A12 Chelmsford to A120 widening scheme TR010060

6.3 ENVIRONMENTAL STATEMENT

APPENDIX 15.1 GREENHOUSE GAS EMISSSIONS METHODLOGY

APFP Regulation 5(2)(a)

Planning Act 2008

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A12 Chelmsford to A120 widening scheme

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ENVIRONMENTAL STATEMENT
APPENDIX 15.1 GREENHOUSE GAS EMISSSIONS METHODLOGY

Regulation Reference	Regulation 5(2)(a)
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1 Introduction

1.1.1 This appendix outlines the methodology, inputs and results of the assessment of greenhouse gas (GHG) emissions for the proposed scheme. A summary of these findings is provided in Chapter 15: Climate, of the Environmental Statement [TR010060/APP/6.1].

1.1.2 This assessment has been undertaken in accordance with the Design Manual for Roads and Bridges (DMRB) LA 114 Climate Version 0.0.1 (Highways England, 2021), hereafter referred to as 'DMRB LA 114'.

1.1.3 The GHG assessment included the estimation of GHG emissions associated with the following activities, each of which is discussed in detail within the subsequent sections of this appendix:

- construction and operational maintenance
- operational energy consumption
- operational road users
- land use change and forestry

1.1.4 GHGs include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), nitrogen trifluoride (NF_3) and sulphur hexafluoride (SF_6), each with differing global warming potentials. In this assessment, the term 'GHG emissions' describes the amount of carbon dioxide equivalent (CO_2e) released into the atmosphere. CO_2e is the amount of carbon dioxide emission that would produce an equivalent global warming effect to an amount of other greenhouse gas emission. It is a standardised metric for measuring carbon footprints.

2 Construction and operational maintenance

2.1 Methodology

2.1.1 This assessment applied the National Highways Carbon Tool v2.4 (National Highways, 2021a) to estimate construction and operational maintenance emissions. National Highways has developed this tool to estimate GHG emissions associated with operational, construction and maintenance activities undertaken across the strategic road network.

2.1.2 It is primarily designed for use during the construction process to calculate actual GHG emissions associated with construction activities (e.g. site energy/utilities consumption, plant machinery energy consumption, employee transport); embodied emissions (i.e. the carbon embodied in the extraction and processing of the raw materials used for construction); emissions associated with the transport of materials to the construction site; and emissions from construction waste treatment and transport. The tool can also, however, be used throughout the design process, from preliminary through to detailed design stages, to understand and compare the likely implications of the design of proposed highway schemes on GHG emissions. It can also be used to compare the effectiveness of potential mitigation options for reducing GHG emissions (e.g. through the use of different materials).

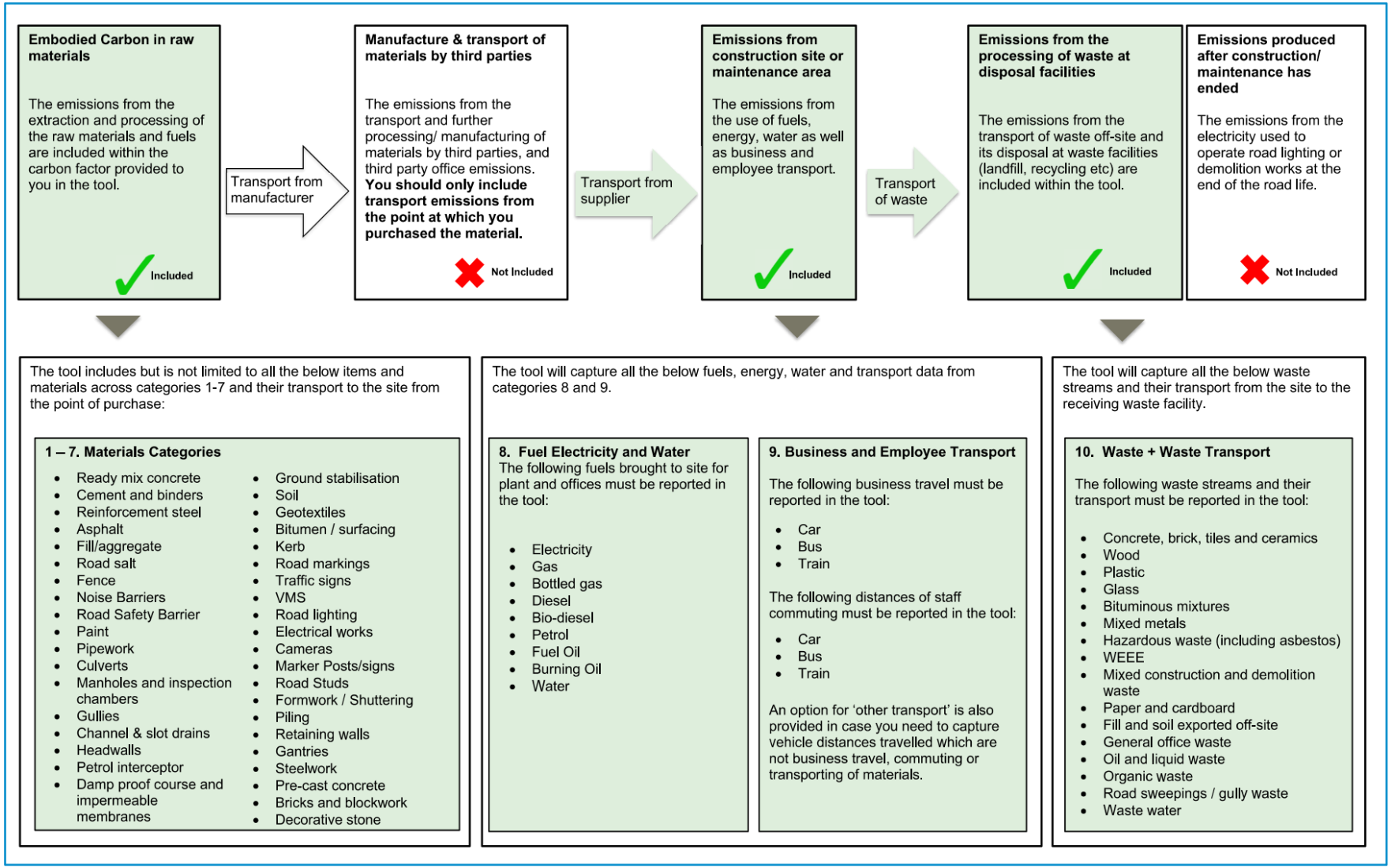
2.1.3 The tool can also be used to estimate GHG emissions associated with routine operational maintenance activities.

