WYCA OBC and FBC Carbon Assessment Guidance

Methodologies for quantitative carbon analysis as part of the WYCA Assurance Process

January 2022

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Issue and Revision Record

Revision	Date	Originator	Checker	Approver	Description
First draft	19.01.21	RM	BH	MC	First draft for client comment
Revision 2	27.04.21	EK, AN, RM, HR, SS	BH		Latest draft for client review
Revision 3	21.05.21	EK, AN, HR, SS, DO	RM	MC	Updated draft for client review
Revision 4	06.09.21	BH, DO, HR	MZ	MC	To issue
Revision 5	26.01.22	BH	MZ	MR	Final version to issue (update to previous revision, to include further information on the counterfactual in section 3)

Document reference:

Information class: Standard

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Glossary

AMAT	Active Mode Appraisal Toolkit
BEIS	UK Government Department for Business, Energy & Industrial Strategy
CHP	Combined Heat and Power
CIBSE	Chartered Institution of Building Services Engineers
CO_2e	Carbon Dioxide Equivalent
DEC	Display Energy Certificate
DfT	Department for Transport
DHN	District Heat Network
DLF	Distribution Loss Factor
DM	Do-minimum
DS	Do-something
EFT	Emission Factors Toolkit
EfW	Energy from Waste
EPC	Energy Performance Certificate
EU ETS	European Union Emissions Trading System
FBC	Full Business Case
GHG	Greenhouse Gas
GLA	Greater London Authority
HGV	Heavy Goods Vehicle
ICE	Inventory of Carbon & Energy
JT	Journey Time

kWh	Kilowatt-hour
kWp	Kilowatts Peak
LCA	Life-cycle Assessment
LETI	The London Energy Transformation Initiative
LGV	Large Goods Vehicle
MEC	Marginal External Costs
OBC	Outline Business Case
OGV	Ordinary Goods Vehicle
PEA	Predicted Energy Assessment
PSV	Public Service Vehicle
RICS	Royal Institution of Chartered Surveyors
RSSB	Rail Safety and Standards Board
TAG	Transport Analysis Guidance
TDCV	Typical Domestic Consumption Value
TUBA	Transport Users Benefit Appraisal
UK GBC	United Kingdom Green Building Council
V.KM	Vehicle Kilometre
VKT	Vehicle Kilometres Travelled
WCC	Woodland Carbon Code
WLC	Whole Life Carbon
WYCA	West Yorkshire Combined Authority

Definitions

Definitions largely taken from PAS 2080: Carbon Management in Infrastructure[1] unless otherwise specified.

Baseline

Scenario for what carbon emissions would have been in the absence of planned measures aiming to reduce emissions.

Capital carbon

GHG emissions associated with the creation, refurbishment and end of life treatment of an asset.

Note: *The term capital carbon is being adopted in the infrastructure sector as it accords with the concept of capital cost. The related term 'embodied carbon' will continue to be used at a product or material level whereas capital carbon will have greater relevance at an asset level.*

Carbon dioxide equivalent (CO_2e)

Unit for comparing the radiative forcing of a greenhouse gas to carbon dioxide.

Note: *Carbon emissions are usually reported as tonne CO_2e (tCO_2e). In all cases, this refers to metric tonnes.*

Emissions factor

Amount of greenhouse gases emitted, expressed as CO_2e and relative to a unit of activity.

Greenhouse gas (GHG) emissions

Gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of infrared radiation emitted by the Earth's surface, the atmosphere, and clouds.

Note 1: *The term 'carbon' is often applied as shorthand for GHGs as defined by the UNFCC Kyoto Protocol six main greenhouse gases.*

Note 2: *The UNFCCC Kyoto Protocol six main greenhouse gases include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6).*

Operational carbon

GHG emissions associated with the operation of infrastructure required to enable it to operate and deliver its service.

Scope 1

"GHG emissions from sources located within the city boundary"[2]

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[1] The British Standards Institution (2016). *PAS 2080: Carbon Management in Infrastructure*.

[2] Greenhouse Gas Protocol (no date). *Global Protocol for Community-Scale Greenhouse Gas Emissions Inventory*. Available online: GHGP_GPC_0.pdf (ghgprotocol.org). (Note that these definitions are different from the corporate version of the GHG Protocol, and that the term city would apply to the region or administrative boundary)

Scope 2	"GHG emissions occurring as a consequence of the use of grid-supplied electricity, heat, steam and/or cooling within the city boundary"[2]
Scope 3	"All other GHG emissions that occur outside the city boundary as a result of activities taking place within the city boundary" [2]
System boundary	Set of criteria specifying the life cycle, spatial and temporal extent of a GHG quantification or management system
Traded emissions	"The traded sector covers emissions from power and heat generation, energy-intensive industry and aviation. Emissions arising from electricity consumption in transport are in the traded sector."[3]
TUBA	"The Transport Users Benefit Appraisal (TUBA) software undertakes the economic appraisal of transport schemes in accordance with the Department for Transport's cost benefit analysis guidance. The software implements a 'willingness to pay' approach to economic appraisal for multi-modal schemes with fixed or variable demand."[4]
Untraded emissions	The untraded sector covers all other emissions that are not covered under the traded sector. Emissions from petrol, diesel and gas oil transport fuels are in the non-traded sector.[3]

[3] DfT (2021). *TAG unit A3 environmental impact appraisal*. Available online: TAG unit A3 environmental impact appraisal - GOV.UK (www.gov.uk).

[4] DfT (2020). *Transport users benefit appraisal: software and user manuals*. Available online: Transport users benefit appraisal: software and user manuals - GOV.UK (www.gov.uk).

1 Introduction

1.1 What should this guidance be used for?

This guidance document provides instructions on how to quantify Greenhouse Gas (GHG) emissions[5] as part of the West Yorkshire Combined Authority (hereafter referred to as the Combined Authority) Assurance Framework. It should be used at Outline Business Case (OBC) and Full Business Case (FBC) stages (Activities 3 and 4 within Figure 1-1).

The guidance provides a consistent approach to carbon impact assessment across the Combined Authority. The objectives are to:

1. Identify the key carbon emissions associated with a project that require a quantitative carbon assessment;
2. Determine what data is required to undertake the carbon assessment; and
3. Provide the methodologies that should be used to calculate the emissions associated with a scheme.

1.2 When should this guidance be used?

This guidance has been developed for use during Stage 2 of the Assurance Framework, namely the OBC and FBC stages, as shown in Figure 1-1 below. The methodologies described within this guidance have been designed for flexibility, given that scheme knowledge is likely to depend upon project maturity.

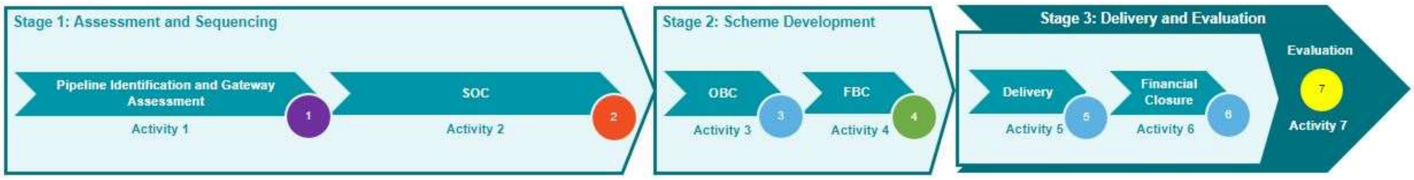

Figure 1-1: Draft Assurance Process (Source: WYCA, 2021)[6]

Note that the process for OBC and FBC assessments is expected to be similar, however the project promoter should endeavour to update the assessment results when more detailed information has become available, likely at the FBC stage. This will also enable the impact of carbon reduction measures which have been adopted since OBC stage to be included in the assessment.

