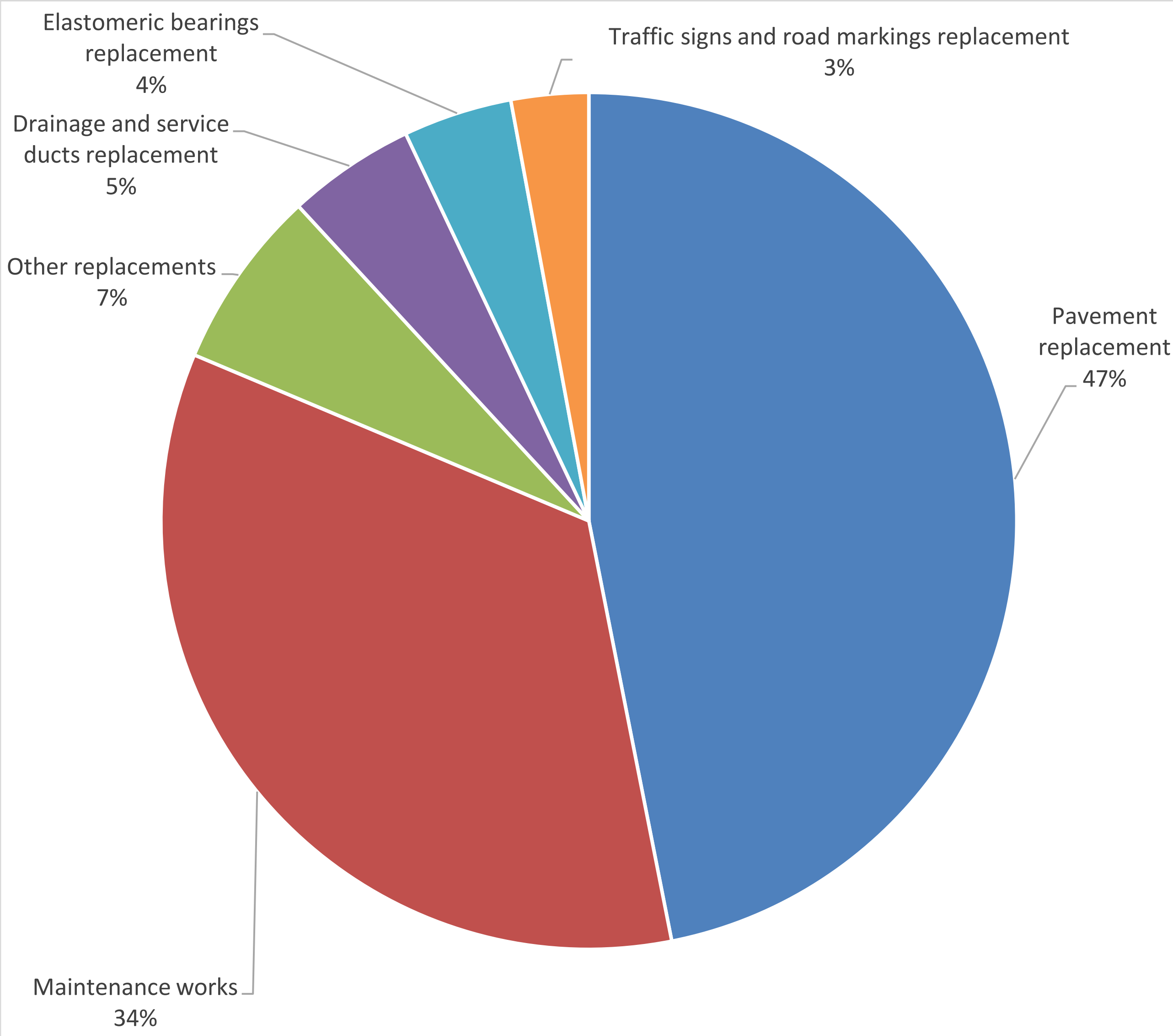
Plate 1.13 Tunnel carbon emissions by material



1.3.29 Therefore, for tunnels, carbon reduction efforts should focus on cement and the above categories of concrete and steel.

1.3.30 **Maintenance, repair and replacement:** The main contributor to the emissions associated with maintenance, repair and replacement is the replacement of the paving, followed by the maintenance works. Emissions from maintenance works cover grass cutting, sign cleaning, and fuel consumption in maintenance vehicles.

Plate 1.14 Maintenance, repair and replacement carbon emissions



1.3.31 **Highways**: 97% of the highways carbon emissions relate to permanent work and only 3% to temporary work. Therefore, the emissions hotspot analysis for highways focuses on the permanent works. Highway temporary works cover the embodied carbon in temporary construction structures and activities. The most carbon-intensive ones are the haul roads and hardstanding areas for compounds.

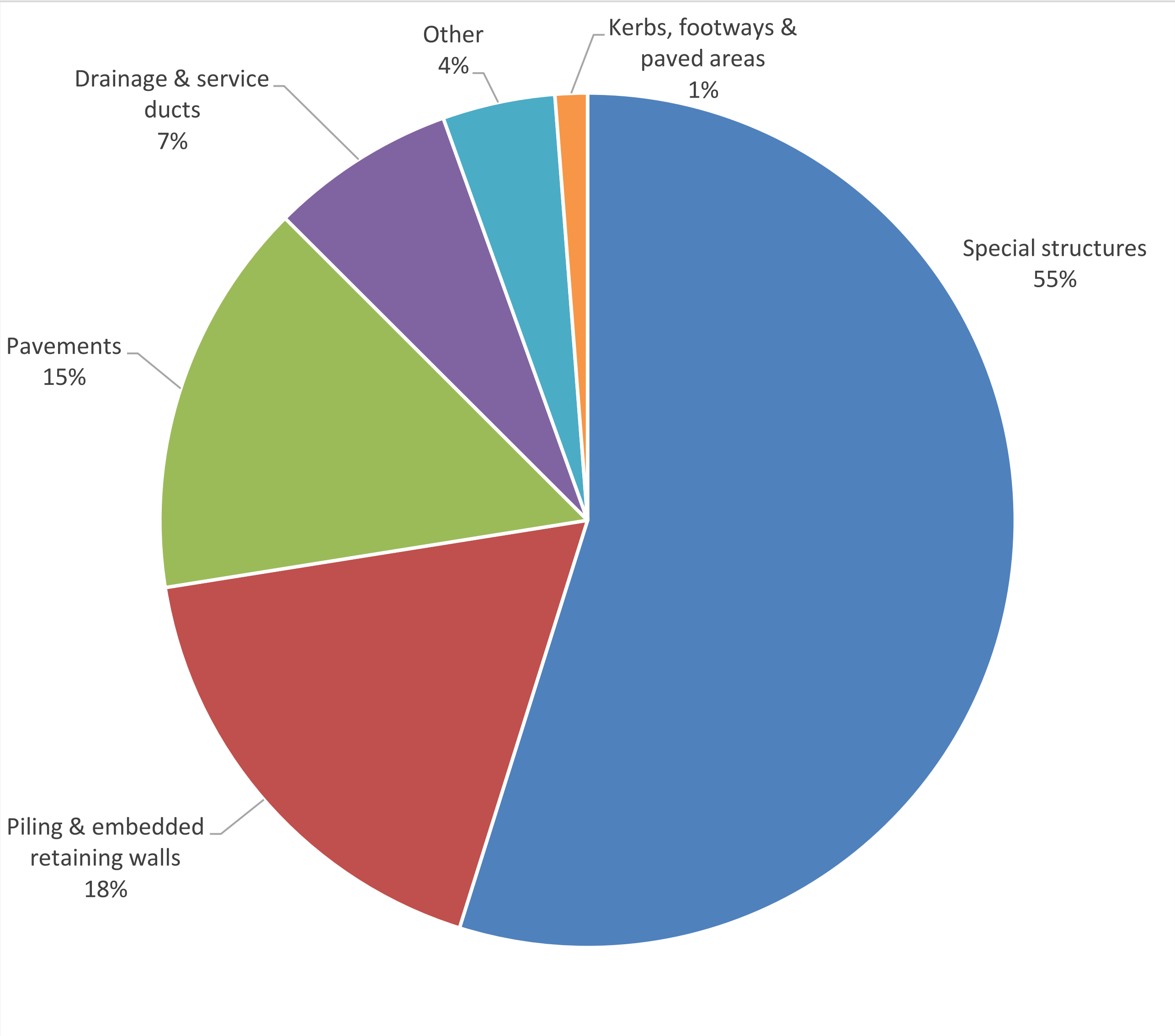
1.3.32 Special structures account for 56% of the highways permanent work emissions, followed by piling and embedded retaining walls at 18% and pavements at 15%. 53 special structures have been identified on the Project.

Table 1.5 Highways special structures

Item	Number
Overbridge	24
Green bridge	7

Item	Number
Underbridge	7
Viaduct	6
Footbridge	4
Accommodation bridge	1
Field bridge	1
River bridge	1
Railway bridge	1
Culvert	1

Plate 1.15 Highways carbon emissions by element



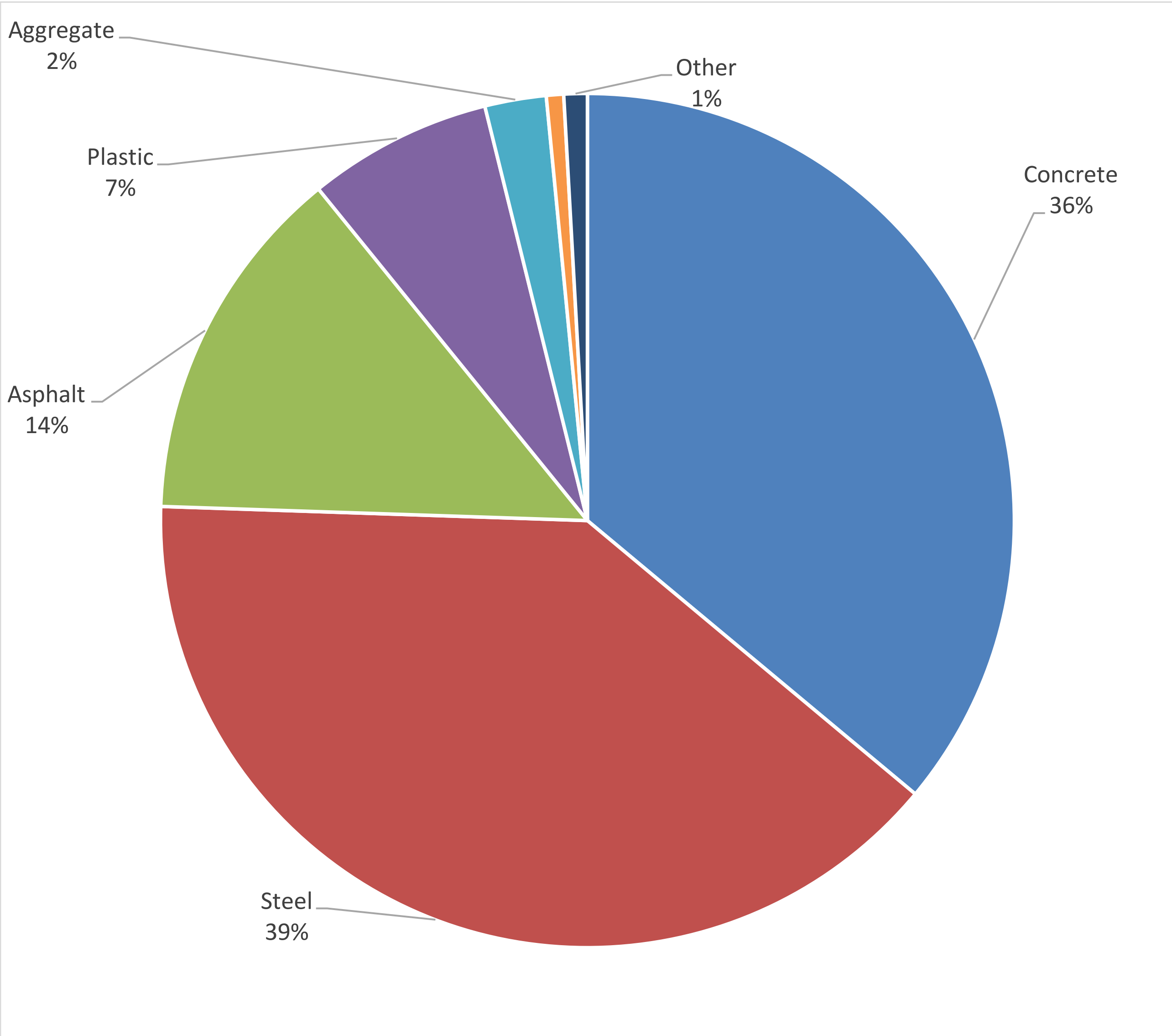
1.3.33 The key materials that contribute to the highways emissions are:

a. Concrete

b. Steel

c. Asphalt

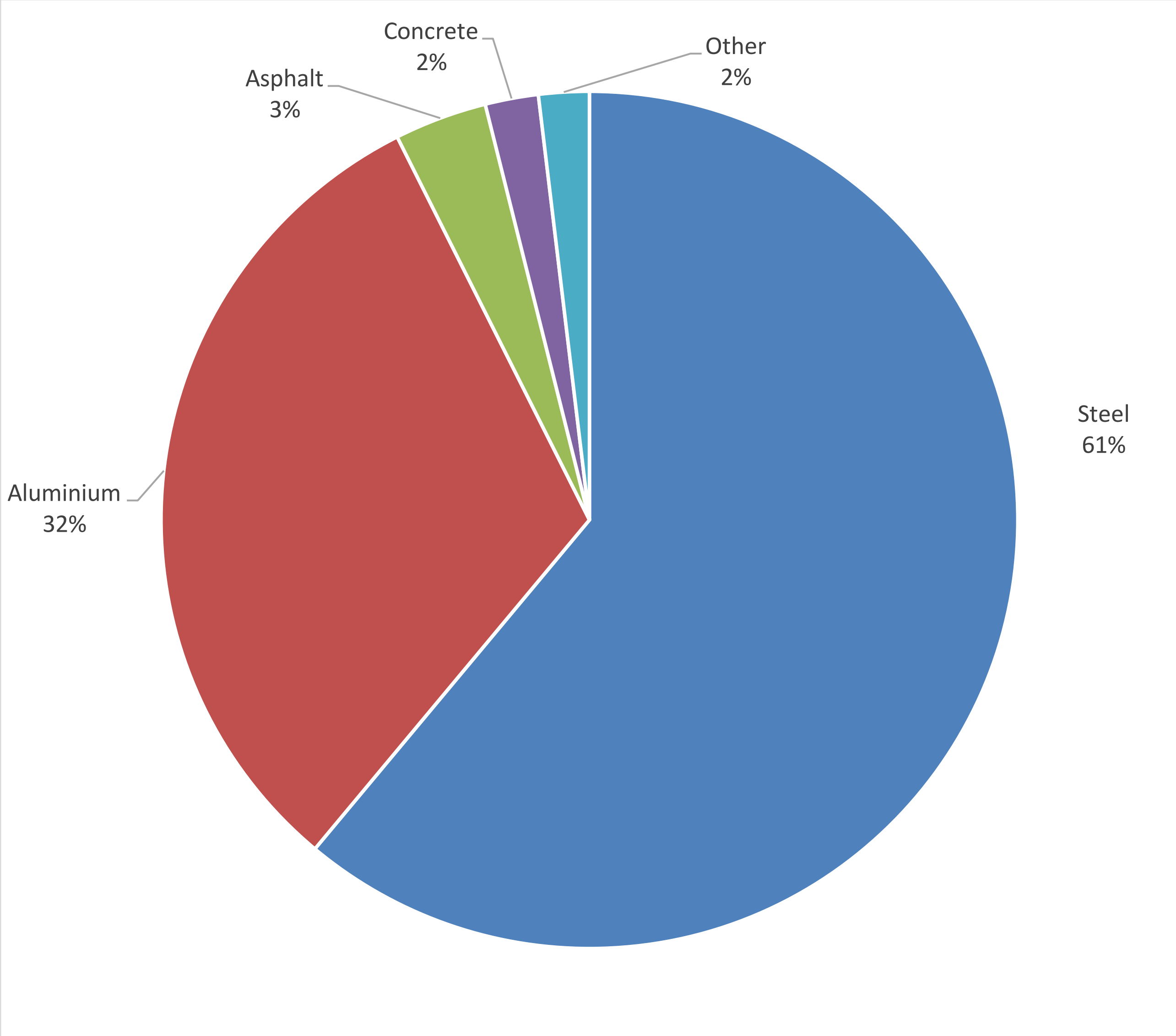
Plate 1.16 Highways carbon emissions by material



1.3.34 Therefore, for highways, carbon reduction efforts should focus on the use of concrete, steel and asphalt in special structures, piling and embedded retaining walls and pavements.