2.1.4 For this assessment, the relevant construction and material quantities were compiled based on input from the highways and design teams for the proposed scheme. The following sections outline the assessment boundary, the information and assumptions applied, and the resulting emissions for construction and operational maintenance emissions.

2.2 Project boundary for the assessment

2.2.1 As shown on Plate 2.1, the National Highways Carbon Tool (National Highways, 2021a) recommends a project boundary that includes embodied carbon in raw materials, transport from the supplier, emissions from construction site/maintenance areas and emissions from the transport to and processing of waste at disposal facilities. The tool specifically excludes the manufacture and transport of materials by third parties to suppliers, and emissions associated with decommissioning of the proposed scheme (in line with DMRB LA 114).

Plate 2.1 Scope of carbon emissions included in the National Highways Carbon Tool



2.2.2 The assessment adopted the National Highways Carbon Tool for the calculation of GHG emissions associated with the emission sources set out in Plate 2.1, which aligns to the life cycle stages and sub-stages defined in Table 3.11.1 of DMRB LA 114:

- Construction phase emissions – including the product stage and construction process stage but excluding emissions associated with land-use change and forestry, which were assessed separately (see Section 5 of this appendix).
- Operational phase ('use stage') – including operational maintenance (including repair, replacement and refurbishment), but excluding operational energy usage, use of the infrastructure by the end user (road user) and emissions associated with land use change and forestry, which were assessed separately (see Sections 3, 4 and 5 of this appendix, respectively).
- Opportunities for reduction – through the tool's ability to provide comparisons of multiple design options and perform sensitivity testing by adjusting quantities (e.g. to demonstrate the impact of reuse/'designing out' of assets) and material specifications (e.g. to demonstrate the impact of substitution of virgin raw materials with those from recovered sources).

2.3 Information used and assumptions

2.3.1 Entries into the tool were based on a Bill of Quantities (BoQ) for the proposed scheme, which was produced in October 2021. It is noted that the design will continue to be refined throughout the design process, which could result in changes in material quantities and associated GHG emissions to that presented herein. Furthermore, where information is incomplete or unknown at this stage, a number of assumptions have been made, which are detailed below.

2.3.2 It should also be noted that the initial step towards carbon management is to identify and map out the emissions sources that can be attributed to a project through its life cycle. Management and reduction of emissions can only occur after this. Whilst the aim of this assessment is to identify and account for as much project related carbon as possible, a proportionate approach has been taken, whereby some carbon sources have been prioritised over others. This is because many components will have a negligible impact on carbon emissions and offer limited opportunities for mitigation compared to the time, effort and cost involved in determining their carbon impact. Where potential sources of carbon emissions have been excluded from this assessment it is noted and justified below.

Embodied carbon in raw materials

2.3.3 The design information and related material quantities that were incorporated into the GHG assessment of construction phase emissions are summarised in Table 2.1 and Table 2.2 for temporary and permanent works, respectively. These material quantities were derived from the relevant BoQ associated with the proposed scheme.

2.3.4 The design information and material quantities used in the GHG assessment include:

- bulk materials
- information on earthworks quantities
- fencing, barriers and road restraint systems
- drainage pipework and associated items (e.g. manholes)
- road pavements and markings
- street furniture, including signs, lighting and road studs
- materials for structures, such as bridges and retaining walls

Table 2.1 Material quantities used in GHG assessment (temporary works)

Project element	Material - item	Material - type	Units	Quantity
Bulk materials	Ready mix concrete	General	m^3	203
		General - C32/40	m^3	713
		General - C40/50	m^3	236
	Reinforcement steel	Steel bar and rod	tonnes	125
	Asphalt	General Asphalt	tonnes	136,018
	Fill and aggregate	Site-won	tonnes	9,838
		Recycled and secondary mixture	tonnes	249,031
		Virgin land won resources	tonnes	140,911
		Expanded clay	tonnes	104,171
Earthworks	Site won soil/muck shift	General soil	tonnes	213,590
Fencing, barriers and road restraint systems	Fence	Timber rail fence (all types, includes posts)	metres	887
		Timber panels and posts	no.	658
		Steel/wire/chain fence (includes posts)	metres	35,219
Drainage	Plastic pipework (HDPE)	150mm diameter	metres	500
		900mm diameter	metres	306
		1800mm diameter	metres	38

Project element	Material - item	Material - type	Units	Quantity
Road pavements	Kerb	Pre-cast concrete 125x150mm	metres	9,935
Civil structures and retaining walls	Retaining walls	Steel sheet piles	tonnes	2,350
	Paint	General paint	litres	1,896
	Steelwork	General steel	tonnes	70