Some types of projects (for example, buildings) will be required to undergo a more detailed assessment at a later date to comply with other relevant regulations. Such results will supersede the initial carbon assessments undertaken during Stage 2 of the Assurance Framework.

[5] Note that GHG emissions refer to all GHGs covered by the Kyoto Protocol. These are measured in units of carbon dioxide equivalent (CO_2e) which expresses the amount of carbon dioxide that would create the same impact. GHGs are commonly referred to as carbon, and both terms are used in this report.

[6] WYCA (2021). *West Yorkshire Combined Authority Assurance Framework*. Available online: AssuranceFramework.pdf (moderngov.co.uk).

1.3 Who should use this guidance?

This guidance has been developed for use by project promoters. Note that in some instances, it is recommended to utilise carbon specialists where a greater level of technical knowledge may be required.

1.4 How to use this guidance effectively

In the first instance, read Section 2: Assessment principles and Section 3: Guidance on filling out the proforma. The reader should then navigate to the most appropriate methodology for the component of the scheme that is being assessed.

Where a scheme is composed of a combination of scheme components, complete the methodologies for all appropriate scheme components and collate the results to provide an estimate of the total scheme carbon impact.

A detailed, overarching methodology has been provided separately for 'Capital carbon'. In addition, the methodology and basis for induced demand impacts on traffic are described in Appendix B.

The process described herein to use the guidance has been summarised as per Figure 1-2 below.

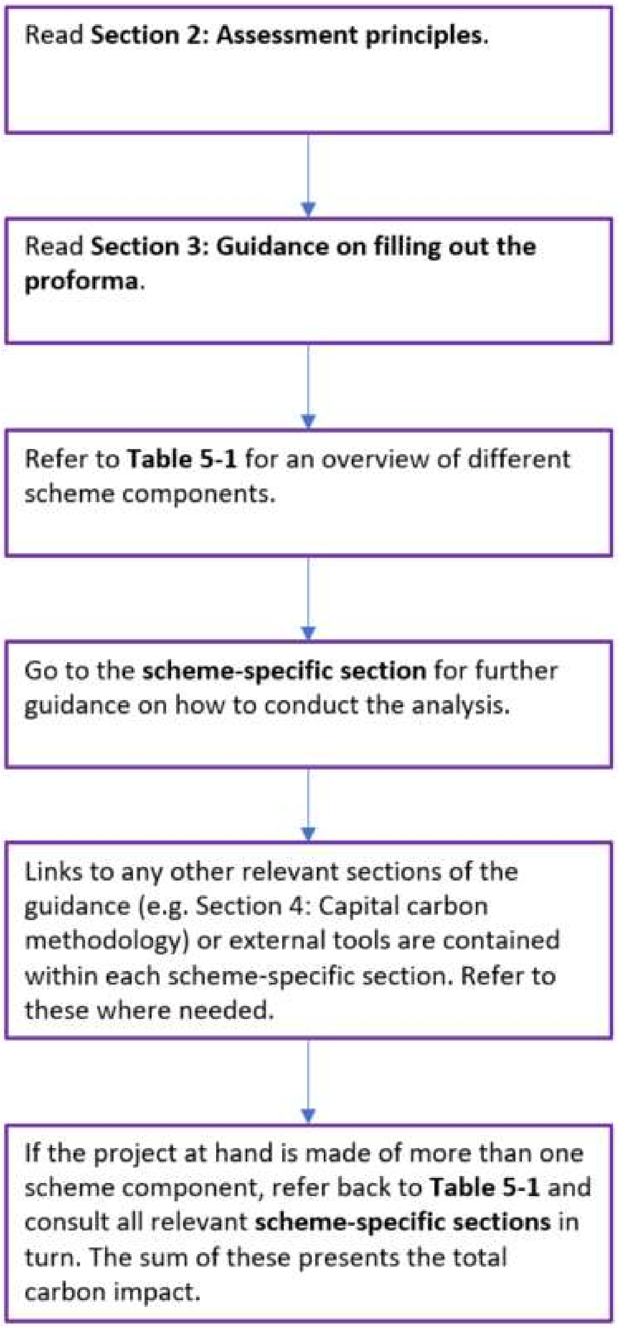

Figure 1-2: Steps to follow this guidance note

2 Assessment principles

An assessment of a scheme's carbon impact should be completed as standard on all projects[7]. This section provides some general assessment principles to be aware of when completing any carbon impact assessment.

The general approach to calculating the carbon associated with an activity is shown in Figure 2-1. This approach is applied when quantifying both operational and capital carbon emissions. More granular "activity" data will provide a more detailed and accurate assessment, however in the absence of project specific data, appropriate benchmarks can also be used under the same approach (e.g., the activity is constructing 'x' metres of cycle path, and the carbon conversion factor is a benchmark expressing carbon emissions per metre of cycle path constructed).

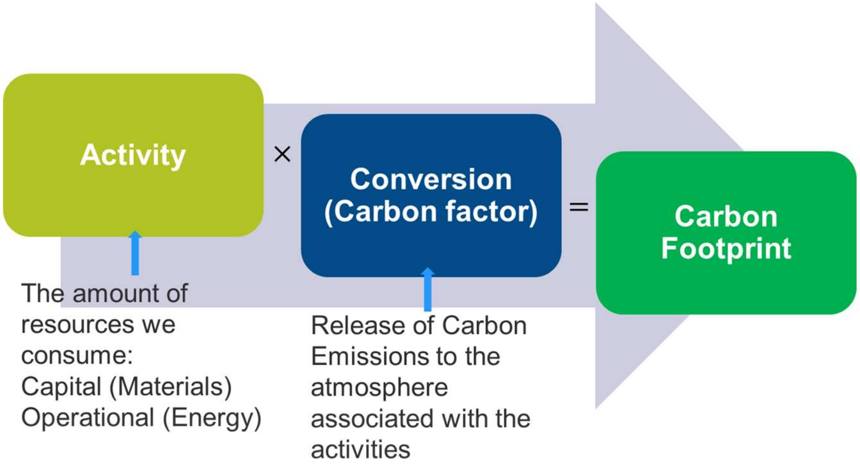

Figure 2-1: How to quantify carbon emissions

The information in Table 2-1 demonstrates standard carbon assessment principles to ensure consistent assessment philosophies are applied across the Combined Authority. These principles should be applied when undertaking carbon assessments on all scheme types. It should be noted that the table below provides general carbon assessment principles, the relevant scheme specific guidance provided in following chapters should also be consulted.

Table 2-1: Overview of carbon assessment principles

Scope of assessment		
1.	Identify assessment boundary	The assessment boundary adopted for carbon quantification should align with the boundary defined for the economic assessment of the scheme. Further benefits which are captured within the strategic case may be qualitatively assessed.
2.	Establish whether quantification is needed	Potential carbon emissions sources within the system boundary should be identified and screened to determine whether a carbon emissions quantification is necessary

[7] It is recommended that a carbon impact assessment is completed in all cases. However, in instances where completing a carbon impact assessment is being scoped out then there must be a justified reason to do so, backed up with alternative guidance or standards.