1.3.35 **Enabling works**: The main contributor to the emissions from enabling works is steel, which is used principally for replacement gas mains, followed by aluminium, used for new power cables.

Plate 1.17 Enabling works carbon emissions by material

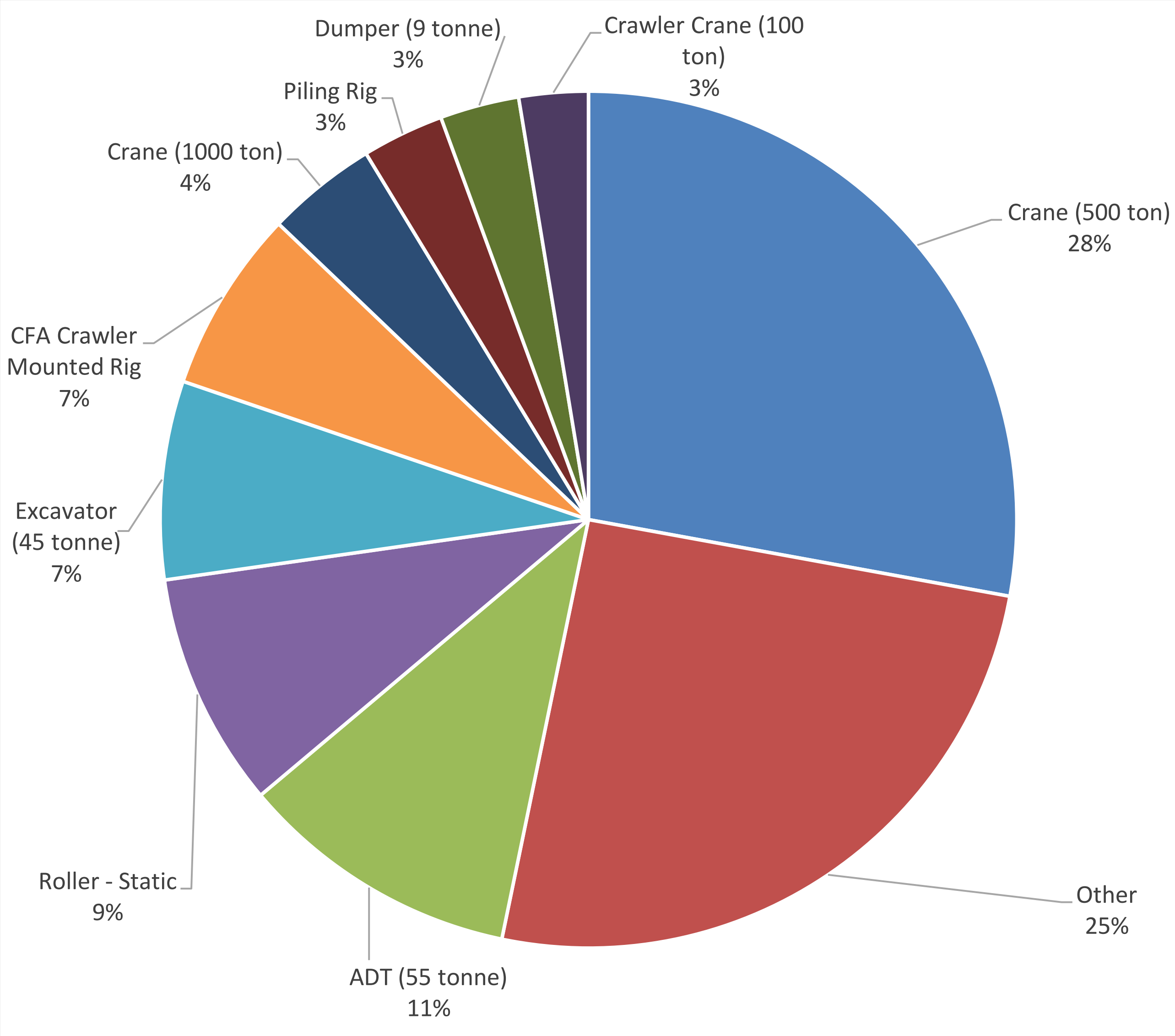


1.3.36 Therefore, for enabling works, key carbon reduction efforts should focus on the use of steel and aluminium in gas mains and power cables respectively.

1.3.37 **Diesel consumption:** Construction compounds account for over 95% of diesel emissions with enabling works making up the remaining 5%.

1.3.38 The pieces of equipment that contribute most to diesel emissions in compounds are the 500 tonne cranes, the 55-tonne articulated dump trucks (ADT) and the static rollers. Carbon reduction efforts should therefore focus on reducing consumption in these pieces of equipment. Although the 'other' category accounts for 25% of diesel emissions, it is made up of numerous categories of plant, none of which accounts for more than 3% of total diesel emissions.

Plate 1.18 Emissions from the use of diesel in compounds broken down by equipment

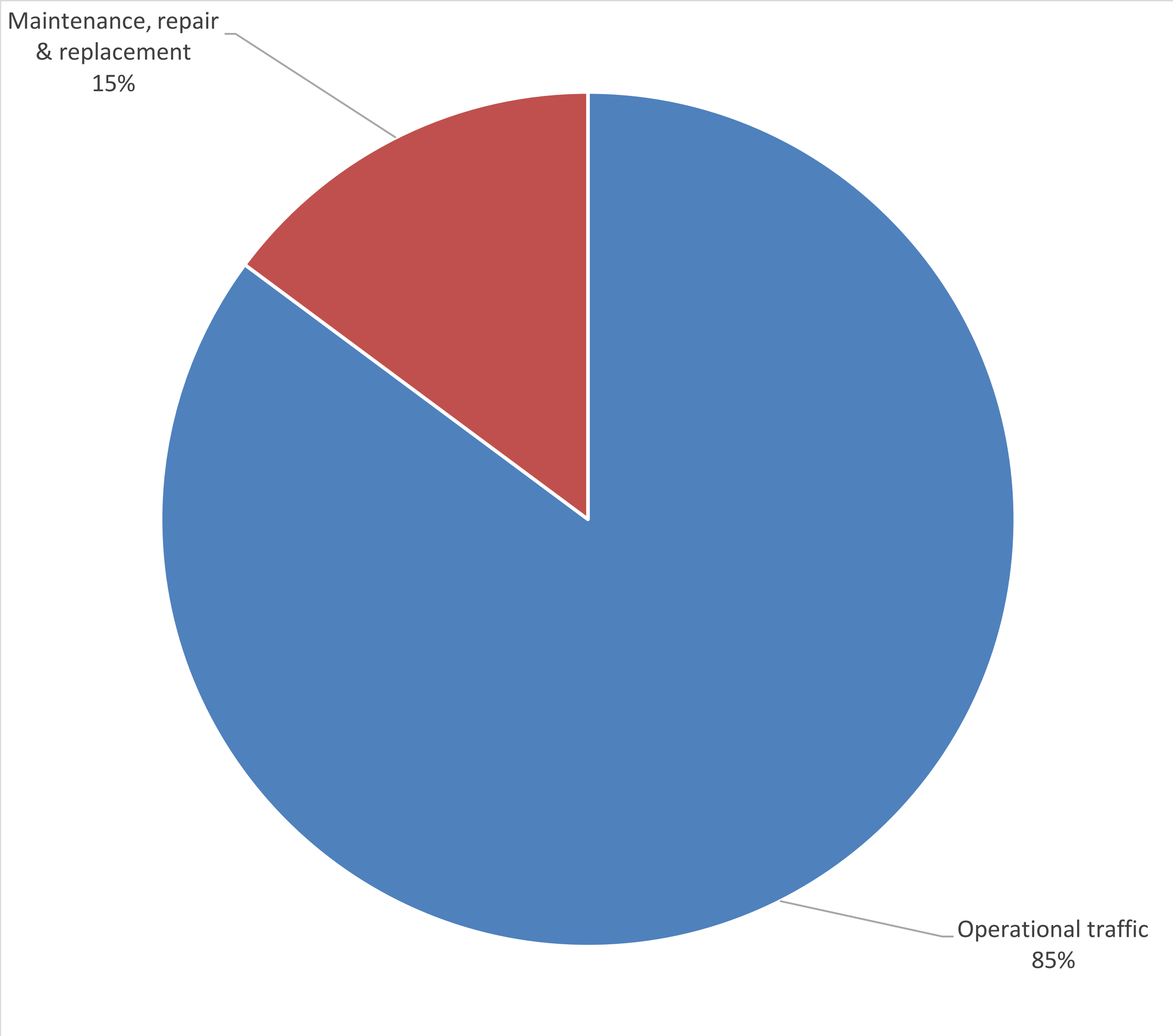


Operational emissions

1.3.39 Eighty-five percent of the emissions from the Project in the operational phase result from increased traffic compared to the situation if the Project is not built. Maintenance, repair and replacement accounts for 15% of the operational emissions. All operational emissions are based on a sixty-year operational phase.

1.3.40 The calculation of operational carbon emissions has taken into account future grid decarbonisation by using the predicted grid electricity emission factors modelled by the Department for Business, Energy & Industrial Strategy (BEIS).

Plate 1.19 Carbon emissions in the operational phase



1.4 Carbon management and minimisation

1.4.1 This section outlines the Project's approach to carbon emission reductions, presents emission reduction opportunities that have already been implemented and identifies other opportunities that can be implemented at a later stage.

Quantification of carbon emissions

1.4.2 Highways England has assessed the Project's carbon impact by developing a carbon model based on the preliminary design (Section 1.3). This carbon model includes a variety of carbon reduction opportunities (Table 1.6).

1.4.3 The Applicant will update the carbon model to take account of design changes and to break down emissions by contract.

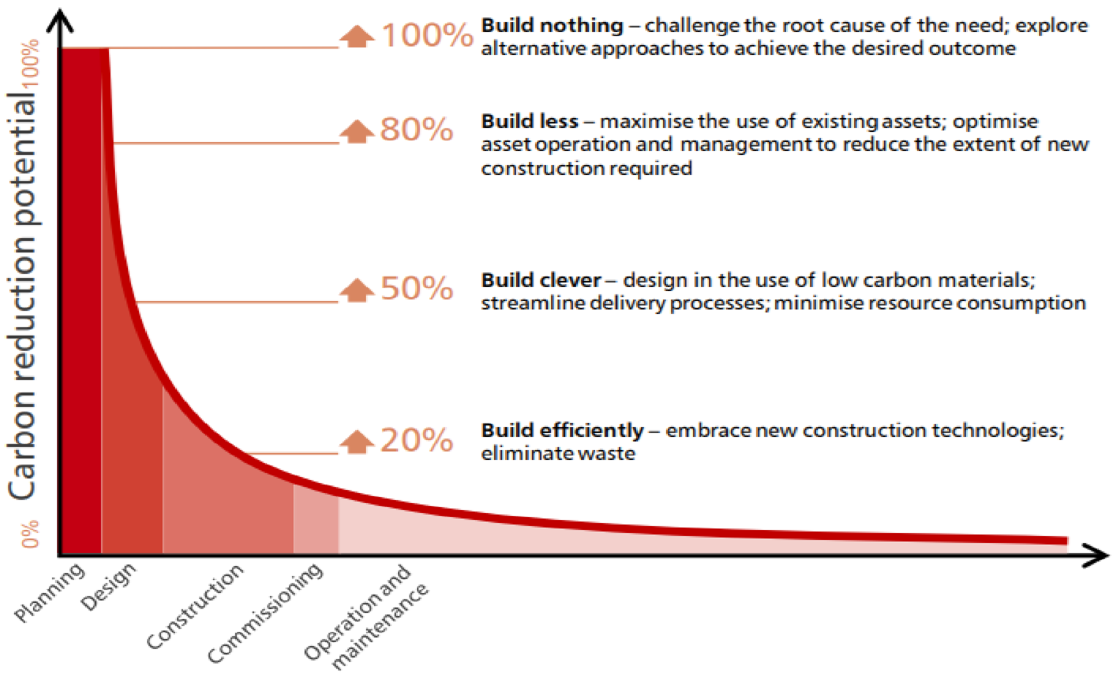
1.4.4 Contractors will be required to quantify and report carbon emissions quarterly (Table 1.1) to demonstrate the impact of reduction opportunities already implemented and to inform the continual improvement process.

Process for reducing carbon emissions

1.4.5 Carbon reduction opportunities have been identified, using the carbon hierarchy developed by the Green Construction Board and set out in PAS 2080 (Plate 1.20).

1.4.6 The hierarchy demonstrates that the greatest carbon reduction potential is at the start of a project, which is why early action to reduce emissions is so important.

Plate 1.20 Carbon hierarchy



1.4.7 To identify carbon reduction opportunities, Highways England ran low carbon workshops with the Project team. Opportunities identified during these workshops are presented in Table 1.4 and Table 1.6.

Emissions reductions achieved

1.4.8 To comply with LA 114, the Applicant has acted to reduce emissions in the preliminary design stage Table 1.6 sets out these actions. The actions relate to the 'avoid' emissions, 'reduce' emissions and 'remediate' emissions options in LA 114 (section 1.2.26).

Table 1.6 Emissions reductions achieved

Opportunity	Detail	Outcome
Removing and reducing the size of assets	The Applicant has reduced the size of some assets which has reduced the amount of material required and therefore the embodied emissions. Examples include: • Removing the bridge at Hornsby Lane • Reducing the number of lanes on the Project road south of the M25 • Widening the existing Rectory Road rather than constructing a new highway • Reducing the span of the Tilbury Viaduct from 1.2km to 600m • Removing the A226 junction • Removing the A128 junctions with the Project and A13	Assumed in carbon model Impact not quantified as these were early design changes
Lower carbon concrete	Concrete is one of the key emissions hotspots for the Project accounting for approximately 19% of the construction emissions. The carbon impact of concrete can be lowered in a variety of ways. The Applicant has examined the option to replace a proportion of the Ordinary Portland Cement (OPC) with Ground Granulated Blast-furnace Slag (GGBS). GGBS is a cementitious material whose main use is in concrete. It is a by-product from blast-furnaces used to make iron. The baseline presented in this report assumes 65% GGBS will be used for C40/50 *in situ* concrete in both tunnels and highways and C50/60 precast concrete in tunnels. Highways construction is not expected to use any precast C50/60 concrete.	Assumed in carbon model Including 65% GGBS in the carbon model has reduced emissions by 118,742 tCO_2e for tunnels and 38,884 tCO_2e for highways.