Table 2.2 Material quantities used in GHG assessment (permanent works)

Project element	Material - item	Material - type	Units	Quantity
Bulk materials	Ready mix concrete	General	m^3	183,232
		General - C8/10 (Gen 1, ST 2)	m^3	3,496
		General - C25/30	m^3	1,952
		General - C32/40	m^3	3,562
		General - C35/45	m^3	53
		General - C40/50	m^3	14,457
	Reinforcement steel	Steel bar and rod	tonnes	5,181
	Asphalt	General Asphalt	tonnes	331,237
	Fill and aggregate	Site-won	tonnes	4,408,930
		General mixture	tonnes	1,023
		Recycled and secondary mixture	tonnes	1,300,000
		Virgin mixture of land won and marine	tonnes	44,612
		Virgin land won resources	tonnes	1,400,434
Earthworks	Imported soil	General soil/top soil	tonnes	2,814
	Site won soil/ muck shift	General soil	tonnes	1,448,525
	Geotextiles	Polypropylene geotextile / matting	m^2	1,011,708

Project element	Material - item	Material - type	Units	Quantity
Fencing, barriers and road restraint systems	Fence	Fence timber (by volume)	m^3	6,455
		Timber rail fence (all types, includes posts)	metres	130,868
		Timber panels and posts	no.	863
		Steel/wire/chain fence (includes posts)	metres	104,426
	Noise barriers	Timber barrier 3m	metres	2,651
	Road Restraint System/ Safety Barrier	Steel RRS barrier single sided	metres	84,714
		Steel RRS barrier double sided	metres	2,270
		Pre-cast concrete step barrier	metres	23,934
Drainage	Plastic pipework (HDPE)	150mm diameter	metres	13,080
		225mm diameter	metres	34,310
		300mm diameter	metres	37,336
		450mm diameter	metres	21,587
		600mm diameter	metres	14,665
		900mm diameter	metres	3,013
	Plastic pipework (PVC)	150mm diameter	metres	1,752
	Precast concrete circular pipework	900mm diameter	metres	8
		1200mm diameter	metres	540
		1500mm diameter	metres	246
	Precast concrete manholes	1050mm diameter, up to 3m depth	no.	13
		1200mm diameter, up to 3m depth	no.	802
		1200mm diameter, 3m - 6m depth	no.	4
		1500mm diameter, up to 3m depth	no.	478
		1500mm diameter, 3m - 6m depth	no.	36

Project element	Material - item	Material - type	Units	Quantity
		1800mm diameter, up to 3m depth	no.	181
		1800mm diameter, 3m - 6m depth	no.	62
		2400mm diameter, up to 3m depth	no.	14
		2400mm diameter, 3m - 6m depth	no.	10
	Plastic inspection chambers	600mm diameter, up to 1.2m depth	no.	176
		600mm diameter, 1.2m - 3m depth	no.	117
	Gullies	Precast concrete gully pots	no.	858
	Channel and slot drains	Precast concrete channel (heavy duty)	metres	307,654
	Damp proof course and impermeable membrane	Polyethylene membrane	m^2	250,365
Road pavements	Bitumen / surface treatment	Straight run bitumen	tonnes	112
		High friction surfacing	tonnes	1
	Kerb	Pre-cast concrete 125x150mm	metres	12,722
		Pre-cast concrete 125x255mm	metres	98,987
		Pre-cast concrete 125x305mm	metres	928
	Road markings	Thermoplastic road marking	tonnes	242
Street furniture and electrical equipment	Traffic signs	Aluminium	m^2	6
	Road lighting and columns	LED light	no.	496
		Steel columns 10m	no.	319
	Cable	Armoured cable / Power cable	metres	23,576
		Miscellaneous cable	metres	108,839
	Cabinets	Any type	no.	230

Project element	Material - item	Material - type	Units	Quantity
	Cameras	Hard shoulder camera and steel pole	no.	68
	Road studs	Any type	no.	6,799
	Handrail	Galvanised steel	tonnes	202
Civil structures and retaining walls	Formwork / shuttering	Plywood	m^3	11,001
	Retaining walls	Steel sheet piles	tonnes	4,383
		Gabion wall (stone and wire mesh)	tonnes	48
	Gantries	9m 'Flagpole' MS4	no.	36
		14m ADS Tubular Cantilever	no.	4
		19m Sign/Signal Cantilever	no.	6
	Paint	General paint	litres	60,858
	Steelwork	General steel	tonnes	3,626
		Galvanised steel	tonnes	1
	Pre-cast concrete	General concrete	tonnes	39,502
	Bricks and blockwork	Concrete blocks (includes mortar)	no.	872,530
		Standard bricks (includes mortar)	no.	57,995

2.3.5 Where unit conversions were required prior to inputting values to the National Highways Carbon Tool, these were undertaken using material densities and conversion factors stated in the National Highways Carbon Tool or from supplier/equivalent product information.

Transport of raw materials

2.3.6 Specific details regarding distances associated with the transportation of raw materials to the construction site were not available at the time of writing. Transport distances of 50km and 300km for locally and nationally sourced materials, respectively, were therefore assumed based on default transport scenarios for materials provided within the Royal Institution of Chartered Surveyors (RICS) professional standards and guidance (RICS, 2017). It was also assumed that all materials would be transported an additional 12.5km following arrival on site (which is the maximum length from traffic entry points to working areas) and that all materials would be delivered by Heavy Goods Vehicle (HGV).