	for relevant emissions sources	(using the thresholds within this guidance to help inform the decision). The carbon emission sources to consider are as follows: • Capital carbon • Operational carbon Carbon emissions from these categories should be reported separately. The degree of accuracy and level of effort required to perform this quantification should be proportionate to the expected magnitude of the impact.
3.	Define the assessment period	The carbon impact of the scheme should be assessed over the lifetime of the intervention.[8] As per the assessment boundary, the assessment period should be aligned to that defined within the economic appraisal. In all circumstances, the appraisal period should be clearly stated[9].
Quantification approach		
1.	Apply relevant quantification methodology	A carbon assessment should be completed for all schemes using consistent assessment principles. Project promoters should assess which of the tiered methodological approaches outlined in Section 2.1 is most applicable at the time of assessment. The approach which provides the most detailed assessment possible given the information available to the project promoters should always be used.
2.	Determine appropriate data sources	To ensure a common quantification methodology, project promoters should primarily seek to use off-the-shelf published tools or datasets for carbon quantification (where applicable, these are specified within the scheme specific guidance). Bespoke calculations or new methodologies should only be used where there is no existing approach. The most recently available datasets or tools at the time of assessment should be used.
Consistent reporting		
1.	Present results in consistent format	Project promoters should ensure that carbon quantification results are presented consistently, using the dedicated proforma. Results should: • Present each capital and operational emissions separately. • Be displayed in units of metric tonnes CO_2e (tCO_2e). Note that CO_2e, or carbon dioxide equivalent, expresses the impact of the gases covered by the Kyoto Protocol in terms of the amount of CO_2 that would create the same impact. • Report total cumulative carbon emissions over the appraisal period and opening year carbon emissions at a minimum. Where possible, year on year carbon emissions should also be calculated as best practice, to allow annual carbon emissions to be aggregated at an investment portfolio level across the Combined Authority. Note: the default presentation of results for this guidance specifies results to be reported as capital and operational emissions (aligned to PAS 2080). However, districts may wish to additionally report their results to show progress against local net zero targets. This could involve reporting Scope 1, Scope 2 and Scope 3 emissions separately. For further information on the each of the scopes, refer to the definitions section of the guidance.
2.	Identify assessment assumptions and limitations	Limitations of the assessment and any explicit and implicit assumptions made should be clearly documented within the proforma. This will allow for clarity and help provide a view on the certainty of the results.
3.	Provide transparency of modelling/ assessment approach	Sufficient details should be provided on the methodology/modelling approaches used to undertake the assessment.

[8] HMT (2020). *The Green Book*. Available online: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/938046/The_Green_Book_2020.pdf.

[9] It is up to the project promoter to decide upon the most suitable assessment period. Whilst the guidance recommends that this should match the appraisal period specified within the economic case, it could be chosen to align with local net zero or other carbon reduction targets, providing that the assessment period is clearly defined.

2.1 Tiered methodology

A tiered calculation approach for each carbon emissions source has been proposed. The tiered approach allows for the assessment to be proportionate and to reflect the level of data likely to be available at various stages of the project.

- **Method 1: Pre-existing assessment**

This method should be applied where a previous assessment has been conducted specifically for the proposed scheme. Minor adjustments such as unit conversions may need to be made to ensure that the results are reported consistently. Where a previous assessment is used, care should be taken to ensure it is aligned with the principles outlined in Table 2-1. As with all carbon impact assessments, the limitations of the assessment should be transparently documented with the proforma. More detail on this is provided in Section 0 which contains guidance on filling out the proforma.

- **Method 2: High-level estimation**

This method has been designed to be used when data is limited (likely more applicable at OBC stage) and therefore avoids placing an unnecessary burden on project promoters. However, because this method involves higher levels of uncertainty, it is only recommended where no detailed data is available or when the scale of emissions does not justify an in-depth assessment. Using basic project information (such as metres of road, construction cost, or floor area and building use), benchmarks can be applied to estimate the associated carbon emissions.

- **Method 3: Detailed assessment**

For some project types, where data granularity allows (likely more applicable at FBC stage), a more detailed approach has been developed. This method requires a higher level of knowledge and time to carry out and, in some cases, might require specialist skills and tools or the guidance of an experienced carbon assessment professional.

Table 2-2 and Figure 2-2 summarise the tiered methodology.

Table 2-2: Overview of tiered methodology

Method	Description	Who would do the assessment?	Stage of assessment	Level of accuracy	Level of data
1	Existing assessment	Scheme promoter	Variable, but likely not in the earliest stages as a previous assessment is unlikely to have been completed. Where the data available is from a comparable project, this constraint does not apply.	Medium	Existence of previous assessment
2	High-level estimation	Scheme promoter	Early stages of assessment.	Low-medium	Basic scheme information
3	Detailed assessment	Likely to require support from a carbon specialist	Given the level of detail required, this method is suitable for schemes at later stages, and likely those that are at least in the design stages.	High, pending data quality	Detailed data (such as materials types and quantities)

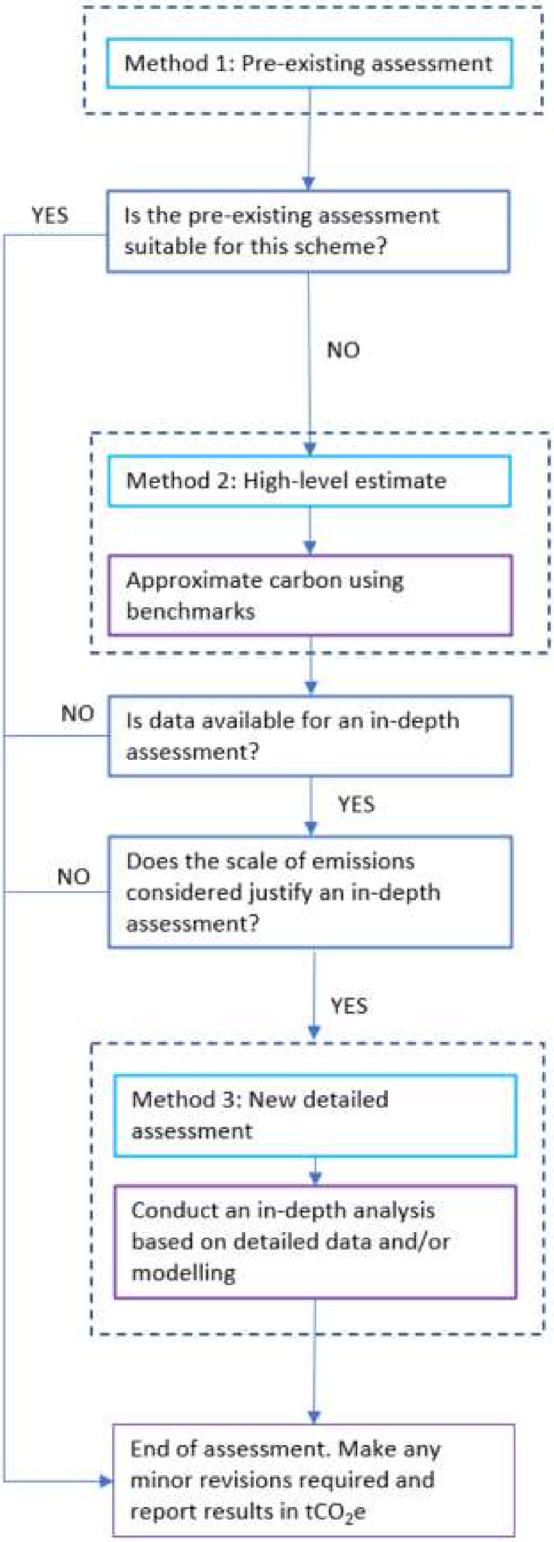

Figure 2-2: Application of tiered approach

3 Guidance on filling out the proforma

This section provides step by step guidance on how to fill out the carbon impact assessment proforma. The proforma is a reporting framework designed to record assessment results and details of the assessment approaches undertaken; this step therefore occurs after a carbon assessment has been undertaken. Use of the proforma will ensure consistency of reporting across all schemes.

3.1 Section A: Overview of results

This section of the proforma is intended to provide a summary of the results and an overview of confidence in the assessment undertaken. To populate this page, complete the following:

- Populate the scheme name and specify the appraisal period.
- The ‘summary of carbon impact’ table and graphs will automatically populate based on the results in Section C of the proforma. The results in the table should be sense checked to ensure the numbers have been populated correctly. Furthermore, the graphs may require minor alterations to reflect the desired appraisal period.
- Provide an indication of the confidence of the assessment, this should be informed by the limitations and assumptions listed within Section C of the proforma
- Specify whether the assessment is an overestimate or underestimate. This should be informed by the commentary around unassessed carbon impacts in Section D of the proforma.
- Specify whether the scheme impact would be different under a low carbon scenario[10] using the list of drop-down options available. If the results are being reported are already from a CERP complaint scenario, please select this option from the drop-down menu. It is likely that low carbon scenario pathway testing will inform the answer to this question. An example is as follows:
  - A highway improvement scheme which shows a significant carbon saving from congestion reduction may have a reduced carbon benefit under a low carbon scenario. The justification for this being that private vehicle transportation demand is expected to decrease and fleet is likely to decarbonise under a low carbon future.
- Populate the box at the bottom of the page highlighting the main conclusions from the assessment. Also use this space to justify the confidence rating, whether it is an over/underestimate and view on whether the result would be different under a low carbon scenario.

