Llywodraeth Cymru
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A487 New Dyfi Bridge

Environmental Statement – Volume 3: Appendix 11.1

Carbon Report

900237-ARP-ZZ-ZZ-RP-YE-00034

Final Issue | September 2017

Contents

Acronyms and Abbreviations

AOD	Above Ordnance Datum
CapCO2	Capital carbon
Carbon / CO_2e	Carbon dioxide equivalent
ILM	Incremental Launching Method
LCA	Life cycle assessment
NMUs	Non-motorised Users
OpCO2	Operational carbon
SNP	Snowdonia National Park
tCO_2e	Tonnes of carbon dioxide equivalent
UseCO2	User carbon

Non-technical Summary

This report provides an assessment of the carbon emissions associated with the A487 New Dyfi Bridge (the Scheme).

The net carbon emissions (expressed in tonnes of carbon dioxide equivalent - tCO_2e) associated with the construction of the Scheme would be 12,116tCO_2e. The baseline carbon emissions including allowance for optimism bias/contingency is 16,962 tCO_2e. This is the estimated target footprint the project is trying to better in the later stages.

1 Introduction

1.1 General

The purpose of the Carbon Report is to provide an indicative carbon footprint associated with the construction of the Scheme.

More specifically, this report aims to:

- set the background and carbon context against which carbon emissions from the Scheme should be considered;
- provide transparency on the methodology, input data and boundary conditions used in the assessment; and
- provide the breakdown of the construction carbon of the Scheme.

1.2 Welsh Government Legislation and Policy Context

The Welsh Government has legislation, strategies and policies that support carbon and greenhouse gas emission reduction. These are detailed in Appendix B.

2 Scheme Description

The proposed A487 New Dyfi Bridge scheme (The Scheme) consists of a new viaduct structure across the floodplain and a river bridge to cross the River Dyfi approximately 480m upstream of the existing Pont-ar-Ddyfi. The length of the Scheme is approximately 1200m with approximately 725m being on structures.

Refer to Scheme General Arrangement Drawing in Appendix A

The scheme lies partly within Snowdonia National Park (SNP) and partly within its landscape setting. The receiving environment is highly sensitive. The potential effects on the environment have been considered through the iterative process of design, environmental assessment and redesign to reduce and where possible avoid adverse effects on the environment. Input from the environment team has shaped the design. These aspects of the Scheme, which have been built into the design to avoid or reduce environmental effects are described below under Environmental Design. The Scheme consists of a new section of single carriageway road. The typical carriageway width would be 9.3 m (excluding verges), which would consist of two 3.65 m wide lanes, with a 1 m hard strip on either side or the carriageway. In addition, the typical cross section would include 2.5 m grass verges along both sides of the proposed bypass, increasing in width to accommodate forward visibility requirements as required.

The typical carriageway width would be the same on the proposed structures across the flood plain and river, although with a reduced verge width on the eastern side of the carriageway from 2.5 m to 0.6 m on the viaduct and bridge.

For most of its route, the Scheme would be elevated across a generally flat floodplain and at its highest point (on the river bridge) it would be some 9m above ground level.

The majority of the Scheme would have a National speed limit. Although a 30mph speed limit would be provided at the southern end of the Scheme, for approximately the first 200m, reflecting the existing speed limit.

The Scheme would not have road lighting, except at the southern end of the scheme within the 30mph speed limit. The requirement for the provision of highway lighting on the remainder of the Scheme has been assessed and concluded that there is no specific requirement for highway lighting.

The highway drainage would be predominately provided by a kerb and gully highway drainage system, with combined kerb drainage units provided on the new structures

The scheme would be earthworks neutral, with potentially a deficit of general earthworks materials

The Scheme crosses the River Dyfi and floodplain on a structure, from a short embankment north of the Cambrian Line Railway Bridge over the A487 on the edge of Machynlleth. A simple priority junction is provided at the southern end of the scheme connecting the proposed works with the existing A487 and the Dyfi Eco Park.

At the northern end of the scheme the alignment ties into the existing A487 in the area of the completed Ffridd Gate Improvement and the existing A487 would be renumbered as the A493, joining the new A487 alignment via a ghost island T-junction.

The existing A487 would be de-trunked between the two tie in points with the new scheme. The Pont-ar-Ddyfi and the section of the existing A487 to the south of the river would be restricted to Non-Motorised Users (NMUs) only.

A maintenance access track would be installed along the side of the new viaduct, at the southern end this would connect to the existing A487. This access track would also form the key access route during the construction phase.

2.1 Ch. 0 – 0+220 Southern Tie In and Embankment

The Scheme commences immediately north of the existing Cambrian Line Railway Bridge. To the north of the bridge the alignment would begin to rise and move off-line to the west of the existing road, to a height of 4.4 m above ground level at the Ch. 0+220.

The junction to the Dyfi Eco Park would be reconfigured with a short connection provided between the existing access road and the new alignment, the junction would be 1.7m above ground level.

A major-minor priority junction is proposed at Ch. 0+140 to connect the new alignment with the existing A487, which would be de-trunked.

The existing 30mph speed limit would be retained with the speed limit signs and a gateway provided at the southern abutment of the new structure, Ch. 0+220. Road lighting would be provided within the 30mph speed limit to replicate the existing provision.

An approximately 1.5m high flood bund (crest level 9.25m AOD) would be provided along the western side of the Scheme, starting from the existing railway embankment at Ch. 0+020 and tying into the earthworks associated with the proposed access to the existing A487 at Ch. 0+130.

A further approximately 2.0 to 2.5m high flood bund (crest level 10.00m AOD at west to 10.30m AOD at the east) would be provided along the northern boundary of the Dyfi Eco Park, connecting to the southern bridge abutment and wingwalls at the western end, and the existing railway embankment at the eastern end of the Eco Park. An agricultural access track to replicate existing access provision would be provide up and over the bund at approximately the mid-point along the bund.

2.2 Ch. 0+220 – 0+815 Viaduct

The proposed viaduct across the flood plain would consist of 18 spans: 16 No. 34m span and 2 No. 27m spans at the southern end. The viaduct structure would be carried by two concrete columns on piled foundations with the bridge deck structure being a multi span steel/concrete composite construction.

The initial section of the viaduct (Ch. 0+220 to Ch. 0+380) is on a right hand bend, with deck widening of the eastern verge to maintain visibility. This section would be crane erected due to the complexity of the structural layout.

The viaduct beyond Ch. 0+380 has a constant horizontal and vertical alignment. Therefore to minimise the works in the flood plain the intention is to construct the majority of the viaduct in sections on a 2m wide temporary platform/embankment between Ch. 0+300 and Ch. 0+380, and 'push launch' it across the flood plain.

Push launching will involve construction using the 'incremental launching method' (ILM). This ILM is considered the most economical procedure for constructing bridges and has been proposed for the viaduct as it offers significant advantages in this location.

By working from the south and pushing the structure from one location access arrangements for delivery of materials and equipment becomes easier and steel fabrication and welding operations are more efficient providing increased quality control. It is also proposed to use precast concrete units to construct the bridge deck. It is proposed to construct one 35 metre span of ladder beam bridge deck and place and fix precast concrete deck slab units on the steelwork prior to jacking the structure forward.

Hydraulic jacks will be used to "push" the bridge deck to the first pier creating the first span and making way for the erection of the next bridge deck span. The process is then repeated until the whole structure of approximately 400 metre is completed.

2.3 Ch. 0+815 – 0+940 River Bridge

The proposed river bridge would have a main span of 74m, and a back span on the south of the abutment of 50m. The northern abutment would be located on the land to the north of the existing river. The deck construction would be of a similar construction to the viaduct, and due to the weight of the bridge beams would be lifted in from the north and south of the river.

2.4 Ch. 0+870 – 1+100 Junction and Northern Tie In

The Scheme would include a priority junction with the existing A487, which would be de-trunked to become the A493. The existing A487 would be realigned slightly to approach the new A487 at near perpendicular, and alterations would be made to the existing residential/agricultural access to the north. A ghost island would be provided as part of the junction layout to accommodate the right turning traffic from the A487 to the A493.

Advance directional reflective traffic signage would be provided in the verge of the existing carriageway north of the junction.

2.5 Existing A487, Pont-ar-Ddyfi and other works

The existing A487 would be de-trunked between the connection with the Scheme at the southern end and a point approximately 40m south of the existing Pont-ar-Ddyfi.

A short section of the existing A487 would be stopped up approximately 40m south of the River Dyfi. The Pont-ar-Ddyfi and approximately 40m section of the existing A487 to the south of the river would be restricted to Non-Motorised Users (NMUs) and authorised vehicles only. Authorised vehicles would be able to access for farmers and for statutory undertakers.

The existing A487 south of the stopping up would be retained for access predominantly by landowners and statutory undertakers, and a new T- junction would be provided to tie into proposed A487 re-alignment.

No vehicular through access would be provided along the old route, with only an NMU connection provided between the existing A487 south and the Pont-ar-Ddyfi. The existing NMU route along the west side of the existing A487 will be retained.

The existing drainage channel, partially along the eastern side of the A487, would be profiled and extended to provide the outfall channel for the highway drainage of the main structure.

The existing A487/A493 junction immediately north of Pont-ar-Ddyfi would be reconfigured to provide a through route connection to the new northern junction. The section of A487 north of the River Dyfi, between Pont-ar-Ddyfi and the new northern junction, would become an extension of the A493.

Flood mitigation measures would be provided to ensure no increase in flood risk to the existing bridge and adjacent residential properties. These measures would be downstream of the Pont-ar-Ddyfi on the southern bank and would involve flood plain re-profiling to accommodate the flood waters, and localised works to strength the foundations of the existing bridge.

3 Scope and Method of Carbon Accounting

3.1 General

3.1.1 The approach followed for the carbon accounting process is based on the current best practice principles of carbon assessments of projects. Whilst there is no specific guidance on carbon assessments for highway schemes, the principles set out in "ISO 14064-2:2006 Greenhouse Gases – Specification with guidance at the project level for quantification, monitoring and reporting of greenhouse gas emission reductions or removal enhancements" (ISO, 2006), the "Greenhouse Gas Protocol – The GHG Protocol for Project Accounting" (World Business Council for Sustainable Development and World Resources Institute, 2005) and the "PAS 2080:2016 Carbon Management in Infrastructure" have been followed.

3.1.2 Carbon is used throughout this report as shorthand for the carbon dioxide equivalent CO_2e of all greenhouse gases.

3.2 Scope

3.2.1 The scope of this carbon assessment only covers the construction phase of the project as part of the requirement for Key Stage 3 of the project.

3.2.2 The boundary for the carbon accounting process is defined by considering the life cycle of a highway project, which can be split into phases, as illustrated in Figure 1 Life cycle of infrastructure projects.

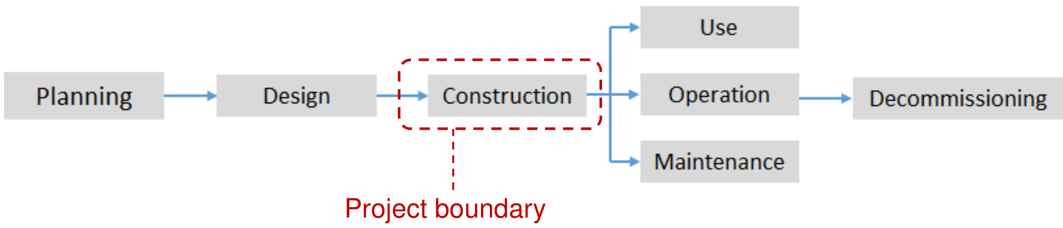


Figure 1 Life cycle of infrastructure projects

3.2.3 The individual phases are detailed below.

Planning – the emissions associated with the planning phase at Key Stages 1 and 2 of highway development are predominantly concerned with paper and office energy consumption as well as emissions produced by staff using vehicles in relation to business (i.e. workers daily commute).

Design – the emissions associated with the design phase at Key Stage 3 are predominantly concerned with paper and office energy consumption as well as emissions produced by staff using vehicles in relation to business (i.e. workers daily commute). Site surveys and ground investigations are also part of this stage.

Construction – this is primarily concerned with the emissions of the construction materials used in structures such as bridges, pavements and supporting infrastructure. It also includes the logistical impact of delivering materials to site, the removal of waste, the use of machinery/plant equipment on site and the transportation of labour to site. Using the Infrastructure Carbon Review (HM Treasury, 2013) definitions, this is defined as Capital carbon, or 'CapCO2'.