Opportunity	Detail	Outcome
Steel fibre reinforced concrete	The Applicant has selected steel fibre reinforced concrete (SFRC) for most of the concrete segments in the bored tunnels. SFRC has lower carbon emissions than steel bar reinforced concrete.	Assumed in carbon model Selecting SFRC has reduced emissions by 31,611 tCO_2e
Warm mix asphalt	The Applicant has assumed the use of warm mix asphalt on the base and binder courses. Warm mix asphalt can reduce carbon emissions by approximately 15% compared to hot mix asphalt (All Party Parliamentary Group on Highways (2019). Working for better roads: Warm Mix Asphalt: reducing carbon emissions and improving efficiencies). Warm mix asphalt also has other benefits including increased speed of installation, reduced risk of burns to workers and reduced fume and odour emissions.	Assumed in the carbon model Using warm mix asphalt in the carbon model has reduced carbon emissions by 6,315 tCO2e
Hybrid or electric plant	To reduce the emissions associated with diesel consumption at compounds and work sites, the Applicant has assumed that the following percentage of hybrid/electric plant: • 5% of articulated 40 tonne and 55 tonne dump trucks • 20% of tracked cranes (55 tonne and 60 tonne) • 20% of dumpers (5 tonne and 9 tonne) • 50% of excavators • 50% of dozers • 50% of forklifts/telescopic handlers • 50% of HIAB cranes • 50% of telehandlers • 75% of 4x4 vehicles • 100% of lighting towers assumed to be solar powered All other plant is assumed to use diesel only.	Assumed in carbon model Including hybrid or electric plant in the carbon model has reduced emissions by 3,009 tCO_2e

Opportunity	Detail	Outcome
Energy efficient equipment	Energy efficient equipment has been included in the carbon model: • Jet fans: Jet fans discharge high velocity jets (as high as 40m/s) to induce longitudinal air flow in tunnels. When combined with carbon monoxide detection, these fans operate more efficiently and reduce carbon emissions, compared to ducted systems. • Soft Start Technology: This enables gradual motor speed acceleration which reduces peak demand which helps to reduce maintenance costs and reduces energy consumption and carbon emissions. • Start-Stop Technology: This improves the control and therefore efficiency of motors and pumps. • Optidrive VTC drive: This provides energy efficient pumping through a range of measures such as advance sleep and wake functions, eco-vector operation and pump blockage detection. • LED Lights: These have much lower energy consumption than traditional sodium or fluorescent lighting. When combined with an intelligent lighting control system, it can more closely match requirements and further reduce energy consumption • Active/Adaptive Lighting: This provides close control of the lighting within the tunnel in accordance with the ambient lighting levels. • Visibility and air quality sensors: Tunnel sensors can be integrated into an air quality management system to trigger ventilation systems when high concentrations of pollutants and/or poor visibility levels are experienced within the tunnel. Tunnel sensors provide energy and carbon savings because they improve ventilation control.	Assumed in carbon model.

Opportunity	Detail	Outcome
Carbon sequestration through planting of trees and vegetation	Land use changes occurring as a result of the Project will result in almost 9,000 tonnes of carbon dioxide equivalent being sequestrated.	Assumed in carbon model
Reuse of material onsite	Reusing topsoil, vegetation and excavated material onsite reduces carbon emissions associated with transport and waste treatment.	Appendix 2.2: REAC (Application Document 6.3) lists this commitment [MW001]. Compliance with the REAC is secured through the Requirements in Part 1 of Schedule 2 of the draft DCO.
Renewable energy for construction	The Applicant will require Contractors to commit to procuring renewable electricity to cover the consumption by compounds (including the consumption of the tunnel boring machine and concrete batching plant).	Appendix 2.2: REAC (Application Document 6.3) lists this commitment [CC004]. Compliance with the REAC is secured through the Requirements in Part 1 of Schedule 2 of the draft DCO. The use of renewable energy for construction electricity has saved 93,480 tCO_2e.
Renewable energy for operations	The Applicant will procure renewable electricity to cover the operational electricity consumption of the Project.	Appendix 2.2: REAC (Application Document 6.3) lists this commitment [CC007]. Compliance with the REAC is secured through the Requirements in Part 1 of Schedule 2 of the draft DCO. The use of renewable energy for operational electricity has saved 110,722 tCO2e.

Opportunity	Detail	Outcome
Emissions reduction target	One of the most effective ways to reduce emissions on an infrastructure project is to set a target reduction from the baseline emissions. To facilitate this, the Applicant has calculated the Project's baseline emissions. It has incorporated emissions reduction opportunities within that baseline to demonstrate its commitment to reduce its carbon impact (see rows above for more detail). The baseline will be adjusted if required as the design progresses. The Applicant will require Contractors to reduce emissions beyond the baseline presented in this report. Carbon reduction will be one of the criteria used during the selection process and the selected Contractor will develop a carbon reduction target. The target will then become a contractual commitment and failure by the Contractors to provide the works in accordance with its commitment will be treated as a defect in accordance with the contract.	Appendix 2.2: REAC (Application Document 6.3) lists this commitment [CC002]. Compliance with the REAC is secured through the Requirements in Part 1 of Schedule 2 of the draft DCO.
PAS 2080 adherence	Contractors will adhere to PAS 2080 and develop a PAS 2080-compliant approach detailing how GHG emissions reductions will be identified, prioritised, implemented and monitored. As taking action early is critical in minimising carbon emissions, the Contractors will submit PAS 2080 compliant carbon management plan to Highways England for approval within three months of appointment and will review it annually. Tier one Contractors will be required to obtain external verification within 12 months of appointment. Where Early Contractor Involvement is used as the procurement model, the tier one Contractor will be required to show substantial progress towards external verification by the end of stage one and to obtain verification within three months of stage two.	Appendix 2.2: REAC (Application Document 6.3) lists this commitment [CC001]. Compliance with the REAC is secured through the Requirements in Part 1 of Schedule 2 of the draft DCO.

Opportunity	Detail	Outcome
Quantifying and reporting emissions	Contractors will quantify and report carbon emissions quarterly using specific emission factors (0). Contractors will present both total emissions and emissions at an asset level.	Appendix 2.2: REAC (Application Document 6.3) lists this commitment [CC003]. Compliance with the REAC is secured through the Requirements in Part 1 of Schedule 2 of the draft DCO.
Environmental Product Declarations	Contractors will identify ten construction products contributing the most to total emissions and provide Environmental Product Declarations to the Project Manager for acceptance	Contractual commitment
Integrating carbon into building information modelling (BIM)	To facilitate the analysis of the emissions impact of design changes and to provide a clear audit trail, the Contractor will input their revised baseline carbon calculation to BIM within six months of the start date and use BIM to generate quantities data for carbon calculations.	Contractual commitment

Further emissions reductions opportunities

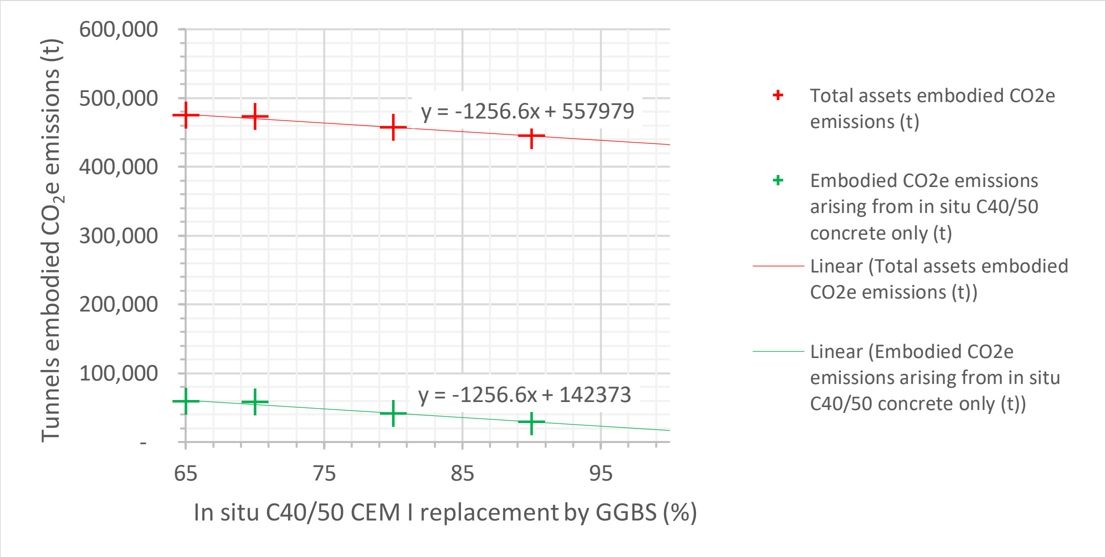
1.4.9 A variety of further emission reduction opportunities have been identified that could be implemented later in the Project lifecycle. None of these are assumed in the carbon model so implementing any of these would reduce emissions below the emissions presented in this report.

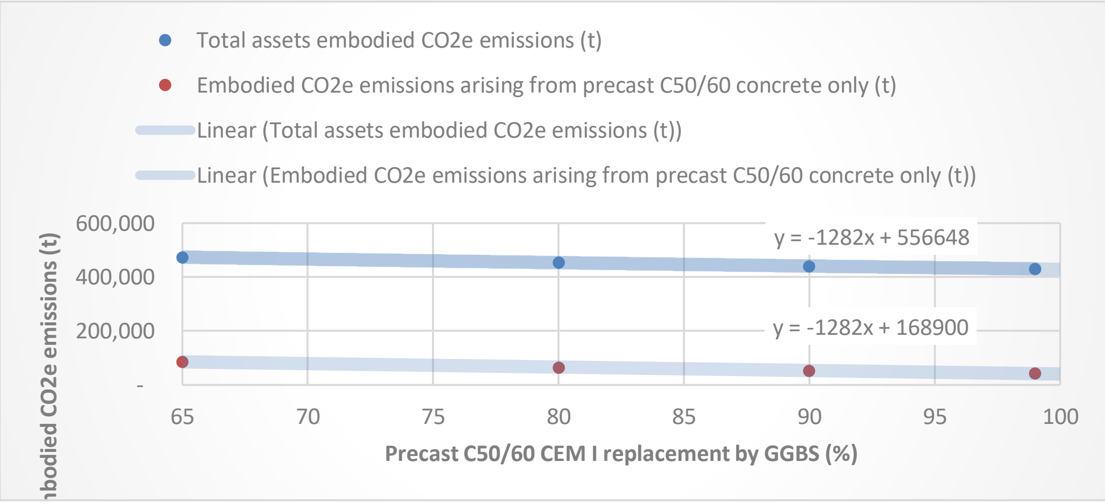
1.4.10 Contractors will need to investigate these opportunities during the detailed design phase to achieve their carbon reduction target (Table 1.7). These opportunities are options that Contractors can use to meet their target. It will be up to each Contractor to select which combination of measures is most appropriate and other measures not listed can also be used. If Contractors choose not to implement any of these measures, they should provide a justification in their PAS 2080 documentation.

Table 1.7 Further opportunities to reduce carbon emissions

Opportunity	Explanation
Reduce the size of assets	Reducing the size of assets reduces the quantity of material required and therefore the emissions. Within the Project, opportunities exist to reduce the size of items such as the tunnel portals, bridges and road junctions. Contractors can examine these opportunities during detailed design.

<table>
<tr><th>Opportunity</th><th>Explanation</th></tr>
<tr><td>Lower carbon concrete</td><td>
By committing to 65% GGBS, the Applicant has gone beyond typical practice, but Contractors can reduce emissions further by increasing the GGBS percentage to 80%, which is allowed for within BS 8500 or even to 90% which is allowed for in the Eurocodes. Increasing the GGBS percentage will reduce carbon emissions, as the graph below for tunnels shows. It will also reduce concrete curing temperatures. Increasing the GGBS percentage from 65% to 80% for the C40/50 in situ and C50/60 precast concrete in the tunnels and the C40/50 in situ in the highways would save 77,550 tCO_2e. Contractors could also commit to using 65% or higher GGBS for the C40/50 in situ and C50/60 precast concrete used in enabling works.





Contractors could make additional savings by using alkali-activated cements, including geopolymer cements, which can reduce emissions by up to 80% compared to OPC. Alkali-activated cements could be investigated for use in non-structural concrete and temporary structural concrete.

The Applicant has focussed on C40/50 in situ concrete and C50/60 precast concrete as these are the most widely used concrete grades. However, Contractors can also apply the GGBS measures to other grades of concrete.
</td></tr>
</table>

Opportunity	Explanation
Fibre reinforced concrete	Steel fibre reinforced concrete is being used in the preliminary design for most of the concrete segments in the bored tunnels. Contractors could consider using steel fibre reinforced concrete in more areas to reduce emissions further, for example replacing anti-crack rebars with steel fibres in the slabs.
Steel	The emission factor used in the carbon model for steel is world average steel. Contractors should look to minimise emissions associated with the use of steel by reducing the amount used and committing to using material with higher recycled content. There are likely to be opportunities to replace steel with concrete on several of the bridges and these should be examined during detailed design. Steel is an important component of the emissions from enabling works and Contractors should consider applying the above opportunities to reduce the emissions associated with replacing gas mains.
Aluminium	The emission factor used in the baseline for aluminium is for general aluminium, European mix including import and assumes a world average recycled content of 31%. Contractors could reduce the emissions associated with aluminium by reducing the amount used, reusing aluminium where possible and by committing to using material with higher recycled content.
Recycled asphalt paving	Contractors could consider using recycled asphalt pavement to reduce the emissions from asphalt. However, there are two constraints to its use on the Project: • The scope for using site won recycled asphalt paving is limited as the quantity of pavement being demolished is low. Contractors could source recycled asphalt paving from elsewhere and this may result in savings of approximately 7% compared to not using recycled paving. • The forecast traffic volumes on most of the Project are too high (cold recycling for example is currently limited to 30 million standard axle (msa, a measure of design traffic) and the forecast msa is higher for most of the Project route).
Lower carbon grout solutions for poor ground conditions	Contractors could examine the opportunity to replace OPC with GGBS (see entry on lower carbon concrete for more information). This should be a high priority opportunity for Contractors due to the amount of cement likely to be used on the Project. They could also investigate the possibility of using non-grout solutions in poor ground conditions, such as geopolymer injections.
Hybrid or electric plant	Contractors can reduce emissions by increasing the percentage of plant that is hybrid or electric. Contractors could also investigate the use of conveyors to move bulk material onsite.
Optimising use of plant and vehicles	Contractors could consider using telematics to help reduce emissions from plant and vehicles. Telematics could be used to optimise material placement and to assess the performance of plant and vehicles through metrics such as hours of idling and fuel consumption per hour. This information could be used for benchmarking and to identify fuel inefficient behaviours such as double handling, over-revving of engines and excess idling. Drivers or operators could then be targeted for training on efficient operation of plant and vehicles.
Optimising highways vertical alignment	Contractors could aim to keep gradients low as this will help reduce operational emissions due to the high fuel consumption of heavy goods vehicles moving up steep gradients.

Opportunity	Explanation
Highways equipment	Contractors could reduce emissions by specifying the most energy-efficient light fittings, using common feeder pillars to reduce the number of pillars required, considering alternatives to steel columns and reducing the amount of aluminium used in road signs. Contractors should focus on whole life costs when selecting equipment. This will help reduce the operational emissions associated with maintenance, repair and replacement.
Tunnel equipment	Contractors should focus on whole life costs when selecting equipment and should review the equipment specified to ensure new energy efficient equipment is considered.
Drainage equipment	Contractors can reduce the emissions associated with drainage equipment by shortening and combining culverts and considering the use of lower carbon materials for gullies.
Use of machine learning & online platforms for accurate tracking of materials	Contractors can investigate opportunities to use machine learning and online platforms to track the movement of materials and use this information to reduce the associated carbon emissions.
Insets and offsets	Contractors can consider the option of sequestering carbon within the Project boundaries (insetting) or sequestering carbon outside the Project boundaries (offsetting). As per the carbon hierarchy, this option should only be considered once emissions have been avoided and reduced as far as practicable.

Monitoring and reporting

1.4.11 Regular monitoring and reporting of both carbon emissions and action taken to reduce them is an important aspect of PAS 2080. Table 1.2 provides information on the requirements for Contractors to calculate and report emissions during the construction period.

1.4.12 Highways England will be measuring the performance of Contractors against the carbon performance indicator for the Road Investment Strategy 2:

1.4.13 'Emissions from Highways England's contractors (including embodied carbon from construction) per million pounds spent'

1.4.14 It is important to also monitor and report emissions during the operational phase of the Project. The road operator will provide quarterly GHG emissions returns covering the operation and maintenance of the Project during the operational phase, in accordance with the requirements of DMRB LA 114 Climate (Highways England 2019). Actual data provided for the GHG returns shall be evaluated by the road operator to inform any ongoing monitoring of GHG emissions [CC005].

Continuous improvement

1.4.15 PAS 2080 highlights the need for continuous improvement. The Applicant will achieve this by:

a. Updating the carbon model to take advantage of the improved data availability and accura cy as the design develops. Updating the model will reduce the uncertainty, improve accuracy and ensure any emissions reductions identified are not based on outdated or inappropriate baselines.

b. Periodically reviewing emissions reduction opportunities to ensure they are relevant and that innovative solutions have been considered. For example, as technologies and costs change, options that are not currently viable, such as solar integrated into the highway or noise barriers, may become viable.

