Appendix A17.2: Carbon Assessment

1 Introduction

1.1 In an attempt to stabilise atmospheric Greenhouse Gas (GHG) concentrations, the United Nations Framework on Climate Change Convention (UNFCCC) established an international framework for countries to reduce GHG emissions. In December 2015 at the Paris Climate Conference (COP21), 195 countries signed the first ever legally binding global climate deal that aimed to limit global temperature increase to below 2^{O}C. The scientific community has stated that limiting global temperature increases to 2^{O}C must be achieved to avoid the most damaging effects of climate change.

1.2 The Intergovernmental Panel on Climate Change (IPCC) 5th Working Group report: Climate Change 2014: The Physical Science Basis (IPCC 2014) summaries recorded historic observations of climatic conditions and projected future climatic trends. Taking cognisance that the global climate system is incredibly complex, the report came to the clear conclusion that *'continued emissions of greenhouse gases will cause further warming and changes in all components of the climate system. Limiting climate change will require sustained reductions of greenhouse gas emissions.'*

1.3 As all GHG emissions are contributing to a global accumulation, the global climate is the ultimate receptor and the impacts of climate change will impact all aspects of the Environmental Impact Assessment (EIA) directive (2011/92/EU as amended by 2014/52/EU). Although GHG emissions to the atmosphere are localised, the impacts are transboundary, meaning no matter where the emissions are released, the social, economic and environmental impacts will be felt on a global scale. GHG emissions associated with an infrastructure project can originate from the combustion of fossil fuels on-site for operating machinery, the manufacture and transport of materials and changes in land-use. Infrastructure is responsible for approximately 515 $MtCO_2e$/year, accounting for 53% of total UK Emissions (UK Green Building Council 2017). Therefore, quantifying and reducing emissions in this sector is vital to enable the UK to meet its carbon budget.

1.4 Throughout this assessment, the term carbon is referred to. This is as shorthand for the carbon dioxide equivalent of all GHGs and is quantified as 'tonnes of carbon dioxide equivalent' (tCO2e). Reporting emissions as CO2e allows for the emissions of the six key GHG: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6) to be expressed in terms of their equivalent global warming potential in mass of CO_2. This assessment will consider the whole life carbon of the A9/A96 Inshes to Smithton scheme which encompasses capital and operational whole life carbon. Capital carbon refers to the GHG emissions associated with the construction of an asset and is more widely used within the infrastructure sector, having been previously referred to as embedded carbon. Operational carbon refers to the emissions associated with the operation and maintenance of the infrastructure but not the emissions from users.

1.5 To determine the boundary of ownership of emissions, they are further divided into the following:

- direct emissions: originating from sources that are owned or controlled by the reporter; and
- indirect emissions that are a consequence of the activities of the reporting entity, but occur at sources owned or controlled by another entity.

1.6 The GHG Protocol (World Resources Institute and World Business Council for Sustainable Development 2004) categorises these direct and indirect emissions into three broad scopes:

- Scope 1: Direct GHG emissions – those that occur from sources that are owned or controlled by the project;
- Scope 2: Indirect emissions from the generation of electricity – through the purchase of heat, cooling, steam or electricity; and
- Scope 3: Other indirect emissions – those from sources that are not owned or controlled by the project but occur as a consequence of the project and its activities.