Use – the consequential emissions from the functional use i.e. emitted by vehicles using the highway (tailpipe emissions) during its operational life. Using the Infrastructure Carbon Review definitions, this is defined as User carbon, or 'UseCO2'.

Maintenance – the emissions associated with the periodic maintenance that is required for the highway to be used as intended. For example, the emissions associated with renewal of the wearing course, kerbs and barriers.

Operation – the emissions associated with the day-to-day operation of the trunk road estate. For example, the electricity consumed by lighting, gantries, signals, signs and Intelligent Transport System (ITS). It would also include activities such as gritting. Using the Infrastructure Carbon Review definitions, this, along with emissions associated with maintenance, is defined as Operational carbon, or 'OpCO2'.

Decommissioning – refers to when infrastructure has reached the end of its serviceable life. If the end-of-life is reached, then the materials can be reused, recycled or disposed of. It is not considered appropriate to include this within the scope of the assessment for this Scheme as it is preferable this phase not be reached with ongoing maintenance keeping it serviceable.

3.3 Construction Emissions

3.3.1 The scope of the capital carbon assessment covers the following:

Embodied carbon in materials -The total amount of carbon produced during resource extraction, transportation, manufacturing and fabrication, to bring a product to its existing state. This includes all construction materials as well as aggregates, the removal of waste, fuel and water use, and transport emissions associated with these material. This is often referred to as 'cradle-to-gate' in life cycle assessment (LCA) terms.

Carbon from the plant used on site - The carbon produced from the combustion of fuel or consumption of energy by machinery and plant used during construction.

Carbon from transportation of materials, plant and people to and from site - The carbon produced from the combustion of fuel or consumption of energy by the transportation used to deliver materials to site. This includes transport for waste from site.

Labour – includes the travel of construction workers to and from site.

3.4 Methodology

3.4.1 Due to limited design details available at Key Stage 3, a top down analysis method was adopted to quantify carbon. This approach uses the data collated from previous works carried out by Arup to estimate carbon emissions. The approach adopted is one of the methods outlined in the Guidance Document for PAS 2080 in developing a carbon baseline. A different carbon quantification method could be adopted when more information has developed at Key Stage 6.

3.4.2 The method applied at Key Stage 3 is based on the construction cost of the project (excluding overheads and profit) multiplied by carbon intensity factors (i.e. $kgCO_2e$/ £ spend) derived from a similar carbon assessment analysis carried out by Arup. The estimated construction cost used for A487 New Dyfi Bridge is based on the priced tender bills of quantities and the addition of an extended viaduct section. The priced bills of quantities has been prepared by the Contractor, Alun Griffiths.

3.4.3 The carbon assessment analysis convert the usage of labour, plant, materials and sub-contractor through the application of emission conversion factors from publically available information, listed in Appendix D. Some assumptions have been made in the application of emission conversion factors which are also applicable to this project as detailed in Appendix E. A carbon factor for labour, plant, material and sub-contractor based on construction cost was then generated and has been applied to the A487 New Dyfi Bridge to estimate the CO_2e for the scheme. Table 1 provides a summary of cost and carbon emissions of the A487 New Dyfi Bridge project calculated based on the carbon factor:

Description	Cost (£)	$kgCO_2e$ / £ spend	tCO_2e
Labour	1,566,309	0.057	89
Plant	3,402,271	0.622	2,148
Material	2,784,268	1.751	4,876
Sub-contractor	5,875,253	0.857	5,034
Total	**13,628,100**		**12,116**

Table 1 Summary of cost and tCO_2e

3.4.4 The carbon factor of the sub-contractor element was further analysed and broken down into labour, plant and materials based on the percentage derived from the previous project, which is shown in Table 2. The total carbon of the project is further discussed in Section 4.

Description	tCO_2e	%
Labour	20	4%
Plant	619	12.3%
Material	4,395	87.3%
Total	**5,034**	**100%**

Table 2 Breakdown of sub-contractor into resource categories

4 Carbon Assessment Results

4.1.1 The carbon assessment results are summarised in Table 3 and Figure 2.

Table 3 provides a breakdown of the overall carbon footprint per resource category in tonnage while Figure 2 provides a summary of this as a percentage split. The estimated carbon figures for the Scheme include sub-contractor values in the respective categories (labour, plant and material).

Carbon component	Estimated net carbon (tCO_2e)	Estimated gross carbon (including contingency) (tCO2e)
Labour	109	153
Plant	2,737	3,832
Material	9,270	12,978
TOTAL	**12,116**	**16,963**

Table 3 Summary of carbon assessment; units expressed in tCO_2e

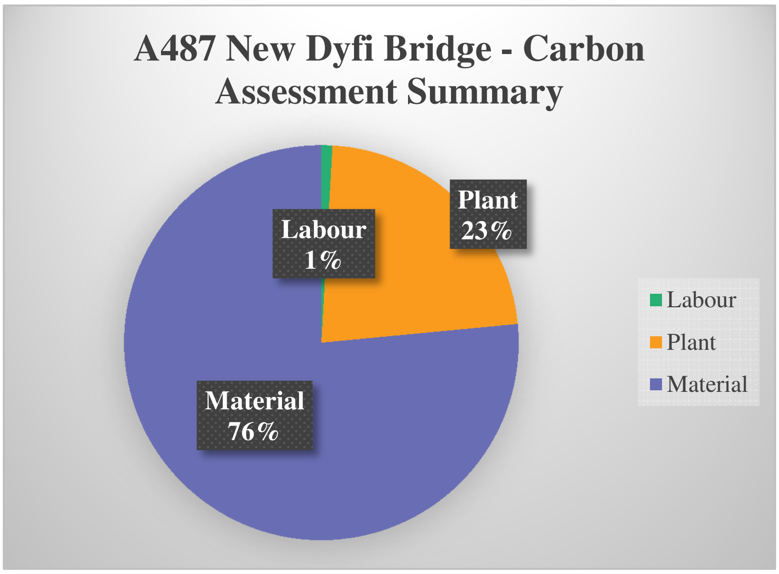


Figure 2 Summary of carbon assessment expressed in percentage

4.1.2 The overall net carbon footprint resulting from the construction of the Scheme is estimated to be 12,116 tCO_2e. It is standard practice to include an allowance for optimism bias/contingency at this stage of the project in line with the HM Treasury Green Book Supplementary Guidance for estimating construction cost. Since the methodology adopted for the carbon quantification is based on construction cost, it is considered 40% allowance of optimism bias is reasonable to be included for setting the baseline carbon emissions at Key Stage 3. Therefore the baseline of the carbon emissions of the Scheme which includes optimism bias allowance is 16,962 tCO_2e.

The majority (76%) of these carbon emissions would be in the construction materials and the remaining 24% comes from the labour (1%) and plant (23%).

4.1.3 A further breakdown of the carbon emissions into different types of construction activities based on the bill of quantities is shown in Figure 3. The methodology used is based on the carbon emissions per £ spent as explained in paragraph 3.4.3 and 3.4.4. A detailed breakdown is included in Appendix F.

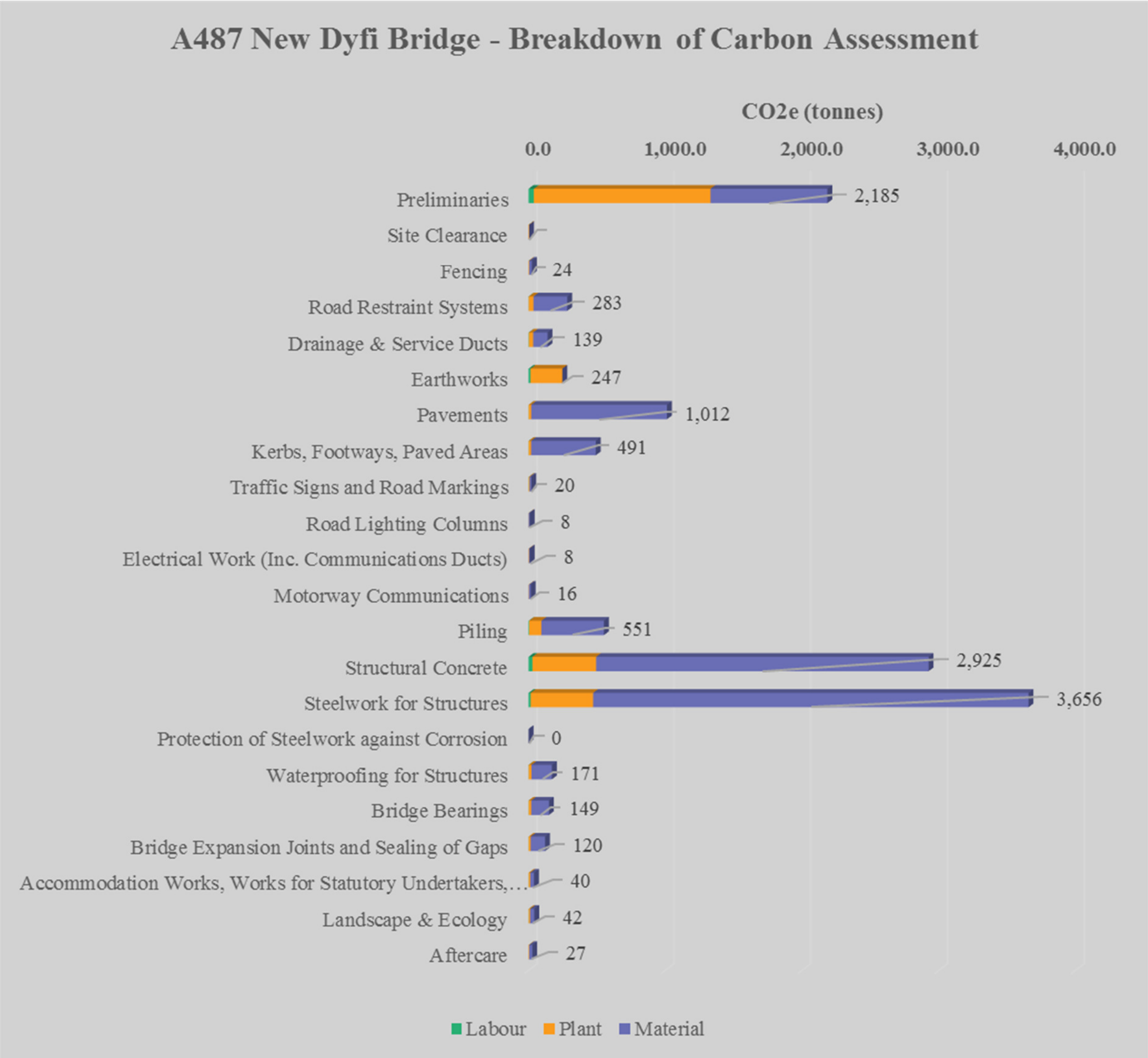


Figure 3 Breakdown of Carbon Emissions

4.1.4 Based on the analysis presented above, the major contributors of the carbon emissions for the project are Steelwork for Structures (30.2%), Structural Concrete (24.1%), Preliminaries (18%) which include traffic management and temporary works and Pavements (8.4%). On this basis, these would be key areas to focus efforts on for carbon reduction opportunities during the design development.

4.1.5 Throughout the development of the Key Stage 3 preliminary design, the design team has looked to minimise the carbon footprint, material usage and wastage:

- Extensive flood modelling has been carried out to minimise the extent of viaduct/ bridge structure, and thereby minimise carbon footprint associated.

- The length of proposed highways construction has been minimised by using straight alignments, and low radius bends as far as possible

- The proposed viaduct cross section has been minimised by reducing the verge width on the eastern side to 600mm, thereby reducing material and carbon footprint

- The viaduct will predominantly be a push launched steel structure constructed of largely pre-fabricated sections. The steel structure has a lesser carbon footprint than a reinforced concrete structure, and the pre-fabricated sections will reduce wastage (and carbon footprint).

- The earthworks design has looked to balance the cut/fill, and maximise re-use of site materials to minimise fill import, and associated carbon footprint.

4.1.6 The design team will continue to optimise the design, and minimise carbon footprint, throughout detailed design. The final quantities of capital carbon may change in the future as the design of the scheme is progressed, subject to the Welsh Government deciding to make the Orders.