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Annexes

Annex A Carbon emissions

A.1 Emissions by Project life cycle stage

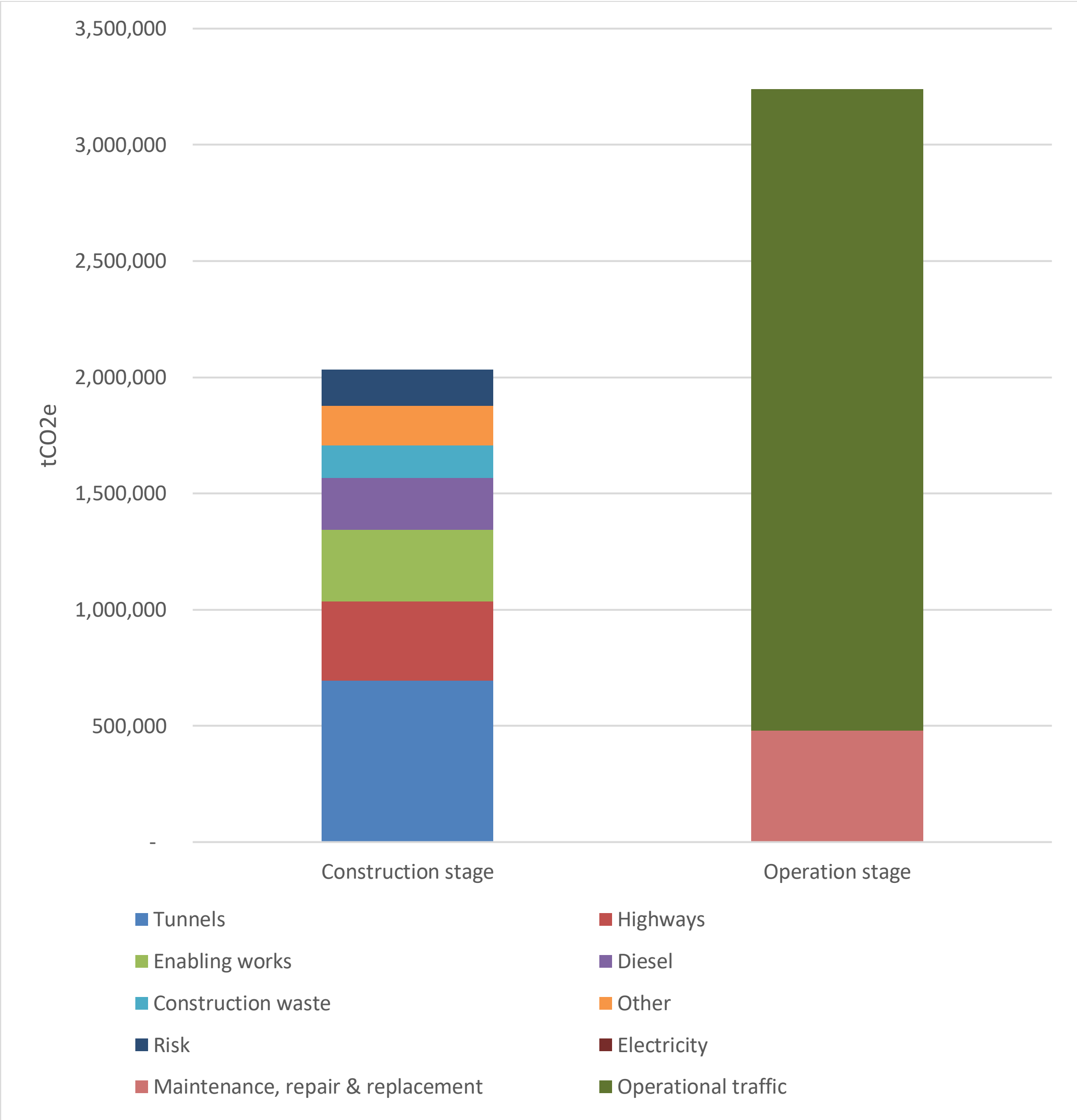
A.1.1 The total emissions of the Project over a sixty-year lifetime are split fairly evenly between the operation stage and construction stage.

Table A.1 Emissions by Project life cycle stage

Project life cycle stage	Emissions (tCO_2e)	% of total emissions
Operation stage	3,240,956	61%
Construction stage	2,031,607	39%
Total	5,272,562	100%

A.1.2 The main contributor to emissions in the construction stage is the construction of the tunnels and in the operational stage it is the operational traffic.

Plate A.1 Breakdown of emissions by Project life cycle stage



A.2 Emissions by sub-stage of life cycle

A.2.1 Fifty-two percent of the emissions associated with the Project occur through the use of the infrastructure, principally the emissions from traffic using the road. Twenty-seven percent occur during the product stage which is part of the before use stage and includes raw material supply, manufacture and transport to the final factory gate.

Table A.2 Emissions by sub-stage of life cycle

Sub-stage of life cycle	Emissions (tCO_2e)	% of total emissions
Use of infrastructure	2,760,059	52%
Product stage	1,408,653	27%

Sub-stage of life cycle	Emissions (tCO_2e)	% of total emissions
Construction process stage	622,954	12%
Operation & maintenance of infrastructure	480,897	9%
Total	5,272,562	100%

A.3 Emissions by category

A.3.1 After operational traffic, the key categories for emissions are tunnels, maintenance, repair and replacement and highways.

Table A.3 Emissions by category

Category	Emissions (tCO_2e)	% of total emissions
Operational traffic	2,760,059	52%
Tunnels	694,546	13%
Maintenance, repair & replacement	480,897	9%
Highways	341,191	6%
Enabling works	307,999	6%
Diesel	223,551	4%
Risk	155,944	3%
Construction waste	140,212	3%
Soil & fill import & treatment	64,916	1%
Construction phase traffic	108,863	2%
Water	2,681	0%
Petrol	571	0%
Land use change	-8,927	0%
Total	5,272,562	100%

*Total does not add up to 100% due to rounding

A.4 Breakdown of emissions for the construction of the tunnel by location

A.4.1 The key locations for tunnels permanent works emissions are the twin bored tunnels, the North Portal structure and the north ramp structure.

Table A.4 Construction product stage emissions for tunnels by location

Location	Emissions (tCO_2e)	% of tunnels emissions
Twin bored tunnels	249,130	51%
North Portal structure	148,365	30%
North ramp structure	47,987	10%
South Portal structure	31,946	6%
Cross passages	6,137	1%
South ramp structure	8,838	2%
Total	492,402	100%

A.5 Breakdown of emissions for the construction of the tunnel by material

A.5.1 The key materials that contribute to the emissions for the tunnels permanent works are cement in grouts, slurries and foamed concrete backfill, steel reinforcement bars, precast steel fibre reinforced concrete and C40/50 *in situ* concrete.

Table A.5 Construction product stage emissions for tunnels permanent works by material

Material	Emissions (tCO_2e)	% of tunnels emissions
Cement in grouts, slurries & foamed concrete backfill	101,534	21%
Steel reinforcement bars	89,716	18%
Precast Steel Fibre Reinforced Concrete	54,578	11%
C40/50 *in situ* concrete	54,672	11%
Steel rebars for ‘precast concrete C50/60’	47,512	10%
Precast concrete C50/60	32,634	7%
Other	30,367	6%
Other steel	29,966	6%
Other concrete	18,675	4%
Foam agent	16,656	3%
Accelerator admixture	16,091	3%
Total	492,402	100%

A.6 Breakdown of emissions for the construction of the highways by location

A.6.1 The key locations of the emissions for the construction of highways are the A13 junction, the M2/A2/Lower Thames Crossing junction and the Ockendon Link.

Table A.6 Construction product stage emissions for highways permanent works by location

Location	Emissions (tCO_2e)	% of highways permanent works emissions
A13 junction	91,114	28%
M2/A2/Lower Thames Crossing junction	75,189	23%
Ockendon Link	55,631	17%
Tilbury junction	25,473	8%
M25 junction 29	24,994	8%
M25 Lower Thames Crossing junction	20,642	6%
A2/M2	15,418	5%
Chadwell St Mary's Link	15,561	5%
Gravesend Link	5,821	2%
Ch.1975 - 2172	627	0%
Ch 6974 - 6885	130	0%
Total	330,599	100%

*Total does not add up to 100% due to rounding

A.7 Breakdown of emissions for the construction of the highways by asset

A.7.1 The key components of the emissions for the construction of highways are special structures (mainly bridges and viaducts), piling and embedded retaining walls and pavements.

Table A.7 Construction product stage emissions for highways permanent works by asset

Asset	Emissions (tCO_2e)	% of highways permanent works emissions
Special structures	181,303	55%
Piling & embedded retaining walls	58,324	18%
Pavements	49,633	15%
Drainage & service ducts	23,225	7%
Other	14,082	4%
Kerbs, footways & paved areas	4,033	1%
Total	330,599	100%

A.8 Breakdown of emissions for the construction of the highways by material

A.8.1 The key materials that contribute to the emissions for the highways permanent works emissions are concrete, steel and asphalt.

Table A.8 Construction product stage emissions for highways permanent works by material

Material	Emissions (tCO_2e)	% of highways permanent works emissions
Concrete	119,214	36%
Steel	130,479	39%
Asphalt	45,038	14%
Plastic	23,089	7%
Aggregate	7,686	2%
Aluminium	2,160	1%
Other	2,933	1%
Total	330,599	100%

A.9 Breakdown of operational emissions

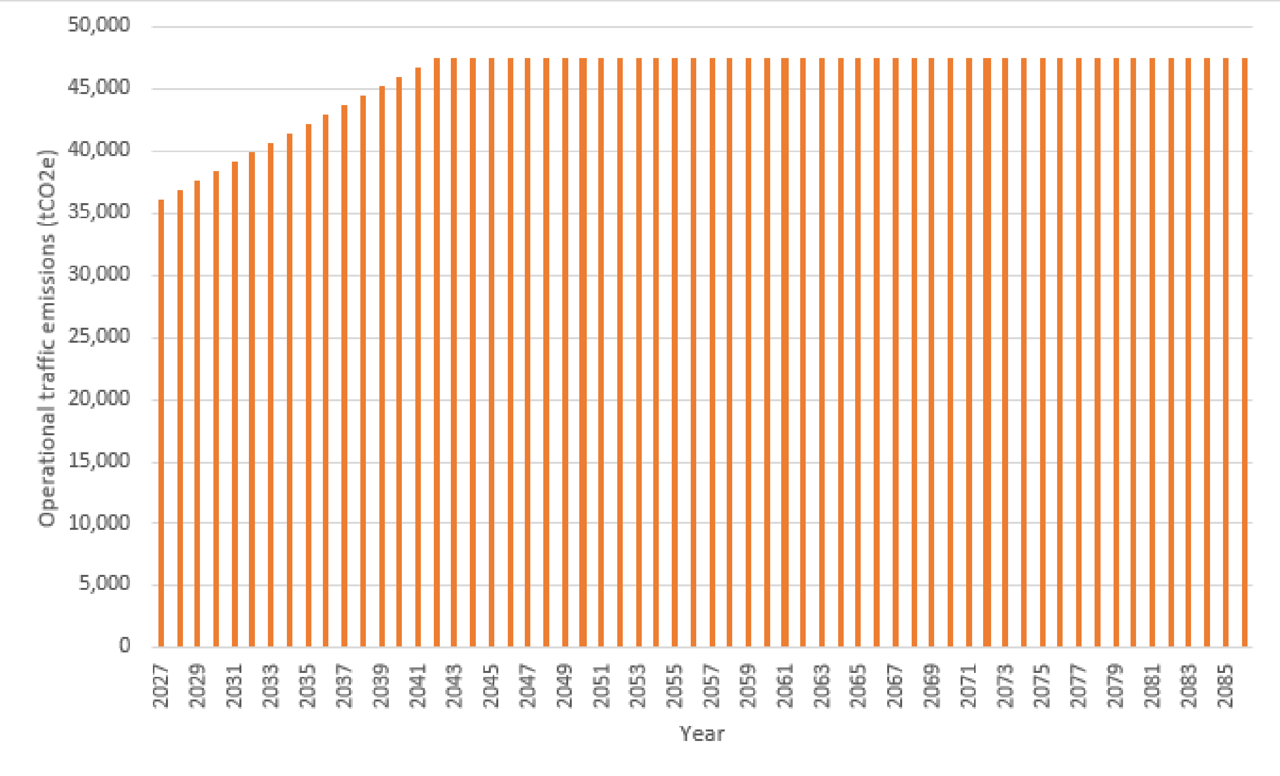
A.9.1 The key components of the operational emissions associated with the Project are operational traffic, followed by maintenance, repair and replacement.

Table A.9 Operational emissions for the Project

Material	Emissions (tCO_2e)	% of operational emissions
Operational traffic	2,760,059	85%

Material	Emissions (tCO_2e)	% of operational emissions
Maintenance, repair & replacement	480,897	15%
Total	3,240,956	100%

Plate A.2 Annual operational traffic emissions



A.10 Breakdown of emissions for maintenance, replacement and repair

A.10.1 The key components of the emissions associated with maintenance, repair and replacement on the Project are paving replacement, maintenance works and drainage and service ducts replacement.

Table A.10 Emissions for maintenance, repair and replacement

Item	Emissions (tCO_2e)	% of maintenance, repair and replacement emissions
Pavement replacement	225,518	47%
Maintenance works	165,604	34%
Other replacements	32,698	7%
Drainage and service ducts replacement	23,225	5%
Elastomeric bearings replacement	19,788	4%

Item	Emissions (tCO_2e)	% of maintenance, repair and replacement emissions
Traffic signs and road markings replacement	14,064	3%
Total	480,897	100%

A.11 Breakdown of emissions for enabling works

A.11.1 The key materials that contribute to the emissions associated with enabling works are steel, aluminium and asphalt.

Table A.11 Emissions for enabling works

Material	Emissions (tCO_2e)	% of enabling works emissions
Steel	188,099	61%
Aluminium	97,082	32%
Asphalt	10,764	3%
Concrete	6,181	2%
Other	5,871	2%
Total	307,997	100%

Annex B Emission factors used

Table A.12 Emission factors

Item	Item detail	Emissions factor	Units	Source
Aggregate	General mixture	0.00700	tCO_2e/t	HE Carbon Tool v2.2
Aggregate	Granular fill to SHW Clause 503.3	0.00747	tCO_2e/t	HE Carbon Tool v2.2
Aggregate	Recycled and secondary aggregate	0.01418	tCO_2e/t	HE Carbon Tool v2.2
Aggregate & soil exported offsite to landfill		0.00126	tCO_2e/t	HE Carbon Tool v2.2
Aggregate & soil exported offsite to recycling		0.00101	tCO_2e/t	HE Carbon Tool v2.2
Aluminium	Aluminium general, European mix, Inc imports	6.67000	tCO_2e/t	HE Carbon Tool v2.2
Asphalt	General asphalt	0.05530	tCO_2e/t	HE Carbon Tool v2.2
Average between Concrete admixtures - Hardening Accelerators and Concrete admixtures - Set Accelerators (from Cement and Mortar, ICE DB V3.0 - 1 Nov 2019)		1.80500	tCO_2e/t	ICE V3.0
Batteries		175	$kgCO_2e/kWh$	ICCT report on the ‘Effects of battery manufacturing on electric vehicle life-cycle greenhouse gas emissions’
Bitumen	Straight run bitumen	0.19100	tCO_2e/t	ICE V3.0
Bituminous mixture to landfill		0.00126	tCO_2e/t	HE Carbon Tool v2.2

Item	Item detail	Emissions factor	Units	Source
Bituminous mixture to recycling		0.00119	tCO_2e/t	HE Carbon Tool v2.2
Boilers		7,204.20560	$kgCO_2e$/item	Specific emission factor for Lower Thames Crossing calculated by the Carbon Trust
Cable tray length		6.19066	$kgCO_2e/m$	Specific emission factor for Lower Thames Crossing calculated by the Carbon Trust
Car travel	Average car	0.00100	tCO_2e/km	HE Carbon Tool v2.2
Cement		0.91200	tCO_2e/t	HE Carbon Tool v2.2
Chilled water pumps		150.88350	$kgCO_2e$/item	Specific emission factor for Lower Thames Crossing calculated by the Carbon Trust
Chillers		41,526.56400	$kgCO_2e$/item	Specific emission factor for Lower Thames Crossing calculated by the Carbon Trust
Clay (bentonite)		0.213	tCO_2e/t	ICE V3.0
Concrete	C25/30 concrete	0.11902	tCO_2e/t	HE Carbon Tool v2.2
Concrete	C32/40 concrete	0.13824	tCO_2e/t	HE Carbon Tool v2.2
Concrete	C32/40 concrete with 25% GGBS	0.12035	tCO_2/t	ICE V3.0
Concrete	C40/50 concrete	0.15900	tCO_2e/t	HE Carbon Tool v2.2
Concrete	C40/50 with CEM I	0.19079	tCO_2e/t	HE Carbon Tool v2.2
Concrete	Concrete 25% GGBS	0.12937	tCO_2e/t	ICE V3.0
Concrete	Ductile Iron	0.47000	tCO_2e/t	ICE V3.0
Concrete	Gen3 concrete	0.10418	tCO_2e/t	HE Carbon Tool v2.2