3.2 Section B: General project information

3.2.1 Decision point

Use the drop-down options to specify the decision point at which the scheme is currently working.

[10] A low-carbon scenario refers to a scenario which is consistent with the West Yorkshire Carbon Emission Reduction Pathways, including the power, buildings, industry, transport land use and agricultural sectors. Further information available here: PowerPoint Presentation (westyorks-ca.gov.uk).

3.2.2 Scheme components

Use the drop-down option to indicate the types of components included within the scheme. Where the scheme includes a combination of different components, select all that apply. For example, for a railway scheme that includes provision of a new station building, both the 'railway station' and the 'building – new' scheme types should be selected. This is to ensure that all applicable sources of emissions are appropriately captured in the assessment and indicate which scheme-specific sections of the guidance have been used.

Refer to Section 5 for more information on the different scheme types considered in this guidance.

3.2.3 Preferred option

State the preferred scheme option within the space provided. The carbon impact assessment should be undertaken on the preferred option. If there is no preferred option at the time of assessment, judgement should be taken on which option to complete the assessment on. This assumption should be documented within the proforma.

3.2.4 'Do-minimum' and 'Do-something' description

Explain what the specific differences are between the 'Do-minimum' (DM) and 'Do-something' (DS) scenarios. This should be aligned with what is presented within the business case.

The DM scenario considers both the current and predicted situation without the scheme intervention. It is the baseline against which the intervention should be assessed. The DM scenario defines the counterfactual situation and is a critical assumption made in any carbon assessment. The method of selecting the DM scenario should be consistent across schemes and should align with the wider appraisal documentation, including the business case (see Table 2-1) . Due to the inherent uncertainty associated with the DM scenario and the sensitivity of the overall scheme results to the selection of the DM scenario, scheme promotors should consider plausible alternative scenarios and, where relevant, provide an indication of how this may change the results. This should ideally be done through a sensitivity test, or alternatively could be described qualitatively. This information should be provided within the Additional Information section of the reporting pro forma (see section 3.5). Transparency over this matter is an effective method of presenting the limitations of an assessment, in line with standard best practice.

The DS scenario refers to the preferred option selected for the scheme. The difference between the DM and DS should focus on highlighting the aspects of the scheme intervention that would not occur under DM conditions.

3.2.5 Scheme benefits

Summarise the primary scheme benefits, as outlined in the strategic and economic business cases. This is to align the economic benefits of the scheme to the boundaries of the carbon assessment. For example, if the scheme includes economic benefits such as 'unlocking new development', these should be noted. The carbon resulting from this should be quantitatively assessed, where data allows, or qualitatively described within Section D of the proforma.

3.2.6 Scheme costs

Provide the total scheme cost, scheme construction cost and Combined Authority funding in the corresponding spaces within the proforma. This should be the same as reported in the business case. Where construction costs are not specifically listed as a single item in the business case documentation, the sum of relevant project activities (for example, delivery and enabling works) should be used.

3.3 Section C: Results of carbon impact assessment

3.3.1 Structure of Section C

There are three sub-sections included within Section C of the proforma:

- **C.1. Operational Carbon impact:** this section should be used to provide the results of the operational carbon assessment, the description of the approach and its limitations.
- **C.2. Capital carbon impact:** this section should be used to provide the results of the capital carbon assessment, the description of the approach and its limitations.
- **C.3. Total carbon impact:** this table provides the sum of capital and operational carbon results over the defined appraisal period. The table should automatically populate, however, this should be sense-checked to ensure the results are being presented correctly.

Figure 3-1 demonstrates how the reported emissions throughout the proforma should correspond to one another.

C.1. Operational carbon emissions			
Operational carbon	Do-minimum (without scheme)	Do-something (with scheme)	Scheme impact (difference)
Total tCO_2e in opening year			-
Total tCO_2e over appraisal period	DMO	DSO	SIO (DSO - DMO)

C.2. Capital carbon emissions			
Capital carbon	Do-minimum (without scheme)	Do-something (with scheme)	Scheme impact (difference)
Total tCO_2e over appraisal period	DMC	DSC	SIC (DSC - DMC)

C.3. Total carbon emissions			
Total carbon emissions*	Do-minimum (without scheme)	Do-something (with scheme)	Scheme impact (difference)
Total tCO_2e over appraisal period	DMO + DMC	DSO + DSC	SIO + SIC
Appraisal period			

	Total operational carbon emissions	**Total capital carbon emissions**	**Total emissions**
Do-minimum (without scheme)	DMO	DMC	DMO + DMC
Do-something (with scheme)	DSO	DSC	DSO + DSC
Impact of scheme (difference)	SIO (DSO - DMO)	SIC (DSC - DMC)	SIO +SIC
Intensity metric of scheme impact (tCO_2e/£m)**	SIO / £m	SIC / £m	(SIO + SIC) / £m

Figure 3-1: Summary of reported emissions

3.3.2 Reporting of emissions

The emissions calculation should be undertaken according to this guidance. The results of the assessment for the operational and capital carbon assessments should be entered into their respective tables within the proforma (Tables C.1 and C.2). Note the following when reporting the results of the analysis:

- Carbon savings should be displayed as negative values.
- Ensure consistency with units (tCO_2e).
- The total carbon footprint should be calculated based on the sum of all carbon emission sources. Ensure that the aggregated carbon emissions are calculated over the same appraisal period.

As evident within Figure 3-2, the emissions should be reported for the DM and DS scenarios. The difference between the DM and DS reflects the carbon impact of the scheme. In certain cases (e.g., the development of a new building), it is possible for the carbon impact of the DM scenario to be zero.

C.1. Operational carbon emissions			
Operational carbon	Do-minimum (without scheme)	Do-something (with scheme)	Impact of scheme (difference)
Total tCO_2e in opening year			-
Total tCO_2e over appraisal period			-
Emissions breakdown (over appraisal period)	Do-minimum (without scheme)	Do-something (with scheme)	Difference
Enter emissions source. E.g. Traded carbon (tCO_2e)			-
Enter emissions source. E.g. Untraded carbon (tCO_2e)			-
Enter emissions source.			-

If applicable, use the space above to break down the tCO_2e into separate sources.

C.1. Operational carbon emissions			
Operational carbon	Do-minimum (without scheme)	Do-something (with scheme)	Impact of scheme (difference)
Total tCO_2e in opening year	320,000	319,000	- 1,000
Total tCO_2e over appraisal period	14,275,000	14,174,000	- 101,000
Emissions breakdown (over appraisal period)	Do-minimum (without scheme)	Do-something (with scheme)	Difference
Operational transport, traded (tCO_2e)	275,000	274,000	- 1,000
Operational transport, untraded (tCO_2e)	14,000,000	13,900,000	- 100,000
Enter emissions source.			-

If applicable, use the space above to break down the tCO_2e into separate sources.

Figure 3-2: Example of emissions reporting within the proforma

The proforma provides space to enter the total carbon emissions in the first row of each table. However, there is also the option to present more granular results where applicable. As demonstrated in Figure 3-2, the greyed-out box can be used to enter results broken down by emissions source. The results should reflect the impact across the defined appraisal period.