Fuel, electricity and water

2.3.7 Estimates of likely on-site fuel, electricity and water consumption during the construction phase of the proposed scheme were not available at the time of this assessment. Consumption was therefore estimated based on recorded fuel consumption for a similar project (the A14 Cambridge to Huntingdon scheme), adjusted to account for the relative difference in scale between the two projects (i.e. 37km (A14) compared to 24km (proposed scheme), so approximately a ratio of 2:3).

2.3.8 The data used are summarised in Table 2.3 and are considered to represent consumption during both temporary and permanent works associated with the proposed scheme.

Table 2.3 Fuel, energy and water consumption used in GHG assessment

Project element	Resource	Units	Quantity
Site offices	Electricity	kWh	2,070,507
	Diesel	litres	64,697
Plant	Gas oil (red diesel)	litres	18,605,339
Water used in construction	Mains	litres	195,280,289
	Abstracted	litres	399,360,000
	Transported (Tanker)	litres	499,200,000

Employee transport

2.3.9 Distances travelled by both site-based and office-based employees have been estimated based on the projected number of construction operatives and office based staff over the entire duration of the construction phase and the following assumptions:

- Office based staff would work four days per week in the office and one day per week from home
- 80% of employees would travel by car (20% of whom would car share)
- 20% of employees would travel by public transport
- Employees travelling by car would travel 25km in each direction
- Employees travelling by public transport would travel 100km in each direction
- Each site-based employee would travel an additional 12.5km within the site to and from their work locations
- When travelling on-site, employees would share a vehicle with four other people

2.3.10 The data used are summarised in Table 2.4 and are considered to represent distances travelled by employees during both temporary and permanent works associated with the proposed scheme.

Table 2.4 Employee transport distances used in GHG assessment

Project element	Mode	Units	Quantity
Employee commuting	Private vehicle (any type)	km	34,693,437
	Train	km	39,261,984

Waste treatment and transportation

2.3.11 The materials quantities and disposal methods used in the estimation of carbon emissions associated with waste treatment and transportation are presented in Table 2.5. These quantities have been derived using the methodology described in Chapter 11: Material assets and waste [TR010060/APP/6.1].

2.3.12 In the absence of specific information, the transportation distance for waste materials disposed of off-site has been assumed to be 50km.

Table 2.5 Information incorporated into the GHG assessment for waste treatment and transport

Material type	Disposal method	Quantity (t)		
		Temporary works	Permanent works	Operational maintenance
Mixed construction & demolition waste	Recycled	-	7,347.6	-
	Landfill	-	386.7	-
Plastic	Recycled	19.8	72.7	49.1
	Landfill	5.0	18.2	12.3
Concrete, brick, tiles and ceramics	Recycled	3,575.0	40,584.0	2,784.1
	Landfill	188.2	2,136.0	146.5
Wood/Timber	Recycled	38.4	667.8	425.0
	Landfill	4.3	74.2	47.2
Bituminous mixtures	Recycled	158,091.7	32,998.3	40,464.2
	Landfill	8,320.6	1,736.8	2,129.7
Mixed metals	Recycled	3,158.9	3,358.4	-
Waste from Electrical and Electronic Equipment (WEEE)	Recycled	-	0.3	-
	Landfill	-	0.1	-

Material type	Disposal method	Quantity (t)		
		Temporary works	Permanent works	Operational maintenance
Aggregate and soil exported off-site	Recycled	613,241.1	512,204.2	-
	Landfill	32,275.8	26,958.1	-
Hazardous waste	Landfill	-	41,461.6	-

Operational maintenance

2.3.13 The estimation of GHG emissions associated with operational maintenance activities during the life cycle of the proposed scheme relied on the materials quantities from the measured cost estimate utilised for the construction phase calculations (Table 2.1) and the assumed replacement frequencies for materials in accordance with their expected design life shown in Table 2.6.

2.3.14 These replacement frequencies apply assumptions regarding the likely maintenance programme for the proposed scheme. The frequencies are guided by experience from other highways projects.

Table 2.6 Assumed replacement frequencies used to inform estimates of operational maintenance GHG emissions

Type	Assumed replacement frequency (years)	Number of replacements over 60-year appraisal period
Carriageway surface course	10	5
Carriageway binder course	20	2
Carriageway base course	40	1
Footway surface course	20	2
Footway binder course	20	2
Carriageway and footway sub-base course	> 60	-
Kerbs and edgings	20	2
Road markings	5	11
Safety barriers	15	3
Structural steel	> 60	-
Timber fence	15	3
Steel fence	15	3
Concrete components	> 60	-
Signage	30	1

Type	Assumed replacement frequency (years)	Number of replacements over 60-year appraisal period
Lights	10	5
Lighting columns	50	1
Armoured cable	> 60	-
Road studs	5	11

2.4 Results

2.4.1 Estimated construction and operational GHG emissions associated with the proposed scheme are summarised in Table 2.7 by element/source and by material/source type in Table 2.8.