Item	Item detail	Emissions factor	Units	Source
Concrete	General - C16/20 (Gen 3, ST 4)	0.10418	tCO_2e/t	HE Carbon Tool v2.2
Concrete	General - C32/40	0.13824	tCO_2e/t	HE Carbon Tool v2.2
Concrete	General - C35/45	0.14870	tCO_2e/t	HE Carbon Tool v2.2
Concrete	General - C40/50	0.15912	tCO_2e/t	HE Carbon Tool v2.2
Concrete	General 32/40	0.13800	tCO_2e/t	HE Carbon Tool v2.2
Concrete	General C30/40 Concrete	0.11902	tCO_2e/t	HE Carbon Tool v2.2
Concrete	General C40/50	0.13800	tCO_2e/t	HE Carbon Tool v2.2
Concrete	General concrete	0.10336	tCO_2e/t	HE Carbon Tool v2.2
Concrete	PAV 2 - C32/40	0.13800	tCO_2e/t	ICE V3.0
Concrete	Plain *in situ* C40/50 with 65% GGBS replacement of OPC	0.07342	tCO_2e/t	ICE Cement, Mortar and Concrete Model (V1.1 Beta - 28 Nov 2019)
Concrete	Plain precast C50/60 with 65% GGBS replacement of OPC	0.10257	tCO_2e/t	ICE Cement, Mortar and Concrete Model (V1.1 Beta - 28 Nov 2019)
Concrete	Precast	0.22786	tCO_2e/t	BCSA TATA Carbon Footprint Tool 2013
Concrete	Precast	0.13200	tCO_2e/t	ICE V3.0
Concrete	Precast	0.12200	tCO_2e/t	HE Carbon Tool v2.2
Concrete	Precast concrete manholes	0.19000	tCO_2e/t	HE Carbon Tool v2.2
Concrete	Precast General C40/50	0.17200	tCO_2e/t	HE Carbon Tool v2.2
‘Concrete admixtures -		1.88000	tCO_2e/t	ICE V3.0

Item	Item detail	Emissions factor	Units	Source
Plasticisers and Superplasticisers’				
Concrete admixtures - Retarders		1.31000	tCO_2e/t	ICE V3.0
Concrete admixtures - Set Accelerators		1.33000	tCO_2e/t	ICE V3.0
Concrete, brick, tiles & ceramics to landfill		0.00126	tCO_2e/t	HE Carbon Tool v2.2
Concrete, brick, tiles & ceramics to recycling		0.00101	tCO_2e/t	HE Carbon Tool v2.2
Condenser (AHU)		16,762.58697	$kgCO_2e$/item	Carbon Trust
Copper		2.71000	tCO_2e/t	ICE V3.0
DI Pipe (DN200)		2.03000	tCO_2e/m	HE Carbon Tool v2.2
DI Pipe (DN300)		2.03000	tCO_2e/m	HE Carbon Tool v2.2
DI Pipe (DN400)		2.03000	tCO_2e/m	HE Carbon Tool v2.2
DI Pipe (DN80)		2.03000	tCO_2e/m	HE Carbon Tool v2.2
Diesel		3.21120	$kgCO_2e/l$	HE Carbon Tool v2.2
Dowel joint connectors – plastic with plastic sockets		8.10285	tCO_2e/t	Specific emission factor for Lower Thames Crossing calculated by the Carbon Trust
Dowel joint connectors - shear cones (plastic coating with steel core) and plastic sockets E.g. SOF-FIX AXIS 110		5.68926	tCO_2e/t	Specific emission factor for Lower Thames Crossing calculated by the Carbon Trust
Drainage pump valves		2.78376	$kgCO_2e$/item	Specific emission factor for Lower Thames Crossing calculated by the Carbon Trust
Ducting 125mm dia duct		7.86499	tCO_2e/m	Specific emission factor for Lower

Item	Item detail	Emissions factor	Units	Source
				Thames Crossing calculated by the Carbon Trust
Ducting 400mm dia duct		31.78878	$kgCO_2e/m$	Specific emission factor for Lower Thames Crossing calculated by the Carbon Trust
Electrical	Various	4.32300	tCO_2e/t	HE Carbon Tool v2.2
Electrical	Various	3.20600	tCO_2e/t	HE Carbon Tool v2.2
Electrical	Various	1.86000	tCO_2e/t	HE Carbon Tool v2.2
Electricity	Forecast UK grid factor for 2028	0.09785	$kgCO_2e/kWh$	BEIS
Electricity	Forecast UK grid factor for 2029	0.09013	$kgCO_2e/kWh$	BEIS
Electricity	Forecast UK grid factor for 2030	0.08126	$kgCO_2e/kWh$	BEIS
Electricity	Forecast UK grid factor for 2031	0.07150	$kgCO_2e/kWh$	BEIS
Electricity	Forecast UK grid factor for 2032	0.06016	$kgCO_2e/kWh$	BEIS
Electricity	Forecast UK grid factor for 2033	0.05577	$kgCO_2e/kWh$	BEIS
Electricity	Forecast UK grid factor for 2034	0.04848	$kgCO_2e/kWh$	BEIS
Electricity	Forecast UK grid factor for 2035	0.04015	$kgCO_2e/kWh$	BEIS
Electricity	Forecast UK grid factor for 2036	0.04015	$kgCO_2e/kWh$	BEIS
Electricity	Forecast UK grid factor for 2037	0.04015	$kgCO_2e/kWh$	BEIS

Item	Item detail	Emissions factor	Units	Source
Electricity	Forecast UK grid factor for 2038	0.04015	$kgCO_2e/kWh$	BEIS
Electricity	Forecast UK grid factor for 2039	0.04015	$kgCO_2e/kWh$	BEIS
Electricity	Forecast UK grid factor for 2040	0.04015	$kgCO_2e/kWh$	BEIS
Electricity	Forecast UK grid factor for 2041	0.03884	$kgCO_2e/kWh$	BEIS
Electricity	Forecast UK grid factor for 2042	0.03754	$kgCO_2e/kWh$	BEIS
Electricity	Forecast UK grid factor for 2043	0.03623	$kgCO_2e/kWh$	BEIS
Electricity	Forecast UK grid factor for 2044	0.03493	$kgCO_2e/kWh$	BEIS
Electricity	Forecast UK grid factor for 2045	0.03362	$kgCO_2e/kWh$	BEIS
Electricity	Forecast UK grid factor for 2046	0.03231	$kgCO_2e/kWh$	BEIS
Electricity	Forecast UK grid factor for 2047	0.03101	$kgCO_2e/kWh$	BEIS
Electricity	Forecast UK grid factor for 2048	0.02970	$kgCO_2e/kWh$	BEIS
Electricity	Forecast UK grid factor for 2049	0.02840	$kgCO_2e/kWh$	BEIS
Electricity	Forecast UK grid factor for 2050 - 2100	0.02709	$kgCO_2e/kWh$	BEIS
Electricity	Fully additional renewable electricity	0.00000	$kgCO_2e/kWh$	BEIS 2019
Electricity	UK grid average	0.25560	$kgCO_2e/kWh$	BEIS 2019

Item	Item detail	Emissions factor	Units	Source
Fans		201.00000	$kgCO_2e$/item	Specific emission factor for Lower Thames Crossing calculated by the Carbon Trust
FCU		1,768.98080	$kgCO_2e$/item	Specific emission factor for Lower Thames Crossing calculated by the Carbon Trust
Fill, aggregate and sand	Recycled resources, with heat treatment	0.11877	tCO_2e/t	HE Carbon Tool v2.2
Fire dampers		27.65360	$kgCO_2e$/item	Specific emission factor for Lower Thames Crossing calculated by the Carbon Trust
Fire pump valves		2.78376	$kgCO_2e$/item	Specific emission factor for Lower Thames Crossing calculated by the Carbon Trust
Fire pumps (200-250kW)		136.82790	$kgCO_2e$/item	Specific emission factor for Lower Thames Crossing calculated by the Carbon Trust
Fire pumps (Jockey pumps)		160.97400	$kgCO_2e$/item	Specific emission factor for Lower Thames Crossing calculated by the Carbon Trust
Fire pumps (Jockey pumps)		80.48700	$kgCO_2e$/item	Specific emission factor for Lower Thames Crossing calculated by the Carbon Trust
General office waste to landfill		1.00000	tCO_2e/t	HE Carbon Tool v2.2
General office waste to recycling		0.02135	tCO_2e/t	HE Carbon Tool v2.2
General paint		3.76000	tCO_2e/t	HE Carbon Tool v2.2
General polyethylene		2.54000	tCO_2e/t	ICE V3.0

Item	Item detail	Emissions factor	Units	Source
General rubber		2.85000	tCO_2e/t	ICE V3.0
General steel		1.55000	tCO_2e/t	HE Carbon Tool v2.2
Glass reinforced plastic GRP (Fiberglass)		8.10000	tCO_2e/t	HE Carbon Tool v2.2
Grout sockets: TYPE IV Grout Lift Sockets with screw caps		0.00149	tCO_2e per product	Specific emission factor for Lower Thames Crossing calculated by the Carbon Trust
Hazardous waste to landfill		0.07549	tCO_2e/t	HE Carbon Tool v2.2
Insulation to landfill		0.00126	tCO_2e/t	HE Carbon Tool v2.2
Insulation to recycling		0.00101	tCO_2e/t	HE Carbon Tool v2.2
Iron	Ductile iron	2.03000	tCO_2e/t	ICE V3.0
Jet Fans		2,527.11543	$kgCO_2e$/item	Specific emission factor for Lower Thames Crossing calculated by the Carbon Trust
Land use change	Cropland to Cropland	0.00001	$tCO_2e/m^2/yr$	National Atmospheric Emissions Inventory
Land use change	Cropland to Grassland	-0.00002	$tCO_2e/m^2/yr$	National Atmospheric Emissions Inventory
Land use change	Cropland to Settlement	0.00006	$tCO_2e/m^2/yr$	National Atmospheric Emissions Inventory
Land use change	Cropland to Woodland	-0.00011	$tCO_2e/m^2/yr$	National Atmospheric Emissions Inventory
Land use change	Grassland to Cropland	0.00003	$tCO_2e/m^2/yr$	National Atmospheric Emissions Inventory
Land use change	Grassland to Grassland	0.00000	$tCO_2e/m^2/yr$	National Atmospheric

Item	Item detail	Emissions factor	Units	Source
				Emissions Inventory
Land use change	Grassland to Settlement	0.00009	$tCO_2e/m^2/yr$	National Atmospheric Emissions Inventory
Land use change	Grassland to Woodland	-0.00011	$tCO_2e/m^2/yr$	National Atmospheric Emissions Inventory
Land use change	Settlement to Cropland	-0.00003	$tCO_2e/m^2/yr$	National Atmospheric Emissions Inventory
Land use change	Settlement to Grassland	-0.00005	$tCO_2e/m^2/yr$	National Atmospheric Emissions Inventory
Land use change	Settlement to Settlement	0.00000	$tCO_2e/m^2/yr$	National Atmospheric Emissions Inventory
Land use change	Settlement to Wetlands	0.00000	$tCO_2e/m^2/yr$	National Atmospheric Emissions Inventory
Land use change	Settlement to Woodland	-0.00011	$tCO_2e/m^2/yr$	National Atmospheric Emissions Inventory
Land use change	Wetlands to Cropland	0.00000	$tCO_2e/m^2/yr$	National Atmospheric Emissions Inventory
Land use change	Wetlands to Grassland	0.00001	$tCO_2e/m^2/yr$	National Atmospheric Emissions Inventory
Land use change	Wetlands to Settlement	0.00000	$tCO_2e/m^2/yr$	National Atmospheric Emissions Inventory
Land use change	Wetlands to Wetlands	0.00005	$tCO_2e/m^2/yr$	National Atmospheric Emissions Inventory

Item	Item detail	Emissions factor	Units	Source
Land use change	Wetlands to Woodland	0.00000	$tCO_2e/m^2/yr$	National Atmospheric Emissions Inventory
Land use change	Woodland to Cropland	0.00019	$tCO_2e/m^2/yr$	National Atmospheric Emissions Inventory
Land use change	Woodland to Grassland	0.00021	$tCO_2e/m^2/yr$	National Atmospheric Emissions Inventory
Land use change	Woodland to Settlement	0.00016	$tCO_2e/m^2/yr$	National Atmospheric Emissions Inventory
Land use change	Woodland to Wetlands	0.00000	$tCO_2e/m^2/yr$	National Atmospheric Emissions Inventory
Land use change	Woodland to Woodland	-0.00005	$tCO_2e/m^2/yr$	National Atmospheric Emissions Inventory
Lime		0.78000	tCO_2e/t	HE Carbon Tool v2.2
Low point sump ventilation fan		201.00000	$kgCO_2e$/item	Specific emission factor for Lower Thames Crossing calculated by the Carbon Trust
Miscellaneous cables		2.52000	tCO_2e/m	HE Carbon Tool v2.2
Mixed construction & demolition waste to landfill		0.09265	tCO_2e/t	HE Carbon Tool v2.2
Mixed construction & demolition waste to recycling		0.00783	tCO_2e/t	HE Carbon Tool v2.2
Mixed metals to recycling		0.02135	tCO_2e/t	HE Carbon Tool v2.2
Nylon (polyamide) 6,6 Polymer		7.92000	tCO_2e/t	ICE V3.0
Organic waste to composting		0.01020	tCO_2e/t	HE Carbon Tool v2.2

Item	Item detail	Emissions factor	Units	Source
Paper and cardboard to landfill		1.04189	tCO_2e/t	HE Carbon Tool v2.2
Paper and cardboard to recycling		0.02135	tCO_2e/t	HE Carbon Tool v2.2
Plasterboard to landfill		0.07195	tCO_2e/t	HE Carbon Tool v2.2
Plasterboard to recycling		0.02135	tCO_2e/t	HE Carbon Tool v2.2
Plastic	General plastic	3.31000	tCO_2e/t	HE Carbon Tool v2.2
Plastic	Geosynthetic Clay Liner	2.54000	tCO_2e/t	HE Carbon Tool v2.2
Plastic	GRP	8.10000	tCO_2e/t	ICE V3.0
Plastic	HDPE	2.52000	tCO_2e/t	HE Carbon Tool v2.2
Plastic	Polypropylene	4.49000	tCO_2e/t	ICE V3.0
Plastic	Polypropylene	0.19000	tCO_2e/t	HE Carbon Tool v2.2
Plastic	Polyurea	4.20000		BCSA TATA Carbon Footprint Tool 2013
Plastic	Thermoplastic High Density Polyethylene	5.70000	tCO_2e/t	HE Carbon Tool v2.2
Plastic	UPVC	3.23000	tCO_2e/t	HE Carbon Tool v2.2
Plastic pipe	100mm dia	3.23000	tCO_2e/m	HE Carbon Tool v2.2
Plastic to landfill		0.00899	tCO_2e/t	HE Carbon Tool v2.2
Plastic to recycling		0.02135	tCO_2e/t	HE Carbon Tool v2.2
Portal building ventilation		6,352.52750	$kgCO_2e/item$	Specific emission factor for Lower Thames Crossing calculated by the Carbon Trust
Portal buildings		925.00000	$kgCO_2e/m^2$	RICS - Method to calculate embodied carbon
Power cables		1.86000	tCO_2e/m	HE Carbon Tool v2.2