5 Conclusions

5.1 Key Stage 3

5.1.1 The report assessed the carbon emissions associated with the construction of the Scheme at a level of detail appropriate to the current stage of the design.

5.1.2 The net carbon emissions associated with the construction of the Scheme is 12,116 tCO_2e. It is considered 40% of optimism bias/contingency allowance, which is equivalent to 4,846 tCO_2e is reasonable to be included for setting the baseline carbon emissions for Key Stage 3. Therefore, the baseline of the carbon emissions of the Scheme which includes optimism bias/contingency allowance is 16,962 tCO_2e. This is the estimated target footprint the project is trying to better in the later stages.

5.1.3 The net capital carbon of the Scheme is equivalent to approximately 0.02% of the total annual Welsh carbon emissions for 2 years of construction.

5.1.4 Opportunities for capital carbon reduction were considered where possible within the Key Stage 3 design development which include minimising the extent of highways and viaduct/bridge structure, use of pre-fabricated steel sections for the structure and maximising re-use of site materials.

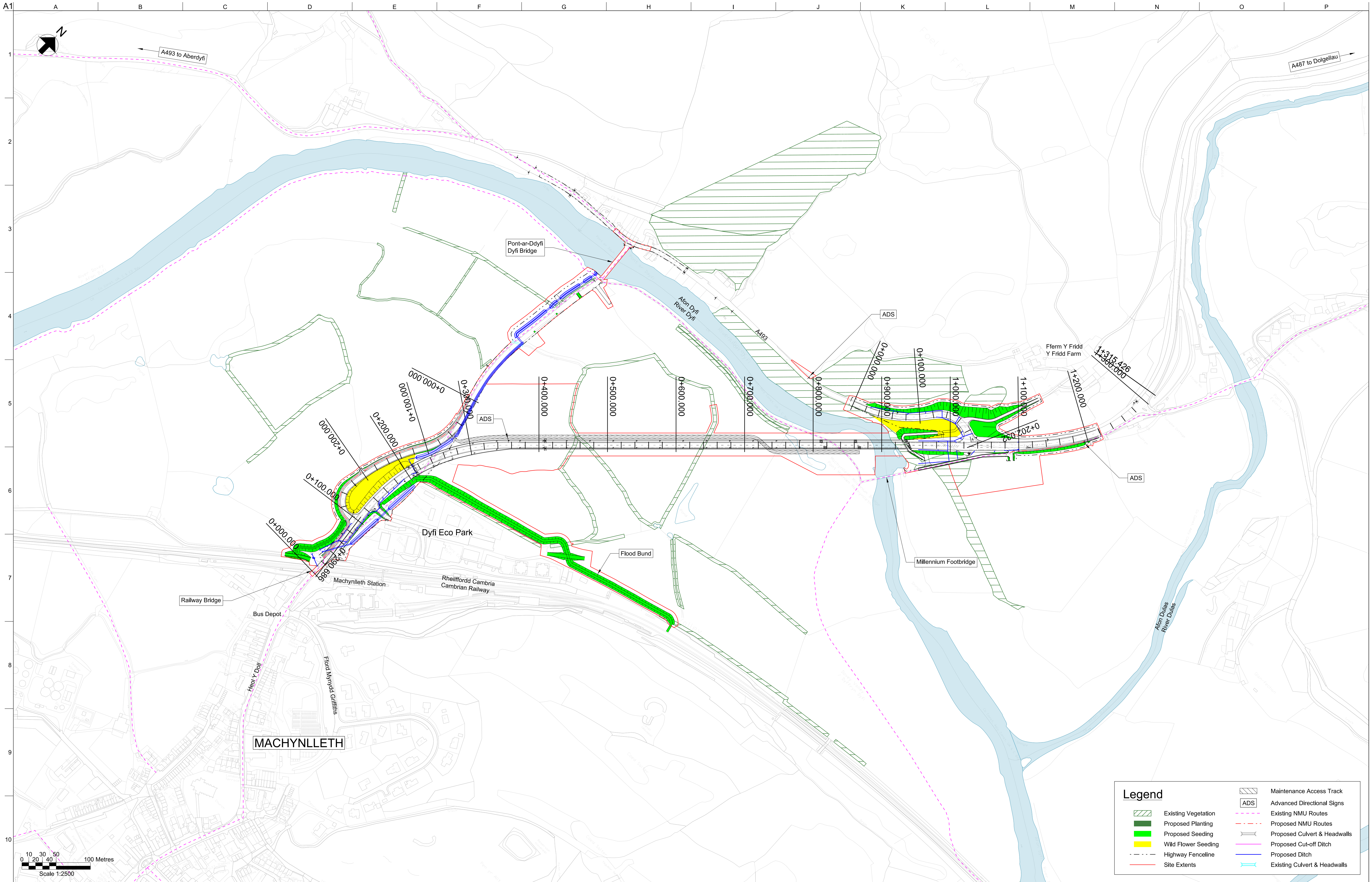
5.2 Key Stage 6

5.2.1 In the next stages of design, there may be an opportunity to reduce construction carbon through a systematic material specification requiring reduced construction carbon. The design will be further optimised to minimise carbon footprint based on similar approach adopted at Key Stage 3.

5.2.2 A "Carbon Accounting Briefing Note" has been drafted that provides to the project team guidance on carbon accounting and reduction (see Appendix C) so that the consideration of carbon continues throughout design development work. It provides examples of how material and transport choices can impact upon the Scheme's carbon footprint.

Appendix A

1:2500 Scheme General Arrangement Drawing



Notes:

Issue	Date	By	Chkd	Appd
P03.2	---	---	---	---
Departure from Standards Approval				

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Client
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Welsh Government

Project Title
A487 New Dyfi Bridge

Drawing Title
Scheme General Arrangement
1:2500

Scale at A1: 1:2500
Role: Civil - Highways
Suitability: S0 - Initial non-contractual
Arup Job No: 244562-00
Rev: P03.2
Name: 900237-ARP-ML-ZZ-DR-CH-00101

Do not scale

Appendix B

Welsh Carbon Policy Context

	Legislation, Policy or Strategy Document	Carbon-related policy aspirations
A.1	One Wales: Connecting the Nation – The Wales Transport Strategy[1] Environmental Outcome (WTSEO) 2008	Environmental Outcome 12: Greenhouse gas emissions - Reduce the impact of transport on greenhouse gas emissions
A.2	Carbon Reduction Commitment Energy Efficiency Scheme[2] 2008	The Welsh Government is seeking to reduce emissions accountable under the Carbon Reduction Commitment Energy Efficiency Scheme. This is a UK-wide mandatory scheme to improve energy efficiency and cut carbon dioxide emissions in large organisations.
A.3	National Transport Plan SEA Objective[3] 2009	Reduce transport related greenhouse gas emissions
A.4	National Transport Plan (NTP)[4] Strategic Priority March 2010	Reducing greenhouse gas emissions and other environmental impacts
A.5	Climate Change Strategy for Wales[5] October 2010	Reduce greenhouse gas emissions by 3% per year from 2011 in areas of devolved competence, against a baseline of average emissions between 2006 and 2010. The transport sector is responsible for approximately a fifth of the emissions covered by the 3% target.
A.6	Welsh Governments Programme for Government[6]Commitment, 2011	Chapter 11 Environment And Sustainability - Living within environmental limits and acting on climate change.
A.7	The Well-being of Future Generations (Wales) Act 2015[7]	The act became law in Wales on 29 April 2015. The act strengthens existing governance arrangements for improving the well-being of Wales to ensure that present needs are met without compromising the ability of future generations to meet their own needs. The act requires all public bodies to embed climate change into their decision-making.
A.8	Environment (Wales) Act 2016[8]– Part 2 Climate Change[9] May 2015	Provides the Welsh Ministers with powers to put in place statutory greenhouse gas emission reduction targets and carbon budgeting to support their delivery. 2050 Greenhouse Gas Emissions Target - To ensure Wales is contributing to the reduction of greenhouse gas emission, the Act places a duty on Welsh Ministers to ensure that in 2050 they are at least 80% lower than the baselines for each greenhouse gas. Interim emission targets – Interim emission targets will be set for 2020,2030, and 2040 and will be introduced by the end of 2018. They will guide the setting of carbon budgets in the medium term and assist in evaluating the progress made towards meeting the long-term 2050 target.

[1] http://www1.bridgend.gov.uk/media/145322/WD76.pdf
[2] http://gov.wales/topics/environmentcountryside/climatechange/emissions/regulations/crc/?lang=en
[3] National Transport Plan Strategic Environmental Assessment Scoping Report, February 2009
[4] http://gov.wales/docs/det/publications/100329ntpen.pdf
[5] http://gov.wales/docs/desh/publications/101006ccstratfinalen.pdf
[6] http://gov.wales/docs/strategies/110929fullen.pdf
[7] http://www.legislation.gov.uk/anaw/2015/2/pdfs/anaw_20150002_en.pdf
[8] http://gov.wales/topics/environmentcountryside/consmanagement/natural-resources-management/environment-act/?lang=en
[9] http://gov.wales/docs/desh/publications/150512-climate-change-en.pdf

	Legislation, Policy or Strategy Document	Carbon-related policy aspirations
A.9	Active Travel (Wales) Act 2013	As part of its 'Rationale for Government Intervention' (see Active Travel (Wales) Bill Explanatory Memorandum), its sets out at (41) that "Encouraging more people to walk or cycle rather than travel by car is also expected to deliver wider benefits through lower greenhouse gas emissions and reduced congestion."
A.10	Planning (Wales) Act 2015	As part its Explanatory Memorandum, its sets out at (7.300) that "delays in development caused by slow decision-making undermine Ministerial aims of encouraging economic recovery and building a sustainable and low-carbon economy."
A.11	Climate Change Act 2008	The Act imposes a duty on the Secretary of State to reduce UK wide greenhouse gas emissions in 2050 to a level which is at least 80% below the level of emissions in 1990. It also obliges the Secretary of State to set carbon budgets for successive five year period and to prepare proposals and policies for meeting those carbon budgets. Part 2 of the Act establishes the Committee on Climate Change. Parts 4 and 5 of the Act impose limited duties and confer limited powers on Welsh Ministers in terms of contributing towards meeting the UK wide carbon targets. The Environment Bill (Wales) 2015 will, when enacted, impose specific carbon budgeting duties on Welsh Ministers similar to those to which the Secretary of State is subject.
A.12	The Wales Spatial Plan (Update 2008)	It is a principle of the Wales Spatial Plan that development should be sustainable. An indicator used to monitor the significant environmental effects and major uncertain effects predicted to result from implementation of the Wales Spatial Plan, is 'Estimated emissions of greenhouse gases in Wales and the UK, million tonnes of carbon dioxide equivalent'.
A.13	Planning Policy Wales (Edition 8, January 2016)	Section 8 of PPW8 refers to the Welsh government's aims to extend choice in transport and secure accessibility in a way which supports sustainable development and helps to tackle the causes of climate change by encouraging a more effective and efficient transport system, with greater use of the more sustainable and healthy forms of travel and minimising the need to travel.
A.14	One Wales: One Planet. (May 2009)	One Wales: One Planet also sets out sustainable development as a core principle of the Welsh Government's founding statute. The Welsh Government has a statutory duty to set out how it proposes to promote sustainable development. Its Scheme for Sustainable Development includes an overarching principle shared with the UK framework, to achieve a sustainable economy: by setting out how we want to transform our economy so that it is low carbon, low waste. In addition, a Main Outcome of its aspiration for sustainable resource use includes that "We have a low carbon transport network which promotes access rather than mobility, so that we can enjoy facilities with much less need for single occupancy car travel."
A.15	Environment Strategy for Wales (2006)	The Environment Strategy for Wales (2006) is the Welsh Government's long-term strategy for the environment of Wales, setting the strategic direction for the next 20 years. The vision is to

	Legislation, Policy or Strategy Document	Carbon-related policy aspirations
		see the distinctive Welsh environment thriving and contributing to the economic and social wellbeing and health of the people in Wales. To achieve this, the Strategy states that the pressures we place on our environment need to be managed more effectively and to address challenges like climate change and sustainable resource use.
A.16	The UK Low Carbon Transition Plan (July 2009)	Within the Low Carbon Plan, a section is dedicated to transport. It highlights that domestic transport in the UK contributes to approximately a fifth of the UK's greenhouse gas emissions. In an effort to combat the increasing emissions the plan states it will: - continue to improve fuel efficiency of new conventional vehicles; - support the low carbon vehicles and fuels of the future; - encourage people to make low carbon travel decisions; and - require international aviation and shipping to reduce emissions.
A.17	Gwynedd Unitary Development Plan 2001-2016 (adopted 2010)	Taking a Precautionary approach – Strategic Policy 1, sets out that development proposals: That would have an adverse or uncertain impact on the environment, the economy or cultural character (including the Welsh language) of the Plan area will be refused unless it can be conclusively shown by an appropriate impact assessment that this can be negated or mitigated in a manner acceptable to the Planning Authority.
A.18	Powys Unitary Development Plan 2001-2016 (adopted 2010)	SP12 – Energy Conservation and Generation All developments shall demonstrate that energy conservation and efficiency measures have been considered and where practicable incorporated. GP1 – Development Control H. The development shall incorporate appropriate measures for energy, water and waste efficiency and conservation (GP3). GP3 – Design and Energy Conservation All proposals for development should make a positive contribution to their local environment and community through imaginative and good quality design, layout, materials and landscaping in accordance with the policies of the UDP. A design statement shall accompany all detailed applications and will describe the actions take to design and adapt the development designed to reduce energy consumption and maximise energy conservation through the use of the appropriate materials, design, layout and orientation.