In the case of capital carbon emissions, if a more detailed assessment has been undertaken, this space could be used to report emissions broken into emissions from materials, construction transport and construction plant (see Section 4 for more information).

The example provided in Figure 3-2 for operational emissions includes the option to present results broken into traded and untraded carbon emissions. This example is applicable to operational transport assessments. In line with the requirements for Greenhouse Gas appraisal in DfT TAG (Section four of Unit A3)[11], both traded and untraded emissions should be

[11] DfT (2021). *TAG unit A3 environmental impact appraisal*. Available online: TAG unit A3 environmental impact appraisal - GOV.UK (www.gov.uk).

reported[12]. It is therefore recommended to report the result of traded and untraded carbon separately in the proforma where data allows. For more information on traded and non-traded emissions, refer to the definitions section of this document.

3.3.3 Description and limitations of assessment approach

3.3.3.1 Method undertaken

Specify the type of method undertaken from the following options:

- Method 1 (pre-existing assessment)
- Method 2 (high-level assessment)
- Method 3 (detailed quantification)

Refer to Figure 2-2 for assistance in understanding which method is most suitable.

3.3.3.2 Scope of assessment

Clearly define the scope of assessment (providing a description of the emissions sources which have been accounted for). The scope definition should be as exhaustive as possible to help identify gaps in modelled emissions. It is important that the carbon assessment includes all significant sources of emissions.

The limitations of the assessment scope should be clearly stated within the proforma. The following questions may be used as prompts to understand what the limitations are:

- Do the carbon emission sources included in the assessment correspond to those recommended for consideration in the relevant scheme section within this guidance?
- Is the assessment boundary consistent with the economic boundary used for the scheme benefits?

It is important that the carbon assessment includes all significant sources of emissions. Where there are additional impacts resulting from differences between DM and DS scenarios that are not assessed, provide further detail within Section D: Unassessed carbon.

3.3.3.3 Methodology/ modelling approach

Describe the assessment method as thoroughly as possibly, specifying any modelling tools that have been used. In instances where the method deviates from what is recommended within this guidance, provide justification for this.

For operational carbon emissions, select "yes" next to each of the impacts that the modelling approach accounts for, or specify additional impacts next to "other".

Limitations of the assessment methodology and/or modelling approach should be detailed within the proforma. The following questions may be used as prompts to understand what the limitations are:

- Does the model correspond to the one(s) recommended within this guidance note?
- Does the model seem appropriate for the scheme type and size?

[12] Note, that it is not required for traded emissions to be valued and included in the Net Present Value, given that it would not have an impact on the UK net carbon account. However, the carbon impact should be reported as it has an implication on the purchase of EU ETS allowances (DfT, 2021).

- Have all of the benefits/impacts of the scheme been incorporated through modelling (i.e., if active modes are impacted, has an AMAT been included?)

With regard to transport modelling specifically, the following questions should be considered:

- Is the scale and scope of transport modelling in line with DfT TAG and making use of the most recent and best-fit data?
- Is this a multimodal transport model, if not, why not?
- If strategic modelling isn't used, has induced demand been accounted for? If not, can the induced demand methodology outlines in Appendix B be applied?
- Is the model detailed enough around the scheme? If not, this can have significant impacts on the reliability of the results. If the scheme is too close to the edge of the fully modelled area, this can increase the likelihood of anomalies and inaccuracies.
- Has the impact on wider highways and active mode users been considered? This is particularly important for public transport interchange facilities and station upgrades. It could be that the scheme impacts the travel behaviour further afield than just at the entrance to the site. This should be considered, ideally quantitatively so that results can be used in the carbon assessment, but qualitatively at the very least to acknowledge the potential impacts.
- Is the method used for the economic case appropriate for the carbon assessment? In some cases, a more detailed assessment using, for example, the Emission Factors Toolkit may be more appropriate than the use of TUBA.

3.3.3.4 Background assumptions

List all assumptions underpinning the assessment within the proforma. This will help provide transparency and valuable context when interpreting the carbon impact of a scheme, and subsequently offer clarity on any limitations.

This should include information on any background assumptions applicable to the do-minimum and do-something scenarios, for example any assumptions related to future decarbonisation and/or, for transport schemes assumptions relating to background travel growth.

Also ensure to state any limitations of the background assumptions within the proforma.

3.4 Section D: Unassessed carbon

Describe any additional sources of carbon which are not included in the assessment results (Section C of the proforma) within Section D of the proforma. This could include indirect impacts of the scheme such as the unlocking of new land for development, which may result in additional construction works or changes to transport patterns. On the other hand, the scheme might have provisions for some mitigation measures.

Where feasible, all carbon sources or mitigation measures should be quantified if they are captured in the assessment of economic benefits of the scheme. However, where it is not possible to quantitatively assess, the emissions sources should be noted in this section of the proforma, with an explanation as to the expected materiality of the emissions.

3.5 Section E: Additional information

Section E provides space to present any further information that is not already captured elsewhere in the proforma. The use of this space is optional.

In some instances, as described in section 3.2.4, it may be relevant to provide a sensitivity test and/or qualitative discussion over the potential impact when compared to a different (yet plausible) do-minimum scenario. This is likely to be more applicable to non-transport projects.

4 Capital carbon methodology

This section outlines a tiered approach to assessing capital carbon. This should be followed for all project types, except woodland schemes. In addition, refer to the relevant section relating to the specific scheme type undergoing assessment for further details on how to apply this methodology. References to specific benchmarks, as well as guidance on assessing other carbon emissions sources, are also provided in Sections 6 to 18.

Unless otherwise specified[13], the scope of assessment of capital carbon for Methods 2 and 3 of the tiered methodology covers the embodied carbon of materials, construction transport and construction plant emissions. It is recommended that as a minimum, these capital carbon emissions are included in the assessment.

Where a pre-existing assessment is used (Method 1), it is preferable that it covers at least these lifecycle stages. The scheme promoter should specify in the assessment what scope is covered by the existing analysis.

4.1 Methodology for assessment

It is recommended that capital carbon is accounted for, unless the scheme does not include construction activities. For example, in the case of a bus priority scheme that solely consists of signalling improvements with no road construction, capital carbon may be omitted as negligible. In all other cases where there is construction activity, capital emissions should at least be calculated using a high-level methodology.

In determining the most suitable methodology for assessing capital carbon, two factors should be accounted for:

- The availability of project-specific data; and
- The expected significance[14] of emissions.

Figure 4-1 shows how to determine which method of assessment should be applied. It should be noted that the availability of project-specific data might be a limiting factor in many cases given that data on material specifications and quantities is usually only available once projects have reached the design stage.

Where the expected significance of capital carbon cannot be clearly established, it is recommended to first calculate capital emissions using Method 2. If capital carbon emissions account for more than 5%[15] of total emissions, then capital emissions should be assessed as per Method 3 where possible.

[13] Where benchmarks include other emission sources, such as end-of-life, this has been highlighted.

[14] Significance is used here to refer to how large capital carbon emissions are, especially in comparison to other project carbon emissions.

[15] Extracted from: EBRD (no date). *EBRD protocol for assessment of greenhouse gas* emissions. Available online: https://www.ebrd.com/documents/admin/ebrd-protocol-for-assessment-of-greenhouse-gas-emissions.pdf. Note: Although the purpose of the EBRD guidance is not directly applicable, the threshold is deemed suitable for use in this context.