Table 2.7 Estimated construction and operational maintenance GHG emissions by element/source

Element / source	Estimated GHG emissions (tCO_2e)					
	Temporary works		Permanent works		Operational maintenance	
	Embodied carbon / direct emissions	Transport	Embodied carbon / direct emissions	Transport	Embodied carbon / direct emissions	Transport
Raw materials						
Ready mix concrete	377	34	53,487	6,045	-	-
Reinforcement steel	248	8	10,310	316	-	-
Asphalt	7,522	1,657	18,317	4,035	40,964	9,024
Fill, aggregate and sand	45,110	6,020	24,803	33,454	-	-
Imported soil	-	-	68	34	-	-
Site won soil/ muck shift	-	-	-	-	-	-
Geotextiles	-	-	2,431	12	-	-
Fence	381	10	2,450	337	7,349	1,010
Noise barriers	-	-	303	21	909	63

Element / source	Estimated GHG emissions (tCO_2e)					
	Temporary works		Permanent works		Operational maintenance	
	Embodied carbon / direct emissions	Transport	Embodied carbon / direct emissions	Transport	Embodied carbon / direct emissions	Transport
Road restraint system/ safety barrier	-	-	12,586	1,869	37,757	5,608
Plastic pipework (HDPE)	53	1	2,853	69	-	-
Plastic pipework (PVC)	-	-	18	0	-	-
Precast concrete circular pipework	-	-	175	73	-	-
Precast concrete manholes	-	-	1,661	462	-	-
Plastic inspection chambers	-	-	306	4	-	-
Gullies	-	-	75	24	-	-
Channel & slot drains	-	-	13,912	2,811	-	-
Damp proof course and impermeable membrane	-	-	604	14	-	-
Bitumen / surface treatment	-	-	29	1	-	-
Kerb	57	26	1,041	480	2,082	961
Road markings	-	-	1,380	3	15,185	32
Traffic signs	-	-	2	0	2	0
Road lighting and columns	-	-	206	4	365	5
Cable	-	-	118	4	-	-
Cabinets	-	-	127	3	-	-
Cameras	-	-	206	5	-	-
Road studs	-	-	1	0	12	0

Element / source	Estimated GHG emissions (tCO_2e)					
	Temporary works		Permanent works		Operational maintenance	
	Embodied carbon / direct emissions	Transport	Embodied carbon / direct emissions	Transport	Embodied carbon / direct emissions	Transport
Handrail	-	-	557	12	-	-
Formwork / shuttering	-	-	4,046	72	-	-
Retaining walls	6,486	143	12,101	270	-	-
Gantries	-	-	1,278	28	-	-
Paint	9	0	275	1	-	-
Steelwork	108	1	5,623	44	-	-
Pre-cast concrete	-	-	4,814	481	-	-
Bricks and blockwork	-	-	1,536	180	-	-
Fuel, electricity and water						
Site offices, site vehicles and plant energy	-	-	63,734	227	-	-
Water	-	-	103	1,216	-	-
Employee transport						
Employee commuting	-	-	5,784	-	-	-
Waste treatment						
Mixed construction & demolition waste	-	-	81	75	-	-
Plastic	0	0	2	1	1	1
Concrete, brick, tiles and ceramics	4	37	43	416	3	29
Wood/timber	4	0	76	7	48	5
Bituminous mixtures	167	1,622	35	339	43	415

Element / source	Estimated GHG emissions (tCO_2e)					
	Temporary works		Permanent works		Operational maintenance	
	Embodied carbon / direct emissions	Transport	Embodied carbon / direct emissions	Transport	Embodied carbon / direct emissions	Transport
Mixed metals	67	31	72	33	4	2
WEEE	-	-	0	0	-	-
Aggregate and soil exported off-site	646	6,291	540	5,255	-	-
Hazardous waste	-	-	3,691	404	-	-

Table 2.8 Estimated construction and operational maintenance GHG emissions by material/source type

Material / source type	Estimated GHG emissions (tCO_2e)					
	Temporary works		Permanent works		Operational maintenance	
	Embodied carbon / direct emissions	Transport	Embodied carbon / direct emissions	Transport	Embodied carbon / direct emissions	Transport
Concrete	433	60	82,316	12,126	23,536	6,209
Steel	7,214	160	36,900	823	19,772	436
Asphalt and Bitumen	7,522	1,657	18,339	4,037	40,964	9,024
Fill, aggregate and sand	45,110	6,020	24,875	33,491	-	-
Plastic	53	1	7,601	103	15,198	33
Timber	10	2	5,697	406	4,955	1,000
Aluminium	-	-	42	0	201	2
Electrical Equipment	-	-	118	4	-	-
Paint	9	<1	275	1	-	-

Material / source type	Estimated GHG emissions (tCO_2e)					
	Temporary works		Permanent works		Operational maintenance	
	Embodied carbon / direct emissions	Transport	Embodied carbon / direct emissions	Transport	Embodied carbon / direct emissions	Transport
Brick and Blockwork	-	-	1,536	180	-	-
Energy and Fuel	-	-	63,838	1,444	32,537	736
Employee transport	-	-	5,784	-	2,948	-
Waste	889	7,981	4,538	6,530	99	451

3 Operational energy consumption

3.1 Methodology

3.1.1 This assessment used estimated energy consumption figures and projected electricity emissions factors from the Green Book supplementary guidance for valuation of energy use and greenhouse gas emissions (Department for Business, Energy and Industrial Strategy (BEIS), 2021a) in order to estimate GHG emissions associated with operational phase electricity usage.

3.1.2 Year specific, grid average, commercial/public sector consumption-based emission factors were used. Over the 60-year appraisal period (2027 to 2086), the emission factors range from 0.075 kgCO_2e/kWh in the Opening Year to 0.007 kgCO_2e/kWh in 2050, reflecting increased decarbonisation of the national grid over time. The emission factors used were held constant from 2050 until 2086, as this is the latest year for which emission factors are currently available.

3.2 Information used and assumptions

3.2.1 The numbers of LED lights of different wattage within the proposed scheme were provided, together expected hours of operation at different brightness levels based on the proposed dimming regime. These data were used to estimate annual electricity consumption, as shown in Table 3.1.