	Legislation, Policy or Strategy Document	Carbon-related policy aspirations
		T2 Traffic management Sensitively designed traffic managements schemes will be approved which utilise the existing road network and improve opportunities to promote public transport, walking, cycling and horse riding, improve road safety reduce traffic congestion and improve the local environment in order to reduce the level of unnecessary road traffic and its adverse impact upon the environment.

Appendix C

Carbon Briefing Note

Introduction to Carbon Accounting - Terminology

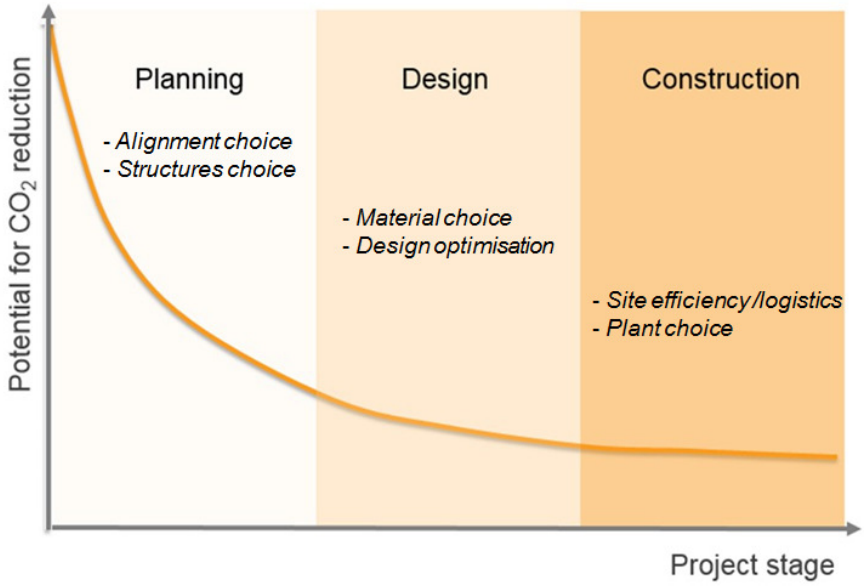
- **Greenhouse gas** (or **GHG** for short) is any gas in the atmosphere which absorbs and re-emits heat, and thereby keeps the planet's atmosphere warmer than it otherwise would be. There are six main greenhouse gases which cause global warming and are limited by the Kyoto protocol. Each gas has a different global warming potential. The six regulated gases are Carbon dioxide (CO_2), Methane (CH_4), Nitrous oxide (N_2O), Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs) and Sulphur hexafluoride (SF_6).
- **Carbon footprint** - The total set of greenhouse gas emissions caused directly and indirectly by an individual, organisation, event or product. Carbon footprints are typically calculated to include all greenhouse gases and are expressed in tonnes of CO2 equivalent (tCO2e)
- **Carbon dioxide (CO_2)** - the most common GHG emitted by human activities, in terms of the quantity released and the total impact on global warming.
- **Carbon dioxide equivalent** or "**CO_{2e}**" is a term for describing different greenhouse gases in a common unit. For any quantity and type of greenhouse gas, CO2e signifies the amount of CO2 which would have the equivalent global warming impact.
- **Embodied carbon** – the amount of carbon released from material extraction, transport, manufacturing, and related activities. This may be calculated from cradle to (factory) gate, cradle to (installation) site, or (ideally) from cradle to grave.

Carbon Emission Factor – a representative value that attempts to relate the quantity of a pollutant released to the atmosphere with an activity associated with the release of that pollutant.

Carbon Accounting – What is in the Works Information Contract

- The Contractor shall be responsible for providing an **indicative carbon footprint** of the carbon emissions associated with delivery of the Scheme.
- The Contractor shall **actively manage, and reduce**, the carbon footprint, wherever possible.
- The Contractor shall include carbon reduction planning in their **design, assessment** and **appraisal work** on the Scheme and provide records for carbon accounting as appropriate for Key Stage 3, Key Stage 4 and Key Stage 6.
- Carbon reduction planning covers the proposed changes to the road network, the design and implementation of the Scheme, waste management and the provision of any offsetting measures, which may be off-site or associated with other projects.

Carbon Reduction during the Project Life Cycle



Opportunities for greater carbon reduction are present at the early stages of a project. As we are now in the design phase, it is critical the design is optimised to reduce the carbon footprint.

Carbon Reduction Plan at Key Stage 3

- The design team must work with the carbon accounting team to identify the most significant cost-effective opportunities to reduce the embodied carbon emissions associated with the Scheme.
- The carbon accounting team will report actions and outcomes as part of the Carbon Report.

Carbon Calculation Approach

- To calculate the carbon footprint, measures of plant, materials, labour and transport are converted into CO2e by using standard emissions factors.
- For example:

Measure of activity	X	Emission Factor	=	Tonnes CO2e
1000 litres of petrol	X	2.315kg CO2/litre	=	2.315 Tonnes CO2e

Types of action the design team should consider and record

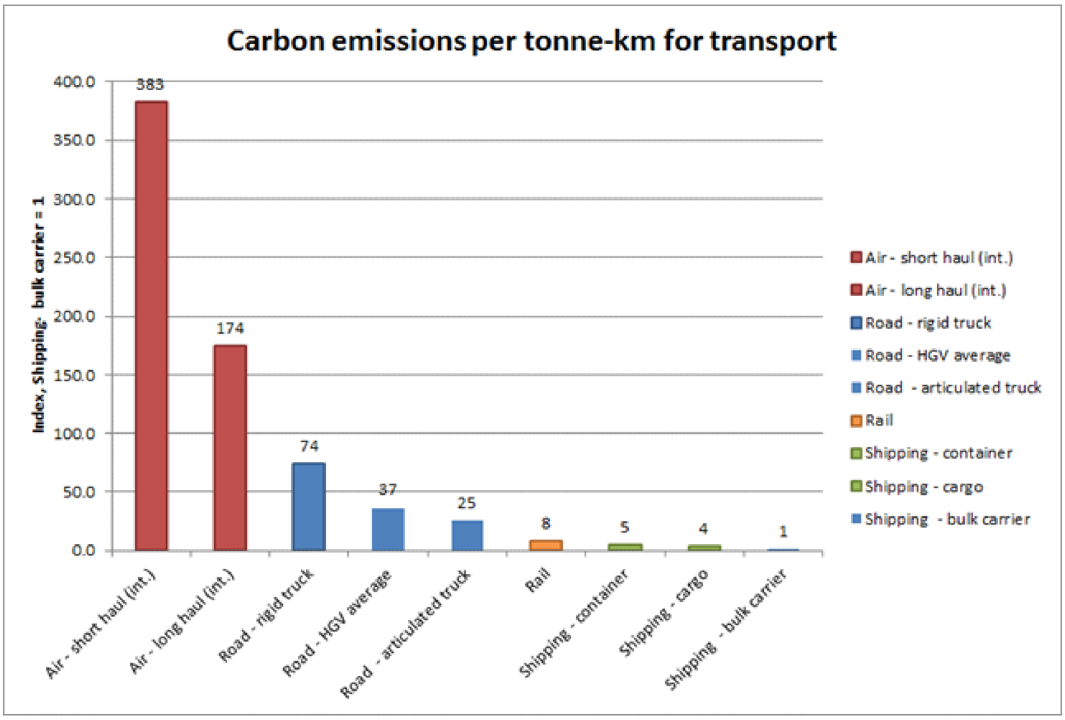
The table provides examples of carbon saving actions which could be considered for the Scheme.

Carbon saving action	**Example**
Using less materials	
Efficient design	Make the most of in-situ materials
Change the specification of elements	Reducing the thickness of carbon-intensive asphalt layers by using hydraulically bound mixtures in the bases and sub-bases
Design for less waste on site	Cut wastage rates on the top 10 materials from baseline to good practice
Design for off-site construction to benefit from lower wastage and efficient fabrication	
Using alternative materials	
Select materials with lower carbon intensities	Buy less energy-intensive materials e.g. cold-mix asphalt, cement substitutes or sustainably-sourced materials such as timber
Select reused or higher recycled content products and materials offering lower carbon intensities	e.g. reclaimed bricks, higher recycled content blocks, locally recycled aggregates
Select materials with lower transport-related carbon emissions	Locally-sourced aggregates
Select materials with high levels of durability and low through-life maintenance	
Designing and implementing energy efficient equipment	
Select most energy efficient and economically viable equipment available	e.g. LED lighting

Transport Consideration - Comparison of Transport Options based on 1 tonne travelling 1km

The bar chart shows how the consideration of transport for materials can impact upon the Schemes carbon footprint.

- For example, the carbon footprint of rail transport is 8 times that of shipping by bulk carrier.
- For road transport, an articulated truck is nearly a third that of a rigid truck.



Appendix D

Carbon Emissions Factors

Appendix D - Carbon Emission Factors

Passenger vehicle carbon factors (source: Defra/ Decc (2015) UK Government conversion factors for Company Reporting)

			Diesel				Petrol				Hybrid			
Activity	Type	Unit	kg CO_2e	kg CO_2	kg CH_4	kg N_2O	kg CO_2e	kg CO_2	kg CH_4	kg N_2O	kg CO_2e	kg CO_2	kg CH_4	kg N_2O
Cars (by size)	Small car	km	0.1437	0.1419	0.0001	0.0017	0.1586	0.1581	0.0001	0.0004	0.108	0.1075	0.0001	0.0004
		miles	0.2312	0.2284	0.0001	0.0027	0.2552	0.2544	0.0002	0.0006	0.1738	0.1731	0.0001	0.0006
	Medium car	km	0.1756	0.1739	0.0001	0.0017	0.1993	0.1988	0.0001	0.0004	0.1177	0.1172	0.0001	0.0004
		miles	0.2826	0.2798	0.0001	0.0027	0.3208	0.3199	0.0002	0.0006	0.1894	0.1887	0.0001	0.0006
	Large car	km	0.2252	0.2235	0.0001	0.0017	0.2907	0.2902	0.0001	0.0004	0.1741	0.1737	0.0001	0.0004
		miles	0.3624	0.3596	0.0001	0.0027	0.4679	0.4671	0.0002	0.0006	0.2802	0.2795	0.0001	0.0006
	Average car	km	0.1823	0.1806	0.0001	0.0017	0.1913	0.1907	0.0001	0.0004	0.1288	0.1283	0.0001	0.0004
		miles	0.2934	0.2906	0.0001	0.0027	0.3078	0.307	0.0002	0.0006	0.2072	0.2064	0.0001	0.0006