Item	Item detail	Emissions factor	Units	Source
Radial joints		2.76000	tCO_2e/t	Carbon Trust
Rubber	Neoprene	2.85000		ICE V3.0
SFRC precast C50/60 with 65% GGBS replacement of OPC		0.27162	tCO_2e/m^3	ICE Cement, Mortar and Concrete Model (V1.1 Beta - 28 Nov 2019)
Soil	Imported soil / general soil / top soil	0.02400	tCO_2e/t	HE Carbon Tool v2.2
Soil conditioning (foams)		1.99732	tCO_2e/t	Specific emission factor for Lower Thames Crossing calculated by the Carbon Trust
Spheroidal Graphite Iron (SGI) opening sets		1.88150	tCO_2e/t	Specific emission factor for Lower Thames Crossing calculated by the Carbon Trust
Spray-applied waterproofing membrane		1.80000	tCO_2/t	Thomas A (2019)
Stabilised soil		0.05800	tCO_2e/t	HE Carbon Tool v2.2
Stainless steel		4.05000	tCO_2e/t	GaBi: Stainless steel cold rolled coil (304) EU-28
Stainless steel pipe		3.02000	tCO_2e/m	HE Carbon Tool v2.2
Steel	Hot dipped galvanised steel	2.76000	tCO_2e/t	HE Carbon Tool v2.2
Steel	Stainless steel	4.40000	tCO_2e/t	ICE V3.0
Steel	Steel bar and rod	1.99000	tCO_2e/t	HE Carbon Tool v2.2
Steel	Steel cold rolled coil	2.53000	tCO_2e/t	ICE V3.0
Steel	Steel plate	2.46000	tCO_2e/t	ICE V3.0
Steel cabinets		2.76000	tCO_2e/item	HE Carbon Tool v2.2
Steel bar reinforcement		1.99000	tCO_2e/t	HE Carbon Tool v2.2

Item	Item detail	Emissions factor	Units	Source
Steel gas mains		3.02000	tCO_2e/t	HE Carbon Tool v2.2
Tailskin grease		1.99732	tCO_2e/t	Carbon Trust
Timber	Softwood no carbon storage	0.26300	tCO_2e/t	HE Carbon Tool v2.2
Timber to landfill		0.82812	tCO_2e/t	HE Carbon Tool v2.2
Timber to recycling		0.02135	tCO_2e/t	HE Carbon Tool v2.2
Transformers (2000 kVA)		27,042.00000	$kgCO_2e$/item	Specific emission factor for Lower Thames Crossing calculated by the Carbon Trust
Tunnel boring machine		44,208.00000	tCO_2e/TBM	Specific emission factor for Lower Thames Crossing calculated by the Carbon Trust
Tunnel drainage pumps		32.19480	$kgCO_2e$/item	Specific emission factor for Lower Thames Crossing calculated by the Carbon Trust
Tunnel fire valves		2.78376	$kgCO_2e$/item	Specific emission factor for Lower Thames Crossing calculated by the Carbon Trust
Under deck gallery ventilation AHU		41,906.46743	$kgCO_2e$/item	Specific emission factor for Lower Thames Crossing calculated by the Carbon Trust
Valves		2.78376	$kgCO_2e$/item	Specific emission factor for Lower Thames Crossing calculated by the Carbon Trust
Water consumption		0.34400	$kgCO_2e/m^3$	BEIS 2019
Water supply		0.00034	tCO_2e/m^3	BEIS 2019
Water treatment		0.70800	$kgCO_2e/m^3$	BEIS 2019
Waterproofing sheet membrane		2.50000	tCO_2/t	Thomas A (2019)

Annex C Assumption used

Table A.13 Assumptions used in the carbon model

Product life cycle stage	Category	Activity phase	Assumption
Construction	Carbon associated with risk		Data on risks was taken from the risk register. For each area (Tunnels, Highways England risk, Highways North, Highways South and Enabling Works), any entries in the top five risk items (on a cost basis) that were already covered in the carbon model or that had no carbon impact (e.g. compensation payments) were ignored. The cost associated with the remaining items plus all items outside the top five for each area, was summed up and then carbon emissions estimated on a project-specific emissions per pound spent rate. Items in the risk portfolio (which includes items such as legislative changes) were not included.
Construction	Structures	Temporary works	Temporary formwork for the substructure has also been discarded as the quantities are deemed negligible.
Construction	Highways	Permanent works	Only cradle to gate carbon emissions have been considered in the Highways permanent works emissions worksheet. Carbon from transport to site and onsite works have been considered in other worksheets.
Construction	Highways	Permanent works	Carbon has been calculated with only bulk material. Any items which are only machinery, labour or construction activities have not been considered in the Highways worksheet permanent works but are covered elsewhere in the carbon model.
Construction	Highways	Permanent works	Conservative assumptions have been used when selecting the carbon factor using the best fit product, material or item.
Construction	Highways	Permanent works	All carbon factors are in tCO_2e per tonne of material or per unit (if an individual item, i.e. lighting column which has then been converted to tonne of material).
Construction	Highways	Permanent works	Where details of the material are not known, generic carbon factors have been used (e.g. general mixture factor used for some quantities of aggregates).
Construction	Highways	Permanent works	Weight factors have been used to convert between the volume, length or area of material to tonnes.

Product life cycle stage	Category	Activity phase	Assumption
Construction	Highways	Permanent works	Where weight factors were not available, they have been calculated based on a weight per metre or metre squared or for an individual item.
Construction	Highways	Permanent works	Where the item is not listed in the HE Carbon tool and it is not a bulk item, product specifications from typical manufacturers have been used for materials and weights etc.
Construction	Highways	Permanent works	Where items comprise of multiple materials, the primary material that the item is composed of has been listed.
Construction	Highways	Permanent works	All site clearance items are deemed to be construction activities and are covered elsewhere in the carbon model.
Construction	Highways	Permanent works	Quantities obtained from Bill of Quantities
Construction	Highways	Permanent works	Fencing assumed to be timber
Construction	Highways	Permanent works	Details of close boarded fence taken from external fencing specification to be 3m wide with the weight and carbon factors in the HE Carbon tool.
Construction	Highways	Permanent works	Assumed concrete block every three metres, for close boarded fence at 0.092 tonnes of concrete per block. Assume rail fence uses rammed backfill.
Construction	Highways	Permanent works	All VRS barriers are assumed to be hot dipped galvanised steel - cradle to gate only including the production of the barriers and no transportation to site or installation at site.
Construction	Highways	Permanent works	Filter drain quantities and carbon estimate has been broken down into the pipe and filter fill material.
Construction	Highways	Permanent works	Carrier drain quantities and carbon estimate has been broken down into the pipe and fill material.
Construction	Highways	Permanent works	Size of filter drain trench assumed to be an average depth and width for a pipe of the stated size.
Construction	Highways	Permanent works	Exact specification of fill material for filter and carrier drains has yet to be determined.
Construction	Highways	Permanent works	Precast concrete chambers have been broken down into several different sizes with an approximation of the quantity for each based on the length of piping for a particular size.

Product life cycle stage	Category	Activity phase	Assumption
Construction	Highways	Permanent works	Chambers are assumed to be used for carrier drains and catchpits used for filter drains.
Construction	Highways	Permanent works	Fin drains have not been accounted for in this assessment as they are not yet designed or part of any drawings.
Construction	Highways	Permanent works	General asphalt mixtures have been used without further detailed specifications, as these are not available.
Construction	Highways	Permanent works	Cold milling of pavements is deemed to be a construction activity and covered elsewhere in the carbon model.
Construction	Highways	Permanent works	It is assumed that the quantities in the BoQ for pavements are for mainline carriageway only. The access loop roads to the portal and the A226 are added in the additional gaps calculation with those quantities based off the DR2.14 Section 03 Earthwork Quantities Rev 1.
Construction	Highways	Permanent works	Footway items (incl. maintenance and paved areas) have been split up into sub-base and base plus any surfacing due to variable materials being used.
Construction	Highways	Permanent works	All footway estimates are on the provision that the CBR of the ground is >2.5%, as the minimum stated by DMRB standard (any lower and ground would need further investigation and to be strengthened).
Construction	Highways	Permanent works	All kerbs and edgings assumed to be precast concrete.
Construction	Highways	Permanent works	All traffic signs and marker posts assumed to be a general aluminium.
Construction	Highways	Permanent works	All road markings and road studs assumed to be plastic. Thermoplastic high-density polyethylene to be used for road markings.
Construction	Highways	Permanent works	For road lighting columns, estimates only include the hot dipped galvanised steel column. Carbon figure for lantern itself omitted due to variety of materials used and small overall impact
Construction	Highways	Permanent works	Earth electrode assumed to be copper but bonded steel also an option.
Construction	Highways	Permanent works	Items are best fit product specifications where there wasn’t an exact match within the HE Carbon Model or the ICE database V3.0.

Product life cycle stage	Category	Activity phase	Assumption
Construction	Highways	Permanent works	Trenches for ducts omitted from the estimate as assumed backfill material on site will be used to fill around the cables.
Construction	Highways	Permanent works	All testing and commissioning items are deemed to be activities so omitted from the Highways permanent works assessment.
Construction	Highways	Permanent works	Assumptions made on size of concrete base. Telephone assumed to consist only of steel case. Data from a manufacturer's website has been used to estimate size of case.
Construction	Highways	Permanent works	All cabling assumed to be an armoured cable as recommended in the HE Carbon Tool.
Construction	Highways	Permanent works	Piling and embedded materials have been broken down into the concrete and reinforcing steel.
Construction	Highways	Permanent works	No ground improvement assumed below flood bunds.
Construction	Highways	Permanent works	No uplift applied to data unlike Application Document 6.1, Chapter 11: Material Assets and Waste chapter which applies a 5% uplift.
Construction	Highways	Temporary works	Assumption on split of primary vs recycled aggregate matches assumption used in Application Document 6.1, Chapter 11: Material Assets and Waste.
Construction	Highways	Temporary works	C50/60 concrete with 65% GGBS assumed for concrete floor pads.
Construction	Highways	Temporary works	C35/45 concrete with 25% GGBS assumed for piles for abutment and wing wall.
Construction	Highways	Temporary works	C40/50 concrete with 65% GGBS assumed for cross beam concrete, wing wall pile cap and deck.
Construction	Tunnels	Permanent works	Quantities are derived from a mix of manual calculations and inputs from BIM models. Much of the portals and ramps baseline quantities have been derived from the BIM models. All of the twin-bored tunnel and cross passage quantities are inputted manually. Almost all ground mitigation measures quantities have been inputted manually.
Construction	Tunnels	Permanent works	The whole length of the South Ramp and Portal is assumed to be 130m, with the northern end at chainage CH2+302 and the transition from Portal to Ramp at CH2+230. Therefore, the assumed chainages for this calculation which determine the lengths of each respective structure of the main crossing are as follows:

Product life cycle stage	Category	Activity phase	Assumption
			North Ramp: 6+885 to 6+477 North Portal: 6+477 to 6+177 Bored Tunnel: 6+177 to 2+302 South Portal: 2+302 to 2+230 South Ramp: 2+230 to 2+172
Construction	Tunnels	Permanent works	Tonnages of (bar and fibre) reinforcement for concrete were calculated by including dosage densities supplied by the tunnel design team.
Construction	Tunnels	Permanent works	The quantity for R.C. tunnel segments used around cross passage opening sets locations has been calculated based on the document HE540039-CJV-STU-S06_TNN0000001-DR-CT-00026 Rev. P01. R.C. segment rings are also assumed to be required at the northern end of the tunnel between chainages Ch.5+959 and Ch.6+177. All other bored tunnel concrete segments are SFRC.
Construction	Tunnels	Permanent works	Asphalt pavement calcs: Highways drawing HE540039-CJV-HPV-S3P_TN000000_Z-DE-CH-00001 'Bored Tunnel Pavement Detail Option 10' Revision P01 provided the basis for pavement calculations. As most of the materials are asphalt-based it was advised to use the 'General Asphalt' material in the carbon calculation with a cross sectional area of 2.82m^2 calculated from the drawing using Bluebeam. This cross-sectional area is assumed to be applied continuously along the whole length of the main crossing from Ch. 6+885 to Ch. 2+172. Any pavement on the Project outside of this is being taken into account in the highways emissions.
Construction	Tunnels	Permanent works	Each bored tunnel ring is assumed to have an average length of 2m along the tunnel drive, as indicated in Bored Tunnel drawing 'HE540039-CJV-STU-S3P_TN0000001-DR-CT-00023' Revision P02. Therefore for these calculations the number of rings in a tunnel are estimated as: 3,875m/2m = 1938 rings.
Construction	Tunnels	Permanent works	An example rubber gasket has been extracted from a product brochure to use for estimating the approximate volume of EPDM rubber used for gaskets around the bored tunnel segments. It was the largest gasket from the brochure that could fit into the segment gasket groove width of 26mm as indicated in the Bored Tunnel drawing 'HE540039-CJV-STU-

Product life cycle stage	Category	Activity phase	Assumption
			S3P_TNN0000001-DR-CT-00031' Revision P02.
Construction	Tunnels	Permanent works	Assumption for total length of gasket in bored tunnels: The total perimeter of all segments in an average ring was estimated from Bored Tunnel drawing 'HE540039-CJV-STU-S3P_TN0000001-DR-CT-00023' Revision P02, to be: 96 + (2*18) = 132m. There are approximately 1,938 rings in a bored tunnel. 938 rings * 132m = 123,816m total length of gaskets.
Construction	Tunnels	Permanent works	Cross passages: Based on the document 'Cross passage categories - geological and construction risk (Draft for Discussion)', it is assumed that 5/26 cross passages are constructed using cast-iron spheroidal-graphite-iron (SGI) linings, while the remaining 21 are constructed using sprayed-concrete-lining (SCL). SGI lining is assumed for specific cross passages situated just below or at least partially within the river terrace deposits and alluvium stratum. The SGI lining segment rings have been estimated to each have an SGI material volume of 0.77m^3. This has assumed an outer radius of 1,850mm, with eight equal segments per ring, maximum thickness of 125mm and eight cells per segment with a lower thickness of 20mm in those places. Based on drawing 'HE540039-CJV-STU-S3P_TNN0000001-DR-CT-00203' Revision P02, the SCL cross passages are assumed to have the following lining layers: 225mm thick primary lining (outer diameter 4300mm, inner diameter 3850mm) 40mm thick regulating layer (outer diameter 3850mm, inner diameter 3770mm) 10mm thick spray-on waterproof membrane (outer diameter 3770mm, inner diameter 3750mm) 150mm thick secondary lining (outer diameter 3750mm, inner diameter 3450mm) The SCL primary lining, regulating layer and secondary lining are all assumed to be C32/40 concrete (based on HE540039-CJV-GEN-GEN-DST-DES-00001 Bored tunnel Preliminary Design Statement). The invert structure of all

Product life cycle stage	Category	Activity phase	Assumption
			the cross passages is assumed to be the same concrete class and reinforcement as the secondary lining of SCL cross passages.
Construction	Tunnels	Permanent works	Ground treatment of cross passages: based on the document ‘Cross passage categories - geological and construction risk (Draft for Discussion)’ it is assumed that one SGI cross passage uses soil mixing in the alluvium, two SGI cross passages use jet grouting in the river terrace deposits (gravels), while two SGI and the 21 SCL cross passages use chalk fissure grouting. A grout take of 5% is assumed for chalk fissure grouting, and 50% for gravels jet grouting. The soil mixing cross passage has already been accounted for by the peat stabilisation ground treatment block. Based on prior experience of grouting on comparable projects: - Recommended assumption of a solid cylinder of grouted rock/soil and subsequently excavated for each of 25 cross passages. Each grout cylinder extends 3m beyond the outer diameter of the cross passage all around. SCL cross passage outer diameter is 4.3m, so grout cylinder diameter is 4.3+6 = 10.3m. SGI cross passage outer diameter is 3.7m, so grout cylinder diameter for each of four of them is 3.7+6 = 9.7m. - Conservatively assuming 5% total grout take of the volume of desired cylinder in chalk - 3% for fissures and 2% for wastage, washout, sleeve grout, and potential loss into any gravel where above or in case of grouting further than expected. - On the other hand, 50% grout take of the intended treated soil volume has been conservatively assumed in case of grouting further than expected in gravels.
Construction	Tunnels	Permanent works	Concrete grade assumptions: C40/50 concrete has been assumed for all *in situ* and precast reinforced concrete elements in the portals and ramps apart from blinding and mass concrete infills (C16/20), guide walls (C32/40), mass concrete infill (C16/20), raised pavements either side of carriageway pavements (C32/40), precast beams (C50/60) used in composite solid slabs. All precast concrete segments are assumed to be C50/60 concrete. Cross passages collars, sprayed SFRC, *in situ* SFRC