2 Methodology, Assumptions and Notes

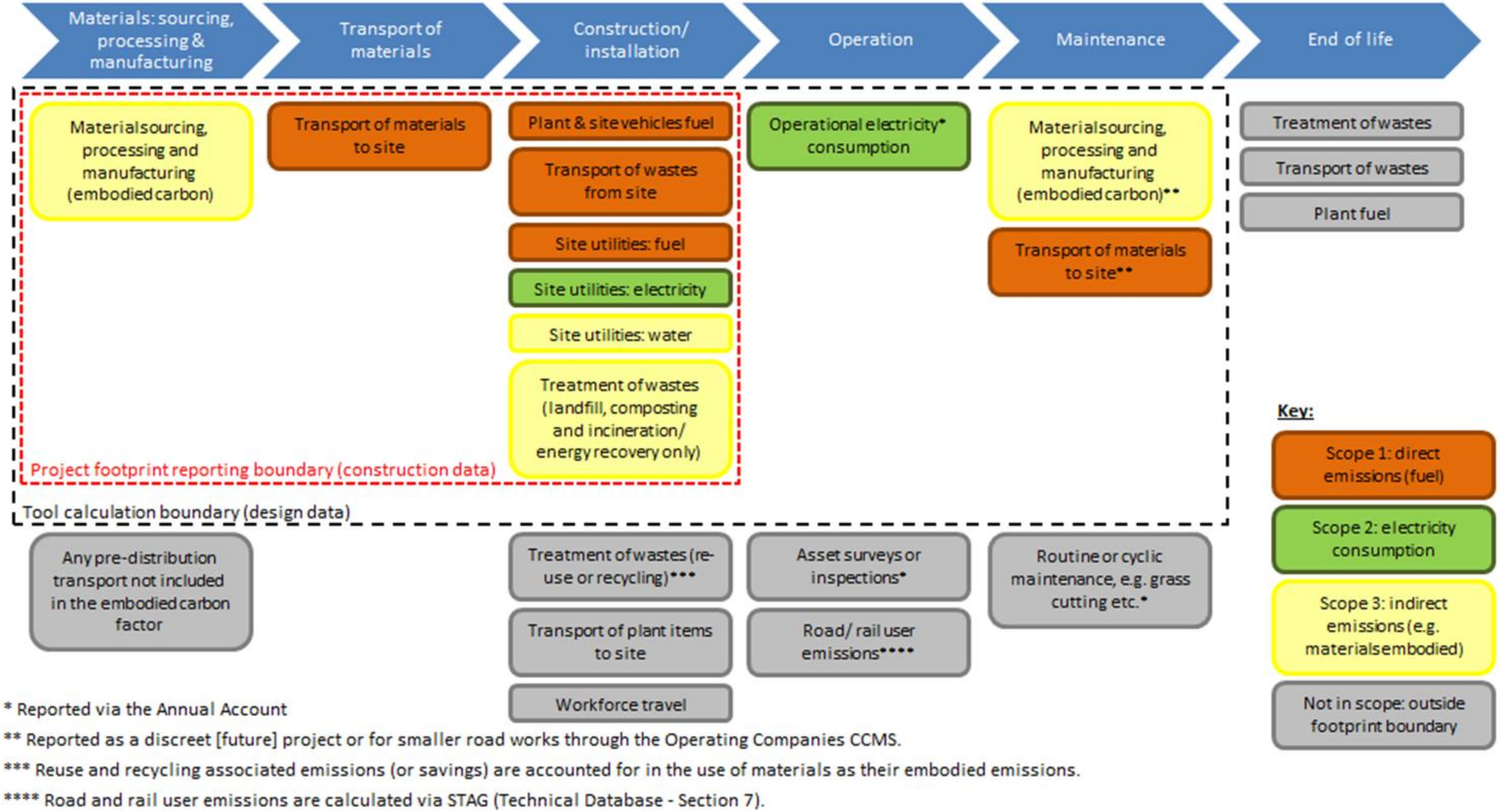
Project Boundary

2.1 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 can only occur after this. Whilst the proposed scheme would aim to identify and account for as much carbon as possible, it is a more efficient approach to prioritise some sources over others, rather than calculating the absolute footprint of the project, as many components will have a negligible impact and offer limited opportunities for mitigation compared to the time, effort and cost involved in determining its carbon impact.

2.2 The Transport Scotland Project Carbon Tool (Transport Scotland 2016) recommends a boundary that varies based on when the carbon assessment is being undertaken, as shown in Diagram 17.1 (Transport Scotland Project Tool Boundary). As can be seen, this includes embodied carbon (material resourcing, processing and manufacturing) and maintenance activities.

2.3 It should be noted that the Transport Scotland 'Projects Carbon Tool' is used to monitor carbon during construction and therefore includes transport within the reporting boundary, however the specific details about material transportation requirements are not available at this stage. Therefore, emissions from transportation of materials has been scoped out.

Diagram 17.1: Transport Scotland Project Carbon Tool Boundary



The Transport Scotland Projects Carbon Tool

2.4 Transport Scotland have developed and implemented a Carbon Management System (CMS) as a suite of tools to measure their scope 1, 2 and 3 carbon emissions associated with their construction and maintenance activities across their road and rail schemes.

2.5 The CMS fulfils two roles:

- It enables consistent transport and objective measurement and reporting of carbon emissions from Transport Scotland's construction and maintenance operations and schemes; and
- It supports design and construction optioneering.

2.6 The 2016 version of Transport Scotland's Projects Carbon Tool is part of the CMS suite of tools. The tool is used to estimate carbon emissions associated with civil and structural engineering projects, including road, rail and buildings. It is intended to be used throughout the design process, from outline design to detailed design, allowing for comparison of design options to be made.

2.7 Whole life carbon options can be estimated for projects based on the embodied carbon associated with the materials used, the transport of materials and waste, site plant energy consumption, any operational energy and emissions associated with structural maintenance.

2.8 For this assessment, only emissions embodied within the materials used and those associated with cyclic maintenance have been reported due to the information currently available regarding material and waste transportation.