			CNG				LPG				Unknown			
Activity	Type	Unit	kg CO_2e	kg CO_2	kg CH_4	kg N_2O	kg CO_2e	kg CO_2	kg CH_4	kg N_2O	kg CO_2e	kg CO_2	kg CH_4	kg N_2O
Cars (by size)	Small car	km									0.1537	0.1529	0.0001	0.0008
		miles									0.2474	0.246	0.0002	0.0013
	Medium car	km	0.1617	0.16	0.0007	0.001	0.1812	0.18	0.0002	0.001	0.188	0.1869	0.0001	0.001
		miles	0.2602	0.2576	0.001	0.0016	0.2916	0.2896	0.0004	0.0016	0.3025	0.3008	0.0002	0.0016
	Large car	km	0.2353	0.2336	0.0007	0.001	0.264	0.2628	0.0002	0.001	0.2431	0.2418	0.0001	0.0013
		miles	0.3786	0.376	0.001	0.0016	0.4248	0.4229	0.0004	0.0016	0.3913	0.3891	0.0001	0.002
	Average car	km	0.1839	0.1823	0.0007	0.001	0.2062	0.205	0.0002	0.001	0.1864	0.1853	0.0001	0.001
		miles	0.296	0.2934	0.001	0.0016	0.3318	0.3299	0.0004	0.0016	0.2999	0.2982	0.0002	0.0015

Activity	Type	Unit	kg CO_2e	kg CO_2	kg CH_4	kg N_2O
Bus	Local bus (not London)	passenger.km	0.1098	0.1089	0.0001	0.0009
	Local London bus	passenger.km	0.0799	0.0794	0.0001	0.0005
	Average local bus	passenger.km	0.1013	0.1004	0.0001	0.0008
	Coach	passenger.km	0.0293	0.0287	0.0001	0.0006

Activity	Type	Unit	kg CO_2e	kg CO_2	kg CH_4	kg N_2O
Rail	National rail	passenger.km	0.0451	0.0448	0.00004	0.0002
	International rail	passenger.km	0.0121	0.012	0.00001	0.0001
	Light rail and tram	passenger.km	0.0546	0.0542	0.00004	0.0004
	London Underground	passenger.km	0.0563	0.0559	0.00004	0.0004

			0% Laden				50% Laden				100% Laden				Average laden			
Activity	Type	Unit	kg CO_2e	kg CO_2	kg CH_4	kg N_2O	kg CO_2e	kg CO_2	kg CH_4	kg N_2O	kg CO_2e	kg CO_2	kg CH_4	kg N_2O	kg CO_2e	kg CO_2	kg CH_4	kg N_2O
HGV (all diesel)	Rigid (>3.5 - 7.5 tonnes)	tonne.km					0.51025	0.50521	0.00013	0.00491	0.27533	0.27281	0.00007	0.00245	0.56246	0.55686	0.00015	0.00545
		km	0.529519	0.52384	0.000149	0.00553	0.575069	0.56939	0.000149	0.00553	0.620619	0.61494	0.000149	0.00553	0.570519	0.56484	0.000149	0.00553
		miles					0.925484	0.916344	0.00024	0.0089	0.99879	0.98965	0.00024	0.0089	0.918162	0.909022	0.00024	0.0089
	Rigid (>7.5 tonnes-17 tonnes	tonne.km					0.27178	0.26915	0.00007	0.00256	0.15271	0.1514	0.00003	0.00128	0.36357	0.35994	0.0001	0.00353
		km	0.628873	0.62192	0.000183	0.00677	0.717713	0.71076	0.000183	0.00677	0.806563	0.79961	0.000183	0.00677	0.698173	0.69122	0.000183	0.00677
		miles	1.012073	1.000883	0.000294	0.010895	1.155047	1.143857	0.000294	0.010895	1.298037	1.286848	0.000294	0.010895	1.1236	1.112411	0.000294	0.010895
	Rigid (>17 tonnes)	tonne.km					0.2327	0.23029	0.00006	0.00234	0.13708	0.13587	0.00003	0.00117	0.17558	0.17383	0.00005	0.0017
		km	0.797484	0.78745	0.000264	0.00977	0.970344	0.96031	0.000264	0.00977	1.143204	1.13317	0.000264	0.00977	1.007974	0.99794	0.000264	0.00977
		miles	1.283426	1.267278	0.000425	0.015723	1.561617	1.545469	0.000425	0.015723	1.839808	1.82366	0.000425	0.015723	1.622177	1.606029	0.000425	0.015723
	All rigids	tonne.km					0.29252	0.28952	0.00008	0.00292	0.17231	0.17082	0.00004	0.00146	0.21445	0.21231	0.00006	0.00208
		km	0.6718	0.66343	0.00022	0.00815	0.81743	0.80906	0.00022	0.00815	0.96306	0.95469	0.00022	0.00815	0.84011	0.83174	0.00022	0.00815
		miles	1.081157	1.067687	0.000354	0.013116	1.315526	1.302056	0.000354	0.013116	1.549895	1.536425	0.000354	0.013116	1.352026	1.338556	0.000354	0.013116
	Articulated (>3.5 - 33t)	tonne.km					0.1441	0.14269	0.00004	0.00138	0.08632	0.08561	0.00002	0.00069	0.13554	0.13419	0.00004	0.00131
		km	0.692186	0.68373	0.00022	0.008236	0.863116	0.85466	0.00022	0.008236	1.034046	1.02559	0.00022	0.008236	0.849436	0.84098	0.00022	0.008236
		miles	1.113965	1.100357	0.000353	0.013255	1.389051	1.375442	0.000353	0.013255	1.664136	1.650527	0.000353	0.013255	1.367035	1.353426	0.000353	0.013255
	Articulated (>33t)	tonne.km					0.10087	0.0998	0.00003	0.00105	0.06291	0.06238	0.00001	0.00052	0.08239	0.08157	0.00002	0.0008
		km	0.698884	0.689	0.000257	0.009627	0.928544	0.91866	0.000257	0.009627	1.158214	1.14833	0.000257	0.009627	0.992854	0.98297	0.000257	0.009627
		miles	1.124744	1.108838	0.000413	0.015493	1.494346	1.47844	0.000413	0.015493	1.863964	1.848058	0.000413	0.015493	1.597843	1.581937	0.000413	0.015493
	All artics	tonne.km					0.10538	0.10426	0.00003	0.00109	0.06312	0.06256	0.00001	0.00054	0.08629	0.08543	0.00002	0.00084
		km	0.75887	0.74886	0.00026	0.00975	0.94608	0.93607	0.00026	0.00975	1.13329	1.12328	0.00026	0.00975	1.00591	0.9959	0.00026	0.00975
		miles	1.221283	1.205173	0.000418	0.015691	1.522568	1.506459	0.000418	0.015691	1.823853	1.807744	0.000418	0.015691	1.618855	1.602746	0.000418	0.015691
	All HGVs	tonne.km					0.1477	0.14617	0.00004	0.00149	0.08785	0.08708	0.00002	0.00074	0.11469	0.11286	0.00005	0.00178
		km	0.718643	0.709463	0.00024	0.00894	0.886678	0.877498	0.00024	0.00894	1.054713	1.045533	0.00024	0.00894	0.922	0.91282	0.00024	0.00894
		miles	1.156544	1.14177	0.000386	0.014388	1.426969	1.412196	0.000386	0.014388	1.697395	1.682621	0.000386	0.014388	1.483815	1.469041	0.000386	0.014388

Fuel carbon factors (source: Defra/ Decc (2015) UK Government conversion factors for Company Reporting)

			Energy - Gross CV				Energy - Net CV				Volume				Tonnes			
Activity	Fuel	Unit	kg CO_2e	kg CO_2	kg CH_4	kg N_2O	kg CO_2e	kg CO_2	kg CH_4	kg N_2O	kg CO_2e	kg CO_2	kg CH_4	kg N_2O	kg CO_2e	kg CO_2	kg CH_4	kg N_2O
	Burning oil	tonnes													3201.1470	3179.1000	8.1300	13.9170
		litres									2.5609	2.5433	0.0065	0.0111				
		cubic metres																
		kWh	0.2494	0.2477	0.0006	0.0011	0.2625	0.2607	0.0007	0.0011								
	Diesel (average biofuel blend)	tonnes													3138.1000	3093.4000	0.9000	43.8000
		litres									2.6238	2.5863	0.0007	0.0368				
		cubic metres																
		kWh	0.2481	0.2446	0.0001	0.0035	0.2640	0.2602	0.0001	0.0037								
	Diesel (100% mineral diesel)	tonnes													3238.7720	3193.9000	0.8610	44.0110
		litres									2.7171	2.6794	0.0007	0.0369				
		cubic metres																
		kWh	0.2554	0.2519	0.0001	0.0035	0.2717	0.2679	0.0001	0.0037								
	Fuel oil	tonnes													3260.0370	3240.7000	3.6000	15.7370
		litres																
		cubic metres																
		kWh	0.2711	0.2695	0.0003	0.0013	0.2884	0.2867	0.0003	0.0014								
	Gas oil	tonnes													3606.1560	3219.8000	3.5790	382.7770
		litres									3.0769	2.7473	0.0031	0.3266				
		cubic metres																
		kWh	0.2867	0.2560	0.0003	0.0304	0.3050	0.2723	0.0003	0.0324								
	Lubricants	tonnes													3217.633	3200.7	3.39	13.543
		litres																
		cubic metres																
		kWh	0.26753	0.2661	0.0003	0.0011	0.2846	0.2831	0.0003	0.0012								
	Petrol (average biofuel blend)	tonnes													3047.2000	3031.4000	4.9000	10.9000
		litres									2.2363	2.2247	0.0036	0.0080				
		cubic metres																
		kWh	0.2374	0.2362	0.0004	0.0009	0.2499	0.2486	0.0004	0.0009								
	Petrol (100% mineral petrol)	tonnes													3205.8770	3189.8000	4.9690	11.1080
		litres									2.3435	2.3317	0.0036	0.0081				
		cubic metres																
		kWh	0.2448	0.2436	0.0004	0.0009	0.2577	0.2564	0.0004	0.0009								
	Processed fuel oils - residual oil	tonnes													3260.0370	3240.7000	3.6000	15.7370
		litres																
		cubic metres																
		kWh	0.2711	0.2695	0.0003	0.0013	0.2884	0.2867	0.0003	0.0014								
	Processed fuel oils - distillate oil	tonnes													3606.1560	3219.8000	3.5790	382.7770
		litres																
		cubic metres																
		kWh	0.2867	0.2560	0.0003	0.0304	0.3050	0.2723	0.0003	0.0324								

UK electricity carbon factors (source: Defra/ Decc (2015) UK Government conversion factors for Company Reporting)

Activity	Country	Unit	Year	kg CO_2e	kg CO_2	kg CH_4	kg N_2O
Electricity generated	Electricity: UK	kWh	2015	0.4621	0.4584	0.0004	0.0033

Steel carbon factors (source: ICE Bath Universtiy)

Material	Embodied Energy - MJ/Kg					Embodied Carbon - Kg CO2e/Kg					Boundaries	Best EE Range - MJ/Kg		Specific Comments
	UK Typical - EU 59% Recy.	R.O.W. Typical - 35.5% Recy.	World Typical - World 39% Recy.	Primary (100% hypothetical virgin)	Secondary	UK Typical - EU 59% Recy.	R.O.W. Typical - 35.5% Recy.	World Typical - World 39% Recy.	Primary (100% hypothetical virgin)	Secondary		Low EE	High EE	
General Steel	20·1	26·2	25·3	35·4	9·40	1.46	2.03	1.95	2.89	0.47	Cradle to Gate	(+/- 30%)		Estimated from UK's consumption mixture of types of steel (excluding stainless). Doesn't include the final cutting of the steel products to the specified dimensions. Estimated from World Steel Association (Worldsteel) data.
Bar & rod	17.4	22.3	21.6	29.2	8·8	1.40	1.95	1.86	2.77	0.45				Doesn't include the final cutting of the bar/rod to length. Estimated from Worldsteel data.
Coil (Sheet)	18·8	24·4	23·5	32·8	*NTMR*	1.38	1.92	1.85	2.74	*NTMR*				NTMR = Not Typical Manufacturing Route. Data doesn't include the cutting of the coil into sheets. Data is as leaves the coil manufacturer. Estimated from Worldsteel data.
Coil (Sheet) - Galvanised	22·6	29·5	28·5	40·0	*NTMR*	1.54	2.12	2.03	3.01	*NTMR*				NTMR = Not Typical Manufacturing Route. Data doesn't include the cutting of the coil into sheets. Data is as leaves the coil manufacturer. Estimated from Worldsteel data.
Engineering steel	-	-	-	-	13·1	-	-	-	-	0.72				Estimated from Worldsteel data.
Pipe	19·8	25·8	24·9	34·7	*NTMR*	1.45	2.01	1.94	2.87	*NTMR*				NTMR = Not Typical Manufacturing Route. Estimated from Worldsteel data.
Plate	25·1	33·2	32·0	45·4	*NTMR*	1.66	2.31	2.21	3.27	*NTMR*				NTMR = Not Typical Manufacturing Route. Doesn't include the final cutting of the plate. Estimated from Worldsteel data.
Section	21·5	28·1	27·1	38·0	10·0	1.53	2.12	2.03	3.03	0.47				Data doesn't include final fabrication stage (cutting of the section). Estimated from Worldsteel data.
Wire	36 (?)					3.02								Uncertain data.
Stainless	56.7					6.15 CO2 only					Cradle to Gate	11	82	World average data from the Institute of Stainless Steel Forum (ISSF) life cycle inventory data. Selected data is for the most popular grade (304). Stainless steel does not have separate primary and recycled material production routes.