Table 3.1 Information used to calculate operational energy consumption

Wattage	No.	Brightness level			Days per year	kWh per year
		20:00 - 22:00	22:00 - 05:00	05:00 - 06:00		
131	220	70%	50%	70%	365	62,590
167	61	70%	50%	70%	365	22,124
227	11	70%	50%	70%	365	5,423
12	70	70%	50%	70%	365	1,824
25	45	70%	50%	70%	365	2,443
81	82	70%	50%	70%	365	14,425
144	4	70%	50%	70%	365	1,251
					Total	110,079

3.3 Results

3.3.1 The GHG emissions associated with operational phase electricity consumption are estimated to be 93.6 tCO_2e over the 60-year appraisal period.

3.4 Opportunities for reduction

3.4.1 The proposed scheme would use LED lights, which have a higher energy efficiency than conventional streetlights and are dimmable, therefore minimising GHG emissions. The GHG emissions associated with operational phase energy consumption would be further reduced by using a Central Management System (CMS) to actively control lighting levels.

3.4.2 The installation and use of renewable energy sources, such as solar panels linked to lighting or signage, could be considered to further reduce operational electricity emissions. National Highways' Net Zero Plan (National Highways, 2021b) commits to developing a plan to deploy solar panels on the Strategic Road Network (SRN), implementing the first pilot site by 2024. National Highways aims to generate 10% of its energy from renewable sources on or near to their sites by 2030, subject to suitable site availability.

4 Operational road users

4.1 Methodology

4.1.1 The DMRB LA 114 Climate guidance states that "*GHG emissions calculation for the project life cycle shall be completed using an industry recognised carbon calculation tool(s) in accordance with the Overseeing Organisation requirements.*" No further guidance is, however, provided on which tools should be used to estimate road user GHG emissions.

4.1.2 For the purposes of this assessment, the latest version of Defra's Emissions Factors Toolkit v11.0 (Defra, 2021) was used to estimate road user GHG emissions.

4.2 Information used and assumptions

4.2.1 The study area for the appraisal of road user GHG emissions comprises the area of the traffic model that is deemed by the competent expert for traffic to be reliable for environmental assessment (as shown on Figure 15.1 [TR010060/APP/6.2]). The study area includes separate traffic networks for the Opening Year (2027) and Design Year (2042) Do-Minimum and Do-Something scenarios.

4.2.2 For each road link within the reliable area of the traffic model, the following data were applied:

- total Annual Average Daily Traffic (AADT) flow
- annual average daily percentage of Heavy Duty Vehicles (HDVs)
- annual average daily vehicle speed

4.2.3 Further information on the traffic modelling is provided in the Transport Assessment [TR010060/APP/7.2].

4.2.4 Operational road user emissions were estimated over a 60-year appraisal period and over the relevant Carbon Budget periods. In order to do this, road user GHG emissions were calculated for the Opening Year (2027) and the Design Year (2042). Emissions between the Opening Year and the Design Year were linearly interpolated, whilst emissions beyond the Design Year to the end of the 60-year appraisal period were assumed to remain constant.

4.3 Results

4.3.1 GHG emissions for the Opening Year and the Design Year under the Do-Minimum and Do-Something scenarios, and the net emissions for the 60-year appraisal and carbon budget periods, are shown in Table 4.1.

Table 4.1 Estimated operational road user GHG emissions (tCO_2e)

Year/period	Estimated road user GHG emissions (tCO_2e)		
	Baseline / Do-Minimum	Do-Something	Net change
2019	734,067	-	-
2027	719,366	748,048	+28,682
2042	536,630	561,747	+25,117
60-year appraisal period (2027 – 2086)	33,659,663	35,195,222	+1,535,559
4th Carbon Budget period (2023 – 2027)	719,366 (2027 only)	748,048 (2027 only)	+28,682 (2027 only)
5th Carbon Budget period (2028 – 2032)	3,414,094	3,553,939	+139,846
6th Carbon Budget period (2033 – 2037)	3,109,533	3,243,437	+133,904

4.3.2 The proposed scheme is estimated to result in an overall increase in road user GHG emissions within the study area, with increases in GHG emissions of 28,682 tCO_2e and 25,117 tCO_2e in the Opening Year (2027) and Design Year (2042), respectively. Relative to the relevant Do-Minimum scenario, the increase in emissions with the proposed scheme is equivalent to a 4.0% and 4.7% increase in road user GHG emissions in the study area in the Opening Year and Design Year, respectively. These increases in emissions are primarily associated with an increase in vehicle kilometres travelled within the study area between the Do-Minimum and Do-Something scenarios.

4.3.3 Between the Opening and the Design Years, operational road user GHG emissions for the Do-Minimum and Do-Something scenarios within the study area considered are estimated to decrease by approximately 25%, despite the total vehicle kilometres travelled increasing by 13% and 14% respectively. This illustrates the overriding influence government policy (e.g. the future ban on the sales of petrol and diesel cars and light duty vehicles) and the associated increased use of low and zero-emission vehicles and related technological advances is expected to have on future year road user GHG emissions.

4.3.4 It should be noted that this assessment is considered likely to be worst case as the estimated operational road user GHG emissions presented in this appendix (derived using Defra's EFT v11) do not fully account for the most recent projections for the uptake of electric cars and vans described in the latest version of the Department for Transport's (DfT's) TAG data book (DfT, 2021a). Nor do they take account of the projected reductions in GHG emissions depicted in Figure 2 of the Transport Decarbonisation Plan (TDP) (DfT, 2021b, page 45). The impacts of the TDP are expected to lead to a substantive decrease in GHG emissions from all forms of road transport between now and 2050. As the TDP has only recently been published, vehicle composition

projections and emission factors have not yet been updated to reflect the emerging policy position described by the TDP.