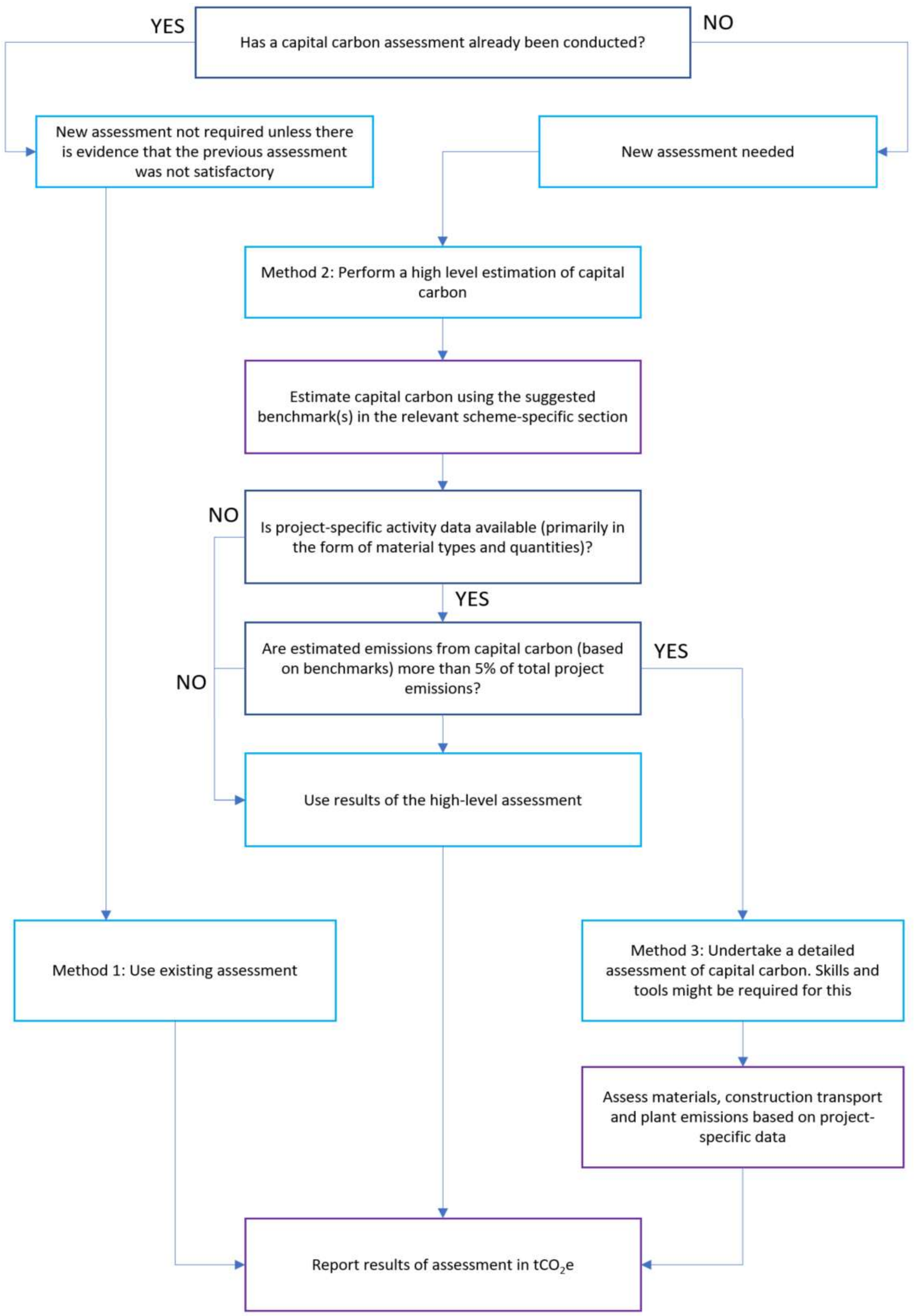

Figure 4-1: Overview of capital carbon methodology

4.1.1 Method 1: Pre-existing assessment

Where a capital carbon assessment has already been undertaken, and the assessment scope and method are deemed appropriate, the results in tCO_2e should be reported.

4.1.2 Method 2: High-level assessment

This method should be used if (i) no previous capital carbon quantification exists and there is no detailed material data available for the project or (ii) the expected relative significance of the capital carbon emissions does not justify an in-depth assessment. To estimate the capital carbon associated with construction activities and materials, a relevant benchmark should be applied. This estimate is simply indicative and often cannot be used to compare different design options for the same project.

Consult the relevant section referring to the scheme type under consideration for guidance on appropriate benchmarks if a Method 2 assessment is to be undertaken.

There is currently limited data available on capital carbon benchmarks across different types of schemes. Nonetheless, the benchmarks provided in this guidance give an indicative estimate of the carbon associated with scheme construction. The benchmarks referred to in this study are taken from industry publications and the modelling of scheme components using representative materials and plant use. All benchmarks are presented in units of tCO_2e. Note that one benchmark source only provided benchmarks as a range in units of tCO_2. The upper value of these ranges has been used to compensate for the lack of inclusion of other GHGs. If more accurate benchmarks are developed in the future, these should be used instead.

4.1.3 Method 3: Detailed quantification

The application of this method relies on the availability of material types and quantities at a minimum. In most cases, this method will require specialist skills and/or tools due to the complexity involved.

Given that FBC is the final audit stage before delivery commences, detailed design information would likely be available. Therefore, a detailed quantification under Method 3 would be highly recommended for all schemes working at FBC stage.

4.1.3.1 Data required

Table 4-1: Data required for capital carbon assessment

Data type	Units	Example source
When project-specific data is available		
Material quantities	m^3, kg, t, etc.	Project data
Transport distances to construction site	Km	Project data, RICS (2017)[16] assumptions
Construction fuel and electricity use*	l, kWh	Project data
Project value (Capex)*	£	RICS (2017) assumptions

*Where fuel and electricity consumption during construction are available, they should be used to calculate construction plant emissions. Otherwise, the project value can be used with a typical benchmark to estimate plant emissions.

[16] RICS (2017). *Whole life carbon assessment for the built environment.* Available online: https://www.rics.org/globalassets/rics-website/media/news/whole-life-carbon-assessment-for-the--built-environment-november-2017.pdf.

4.1.3.2 Quantification methodology

To calculate capital carbon emissions, activity data (for example, material quantities) should be multiplied by appropriate emissions factor. The total footprint will consist of the sum of all individual component emissions. The tools recommended below are based on the same calculation methodology. Similarly, where databases and industry standards are used to quantify materials, construction transport or plant emissions, the same calculation principles apply.

4.1.3.3 Recommended tools

Table 4-2 provides a list of suggested tools to quantify capital carbon for different scheme types. When using a carbon tool, material types and quantities should be selected to match project-specific specifications as closely as possible.

Table 4-2: Tools for quantification of materials emissions

Scheme type	Tool
Transport schemes • Cycling and walking • Bus priority • Highways	Highways England Carbon Tool[17]
Transport (railway station)	RSSB Rail Carbon Tool[18]
Transport schemes: • Park and ride • Bus interchange	No industry standard tool available. Complete a bottom-up calculation using the method, databases and industry standards outlined within this guidance.
Buildings (all)	No industry standard tool available. A list of tools can be found in the GLA's Whole Life Carbon Guidance, Appendix A although most require software license fees.[19] The RICS publishes more detailed guidance but the analysis method requires specialist knowledge.[20]

4.1.3.4 Databases and industry standards

If it is not possible to use the tools in Table 4-2 to calculate one or all components of capital carbon emissions, then databases can be directly consulted. Suggested sources include:

- **Materials emissions**

If a tool is not available, then it is recommended to refer to industry databases to calculate these carbon emissions. Note that specialists may need to be consulted to determine the most suitable factors to use. The ICE v3 (2019)[21] database is one of the most comprehensive free sources of carbon emission factors available currently.

- **Construction transport emissions**

If supplier information is available, it is possible to determine the exact transport distances for materials to the construction site. However, at OBC or FBC stage, it is unlikely that specific

[17] Highways England (2019). *Carbon emissions calculation tool*. Available online: https://www.gov.uk/government/publications/carbon-tool.

[18] RSSB (2021). *Rail Carbon Tool*. Available online: https://www.rssb.co.uk/sustainability/Rail-Carbon-Tool.

[19] GLA (2020). *Whole Life-Cycle Carbon Assessments Guidance*. Available online: wlc_guidance_april_2020.pdf (london.gov.uk).