Brick carbon factors (source: ICE Bath Universtiy)

Material	Embodied Energy - MJ/Kg	Embodied Carbon - Kg CO2e/Kg	Boundaries	Best EE Range - MJ/Kg		Specific Comments
				Low EE	High EE	
General Clay Bricks	3.0	0.24	Cradle to Gate	0.63	6	
EXAMPLE: Single Brick	6.9 MJ per brick	0.55 kgCO2 per brick		-	-	Assuming 2.3 kg per brick (Brick Development Association estimate)
Limestone Bricks	0.85	?		0.7	1.01	

Mortar carbon factors (source: ICE Bath Universtiy)

Material	Embodied Energy - MJ/Kg	Embodied Carbon - Kg CO2e/Kg
Mortar (1:3 cement:sand mix)	1.33	0.221

Material	Condition	Density (kg m -3)
cement mortar	Dry	1900

Concrete carbon factors (source: ICE Bath Universtiy)

READY MIX CONCRETE (ICE CMC Model Results) BS 8500:2006 CONCRETE DESIGNATIONS							
Material	**Embodied Energy - MJ/kg**			**Embodied Carbon - kgCO2e/kg**			**NOTE: Cradle to Gate**
FLY ASH							
% Cement Replacement - Fly Ash	**0% (using CEM I)**	**15%**	**30%**	**0% (using CEM I)**	**15%**	**30%**	**Note 0% is a concrete using a CEM I cement**
GEN 0 (6/8 MPa)	**0.55**	0.52	0.47	**0.076**	0.069	0.061	**Compressive strength designation C6/8 Mpa. 28 day compressive strength under British cube method of 8 MPa, under European cylinder method 6 MPa**. Possible uses: Kerb bedding and backing. Data is only cradle to factory gate but beyond this the average delivery distance of ready mix concrete is 8.3 km by road (see reference 244).
GEN 1 (8/10 MPa)	**0.70**	0.65	0.59	**0.104**	0.094	0.082	Possible uses: mass concrete, mass fill, mass foundations, trench foundations, blinding, strip footing.
GEN 2 (12/15 MPa)	**0.76**	0.71	0.64	**0.114**	0.105	0.093	-
GEN 3 (16/20 MPa)	**0.81**	0.75	0.68	**0.123**	0.112	0.100	Possible uses: garage floors.
RC 20/25 (20/25 MPa)	**0.86**	0.81	0.73	**0.132**	0.122	0.108	-
RC 25/30 (25/30 MPa)	**0.91**	0.85	0.77	**0.140**	0.130	0.115	Possible uses: reinforced foundations.
RC 28/35 (28/35 MPa)	**0.95**	0.90	0.82	**0.148**	0.138	0.124	Possible uses: reinforced foundations, ground floors.
RC 32/40 (32/40 MPa)	**1.03**	0.97	0.89	**0.163**	0.152	0.136	Possible uses: structural purposes, in situ floors, walls,
RC 40/50 (40/50 MPa)	**1.17**	1.10	0.99	**0.188**	0.174	0.155	Possible uses: high strength applications, precasting.
PAV1	**0.95**	0.89	0.81	**0.148**	0.138	0.123	Possible uses: domestic parking and outdoor paving.
PAV2	**1.03**	0.97	0.89	**0.163**	0.152	0.137	Possible uses: heavy duty outdoor paving.
GROUND GRANULATED BLAST FURNACE SLAG							
% Cement Replacement - Blast Furnace Slag	**0% (using CEM I)**	**25%**	**50%**	**0% (using CEM I)**	**25%**	**50%**	**Note 0% is a concrete using a CEM I cement**
GEN 0 (6/8 MPa)	**0.55**	0.48	0.41	**0.076**	0.060	0.045	See comments for relevant category with fly ash additions (table directly above).
GEN 1 (8/10 MPa)	**0.70**	0.60	0.50	**0.104**	0.080	0.058	
GEN 2 (12/15 MPa)	**0.76**	0.62	0.55	**0.114**	0.088	0.065	
GEN 3 (16/20 MPa)	**0.81**	0.69	0.57	**0.123**	0.096	0.070	
RC 20/25 (20/25 MPa)	**0.86**	0.74	0.62	**0.132**	0.104	0.077	
RC 25/30 (25/30 MPa)	**0.91**	0.78	0.65	**0.140**	0.111	0.081	
RC 28/35 (28/35 MPa)	**0.95**	0.83	0.69	**0.148**	0.119	0.088	
RC 32/40 (32/40 MPa)	**1.03**	0.91	0.78	**0.163**	0.133	0.100	
RC 40/50 (40/50 MPa)	**1.17**	1.03	0.87	**0.188**	0.153	0.115	
PAV1	**0.95**	0.82	0.70	**0.148**	0.118	0.088	
PAV2	**1.03**	0.91	0.77	**0.163**	0.133	0.100	
Material	**Embodied Energy - MJ/Kg**	**Embodied Carbon - Kg CO2e/Kg**					Specific Comments
Average CEM I Portland Cement, 94% Clinker	**5.50**	0.95	Cradle to Gate				This is a standard cement with no cementitious additions (i.e. Fly ash or blast furnace slag). Composition 94% clinker, 5% gypsum, 1% minor additional constituents (mac's). This data has been estimated from the MPA factsheets (see Ref. 59).
General CEMENT (UK weighted average)	**4.51**	0.74	Cradle to Gate				Weighted average of all cement consumed within the UK. This includes all factory made cements (CEM I, CEM II, CEM III, CEM IV) and further blending of fly ash and ground granulated blast furnace slag. This data has been estimated from the Mineral Products Association (MPA) factsheets (see Ref. 59). 23% cementitious additions on average.
General Aggregate	**0.08**	0.01	Cradle to Gate				Estimated from UK industrial fuel consumption data.
General Lime	**5.30**	0.78	Cradle to Gate				Wide range, dependent upon manufacturing technology. Although the embodied energy was higher than for cement the UK lime industry mix of fuels were cleaner thank cement, as such its embodied carbon was lower.
General Sand	**0.01**	0.01	Cradle to Gate				Estimate from UK industrial fuel consumption data

PRECAST (PREFABRICATED) CONCRETE - Modification Factors			
Material	**Embodied Energy - MJ/Kg**	**Embodied Carbon - Kg CO2e/Kg**	
For precast add this value to the selected coefficient of the appropriate concrete mix		**0.029**	For each 1 kg precast concrete. This example is using a RC 40/50 strength class and is not necessarily indicative of an average precast product. Includes UK recorded plant operations and estimated transportation of the constituents to the factory gate. Data is only cradle to factory gate but beyond this the average delivery distance of precast is 155km by road (see Ref. 244). UK weighted average cement. See also the new report on precast concrete pipes (Ref 300).
Precast RC 40/50 MPa		**0.217**	
Precast RC 40/50 with reinforcement (80kg per m^3)		**0.242**	

PRECAST (PREFABRICATED) CONCRETE - Modification Factors			
Material	**Embodied Energy - MJ/Kg**	**Embodied Carbon - Kg CO2e/Kg**	
For precast add this value to the selected coefficient of the appropriate concrete mix		**0.029**	For each 1 kg precast concrete. This example is using a RC 40/50 strength class and is not necessarily indicative of an average precast product. Includes UK recorded plant operations and estimated transportation of the constituents to the factory gate. Data is only cradle to factory gate but beyond this the average delivery distance of precast is 155km by road (see Ref. 244). UK weighted average cement. See also the new report on precast concrete pipes (Ref 300).
GEN 0 (6/8 MPa)		**0.105**	
~~**Precast RC 40/50 with reinforcement (80kg per m^3)**~~	**no need for reinforcement for manhole!!!**		

Plastic carbon factors (source: ICE Bath Universtiy)

Material	Embodied Energy - MJ/Kg	Feedstock Energy (Included) - MJ/Kg	Embodied Carbon - Kg CO2e/Kg
General Plastic	80.5	35.6	3.31
ABS	95.3	48.6	3.76
General Polyethylene	83.1	54.4	2.54
High Density Polyethylene (HDPE)	76.7	54.3	1.93
HDPE Pipe	84.4	55.1	2.52
Low Density Polyethylene (LDPE)	78.1	51.6	2.08
LDPE Film	89.3	55.2	2.6
Nylon (Polyamide) 6	120.5	38.6	9.14
Nylon (Polyamide) 6,6	138.6	50.7	7.92
Polycarbonate	112.9	36.7	7.62
Polypropylene, Orientated Film	99.2	55.7	3.43
Polypropylene, Injection Moulding	115.1	54	4.49
Expanded Polystyrene	88.6	46.2	3.29
General Purpose Polystyrene	86.4	46.3	3.43
High Impact Polystyrene	87.4	46.4	3.42
Thermoformed Expanded Polystyrene	109.2	49.7	4.39
Polyurethane Flexible Foam	102.1	33.47	4.84
Polyurethane Rigid Foam	101.5	37.07	4.26
PVC General	77.2	28.1	3.10
PVC Pipe	67.5	24.4	3.23
Calendered Sheet PVC	68.6	24.4	3.19
PVC Injection Moulding	95.1	35.1	3.30
UPVC Film	69.4	25.3	3.16

Logistics Vehicles carbon factors (source: Defra/ Decc (2015) UK Government conversion factors for Company Reporting)

			0% Laden				50% Laden				100% Laden				Average laden			
Activity	Type	Unit	kg CO_2e	kg CO_2	kg CH_4	kg N_2O	kg CO_2e	kg CO_2	kg CH_4	kg N_2O	kg CO_2e	kg CO_2	kg CH_4	kg N_2O	kg CO_2e	kg CO_2	kg CH_4	kg N_2O
HGV (all diesel)	Rigid (>3.5 - 7.5 tonnes)	km	0.5295	0.5238	0.0001	0.0055	0.5751	0.5694	0.0001	0.0055	0.6206	0.6149	0.0001	0.0055	0.5705	0.5648	0.0001	0.0055
		miles	0.8522	0.8430	0.0002	0.0089	0.9255	0.9163	0.0002	0.0089	0.9988	0.9896	0.0002	0.0089	0.9182	0.9090	0.0002	0.0089
	Rigid (>7.5 tonnes-17 tonnes	km	0.6289	0.6219	0.0002	0.0068	0.7177	0.7108	0.0002	0.0068	0.8066	0.7996	0.0002	0.0068	0.6982	0.6912	0.0002	0.0068
		miles	1.0121	1.0009	0.0003	0.0109	1.1550	1.1439	0.0003	0.0109	1.2980	1.2868	0.0003	0.0109	1.1236	1.1124	0.0003	0.0109
	Rigid (>17 tonnes)	km	0.7975	0.7875	0.0003	0.0098	0.9703	0.9603	0.0003	0.0098	1.1432	1.1332	0.0003	0.0098	1.0080	0.9979	0.0003	0.0098
		miles	1.2834	1.2673	0.0004	0.0157	1.5616	1.5455	0.0004	0.0157	1.8398	1.8237	0.0004	0.0157	1.6222	1.6060	0.0004	0.0157
	All rigids	km	0.6718	0.6634	0.0002	0.0082	0.8174	0.8091	0.0002	0.0082	0.9631	0.9547	0.0002	0.0082	0.8401	0.8317	0.0002	0.0082
		miles	1.0812	1.0677	0.0004	0.0131	1.3155	1.3021	0.0004	0.0131	1.5499	1.5364	0.0004	0.0131	1.3520	1.3386	0.0004	0.0131
	Articulated (>3.5 - 33t)	km	0.6922	0.6837	0.0002	0.0082	0.8631	0.8547	0.0002	0.0082	1.0340	1.0256	0.0002	0.0082	0.8494	0.8410	0.0002	0.0082
		miles	1.1140	1.1004	0.0004	0.0133	1.3891	1.3754	0.0004	0.0133	1.6641	1.6505	0.0004	0.0133	1.3670	1.3534	0.0004	0.0133
	Articulated (>33t)	km	0.6989	0.6890	0.0003	0.0096	0.9285	0.9187	0.0003	0.0096	1.1582	1.1483	0.0003	0.0096	0.9929	0.9830	0.0003	0.0096
		miles	1.1247	1.1088	0.0004	0.0155	1.4943	1.4784	0.0004	0.0155	1.8640	1.8481	0.0004	0.0155	1.5978	1.5819	0.0004	0.0155
	All artics	km	0.7589	0.7489	0.0003	0.0098	0.9461	0.9361	0.0003	0.0098	1.1333	1.1233	0.0003	0.0098	1.0059	0.9959	0.0003	0.0098
		miles	1.2213	1.2052	0.0004	0.0157	1.5226	1.5065	0.0004	0.0157	1.8239	1.8077	0.0004	0.0157	1.6189	1.6027	0.0004	0.0157
	All HGVs	km	0.7186	0.7095	0.0002	0.0089	0.8867	0.8775	0.0002	0.0089	1.0547	1.0455	0.0002	0.0089	0.9220	0.9128	0.0002	0.0089
		miles	1.1565	1.1418	0.0004	0.0144	1.4270	1.4122	0.0004	0.0144	1.6974	1.6826	0.0004	0.0144	1.4838	1.4690	0.0004	0.0144