4.3.5 Over the 60-year appraisal period, the proposed scheme is estimated to result in an increase in GHG emissions of 1,535,559 tCO_2e. Within the 4th, 5th and 6th carbon budget reporting periods, the proposed scheme is estimated to result in an increase in GHG emissions of 28,682 tCO_2e (2027 only), 139,846 tCO_2e and 133,904 tCO_2e, respectively. The decreasing trend between the 5th and 6th carbon budget period indicates that the magnitude of the impact of the proposed scheme on road user GHG emissions will reduce over time as more and more electric vehicles enter the UK fleet.

5 Land use change and forestry

5.1 Methodology

Construction phase – land use change

5.1.1 The GHG emissions associated with land-use change during the construction phase (i.e. GHG emissions mobilised from the loss of vegetation and soil during construction) were calculated based on carbon stock average estimates by broad habitat provided in the Natural England NERR043 report (Natural England, 2012). The area affected by construction activities (which was conservatively assumed to be the Order Limits for the proposed scheme) was divided into different land use types using the Ordnance Survey MasterMap dataset (Ordnance Survey, 2021). The average carbon stocks in the soil and vegetation based on the current land use, in tonnes of carbon per hectare, were factored by 0.25 and 1.0, respectively, to reflect an assumed 25% loss/emission of carbon from disturbed soil and 100% loss/emission of carbon from vegetation. The factored carbon stocks were then multiplied by the area of each land use type that will potentially be disturbed during construction and then by 3.6667 (the ratio of the molar mass of CO_2 to the atomic mass of carbon) to estimate total CO_2e emissions.

Operational phase – land use change

5.1.2 The GHG emissions associated with operational phase land use change (i.e. the change in GHG emissions that would occur on an ongoing basis due to changing the existing land use to highways infrastructure) applied net changes in equilibrium soil carbon density from the Department for Business, Energy and Industrial Strategy UK Annual National Inventory Report (BEIS, 2021b). The area of permanent land take associated with the Proposed Scheme was divided into different land use types using the Ordnance Survey MasterMap dataset. The area occupied by each initial land use type was then multiplied by the reduction in equilibrium soil carbon density for each land use, assuming a change in land use to ‘settlements’, and then by 3.6667 to estimate total CO_2e emissions.

Construction and operational phase – forestry

5.1.3 Changes in carbon sequestration (i.e. the removal of CO_2 from the atmosphere by vegetation) as a result of changes in forestry associated with the proposed scheme were estimated using the Woodland Carbon Code Carbon Calculation Spreadsheet (Woodland Carbon Code, 2021). The tool allows the amount of carbon sequestered by woodland (in tonnes CO_2e) to be estimated over a 100 year period, accounting for differences in the rate of carbon sequestration over time as tree species mature. Carbon sequestration was estimated for the Do-Minimum and Do-Something scenarios respectively, based on the area of different tree species present, tree spacing and yield class. The outputs of these calculations were combined to estimate the net change in carbon sequestration as a result of the proposed scheme.

5.1.4 The areas of each tree species used in these calculations are shown in Table 5.1. It should be noted that these data should be considered indicative as the exact quantities of different types of tree species which are currently present, and which will be planted in future, are not known. Assumptions have therefore been made about the existing mix of tree species on-site (e.g. based on available survey data) and those which will be planted within the proposed scheme extents (i.e. by assuming an equal distribution of existing species).

Table 5.1 Areas of woodland used in Woodland Carbon Code Calculations

Tree species	Area of woodland (ha)		
	Do-Minimum	Do-Something (retained)	Do-Something (new planting)
Alder	8.9	2.4	14.7
Willow	8.9	2.4	14.7
Ash	7.3	0.9	14.7
Hawthorn	5.4	0.7	14.7
Hazel	5.4	0.7	14.7
Holly	5.4	0.7	14.7
Elm	6.1	0.9	14.7
Hornbeam	5.4	0.7	14.7
Pedunculate oak	8.0	1.0	14.7
Scots pine	1.7	0.1	-
Cricket-bat willow	14.1	3.0	-
Total	**76.7**	**13.6**	**132.1**

5.2 Information used and assumptions

Land use change

5.2.1 The land use types for the construction and operational phase assessments were derived from the Ordnance Survey MasterMap topographic dataset. Table 5.2 shows the land use types applied in the construction and operational stage calculations. Figure 15.2 and Figure 15.3 [TR010060/APP/6.2] show the study area and spatial coverage of the land use types used for construction and operation respectively.