Source Data

<u>Information Used</u>

2.9 Entries into the tool are based on the Design Manual for Roads and Bridges (DMRB) Stage 3 design and information available at the time of the assessment. It is noted that elements of the design would continue to be refined throughout the design process resulting in changes in material quantities.

2.10 Design information that was incorporated into this carbon assessment includes:

- information on earthworks required in the project;
- detailed pavement specifications for the different sections of the project;
- structures such as bridges, culverts and underpasses;
- drainage filter material;
- kerbs;
- safety barriers;
- boundary fencing; and
- and signage.

2.11 This information allowed for the calculation of material used, which is presented in Table 1 by broad material type and construction component. Furthermore, each scheme component has an associated replacement frequency, which was used to determine emissions associated with the scheme renewal over a 100-year period.

Table 1: Carbon Emissions by Broad Material Type and Construction Components

Materials	Units	Approximate Estimated Quantity	Worst Case Scenario Quantity (Including 10% Contingency)	Assumed Indicative Replacement Frequency	Comments/Assumptions
Bulk Earthworks (soils and/or rock)	m^3	327,300	360,030	N/A	This is the total fill earthworks (i.e. Import + On-Site Acceptable)
Pavement (surfacing, binder and base)	m^3	13,900	15,290	Surface – 10 years Binder – 20 years Base – 40 years	Based on 0.3m depth of bituminous layers. May change with traffic info.
Sub-base	m^3	23,660	26,025	40 years	Foundation layers assumed to be type one sub-base totalling 0.45m. May change with Geotech info.
Concrete	m^3	5,290	5,820	120 years	Based on structures in the design
Steel	Tonnes	810	890	120 years	Structural steel only
Drainage filter material	m^3	1,130	1,245	10 years	Based on full length on one side of road.
Kerbs	m	17,210	18,930	40 years	Based on full length both sides of road and shared centre.
Road markings	m	10,720	11,790	10 years	Based on full length both sides of road and centre.
Safety Barriers	m	3,160	3,480	25 years	Assumed on embankments over 2.5m – in addition to the 2,065m of barrier, 24no. P4 terminals will be required.
Boundary Fencing: Standard fencing	m	10,640	11,705	25 years	Based on design requirements
Signs Large ADS	m^2	340	375	20 years	Based on design requirements
Signs: Smaller signs	m^2	55	60	20 years	Based on design requirements
Signs: Triangular or circular sign on a single post	m^2	13	15	20 years	Based on design requirements

Exclusions due to incomplete or unknown design information:

- embodied material: detailed information on road lighting and signals is not available and therefore has not been included;
- plant and site vehicle fuel usage;
- site utilities: fuel usage; electricity and water;

- treatment of wastes;
- transportation of waste and material;
- operational electricity consumption; and
- emissions associated with maintenance activities.

2.12 Footway quantities are not included in the pavement/sub base materials in Table 1, but are modelled and the impacts included in the results below. Footway construction depth is assumed to be 220mm, comprising Type 1 unbound mixture sub-base 150mm thick, dense macadam binder course with 20mm aggregate 50mm thick, close graded macadam surface course with 6mm aggregate 20mm thick = 5,245m^3 (including 10% worst-case scenario contingency).

3 Results

3.1 Transport Scotland's Projects Carbon Tool was used to estimate the carbon emissions associated with the proposed scheme. The results are set out in Table 2, Table 3 and Table 4. The calculations are based on a worst-case scenario, including a 10% contingency to cover unknown items.

3.2 Table 2 shows the total carbon emissions anticipated from the proposed scheme throughout its lifetime, during construction and maintenance. It should be noted that that due to rounding of data outputs there are slight discrepancies between the totals presented in Tables 3 and 4, when compared to Table 2. It is confirmed that the information provided in these tables is correct as an output of the Carbon Tool.

Table 2: Proposed Scheme Emissions Summary (Worst Case Scenario Including 10% Contingency)

Carbon source	tCO_2e
Construction: Materials embodied	15,050
Maintenance: Materials embodied	13,975

3.3 Table 3 and Table 4 provide more detailed information on the carbon emissions for each of the 3 stages by splitting the figures into individual project elements and the carbon emissions for construction materials by type. All volumes shown are based on the worst-case scenario figures that include a 10% contingency.