[20] RICS (2017). Whole life carbon assessment for the built environment. Available online: https://www.rics.org/globalassets/rics-website/media/news/whole-life-carbon-assessment-for-the--built-environment-november-2017.pdf.

[21] ICE (2019). Available at: https://circularecology.com/embodied-carbon-footprint-database.html.

suppliers will be known for construction materials. In this situation, the RICS guidance should be referred to for typical transport distance assumptions (Table 4-3).

Table 4-3: Typical transport distance assumptions

Transport scenario	km by road*	km by sea**
Locally manufactured E.g., concrete, aggregate, earth	50	-
Nationally manufactured E.g., plasterboard, blockwork, insulation	300	-
European manufactured E.g., CLT, façade modules, carpet	1,500	-
Globally manufactured E.g., specialist stone cladding	200	10,000
** Means of transport assumed as average rigid HGV with average laden – average laden as per BEIS carbon conversation factors.* *** Means of transport assumed as average container ship.*		

Source: RICS (2017)

Based on transport distances (km) and the weight of materials (metric tonnes), emission factors can be used to estimate transport emissions. The BEIS[22] database provides factors based on the mode of transport and vehicle type. A typical assumption as per the RICS guidance is to use a rigid HGV average laden emission factor. The corresponding emission factor is **0.2078 kgCO$_2$e/tkm** (BEIS, 2021). Note that the BEIS emission factors update on an annual basis.

- **Construction plant emissions**

If data on fuel and electricity use during construction are known, then the BEIS database should be used to assess construction plant emissions based on these quantities. Although it is recommended that the BEIS database is referred to directly, Appendix A shows the emission factors for UK electricity and diesel, which are likely to be relevant. These emission factors are updated on an annual basis so care should be taken to use the most recent values.

If there is no data on plant use, construction plant emissions can be estimated using the benchmark of **1,400 kgCO$_2$e/£100k project value**. This benchmark is an estimate taken from industry guidance (RICS, 2017)[23]. Note that this value is provided based on a project value in 2015. Therefore, the cost should either be adjusted to a 2015 value or the benchmark can be converted in (kgCO$_2$e/£100k) based on the current year. The Office of National Statistics CPI Index data[24] can be used for this conversion.

[22] BEIS (2021). *Greenhouse Gas Reporting: Conversion factors 2021*. Available online: Greenhouse gas reporting: conversion factors 2021 - GOV.UK (www.gov.uk).

[23] RICS (2017). Whole life carbon assessment for the built environment. Available online: https://www.rics.org/globalassets/rics-website/media/news/whole-life-carbon-assessment-for-the--built-environment-november-2017.pdf.

[24] ONS (no date). *CPI Index*. Available online: https://www.ons.gov.uk/economy/inflationandpriceindices/timeseries/l522/mm23.

5 Index of scheme specific guidance

Refer to the relevant section(s) presented within the table below for scheme specific guidance to undertake operational and capital carbon impact assessments.

If the scheme is made up of multiple components, the guidance should be used to undertake carbon assessments for each component individually. The sum of each scheme component will provide the total scheme carbon impact.

Table 5-1: Overview of scheme components

Section	Scheme components	Description
6	Transport (highways) schemes	Highways schemes which are designed to primarily benefit motor vehicles.
7	Transport (cycling and walking) schemes	Projects involving cycling and walking (active travel).
8	Transport (bus priority) schemes	Bus priority schemes such as traffic signal improvements or the construction of new bus lanes.
9	Transport (bus interchange) schemes	Bus interchange schemes are typically focussed on facilities which host multiple bus routes.
10	Transport (park and ride) schemes	Park and ride schemes are typically a combination of parking facilities and public transport.
11	Transport (railway station) schemes	Railway station schemes are schemes which involve the construction or renovation of a station building and/or platform.
12	Building schemes – new	Projects involving the construction of new buildings. For discussion on carbon issues relating to greenfield versus brownfield development, please see Appendix E. Noting that there is no universally accepted methodology for calculating these differences, the information has been provided for guidance only.
13	Building schemes – refurbishment and energy efficiency	Projects involving building refurbishment or energy efficiency improvements.
14	Building schemes – demolition and land remediation schemes	Projects involving the demolition of existing buildings and land remediation works. For discussion on carbon issues relating to greenfield versus brownfield development, please see Appendix E. Noting that there is no universally accepted methodology for calculating these differences, the information has been provided for guidance only.
15	Renewable energy schemes	Projects involving the installation of renewable energy generation.
16	Woodland schemes	Projects involving the creation or removal of areas of woodland.
17	Heat networks	Projects involving the construction of district heat networks (DHNs) or communal heating
19	Other schemes	All schemes not defined by any of the above.

Other helpful resources:

- To refer back to the overarching assessment principles, click here.
- For guidance on filling out the proforma, click here.
- To refer back to the capital carbon methodology, click here.

6 Transport (highways) schemes

This section provides guidance for schemes which contain a highway component which is designed to primarily benefit motor vehicles such as the expansion of existing highways or the construction of new roads.

6.1 Assessment threshold

An operational carbon assessment should be undertaken where it is required under the DfT TAG guidance for highways schemes. Capital carbon should also be accounted for as per Section 4. Where possible, carbon emissions resulting from induced impacts which are not already included in the operational carbon assessment should be accounted for where they are included in the assessment boundaries (see scope of assessment in Table 2-1). A screening methodology has been included in the induced demand toolkit (see Appendix B).

6.2 Sources of emissions

Operational (also referred to as in-use) carbon emissions and savings emerge from changes in vehicle use over the road network. The changes in carbon emissions should be assessed for all highways schemes as required under DfT TAG. Effects resulting from induced vehicle use (i.e., a behavioural response to the scheme intervention) can be significant and should be assessed separately where they are not already included in traffic modelling (e.g., a variable demand model is not used). A screening methodology has been developed to assess whether induced vehicle use should be separately calculated, with the results to be included in the operational assessment. Capital carbon emissions associated with construction activities and materials used in the creation of an asset should be assessed for highways schemes. The impacts of refurbishment, and end-of-life can be excluded if there is a lack of project-specific data at OBC and FBC design stages.

Table 6-1: Carbon emission sources which require assessment

Emission source	Assessment required
Operational/in-use	Yes
Capital	Yes

6.3 Data required

6.3.1 Operational/in-use carbon

Carbon assessments using traffic modelling (for example calculated using a TUBA[25] assessment) should be used to account for the change in operational/in-use carbon emissions.

The advantage of using TUBA is that it provides a consistent, quantified, and established method of calculating in-use transport carbon. TUBA is the established standard for economic assessment and will already be undertaken on many schemes. The consistent method is beneficial for scheme assessors as it makes scheme assessments comparable and easy to understand.

[25] For further information on TUBA, refer to the definitions section of this guidance or visit Transport users benefit appraisal: software and user manuals - GOV.UK (www.gov.uk).

If a more detailed and project-tailored assessment is available, through the use of MEC outputs or from the Defra Emission Factors Toolkit (EFT[26]), then this should be used. For example, the EFT uses a similar methodology to TUBA however has a more detailed representation of the vehicle fleet split but a more simplistic representation of transport changes. Furthermore, as per the requirements for Greenhouse Gas appraisal in DfT TAG[27], the TAG Greenhouse Gases Workbook can also be used to carry out the monetisation of carbon impacts/benefits, generating the same outputs as TUBA.

See Appendix B for detailed guidance on assessing the impacts of induced demand effects using the 'WYCA Induced Travel Calculation' Spreadsheet. For projects which have met the screening criteria, the vehicle flow through the scheme area, opening year, location and number of assessment years are required for the assessment as a minimum.