Clay carbon factors (source: ICE Bath Universtiy)

Selected Embodied Energy & Carbon Coefficients and Associated Data						
Material	**Embodied Energy - MJ/Kg**	**Embodied Carbon - Kg CO2e/Kg**	**Boundaries**	**Best EE Range - MJ/Kg**		**Specific Comments**
				Low EE	**High EE**	
General simple baked clay products	3	0.24	Cradle to Gate	1	5	None
Tile	6.5	0.48		2.88	11.7	
Vitrified clay pipe DN 100 & DN 150	6.2	0.46		Estimated range +/- 30%		
Vitrified clay pipe DN 200 & DN 300	7.0	0.50				
Vitrified clay pipe DN 500	7.9	0.55				
General Clay Bricks	3.0	0.24		0.63	6	
EXAMPLE: Single Brick	6.9 MJ per brick	0.55 kgCO2 per brick		-	-	Assuming 2.3 kg per brick (Brick Development Association estimate)
Limestone Bricks	0.85	?	Cradle to Gate	0.7	1.01	

Material	**Embodied Energy - MJ/Kg**	**Feedstock Energy (Included) - MJ/Kg**	**Embodied Carbon - Kg CO2e/Kg**	**Boundaries**
General Bitumen	51	42	0.49	Cradle to Gate

Selected Embodied Energy & Carbon Coefficients and Associated Data						
Material	**Embodied Energy - MJ/Kg**	**Embodied Carbon - Kg CO2e/Kg**	**Boundaries**	**Best EE Range - MJ/Kg**		**Specific Comments**
				Low EE	**High EE**	
Primary Glass	15	0.91	Cradle to Gate	(+/- 30%)		Includes 0.185 kgCO2/kg of process CO2 emissions.
Secondary Glass	11.5	0.59		(+/- 30%)		EE estimated from Ref 115.
Fibreglass	28	1.54		16.5	42	Large data range, but the selected value is inside a small band of frequently quoted values.
Toughened Glass	23.5	1.35	Cradle to Gate	-	-	Only three data sources

Selected Embodied Energy & Carbon Coefficients and Associated Data						
Material	**Embodied Energy - MJ/Kg**	**Embodied Carbon - Kg CO2e/Kg**	**Boundaries**	**Best EE Range - MJ/Kg**		**Specific Comments**
				Low EE	**High EE**	
General	10	$0.31_{fos}+0.41_{bio}$	Cradle to Gate	High range for all timber products, see main comments for discussion.		Estimated from UK consumption mixture of timber products in 2007 (Timber Trade Federation statistics). Includes 4.4 MJ bio-energy. All values do not include the CV of timber and exclude carbon storage.
Glue Laminated timber	12	$0.42_{fos}+0.45_{bio}$		8	14	Includes 4.9 MJ bio-energy.
Hardboard (High Density Fibreboard)	16	$0.58_{fos}+0.51_{bio}$		15	35	Hardboard is a type of fibreboard with a density above 800 kg/m^3. Includes 5.6 MJ bio-energy.
Laminated Veneer Lumber	9.5	$0.33_{fos}+0.32_{bio}$		-	-	Ref 148. Includes 3.5 MJ bio-energy.
Medium Density Fibreboard (MDF)	11 (?)	$0.39_{fos}+0.35_{bio}$ (?)		Not enough data for accurate range. Likely to be high.		Wide density range (350-800 kg/m^3). limited data to analyse. Includes 3.8 MJ bio-energy.
Oriented Strand Board (OSB)	15	$0.45_{fos}+0.54_{bio}$		Not enough data for accurate range. Likely to be high.		Estimated from Refs. 101 and 148. Includes 5.9 MJ bio-energy.
Particle Board	14.5	$0.54_{fos}+0.32_{bio}$ (?)		4	15	Very large data range, difficult to select appropriate values. Includes 3.4 MJ bio-energy (uncertain estimate).
Plywood	15	1.1		10	20	Includes 7.1 MJ bio-energy.
Sawn Hardwood	10.4	0.87		0.72	16	It was difficult to select values for hardwood, the upper end of the range was estimated from the CORRIM studies (Ref. 86).
Sawn Softwood	7.4	0.59		0.72	13	Includes 4.2 MJ bio-energy.
Veneer Particleboard (Furniture)	23	(?)		(perhaps +/- 40%)		Unknown split of fossil based and biogenic fuels.

Material	**Condition**	**Thermal conductivity (W-m-1 K-1)**	**Density (kg m -3)**	**Specific heat (J kg-1 K-1)**	**Thermal Diffusivity (M^2 S-1)**
softwood		0.12	510	1380	1.705E-07
hardwood (unspecified)		0.05	90	2810	1.977E-07
softwood		0.12	510	1380	1.705E-07
timber	At 50'C	0.072	480	1680	8.929E-08
timber flooring		0.14	650	1200	1.795E-07
hardboard		0.08	600	2000	6.667E-08

Material Properties (CIBSE Data) for Concrete					
Material	**Condition**	**Thermal conductivity (W-m-1 K-1)**	**Density (kg m -3)**	**Specific heat (J kg-1 K-1)**	**Thermal Diffusivity (M^2 S-1)**
dense		**1.7**	**2200**	**840**	**9.2E-07**
compacted,		**2.2**	**2400**	**840**	**1.09E-06**
dense, reinforced		**1.9**	**2300**	**840**	**9.83E-07**
compacted		**2.3**	**2500**	**840**	**1.1E-06**
Concrete blocks/tiles					
block, aerated		0.24	750	1000	3.2E-07
block, heavyweight, 300mm		1.31	2240	840	6.96E-07
block, lightweight, 150mm		0.66	1760	840	4.46E-07
block, lightweight, 300mm		0.73	1800	840	4.83E-07

Data source: Assessing the CO2 impact of current and future rail track in the UK, Department of Engineering, University of Cambridge (2009)

Embedded carbon Factors						
Rail Section	Weight (kg/metre)	kgCO2/kg	Service life (years) (min)	Service life (years) (max)	Service life (years) (Central value)	Service life factor for defined assessment period
Conventional Rail	74	2.78	22	49	35.5	2
BB embedded rail track	74	2.64	22	49	35.5	2
Double-headed embeded rail track	74	2.64	44	98	71	1
Double-headed conventional track	60	2.78	34	76	55	2
Quadruple-headed embedded rail track	112	2.64	88	198	143	1

Desnity of steel

Material Properties (CIBSE Data)						
Material	**Condition**		**Thermal conductivity (W m-1 K-1)**	**Density (kg m -3)**	**Specific heat (J kg-1 K-1)**	**Thermal Diffusivity (M^2 S-1)**
stainless steel, 5% Ni			29	7850	480	7.6964E-06
stainless steel, 20% Ni			16	8000	480	4.1667E-06
steel			45	7800	480	1.2019E-05

Water supply emissions

Activity	Type	Unit	kg CO_2e
Water supply	Water supply	cubic metres	0.344
		million litres	344.0

Material	**Condition**	**Thermal conductivity (W-m-1 K-1)**	**Density (kg m -3)**	**Specific heat (J kg-1 K-1)**	**Thermal Diffusivity (M^2 S-1)**
Bitumen, composite, flooring		0.85	2400	1000	3.54E-07
Bitumen, insulation, all types		0.2	1000	1700	1.18E-07

Selected Embodied Energy & Carbon Coefficients and Associated Data							
Material	**Embodied Energy - MJ/Kg**	**Feedstock Energy (Included) - MJ/Kg**	**Embodied Carbon - Kg CO2e/Kg**	**Boundaries**	**Best EE Range - MJ/Kg**		**Specific Comments**
					Low EE	**High EE**	
General Bitumen	51	42	0.43 - 0.55 (?)	Cradle to Gate	(+/- 30%)		Uncertain embodied carbon

Selected Embodied Energy & Carbon Coefficients and Associated Data							
Material	**Embodied Energy - MJ/Kg**	**Feedstock Energy (Included) - MJ/Kg**	**Embodied Carbon - Kg CO2e/Kg**	**Boundaries**	**Best EE Range - MJ/Kg**		**Specific Comments**
					Low EE	**High EE**	
Asphalt, 4% (bitumen) binder content (by mass)	2.86	1.68	0.066	Cradle to Gate	(+/- 30%)		Modelled from the bitumen binder content. The fuel consumption of asphalt mixing operations was taken from the quarry products association, it represents typical UK industrial data. Feedstock energy is from the bitumen content.
Asphalt, 5% binder content	3.39	2.1	0.071				
Asphalt, 6% binder content	3.93	2.52	0.076				
Asphalt, 7% binder content	4.46	2.94	0.081				
Asphalt, 8% binder content	5.00	3.36	0.086				

Material Properties (CIBSE Data)						
Material	Condition	Thermal conductivity (W-m-1 K-1)	Density (kg m -3)	Specific heat (J kg-1 K-1)	Thermal Diffusivity (M^2 S-1)	Comments
Asphalt A		0.5	1700	1000	2.941E-07	The CIBSE guide provides two sets of values from different sources
Asphalt B		1.2	2300	1700	3.069E-07	
poured		1.2	2100	920	6.211E-07	
reflective coat		1.2	2300	1700	3.069E-07	
roofing, mastic		1.15	2330	840	5.876E-07	

Selected Embodied Energy & Carbon Coefficients and Associated Data							
Material	Embodied Energy - MJ/Kg	Feedstock Energy (Included) - MJ/Kg	Embodied Carbon - Kg CO2e/Kg	Boundaries	Best EE Range - MJ/Kg		Specific Comments
					Low EE	High EE	
Epoxide Resin	137	42.6	5.7 CO2 only	Cradle to Gate	(+/- 20%)		Source: www.plasticseurope.org
Mastic Sealant	62 to 200	?	?	Cradle to Gate	-	-	Only two data sources, with large range, data includes an unknown value of feedstock energy.
Melamine Resin	97	18	4.19 CO2 only	Cradle to Gate	(+/- 30%)		Feedstock energy 18 MJ/kg - estimated from Ref. 34.
Phenol Formaldehyde	88	32	2.98 CO2 only	Cradle to Grave	-	-	Feedstock energy 32 MJ/kg - estimated from Ref. 34.
Urea Formaldehyde	70	18	2.76 CO2 only	Cradle to Site	(+/- 30%)		Feedstock energy 18 MJ/kg - estimated from Ref. 34.