Product life cycle stage	Category	Activity phase	Assumption
			secondary lining and invert structure are all assumed to use C32/40 concrete.
Construction	Tunnels	Permanent works	Typical products were used as examples of bored tunnel lining accessories from which to derive embodied carbon emissions. Information was received on the mass of each material for typical dowel joint connectors. The Carbon Trust calculated carbon factors based on these typical products.
Construction	Tunnels	Permanent works	Shotcrete admixtures for cross passages have been taken from the example of the document 'Crossrail C300/410 Western Tunnels & Caverns Project - Material Compliance Record - Secondary Lining (BFK17.2 Mix)'. It also provided the dosages and densities. For superplasticiser, accelerator and HCA retarder, the dosages were taken from Technical Data Sheets and Mix Designs.
Construction	Tunnels	Permanent works	Bored Tunnel drawing 'HE540039-CJV-STU-S3P_TN0000001-DR-CT-00023' Revision P02 has been used to quantify the number of each bored tunnel lining component in these calculations: spear bolts (and sockets), dowel joint connectors, grout sockets, guide rods.
Construction	Tunnels	Permanent works	All calculations for East Tilbury Landfill slurry wall, North Portal base grouting in chalk, North Portal diaphragm wall deepening, peat stabilisation ground treatment, ground protection tunnel under Ramsar site, North Kent railway settlement mitigation, and TBM mode change grout block are based on the document 'HE540039-CJV-GEN-GEN-TNT-TUN-00008' Revision 1.0 - Main Crossing Civil/Structural Engineering Summary for DR2.14, unless otherwise stated.
Construction	Tunnels	Permanent works	Unless otherwise stated, assumptions for the Ground Protection Tunnel (GPT) and Reception Caisson Shaft (RCS) segment linings sheet are based on the main twin-bored tunnels segment lining: - GPT: 2m wide rings along the tunnel drive. Therefore (assuming 800m long tunnel)/2m = 400 rings for Ground Protection Tunnel. - GPT and RCS: Using same numbers of lining accessories per ring (e.g. dowel joint connectors).
Construction	Tunnels	Permanent works	It is assumed that Ground Protection Tunnel's Reception Caisson Shaft segment lining rings will be 1.2m deep. Therefore (14m deep

Product life cycle stage	Category	Activity phase	Assumption
			shaft)/1.2m ≈ 12 rings for Reception Caisson Shaft.
Construction	Tunnels	Permanent works	Temporary guide walls are assumed to be used along the full length of all diaphragm walls during construction. - Per metre run the following reinforcement bars are one metre long: 22 no. 20mm bars, 22 no. 16mm bars. - The estimated total length of links bars is [(1160mm x 2) + (380mm x 2)] x (five links per metre run) x (two guide walls per metre run) = 30800mm per guide wall pair. Links are 12mm bars. - 20mm bars are 2.466kg/m, therefore total weight = 22 x 1 x 2.466 = 54.3 kg. - 16mm bars are 1.579kg/m, therefore total weight = 22 x 1 x 1.579 = 34.7 kg. - 12mm bars are 0.888kg/m, therefore total weight = 1 x 30.8 x 0.888 = 27.4 kg. - Per metre run the total volume of concrete is 0.45m x 1.2m x 1m x 2 = 1.08m^3 - Rebar dosage per m^3 of concrete is therefore: (54.3 + 34.7 + 27.4) / 1.08 = 108 kg/m^3. The concrete is conservatively assumed to be class C32/40.
Construction	Tunnels	Permanent works	Polyethylene packers of thickness 3mm are assumed to be applied to the full contact width (400mm) on the trailing edge of every segment ring in the twin-bored tunnels and ground protection tunnel. The packers are assumed to form a loop on each ring, interrupted only by location of dowel joints connectors. The gaps are assumed to be 400mm by 400mm square areas around each dowel, and there are 28 dowels per ring. For the twin-bored tunnels, the circumference of the centreline of this loop is assumed to be the same as the average circumference of the tunnel ring = π x (OD + ID)/2 = π x (16.04m + 14.94m)/2 = 48.7m. Therefore the area of packers per tunnel ring is assumed to be (48.7m x 0.4m) - (0.4m x 0.4m x 28) = 15m^2. For the ground protection tunnel ring, the average circumference = π x (OD + ID)/2 = π x (5.8m + 5.3m)/2 = 17.4m. Therefore the area of packers per tunnel ring is assumed to be (17.4m x 0.4m) - (0.4m x 0.4m x 28) = 2.48m^2.

Product life cycle stage	Category	Activity phase	Assumption
			Assuming density of polyethylene as 0.94t/m3 estimated from average of HDPE and LDPE.
Construction	Tunnels	Permanent works	It is intended and most likely that no more than three intervention grout blocks will be created. Each one is assumed to be 5m along the drive, the depth of the RTD at its thickest below the Ramsar site, and a width stretching across both bored tunnels with an overhang each side of D/2. Bored tunnels are separated by 1D. Width of block is therefore 4D = 4 x 16.04 = 64.16m. From drawing 'HE540039-CJV-STU-SSP_ZZZZZZZZZZ-DR-CT-00005' Rev. P01, the thickest RTD under the Ramsar site is assumed to be about 10m.
Construction	Tunnels	Permanent works	For the purpose of these Main Crossing calculations, all engineered/graded granular fill is assumed to have the following average characteristics: - 'Recycled and secondary mixture' material category is assumed. There is no suitable granular fill on site so none will be site-won. - Granular fill self-compacts and will be pretty dense apart from interstitial void space - it is therefore assumed the material takes up 100% volume for all uses. Note: in reality any engineered/graded granular fill would be variable depending on location and needs to be specified in each case.
Construction	Tunnels	Permanent works	In the North Portal, it is assumed that stainless steel M32 dowels @1.7m vertical and horizontal centres, are used to connect the temporary-left-in-place diaphragm walls to the mass concrete infill between them and the permanent RC walls. This mass concrete infill is 29m high at its maximum, and 65m long, one on each side of the structure. Assuming a grid of dowels in two rectangles of area 29m x 65m, the estimated number of dowels is: (29m/1.7m) x (65m/1.7m) x 2 ≈ 1,305 no. dowels.
Construction	Tunnels	Permanent works	Wastage of any segmental linings and tunnel precast road deck structure (assuming 10%) and rebound wastage of sprayed concrete (assuming 50%) have been taken into account in these calculations.
Construction	Tunnels	Permanent works	South Portal grouted soil nails - number required

Product life cycle stage	Category	Activity phase	Assumption
			Based on draft document 'HE540039-CJV-STU-S06-TNT-TUN-0001' - Outline Soil Nail Design for South Portal, Revision 1.0. Soil nails of varying lengths and steel-wire mesh are assumed for rockfall mitigation of the chalk cutting around the South Portal in this preliminary assessment. All soil nails are assumed to be plain steel. Note that those in the tunnel soft-eye areas would be GFRP material instead of steel - however a product hasn't been assumed and the effect on the overall calculation is considered negligible. The document came up with three difference cases for the geometry and quantity of soil nail distribution: Case 1 - South Portal headwall: 398m total length of soil nails going up the temporary slope @1.5m horizontal centres (idealised). Conservatively assuming horizontal dimension of grid is approx. 90m, therefore total length of nails in grid is 398m x (90m/1.5m) = 23880m. Case 2 - South Portal side slopes: 432m total length of soil nails going up the temporary slope @ 1.5m horizontal centres (idealised). Conservatively assuming horizontal dimension of grid is approx. 2 no. 145m, therefore total length of nails in grid is 432m x 2 x (145m/1.5m) = 83520m. Case 3 - South approach ramp side slopes: 110m total length of soil nails going up the permanent slope @ 1.5m horizontal centres (idealised). Conservatively assuming horizontal dimension of grid is approx. 2 no. 100m, therefore total length of nails in grid is 110m x 2 x (100m/1.5m) = 14667m.
Construction	Tunnels	Permanent works	South Portal grouted soil nails - quantity calculation The mass of steel nails per metre length have been provided in the document 'Appendix C to draft HE540039-CJV-STU-S06-TNT-TUN-0001' - 5.85kg/m length for R38-500 (R38N) type. Therefore the total mass of steel used is: 5.85kg/m x (23,880m + 83,520m + 14,667m) /(1,000 kg per t) = 714 t. The document shows the grouting quantity used could reach as high as 42kg per metre length of R38 soil nail. It shows a low water: cement ratio grout mix would be 0.4 (40 litres water: 100kg cement). Therefore the total amount of grout is conservatively estimated to

Product life cycle stage	Category	Activity phase	Assumption
			be 42kg/m x (23,880m + 83,520m + 14,667m) /(1,000 kg per t) = 5,127 t. Approximately 100kg cement per 140kg grout, therefore there is an estimated 3,662 t of cement and 1,465 m^3 of water.
Construction	Tunnels	Permanent works	South Portal wire mesh (used with soil nails) The mesh assumed for this design is shown in the document 'Appendix C to draft HE540039-CJV-STU-S06-TNT-TUN-0001', which specifies 0.65 kg weight per m^2 of stainless-steel mesh roll used. The following horizontal dimensions of soil nail/mesh grids have been conservatively assumed for the three cases outlined above for soil nails: Case 1 (90m), Case 2 (2 no. 145m), Case 3 (2 no. 100m). The vertical dimensions of soil nail/mesh grids is estimated using the document 'Appendix B to draft HE540039-CJV-STU-S06-TNT-TUN-0001' as follows: Case 1: (24.8m + 7.9m)/sin(70 deg.) = 35m Case 2: (16.3m + 16.4m)/sin(60 deg.) = 38m Case 3: [(10m)/sin(45 deg.)] + [(10m)/sin(60 deg.)] = 26m Total mass of stainless-steel wire mesh used is estimated: 0.65kg/m2 x [(90m x 35m)+(2 x 145m x 38m)+(2 x 100m x 26m)] = 12591kg = 13 t.
Construction	Tunnels	Permanent works	Assumptions for anti-recirculation walls are: - C40/50 cast *in situ* reinforced concrete (like the other portals permanent walls) - 40m long - 1m thick - 5m to 16m variable height between the ends (trapezium-shaped wall elevation) - Therefore a concrete volume of: [0.5 x (5m + 16m) x 40m] x 1m = 420m^3 for each wall - Steel rebar dosage of 0.1t/m3 - therefore 42t for each wall.
Construction	Tunnels	Permanent works	Precast and infill concrete beam slabs assumed for roof slabs and top slabs of the portals. Conservatively assuming all slabs are 1m thick. Reinforcement has been uplifted by 10% to take account for shear links.
Construction	Tunnels	Permanent works	Concrete mix specification: Assumed all C40/50 *in situ* and C50/60 precast concretes contain cementitious material of which 65% is ground granulated blast furnace slag (GGBS) while 35% is Ordinary Portland Cement (OPC) /

Product life cycle stage	Category	Activity phase	Assumption
			CEM I. Embodied carbon factors are used which were calculated separately using ICE Cement, Mortar and Concrete Model with inputs based on assumptions of all the constituents and contributors of the two concretes. Admixture variation between different levels of GGBS in the C40/50 *in situ* mixes have not been considered.
Construction	Tunnels	Permanent works	The cement material constituents assumed for all slurries and grouts have not been specified but pure OPC (CEM I) is used here which is unlikely for all cases in reality. It is possible that they will contain varying amounts of GGBS depending on the purpose of the particular grouting. For example, cement replacement may not work for fine or microfine applications as the particle could be too large.
Construction	Tunnels	Permanent works	Soil mixing base grouting in alluvium below the North Ramp and Portal inside the diaphragm walls assumed between chainages Ch. 6+330 to Ch. 6+477 (North Portal) and chainages Ch. 6+477 to Ch. 6+625 (North Ramp), based on sketch 'HE540039-CJV-SSP-SZZ_ZZZZZZZZZZ-SK-CT-01070'. Thickness of plug varies: full penetration depth of the alluvium to be assumed until a minimum thickness of 8.5m is achieved (approx. at Ch. 6+477, i.e. at the North Portal), then 8.5m constant thickness from that point onwards. For the North Portal, the width between the diaphragm walls is variable, and assumed at an average of 38m. The depth of mixed soil fills the alluvium soil layer, increasing up to the maximum of 8.5m at Ch. 6+477, forming a trapezium area in the long section. Considering a 3% gradient at the top and a level interface with river terrace deposits at the bottom, the minimum alluvium thickness at Ch. 6+330 is estimated to be: 8.5m - [(6,477m – 6,330m)*0.03] = 4m. Trapezium long section area is therefore: 0.5 x (4m + 8.5m) x (6,477m – 6,330m) = 918.75m^2 Volume of mixed soil plug is therefore: 38m x 918.75m^2 = 34,913m^3
Construction	Tunnels	Permanent works	It is assumed that waterproofed joints are not used. It is instead assumed that waterproof membranes surround the permanent portal and

Product life cycle stage	Category	Activity phase	Assumption
			ramp structures which achieve the same purpose.
Construction	Tunnels	Permanent works	It is assumed that polypropylene fibres are not used for concrete fire design. Main lining segments have not been designed with polypropylene fibres. They are not required structurally as the cross passages have doors at each end so therefore extreme temperatures (which would require inclusion of polypropylene fibres) should not be experienced.
Construction	Tunnels	Permanent works	It is assumed that no slurry or grout admixtures except water/cement/bentonite, are used in places (other than TBM tailskin grouts). If such admixtures are used, they need to be specified for each case later in the development process.
Construction	Tunnels	Permanent works	The fact that one cross passage, located at low point sump, is larger than the others is assumed to be insignificant. All SCL cross passages have been assumed the same standard size instead of calculating one to be slightly larger than the rest. The contribution of this change is considered negligible to the cross-passage material quantities and the overall main crossing.
Construction	Tunnels	Permanent works	Some design changes have not been included: - Mass concrete infill under the south ramp slab becomes engineered granular fill. - Removal of all wall structures from the south ramp. - Change in north ramp chainage (extension to Ch. 6+892) is to take it over the culvert. - Change in southern interface between tunnels carriageway pavement and highways carriageway pavement, moved to the beginning of the South Portal sump (Ch. 2+221.5). However the total length of the south TBM base slab would still remain 130m.
Construction	Tunnels	Permanent works	It has been assumed that micro silica is not required in precast concrete C50/60 mix. If that changes, it will need to be included here.
Construction	Tunnels	Permanent works	Ground improvement component of the flood bunds north of the River Thames Prefabricated band drains are installed in the alluvium to accelerate consolidation/settlement, plus a working platform comprising class 6F material and geosynthetic, quantities based on sketch ‘HE540039-CJV-SSP-SZZ_ZZZZZZZZZZ-SK-CT-01076’.