Table 5.2 Land use categories applied in the GHG assessment

Ordnance Survey MasterMap topographic group and term	Construction stage land use category	Operation stage land use category
Building / Building, Road or Track	Urban	Settlement
General Surface	Urban	Settlement
General Surface - Agricultural Land	Arable and Horticulture	Cropland
General Surface - Electricity Sub Station / Mineral Workings / Multi Surface / Sloping Masonry / Step	Urban	Settlement
General Surface, Roadside, Structure / General Surface, Structure	Urban	Settlement
Inland Water / Inland Water, Natural Environment	Water	Water
Inland Water, Structure	Urban	Settlement
Landform / Landform, Rail / Landform, Road or Track	Urban	Settlement
Natural Environment - Coniferous Trees / Coniferous Trees, Nonconiferous Trees / Coniferous Trees, Nonconiferous Trees, Scrub / Coniferous Trees, Scrub	Coniferous woodland	Forestland
Natural Environment - Coppice or Osiers	Broad leaf, mixed & yew woodland	Forestland
Natural Environment - Nonconiferous Trees / Nonconiferous Trees (Scattered) / Nonconiferous Trees (Scattered), Rough Grassland / Nonconiferous Trees (Scattered), Scrub / Nonconiferous Trees, Scrub	Broad leaf, mixed & yew woodland	Forestland
Natural Environment - Rough Grassland, Scrub / Scrub	Neutral grassland	Grassland
Natural Environment - Scrub, Nonconiferous Trees / Scrub, Nonconiferous Trees, Coniferous Trees	Broad leaf, mixed & yew woodland	Forestland
Natural Environment - Scrub, Rough Grassland	Neutral grassland	Grassland
Natural Environment, Rail - Coniferous Trees, Scrub	Coniferous woodland	Forestland
Natural Environment, Rail - Nonconiferous Trees / Nonconiferous Trees, Scrub	Broad leaf, mixed & yew woodland	Forestland

Ordnance Survey MasterMap topographic group and term	Construction stage land use category	Operation stage land use category
Natural Environment, Rail - Scrub	Neutral grassland	Grassland
Natural Environment, Rail - Scrub, Nonconiferous Trees	Broad leaf, mixed & yew woodland	Forestland
Natural Environment, Roadside - Coniferous Trees (Scattered) / Coniferous Trees, Nonconiferous Trees / Coniferous Trees, Scrub	Coniferous woodland	Forestland
Natural Environment, Roadside - Nonconiferous Trees / Nonconiferous Trees (Scattered) / Nonconiferous Trees, Scrub	Broad leaf, mixed & yew woodland	Forestland
Natural Environment, Roadside - Rough Grassland / Rough Grassland, Scrub / Scrub	Neutral grassland	Grassland
Path / Path, Structure	Urban	Settlements
Rail	Urban	Settlements
Road or Track / Road or Track, Structure / Roadside / Roadside, General Feature / Roadside, Structure	Urban	Settlements
Structure	Urban	Settlements
Unclassified	Urban	Settlements

5.2.2 The construction phase land use change GHG emission calculations assumed all land within the Order Limits (an area of approximately 835 hectares) would be disturbed as a result of construction. This is a worst-case assumption as there are areas within this boundary where soil and vegetation would not be disturbed.

5.2.3 The construction phase GHG calculations assumed that the disturbance of topsoil led to a 25% loss of the carbon stock in the soil (i.e. emitted as CO_2 to the atmosphere) and removal of the existing vegetation led to a 100% loss in carbon stock. The Natural England average carbon stock estimates for soil and vegetation, applied in the calculation of CO_2 emissions during the construction phase, are shown in Table 5.3 (Natural England, 2012).

Table 5.3 Natural England average carbon stock estimates in soil and vegetation per habitat (Natural England, 2012)

Broad habitat type	Carbon stock in soils (t C ha^{-1})	Carbon stock in vegetation (t C ha^{-1})
Dwarf shrub Heath	88	2
Acid grassland	87	1
Fen, marsh and swamp	76	-
Bog	74	2
Coniferous woodland	70	70
Broad leaf, mixed and yew woodland	63	70
Neutral grassland	60	1
Improved grasslands	59	1
Arable and horticulture	43	1
Coastal margins (UK)	48	-
Urban	0	0
Water	0	0

5.2.4 The study area for the operational phase land use change GHG emission calculations was based on the area of permanent land take, which was deemed to be approximately 647 ha. The weighted average change in equilibrium soil carbon density (t ha^{-1}) to 1m deep for changes between different land types in England (BEIS, 2021b) are shown in Table 5.4. The greatest carbon emission is expected from the near surface layer (i.e. up to 1m deep). For these calculations, all land types within the area of permanent construction were assumed to be converted to 'settlements' as a result of the proposed scheme. This is a conservative assumption, because in reality some areas of the permanent land take would be landscaped, maintained as ecological features or returned to cropland after construction.

5.2.5 For a change in land use type to 'settlements', the timescale range for the reductions in equilibrium soil density set out in Table 5.4 is 50 to 150 years (BEIS, 2021b). Taking a largely conservative approach, the values in Table 5.4 are therefore considered to be representative of the change which would occur over the 60-year appraisal period of the proposed scheme. The change in land use from forestland, grassland and cropland to settlements was therefore associated with a carbon emission of 79 t ha^{-1}, 73 t ha^{-1} and 50 t ha^{-1}, respectively over the operational phase of the proposed scheme.

Table 5.4 Weighted average change in equilibrium soil carbon density (t ha^{-1}) to 1m deep for changes between different land types in England (BEIS, 2021b)

Change in equilibrium soil carbon density (t ha^{-1})	Initial land use			
Final land use	**Forestland**	**Grassland**	**Cropland**	**Settlements**
Forestland	0	5	30	79
Grassland	-5	0	24	75
Cropland	-30	-24	0	49
Settlements	-79	-73	-50	0

5.3 Results

5.3.1 The construction phase GHG emissions associated with changes in land use and forestry as a result of the proposed scheme are estimated to be 39,823 tCO_2e and 678 tCO_2e, respectively.

5.3.2 The operational phase GHG emissions associated with changes in land use and forestry over the 60-year appraisal period are estimated to be 24,312 tCO_2e and -39,814 tCO_2e (i.e. a net benefit), respectively.

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