Source: Measuring the carbon footprint of road surface treatments
Alan Spray, Tony Parry and Yue Huang

Item	unit	kgCO2e/unit	source
aggregate	tonne	5.2	see paper
articulated hgv >3.5-33t	km	1.08	see paper
articulated hgv >33t	km	1.21	see paper
bitumen emulsion (residual bitumen)	tonne	220	see paper
calcinated bauxite	tonne	124	see paper
cement	tonne	950	see paper
compressed natural gas	litres	1.66	see paper
diesel	litres	3.17	see paper
eva	tonne	1700	see paper
gas oil	litres	3.6	see paper
heavy fuel oil	MJ	0.09	see paper
lime	tonne	780	see paper
lgp	litre	1.72	see paper
mineral oil	tone	420	see paper
petrol	litre	2.72	see paper
polymer modified bitumen emulsion	tonne	350	see paper
polymer modified resins	tonne	6000	see paper
resins	tonne	5800	see paper

Appendix E

Assumptions made in Carbon Assessment

Labour

No.	Assumption
1	Assumed that the average working day for labourers is 9 hours. Divided total working hours (Usage Rate) by 9 to estimate number of trips made by the labour force and multiplied by 2 to assume a return trip
2	Assumed that the average single trip is 20 km long (40km return) by the labour force
3	100% of the labour force travels by car. Assumed there is no public transport access to the site

Plant

No.	Assumption
1	The average working day is 9 hours - but cannot assume that plant equipment will be in use for 100% of the time. For example, lighting or concrete mixers won't be used every single minute of the 9 hours therefore a 50% usage rate is assumed
2	Assumed a 50 hour working week (9 hours Mon-Fri, and 5 hours on Sat)
3	For lighting assumed a 15 kW generator was needed
4	Compressed air tools - no data on energy consumptions (kWh or lts of diesel)
5	Compressors - assumed an average of 15 lts/hr consumption (range size 20-150kW)
6	Lighting - assumed a 15kW generated used
7	Mixers - assumed an average of 3 lts/hr consumption (range size 5 - 20kW)
8	Concrete Mixers - assumed around 5 ltr/hr of diesel consumptions, or a power rating of 167kW for a large concrete mixer
9	Water pump - assumed an average power rating of 15kW (electric water pump)
10	Concrete equipment - no energy use
11	Concrete pumps - assumed an average power rating of 100kW (vehicle size range 24-42 m truck concrete pump)
12	Cherry pickers - assumed an average fuel use of 8 ltr/hr (size range 40-60ft reach) based on 'access platforms' data
13	Scaffolding - no fuel consumption, assumed hired material and scoped out of the assessment
14	Scissor lifts - assumed to be similar to cherry pickers, 8 lts/hr fuel use, data based on 'access platforms' data
15	Crawler cranes - assumed fuel use to differ depending on weight and size of the crane, ranging from 20 to 40 ltr/hr (50 to 600 tonne crane)

No.	Assumption
16	Mobile cranes - assumed average fuel use of 36 lts/hr (range of size 100 - 300kW)
17	JCBs - assumed average fuel use of 11 lts/hr
18	Compactors & Rollers - assumed average fuel use of 8.5 lts/hr (range of size 10 -100kW)
19	Dumpers - assumed average fuel use of 5 lts/hr apart for the larger 23t dumper where we assumed 39 lts/hr. Rest of dumpers size ranged 5-9t
20	Tracked excavators - assumptions on fuel consumption based on size (t): 12t - 13 lts/hr, 20t - 21 lts/hr, 32t - 38 lts/hr
21	Rubber ducks - fuel consumption assumptions based on size (t): 13t - 31 lts/hr, 20t - 21 lts/hr
22	Manhole boxes - assumed to be hire equipment and re-useable so scoped out of the assessment and is not fuel consuming equipment
23	Trench boxes - assumed to be hire equipment and re-useable so scoped out of the assessment and is not fuel consuming equipment
24	Trench sheets - assumed each sheet is 600mm wide and 50kg/m width. Assumed made of steel and not temporary so included in assessment
25	Piling plant - assumed crawler mounted rig with 150kW size engine
26	Environmental plant (siltbuster, 6yrd skip, TVCB and cash plant) assumed to be re-useable equipment and excluded from the carbon assessment

Material

No.	Assumption
1	Bricks - assumed 2.3kg per brick, and ready-mix mortar 1:3 density if 1,900 kg/m3
2	Concrete - assumed 2,200 kg/m3, ST1 = GEN0, ST2 = GEN1, ST4 = RC 25/30, and that zero recycled content (flyash or ggbs) is specified
3	Portland Cement - assumed 2,200 kg/m3, CEM1 Portland Cement
4	C32/40 pump mix - assume a density of 2,300 kg/m3
5	Grano - assumed similar to general or typical aggregates
6	Precast concrete for beams - assumed RC40/50 with steel reinforcement concrete specified w/ zero fly ash or ggbs
7	DtP granular fill - assumed general aggregates carbon factor

No.	Assumption
8	Drainage aggregates - again, assumed the same as general aggregates carbon factor
9	Pavement aggregates - assumed the same as general aggregates carbon factor
10	Sand aggregates - assumed to be the same as general or typical sand (applied carbon factor)
11	Single size aggregates, aggregate & fill sundries and surfacing - assumed density of 2.1t/m3
12	Teram 3000 aggregate- assumed made of polyethylene / polypropylene
13	Surfacing - assumed the same as general aggregate density of 2.3 t/m3
14	Muckaway - assumed this was construction / excavation waste removal using >17t rigid vehicles with 8.5m3 capacity
15	Muckaway - assumed distance travelled 19.3km
16	Muckaway - assumed that trip out the vehicle load is full (100%) and return is empty (o%)
17	Manhole covers - assumed to be made of precast concrete with 1.9t/m3 density
18	Tokstrip - assumed to be rubber sealant (PVC injection molding) with density of 1.32 grams/m3
19	Vitrified clay pipes - assumed to be 1cm thick and clay to have a density of 1.9 t/m3 (same a clay tiles)
20	Plastic pipes & ducts - assumed to be made of HDPE plastic and typical length of 6m per unit. 150mm = 1.5 kg/m, 225mm = 3.7 kg/m, 300mm = 5.9 kg / m
21	UPVC perforated land drain - assumed to be made of HDPE plastic and typical length of 6m per unit. 150mm = 1.5 kg/m, 225mm = 3.7 kg/m, 300mm = 5.9 kg / m
22	Permeable drainage layer - assume 270 g/m2 of polyethylene / polypropylene
23	PCC prestressed beams - assumed a 225mm beam with 57 kg/m of unit, and each beam being 24.7m long. Assumed precast concrete
24	PCC culverts - depending on size of culvert had 10t or 18t per culvert with headwalls 450mm thick, and 1.9t/m3 precast concrete density
25	Bridge bearings - assumed that all bearings weight and average of 23 kg/ unit and made of steel
26	Waterproofing - assumed that bitumen paint weighed 1kg per litre of paint
27	EMJ GRP panels - assumed 14.5 kg/m2, made of steel reinforced glassfibre
28	Rebar - assumed steel with typical UK recycled content
29	Assumed that all reinforcement mesh and sundries is either engineering steel or steel wire
30	Drainage equipment (pipes etc) assumed to be HDPE plastic with varying weights (1.5 to 3.6 kg per meter of pipe)

No.	Assumption
31	Pourform is assumed to be plywood formwork with a density of 9.3 kg/m2, along with separate softwood formwork (assumed to be sawn softwood) of 510 kg/m3
32	Mould oil assumed to be lubricant oil (0.85 kg/ltr)
33	Tie rods (0.029 kg/m) waler plate bolts (1.3 - 2.3 kg/unit) and racking prop connectors (0.5 kg/unit) all assumed to be made of engineering steel
34	Nails, clamps and bolts (0.5 kg/m2) assumed to be all made of engineering steel
35	Traffic Management equipment, cones and signs (0.77 kg/unit) all assumed to be made of engineering steel
36	Wood (90 kg/m2) assumed to be general hardwood, and marine plywood (540 kg/m2) assumed to be typical plywood
37	Expanded mesh assumed to be made of engineering steels (2.0 kg/m2)

Transport

No.	Assumption
1	It was assumed that construction material would be transported to site by road
2	The vehicle type assumed is a Rigid Lorry (>17 tonnes, 100 % layden i.e. that the lorries are full)
3	Distances travelled assumed either 50, 100 or 150 km
4	A return trip was not included as it was assumed that lorries may have had other deliveries as well

Sub-contractor and Earthworks

No.	Assumption
1	It was assumed that engineering steel would be used for the viaduct
2	Surfacing (material use) - Cement bound granular material and sub base was assumed to be similar to 'general aggregate' with a density of 2,240 kg/m3
3	Surfacing (material use) - Dense bitumen macadam (DBM50) was assumed as similar as 'general bitumen', again with a density of 2,240 kg/m3

No.	Assumption
4	Surfacing (material use) - The thin surface course system (35mm thick) as assumed to be asphalt (8% binder) with a density of 2,300 kg/m3
5	Surfacing (plant) - 'Plane out 100mm depth' assumed to be the use of a milling machine (550 m3/hr and 145 litres/hr)
6	Surfacing (plant) - 'High friction surfacing' assumed to be the use of a polymeric binder (1.35kg/m2) and calcinated bauxite (7.5 kg/m2)
7	Surfacing (plant) - 'Perforation of redundant pavement' assumed the same energy use of a milling maching (550 m3/hr and 145 litres/hr)
8	Earthworks excavation (plant) - assumed a rate of 185 m3/hr (gang) and 32 litres/hr (machinery)
9	Earthworks excavation (plant) - assumed a rate of 185 m3/hr (gang) and 32 litres/hr (machinery)
10	Earthworks imported fill (plant) - 1,460 kg/m3 (common earth) and 7,862,897 tonne-kms
11	Earthworks (material) - the use of geotextile lining assumed to be HDPE membrane (0.25 - 3.5mm thick with a density of 940 kg/m3)
12	Piles (material) - 150 kg/m3 of steel (rebar)
13	Piles (material) - assumed GEN1 (8/10 Mpa) concrete used at a density of 2,400 kg/m3
14	Precast Piles (material) - assumed 900,000 m of pilling in total with pile dimensions of 0.275m * 0.275m
15	Ground remediation - 2.36 kgCO_2e per m3 of soil treated (source: Celtic enGlobe)
16	Communication (material) - duct chambers size (1m*1m with a 10cm thickness), copper cables (0.30 kgCO_2e/m), gantries (6t rebar and 30 m3 of concrete/unit), CCTV cameras (3 m3 of concrete/unit, and 0.5t steel/unit), cabinets (1 m3 of concrete/unit, and 0.15 t of steel/unit), and Cantilever gantries and signs (6 m3 of concrete/unit, and 1t of steel/unit)
17	Communication (labour) - assumed 120,000 manhours, 9hr day, 15km single trip to site
18	Communication (labour) - 60,000 hrs of van use (1.5ltrs/hr)
19	Communication (labour) - JCB or Hiab use (20,000 hrs at 13 litres/hr based on a 60kw excavator hydraulic backbone)

Appendix F

Breakdown of CO_2e in different construction activities

Item	Description	CO_2 e (tonnes)				
		Labour	Plant	Material	Total	%
1	Preliminaries (including traffic management and temporary works)	39	1,292	854	2,185	18.0%
2	Site Clearance	0	4	0	4	0.0%
3	Fencing	0	4	21	24	0.2%
4	Road Restraint Systems	1	35	247	283	2.3%
5	Drainage & Service Ducts	2	31	105	139	1.1%
6	Earthworks	14	232	0	247	2.0%
7	Pavements	1	18	993	1,012	8.4%
8	Kerbs, Footways, Paved Areas	1	17	473	491	4.1%
9	Traffic Signs and Road Markings	0	7	13	20	0.2%
10	Road Lighting Columns	0	1	7	8	0.1%
11	Electrical Work (Inc. Communications Ducts)	0	3	5	8	0.1%
12	Motorway Communications	0	2	13	16	0.1%
13	Piling	4	90	457	551	4.5%
14	Structural Concrete	28	466	2,431	2,925	24.1%
15	Steelwork for Structures	15	457	3,184	3,656	30.2%
16	Protection of Steelwork against Corrosion	0	0	0	0	0.0%
17	Waterproofing for Structures	1	21	150	171	1.4%
18	Bridge Bearings	1	18	130	149	1.2%
19	Bridge Expansion Joints and Sealing of Gaps	1	14	105	120	1.0%
20	Accommodation Works, Works for Statutory Undertakers, Provisional Sums and Prime Cost Items	1	11	28	40	0.3%
21	Landscape & Ecology	1	11	31	42	0.3%
22	Aftercare	0	3	24	27	0.2%
	Total	**109**	**2,737**	**9,270**	**12,116**	**100.0%**