Product life cycle stage	Category	Activity phase	Assumption
			From that sketch, the total area of working platform = 106,070m^2, and the total length of band drains = 1,589,075m. When separately allowing for the drainage pond area as well, an extra 35,000m^2 working platform area is assumed with band drains at 1m spacing - therefore 35,000 no. band drains. If the band drains are assumed to vary in length from 16m to 14m then an average of 15m is assumed, giving a total extra band drain length of 525,000m. Therefore, the total area of working platform is 106,070 + 35,000 = 141,070 m^2, and the total length of band drains = 1,589,075 + 525,000 = 2,114,075m.
Construction	Tunnels	Permanent works	Assumptions for working platforms under flood bunds - A geotextile separator at a total weight of 189 tonnes. - Two geogrids at a total weight of 90.3 tonnes. - 500mm of Class 6F material (sand). Total volume of sand = 141,070m2 x 0.5m = 70,535 m^3.
Construction	Tunnels	Permanent works	Band drains for flood bund ground improvement: Using a sample product, a band/wick drain could consist of a polypropylene/polyethylene drain core in a polyethylene-terephthalate drain filter. The general weight of the wick drain is provided as 22.5kg per 300m length of roll = 0.075kg/m. Generalising the combined materials, the total mass of plastic for band drains = 2,114,075m x 0.075kg/m = 158,556kg = 159 tonnes.
Construction	Tunnels	Permanent works	Rebar dosage in concrete for the RC precast bored tunnel segments: Assumptions and estimations taken from the draft document 'HE540039-CJV-STU-S06_TNN0000001-DR-CT-00041'. Assuming average segment ring width of 2m, and the circumference of the centreline of the loop is assumed to be the same as the average circumference of the tunnel ring = π x (OD + ID)/2 = π x (16.04m + 14.94m)/2 = 48.7m. Assuming ring is split into nine equal segments, the curved length of each segment is 48.7/9 = 5.4m.
Construction	Tunnels	Permanent works	Rebar dosage in concrete for the RC precast bored tunnel segments (at northern end of bored tunnel, between chainages Ch. 6+177 and Ch. 5+959):

Product life cycle stage	Category	Activity phase	Assumption
			Bars B16@200 = 2 layers x 10 no. bars x 5m length = 201mm2 cross sectional area x 5,000mm x 2 x 10 no. bars = 20,100,000mm^3 = 0.0201m^3 volume per segment. Links B12@200 = (5,400mm/200mm = 27) no. links x 4,534mm perimeter = 113mm^2 cross sectional area x 4,534mm x 27 no. links = 13,833,234 mm^3 = 0.014 m^3 volume per segment. Assuming nine segments, total rebar per ring = (0.0201 + 0.014) x 9 = 0.3069m^3 volume per ring. Material density of steel is 7,850kg/m^3, therefore total weight of rebar in segment ring is 7,850 x 0.3069 = 2,410kg. 20% uplift for wastage and laps = 2,410 x 1.2 = 2,892kg. Volume of an average segment ring is (((16.04m)2 - (14.94m)2) x π/4) x 2m = 54m^3. Therefore, the rebar dosage of segments at northern end of bored tunnel is 2,892kg / 54m^3 = 54 kg/m^3. Assuming a 30kg/m^3 allowance (from Tunnels team) for bursting reinforcement = 54 + 30 = 84 kg/m^3 ≈ 90 kg/m^3 = 0.09 t/m^3.
Construction	Tunnels	Permanent works	Rebar dosage in concrete for the RC precast bored tunnel segments (at opening sets locations): Bars B25@125 = 2 layers x 10 no. bars x 5m length = 491mm2 cross sectional area x 5,000mm x 2 x 10 no. bars = 49,100,000mm^3 = 0.0491m^3 volume per segment. Links B16@125 = (5,400mm/200mm = 27) no. links x 4,534mm perimeter = 201mm^2 cross sectional area x 4,534mm x 27 no. links = 24,606,018mm^3 = 0.0246m^3 volume per segment. Assuming nine segments, total rebar per ring = (0.0491 + 0.0246) x 9 = 0.6633m^3 volume per ring. Material density of steel is 7,850kg/m^3, therefore total weight of rebar in segment ring is 7,850 x 0.6633 = 5,207kg. 20% uplift for wastage and laps = 5,207 x 1.2 = 6,248kg. Volume of an average segment ring is (((16.04m)2 - (14.94m)2) x π/4) x 2m = 54m^3. Therefore, the rebar dosage of segments at northern end of bored tunnel is 6,248kg / 54m^3 = 116kg/m^3. Assuming a 30kg/m^3 allowance (from Tunnels team) for bursting reinforcement = 116 + 30 = 146kg/m^3 ≈ 150 kg/m^3 = 0.15 t/m^3.
Construction	Tunnels	Permanent works	A grouting shaft for the railway settlement mitigation has not been included because the

Product life cycle stage	Category	Activity phase	Assumption
			ground protection tunnel reception shaft is already included. The grouting shaft would only be required if the ground protection tunnel was not built.
Construction	Tunnels	Permanent works	In the launch shaft of the Ground Protection Tunnel, a tunnel eye structure (collar) will need to be designed and this has not been included in this assessment.
Construction	Tunnels	Permanent works	No uplift applied to data (unlike Application Document 6.1, Chapter 11: Material Assets and Waste) chapter which applies a 5% uplift.
Construction	Tunnels	Temporary works	Spoil storage foundations assumed to be reinforced concrete slab, 500mm concrete, two layers of mesh.
Construction	Tunnels	Temporary works	Slurry Treatment Plant foundations assumed to be CFA piles to the Chalk on a 2x2 grid (one every $4m^2$).
Construction	Tunnels	Temporary works	Batching plant foundations assumed to be 300mm reinforced slab with piles under silos down to the chalk.
Construction	Tunnels	Temporary works	Water treatment plant foundations assumed to be 200mm thick slab.
Construction	Tunnels	Temporary works	Engineered Working Platforms for piling, dewalling, Jetgrouting, deep soil mixing assumed to be concrete, 1.5m of 6F2 or similar and two geogrid layers.
Construction	Tunnels	Temporary works	Segment factory foundations assumed to be Storage: 300mm CFA piles to the Chalk on a 2x2 grid (1 every $4m^2$) + slab foundation. Factory Foundations: 500mm thick with two layers of reinforcement.
Construction	Tunnels	Temporary works	Culvert factory foundations assumed to be Storage: 300mm CFA piles to the Chalk on a 2x2 grid (one every $4m^2$) + slab foundation. Factory Foundations: 500mm thick with two layers of reinforcement.
Construction	Tunnels	Temporary works	Welfare/offices/canteen foundations assumed to be 200mm slab with one layer of steel mesh + crushed stone layer Possibly mini piles depending on ground conditions 250mm thick layer of crushed stone assumed
Construction	Tunnels	Temporary works	Accommodation foundations assumed to be 200mm slab with one layer of steel mesh + crushed stone layer

Product life cycle stage	Category	Activity phase	Assumption
			Possibly mini piles depending on ground conditions
Construction	Tunnels	Temporary works	TBM and crane mat assumed to be CFA piles to the Chalk on a 3x3 grid (one every 9m^2) + slab foundation.
Construction	Tunnels	Temporary works	Temporary substation base assumed to be Piles in locations of heavy switch gear, rest of it 200mm slab with steel mesh.
Construction	Tunnels	Temporary works	Car park assumed to be tarmac and base layer.
Construction	Tunnels	Temporary works	Access road assumed to be 1.7m thick of crushed stone, with Tarmac top
Construction	Tunnels	Temporary works	Plant yard assumed to be 500mm slab with two layers of mesh.
Construction	Tunnels	Temporary works	General laydown area assumed to be 1m thick stone layer with 100mm slab and mesh.
Construction	Tunnels	Temporary works	Joiners/Electricians/Fitters Workshop assumed to be 1m thick stone layer with 100mm slab and mesh.
Construction	Tunnels	Temporary works	Additional portal accommodation assumed to be 200mm slab with 1no layer of steel mesh + crushed stone layer. Possibly mini piles depending on ground conditions (as per the main accommodation but only 25% of the size).
Construction	Tunnels	Temporary works	Additional car park assumed to be tarmac and base layer (as per the main car park but only 25% of the size).
Construction	Tunnels	Temporary works	Additional laydown area assumed to be 1m thick stone layer with 100mm slab and mesh (as per general laydown area but only 25% of the size).
Construction	Tunnels	Temporary works	Tarmac and Geotextiles are not included in the carbon assessment. Although they have large carbon factors, their sum quantity is insignificant and hence has been neglected from the carbon assessment.
Construction	Tunnels	Temporary works	Assumed 32,000m^2 of soil for soil mixing/stabilisation on top of bored tunnels for reception south of Ramsar with assumed depth of 3m.
Construction	Tunnels	Temporary works	Assumed South Portal temporary office and the segment factory will be modular and will be reused in next project so the embodied carbon

Product life cycle stage	Category	Activity phase	Assumption
			of them has not been included in this assessment.
Construction	Tunnels	Temporary works	Assumed 25% GGBS for C32/40 concrete
Construction	TBM	Other	Assumed length of pipes is twice the length of the tunnel plus 300m distance to STP.
Construction	TBM	Other	Length of water pipes (clean in and dirty out) and air pipes multiplied by 1.5 to take account of pipe length required for cross passages.
Construction	Enabling works	Enabling works	Where available, actual has been extrapolated up to cover assumed full length of programme.
Construction	Enabling works	Enabling works	Where concrete density data is not available, assumptions have been made based on concrete densities being used elsewhere on the Project.
Construction	Enabling works	Enabling works	All cabins assumed to be hired and returned for reuse.
Construction	Portal buildings	Permanent works	Embodied carbon assumed to be 925kgCO_2e/m^2, based on RICs method to calculate embodied carbon, using data for low rise offices.
Construction	Enabling works	Enabling works	Water mains assumed to consist of: * Granular bed end surround, 150mm each side, Type 2 back fill used in road, assume all in existing or new carriageway * Granular bed and surround * Type 2 backfill * 225mm Tarmac reinstatement With pipe length of 0.225m, width of 0.7m and depth of between 0 and 1.5m.
Construction	Enabling works	Enabling works	Telecommunications assumed to consist of: * x2 150 diameter ducts, 100 gap, assume within service trench, won't include tarmac on top * Backfill with cement bound sand * Imported backfill * 225mm Tarmac reinstatement With pipe length of 0.15m, width of 0.5m and depth of between 0 and 1m.
Construction	Enabling works	Enabling works	Electricity cables assumed to consist of: * Backfill with sand and imported backfill, tarmac used for in road work * Backfill with cement bound sand * Imported backfill

Product life cycle stage	Category	Activity phase	Assumption
			* 225mm Tarmac reinstatement With pipe length of 0.2m, width of 0.7m and depth of between 0 and 1.2m.
Construction	Enabling works	Enabling works	Gas mains assumed to consist of: * Backfill with sand and imported backfill, tarmac used for in road work * Backfill with cement bound sand * Imported backfill * 225mm Tarmac reinstatement With pipe length of 0.2m, width of 0.7m and depth of between 0 and 1.5m.
Construction	Enabling works	Enabling works	Assumed all utility trench fill is imported material
Construction	Enabling works	Enabling works	Assumed each utility has its own trench
Construction	Enabling works	Enabling works	Quantities from Area C's diverted utility connections have been extrapolated to cover for Areas A, B and D.
Construction	Enabling works	Enabling works	Quantities from Area C's new utility connections have been extrapolated to cover for Areas A, B and D.
Construction	Enabling works	Enabling works	The quantity of granular sub-base material for access roads and compounds is assumed to covered in the Main Works and the enabling works only covers the top surface of the access road.
Construction	Enabling works	Enabling works	The quantity of tarmac surfacing material is assumed to be 225mm deep
Construction	Enabling works	Enabling works	For new connection and utility diversion tarmac import, a maximum width of 0.7m and a maximum depth of 0.225m has been assumed, with length being in line with utility length.
Construction	Enabling works	Enabling works	For new connection and utility diversion tarmac import, only 50% of the surface is assumed to require tarmac.
Construction	Enabling works	Enabling works	All existing underground assets are assumed to remain *in situ.*
Construction	Soil & fill import	Soil & fill import	Data comes from Application Document 6.1, Chapter 11: Material Assets and Waste and uses the same assumptions.
Construction	Soil & fill import	Soil & fill import	Assumed only material required to store the earthworks is a reuseable protective sheet so no embodied carbon emissions.

Product life cycle stage	Category	Activity phase	Assumption

Construction	Construction phase traffic	Construction phase traffic	Construction phase traffic calculated from Department for Transport (2019) TAG greenhouse gas emissions workbook, accessed October 2020.
			The construction traffic model provides an extensive quantitative assessment of the impact of construction works on the regional road network and incorporates:
			• Estimated HGV movements associated with the construction of the Project
			• Temporary traffic management measures associated with:
			    • the modifications of the M25 and A2
			    • the construction of the new junctions with the A122 road
			    • the construction of new structures over existing highways
			    • the modification of existing side roads

Construction	Construction phase traffic	Construction phase traffic	Construction phase traffic includes transport of workers but this cannot be split out.
Construction	Construction waste	Construction waste	Waste data taken from Application Document 6.1, Chapter 11: Material Assets and Waste and uses the same assumptions.
Construction	Construction waste	Construction waste	Onsite composting emissions factor has been applied to vegetation reused on site to account for any composting that may occur naturally.
Construction	Construction	Earthworks	The volume of earthworks removed for the installation of the piles has not been included.
Construction	Electricity	Compounds	Twenty working days per month assumed for all compounds except compound five.
Construction	Electricity	Compounds	Eight working hours per day assumed for all compounds except compound five.
Construction	Electricity	Compounds	Average demand as % of peak assumed to be 50% for all compounds except compound three.
Construction	Electricity	Compounds	Power factor assumed to be 0.8 based on experience on similar infrastructure projects. This is a conservative assumption as increasing the power factor to 1 would decrease emissions.
Construction	Electricity	Compounds	Calculations included grid decarbonisation using the future emission factors modelled by BEIS (Data from BEIS Table 1: Electricity emissions factors to 2100 (in $kgCO_2e/kWh$), last updated March 2019).

Product life cycle stage	Category	Activity phase	Assumption
Construction	Electricity	Enabling works	Where available, actual data has been extrapolated up to cover assumed full length of programme.
Construction	Plant fuel use	Compounds	Assumptions made on percentage of time that equipment is used and fuel usage rates and use of hybrid equipment.
Construction	Plant fuel use	Compounds	Eight-hour daily run-time assumed for vast majority of plant at compounds based on a ten-hour working day where it was assumed that an hour will be used by the operator to prepare themselves for a working day and another hour at the end of the day for closure.
Construction	Plant fuel use	Compounds	Assumptions made on the proportion of specific plant types that could be hybrid, based on experience on another major infrastructure project. 15% fuel saving assumed for hybrid plant.
Construction	Pre construction	All	Aside from enabling works, no other pre-construction works have been included.
Construction	Water	Compounds	Assumptions made on durations of processes, e.g. TBM duration amended to reflect duration assumed in electrical demand data.
Construction	Water	Compounds	Potable water is assumed to come from the mains for every compound. There are no plans to deliver water to site.
Construction	Water	Compounds	Sewage is assumed to be discharged to the local sewer. Wastewater from the tunnel boring machine, slurry treatment plant and dewatering at the North Portal is assumed to be treated onsite and then discharged into local watercourses. The carbon associated with the water treatment has been included in the carbon model, so a zero-emission factor has been applied.
Construction	Water	Enabling works	Where available, actual data has been extrapolated up to cover assumed full length of programme.
Construction	Plant fuel use	Enabling works	Assumptions made on diesel fuel use for enabling works utilities, archaeological trial trenches and utility trial trenches. Where available, actual data has been extrapolated up to cover assumed full length of programme.
Construction	Land use change	Land use change	Assumptions made to categorise land use change into those categories used by the National Atmospheric Emissions Inventory.

Product life cycle stage	Category	Activity phase	Assumption
Operation	Electricity	Operation	Calculations included grid decarbonisation using the future emission factors modelled by BEIS (Data from BEIS Table 1: Electricity emissions factors to 2100 (kgCO2e/kWh), last updated March 2019).
Operation	Fuel use	Operation	Operational fuel use covered under operational traffic emissions.
Operation	Maintenance, repair & replacement	Operation	For pavement, assumed surface course and tack coat replaced every ten years. Same assumptions used for pavement on highways and in tunnel.
Operation	Maintenance, repair & replacement	Operation	For pavement, assumed sub-base, base, binder and tack coat replaced every thirty years.
Operation	Maintenance, repair & replacement	Operation	For kerbs and footways, assumed worst case 20-year renewal as not possible to split quantities data between kerb and footway.
Operation	Maintenance, repair & replacement	Operation	Assumed renewal frequency for road studs and road marker posts is the same as for traffics signs and road marks.
Operation	Maintenance, repair & replacement	Operation	Data on renewal rates for waterproofing, elastomeric bearings and joints and gaskets taken from other major infrastructure projects where no project-specific data available.
Operation	Maintenance, repair & replacement	Operation	Portal buildings assumed to be replaced after 30 years.
Operation	Maintenance, repair & replacement	Operation	Based on maintenance assumptions used in similar projects. These assumptions include operational energy use and maintenance works so actual emissions should be lower as operational energy is already included in the carbon model. Data from A465 has been excluded as an outlier. Data used was: * M4CaN: Maintenance estimated at 0.07% of operational traffic emissions * A14: Maintenance estimated at 0.05% of operational traffic emissions
Operation	Traffic	Operation	Assumptions are detailed in Combined Modelling and Appraisal Report which presents the estimates of the GHG emissions arising from operational traffic (Application Document 7.7).

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