Table 3: Summary by Project Elements (Worst-case scenario including a 10% contingency)

Project elements	Materials embodied (tCO_2e)	Maintenance (materials embodied) (tCO_2e)
Drainage	60	615
Earthworks	8,290	0
Fencing	120	470
Road Pavement	3,085	12,230
Safety Barriers	125	490
Signs	35	165
Structures (civils & buildings)	3,345	0

Table 4: Summary by Material Types: Construction Embodied Only (Worst-Case Scenario including 10% Contingency)

Material types	tCO_2e
Aggregate	685
Aluminium	35
Asphalt and bitumen	2,180
Concrete, cement, and cement substitutes (including steel reinforcement)	2,280
Iron and steel	1,485
Paint and coating	15
Plastic	20
Soil	8,285

4 Carbon Saving Measures

4.1 Carbon quantification is necessary for understanding the carbon impacts of the project and enabling opportunities for carbon savings to be identified.

4.2 Reporting and guidance, such as the Infrastructure Carbon Review (HM Treasury 2013) and PAS 2080:2016 (BSI 2016) indicate that the potential to influence carbon emissions decreases as a project progresses. The largest savings can be achieved during the planning stage, with more modest reductions achievable during design and construction.

4.3 Taking this into consideration, the key early intervention procedure, as identified in the Infrastructure Carbon Review (HM Treasury 2013) can be considered to be:

- avoid and/or eliminate or ‘build nothing’: challenge the need; explore alternative approached to achieve the desired outcome;
- reduce or ‘build less’: maximise the use of existing assets, optimise asset operation and management to reduce the extent of new construction required;
- substitute, replace or ‘build clever’: design in the use of low carbon materials, streamline the delivery process, minimise resource consumption; and
- compensate or ‘build efficiently’: embrace new construction technologies, eliminate waste.

4.4 As a starting point, the planning and design specification should aim to reduce or avoid where practicable, the use of significant high impact materials, (e.g. steel and aluminium), or processes (e.g. significant earthwork excavations). Where this is not possible, material volumes or processes should be substituted with lower intensity replacements if achievable within the bounds of the design standards for safety and quality.

4.5 Where it would not significantly impact upon engineering, safety and maintenance characteristics, the principle of substitution requires that low carbon alternatives for materials be considered.

4.6 Imported earthworks fill is a significant part of the overall carbon footprint. Opportunities to obtain additional earthworks fill on-site if near the construction area should be maximised and, where it would not significantly alter the safety of the characteristics of the road, earthworks fill should be reduced. While this assessment does not take into account emissions associated with on-site vehicles, including those that would be used to dig up and move earthworks fill material, on-site soil movements will generate lower emissions than long-distance transport.

4.7 The operational carbon, encompassing the regular maintenance of the road pavement, including the surface course, sub-base and base course accounts for 50% of the whole-life emissions. Investigation of either a more hard-wearing material for the road surface course or a material with a lower emissions factor should be a priority for any mitigation measures.

5 Conclusions

5.1 The information provided accounts for emissions associated with the DMRB Stage 3 design, as it is currently known. This would be further developed by the contractor going forwards and should be a point of discussion where construction methods may contribute to a reduction or increase in emissions.

5.2 The results of this assessment can be reviewed in comparison to other schemes with the published emissions and with industry benchmarks. It should be noted that currently there are not many public embodied carbon assessments of highways schemes and that the characteristics of those schemes can vary considerably in terms of the required structures. Furthermore, the assessment of embodied emissions will not be fully consistent as it is always based on the available information for the scheme and may differ in terms of exclusions. However, two other road schemes and a Scottish benchmark are presented in Table 5.

Table 5: Comparison of Emissions from Other Road Schemes

Scheme Name	Approximate Lane-Kilometres and Notes	Embodied Emissions (including a worst-case scenario 10% contingency) (tCO_2e)	Embodied tCO_2e / lane.km	tCO_2e / lane.km
Proposed Scheme	4.9km	15,050	3,070	1,535
A14	204 lane kms Including 30 bridges	740,060	3,630	4,785
A737 Dairy Bypass (Scottish Benchmark)	7.6 lane kms One major viaduct	16,090	2,120	2,400
Silvertown Tunnel	4 lane kms. Including 2 major tunnels under Thames	391,095	97,775	

6 References

Reports and Documents

British Standards Institution (BSI) (2016). PAS 2080:2016: Carbon Management in Infrastructure

HM Treasury (2013). Infrastructure Carbon Review

The Intergovernmental Panel on Climate Change 5th Working Group report "Climate Change 2014: The Physical Science Basis"

Transport Scotland (2016) Transport Scotland Projects Carbon Management Tool.

UK Green Building Council (2017). Delivering Low Carbon Infrastructure.

World Resources Institute and World Business Council for Sustainable Development (2004), The Greenhouse Gas Protocol, A Corporate Accounting and Reporting Standard, March 2004.

EU Directives and Legislation

European Commission (2014). Directive 2014/52/EU regarding the assessment of the environmental effects of certain public and private projects.