Table 6-2: Data required for operational/in-use carbon assessment

Data type	Units	Example source
GHG outputs from traffic modelling	tCO_2e	TUBA assessment*

**The annual and total carbon values (in tCO_2e) can be extracted from the TUBA output file. The results are under the headings "CO2_EMISSIONS_UNTRADED" and "CO2_EMISSIONS_TRADED."*

6.3.2 Capital carbon

Refer to Section 4 for detailed guidance on capital carbon. In order to perform a high-level estimate (Method 2 in the capital carbon methodology), the following data would be required.

Table 6-3: Data required for capital carbon assessment

Data type	Units	Example source
Scheme length	Metres	Project data
Asset/ facility type	N/A (description)	Project description

6.4 Assessment methodology

6.4.1 Operational/in-use carbon

DfT Transport Analysis Guidance (TAG) UNIT A3[28] for environmental impact appraisal should be followed to calculate the carbon impact of the scheme intervention. Scheme promoters should use the methodology, software and assumptions outlined within the guidance to ensure the carbon impact of proposed highways schemes are reported and incorporated within the appraisal in a consistent and transparent way. This can allow for comparisons to be made across schemes. The assessment principles listed in Table 2-1 are consistent with TAG UNIT A3 however, for a greater level of detail refer to the TAG guidance document itself. These results should be presented in units of tCO_2e as a total over the appraisal period and on an annual basis where possible.

See Appendix C – Technical Note detailing the development and basis of the induced travel assessment for detailed guidance on assessing the impacts of induced demand effects using the 'WYCA Induced Travel Calculation' Spreadsheet.

[26] Defra (2020). *Emission Factors Toolkit*. Available online: Emissions Factors Toolkit | LAQM (defra.gov.uk).

[27] DfT (2021). TAG unit A3 environmental impact appraisal. Available online: TAG unit A3 environmental impact appraisal - GOV.UK (www.gov.uk).

[28] DfT (2021). TAG unit A3 environmental impact appraisal. Available online: TAG unit A3 environmental impact appraisal - GOV.UK (www.gov.uk).

6.4.2 Capital carbon

See Section 4 for detailed instructions on undertaking a capital carbon assessment.

A capital carbon assessment should be undertaken for all projects. A tiered approach to assessment has been developed:

Method 1: Pre-existing assessment

Where a capital carbon assessment has been already undertaken, the results in tCO_2e should be reported.

Method 2: High-level assessment

This method should be used where no previous capital carbon quantification exists. To obtain a high-level estimate of the carbon associated with construction activities and materials, a relevant benchmark should be applied.

Suggested benchmarks based on lengths and types of road are provided below.[29] The carbon emissions in tCO_2e should be reported.

Table 6-4: Capital carbon benchmarks

Asset/ facility type	Capital carbon (tCO_2e/metre)	Source
Motorways - dual four lane	7	Little Black Book (2010)
Motorways – dual three lane	5.7	
Motorways – dual two lane	4.5	
Motorways – A roads	2.8	
Wide single carriageway	1.8	
Single carriageway	1.3	
Single lane slip road	1	
Single lane link road	0.8	

Method 3: Detailed quantification

If the high-level assessment indicates that capital carbon emissions account for more than 5% of total emissions, then construction emissions should be assessed as per Method 3 if project-specific data are available.

The Highways England Carbon Tool[30] should be used to calculate the carbon emissions associated with construction activities.

To navigate back to scheme descriptions, click here.

[29] Little Black Book (2010). *Construction benchmarks: Highways construction and asset management 2010 – 2011*.

[30] Highways England (2019). *Carbon emissions calculation tool*. Available online: https://www.gov.uk/government/publications/carbon-tool.

7 Transport (cycling and walking) schemes

This section provides guidance for schemes containing a cycling and walking component.

7.1 Assessment threshold

An operational carbon assessment should be carried out for all cycling and walking scheme components where required by the Department for Transport Active Mode Appraisal Toolkit (AMAT). The AMAT assessment quantifies impacts associated with the behavioural effect of modal shift to active travel modes. Calculation of the capital carbon emissions associated with construction should also be undertaken.

7.2 Sources of emissions

Operational/in-use carbon emissions and savings result from changes in vehicle use over the road network and should be assessed for all cycling and walking scheme components. Capital carbon emissions associated with construction activities and materials used in the creation of an asset should be assessed. The impacts of refurbishment, and end-of-life can be excluded if there is a lack of project-specific data at OBC and FBC design stages.

Table 7-1: Carbon emission sources which require assessment

Emission source	Assessment required
Operational/in-use	Yes
Capital	Yes

7.3 Data required

7.3.1 Operational/in-use carbon

Table 7-2: Data required for operational/in-use carbon assessment

Data type	Units	Example source
Avoided vehicle kilometres	v.km	AMAT results*

**The annual avoided vehicle-km can be found on the "General Calculations" tab*

7.3.2 Capital carbon

Refer to Section 4 for detailed guidance on capital carbon. To perform a high-level estimate (Method 2 in the capital carbon methodology), Table 7-3 indicates the data that will be required:

Table 7-3: Data required for capital carbon assessment

Data type	Units	Example source
Scheme length	Metres	Business case documentation
Asset/ facility type	N/A (description)	Project description

7.4 Assessment methodology

7.4.1 Operational/in-use carbon

The DfT Active Mode Appraisal Toolkit[31] available here should be used to determine the reduction in vehicle kilometres (v.km) from the scheme intervention. Once the required inputs have been entered, the annual reduction in v.km can be obtained from the 'General Calculations' sheet:

- Annual avoided car kilometres can be extracted from the sum of Cells D25 and E25
- Annual avoided taxi kilometres can be extracted from the sum of Cells D27 and E27

A high-level assessment can be completed by applying the DfT TAG fleet mix predictions (sheet A1.3.9)[32] to the car kilometres on an annual basis over the appraisal period (see Appendix D). This will provide an understanding of the annual car kilometres undertaken by petrol, diesel and electric vehicles. Applying relevant carbon emissions factors to those distances for each year of the assessment period enables the change in carbon emissions to be calculated. In addition, the applicable carbon emission factor should also be applied to the taxi kilometres. Note that DfT TAG does not have predicted fleet mix predictions for taxis.

Note that emissions from petrol and diesel vehicles can be reported as non-traded emissions, whilst emissions from electric vehicles can be reported as traded emissions. View the definitions section for further information.

The following benchmarks in Table 7-4 enable an estimate of the carbon savings to be calculated by assuming that all vehicles displaced are average cars. These benchmarks are taken from the BEIS greenhouse gas reporting: conversion factors database which is updated on an annual basis. Consequently, the most up to date emissions factor from the BEIS guidance should be used in future years.

Table 7-4: Car kms savings emission factors

Activity	Carbon savings (tCO_2e/km)	Source
Average petrol car (tCO_2e/km)	0.00017431	BEIS (2021)[33]
Average diesel car (tCO_2e/km)	0.00016843	
Average electric car (tCO_2e/km)	0.00005477	
Regular taxi (tCO_2e/km)	0.00020826	

*This factor assumes an average petrol car

The operational carbon emission savings in tCO_2e over the appraisal period should be reported.

For a more accurate quantification, future decarbonisation of both taxis and cars from electrification of the grid and vehicle efficiency improvements could be accounted for over the appraisal period. Where this calculation is completed, the methodology and background assumptions should be clearly stated within the proforma.

7.4.2 Capital carbon

See Section 4 for detailed instructions on undertaking a capital carbon assessment.

[31] DfT (2020). *Active Mode Appraisal Toolkit User Guide*. Available online: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/888754/amat-user-guidance.pdf.

[32] DfT (2021). *TAG data book*. Available online: TAG data book - GOV.UK (www.gov.uk).

[33] BEIS (2021). *Greenhouse Gas Reporting: Conversion factors 2021*. Available online: Greenhouse gas reporting: conversion factors 2021 - GOV.UK (www.gov.uk).

A capital carbon assessment should be undertaken for all projects. A tiered approach to assessment has been developed:

Method 1: **Pre-existing assessment**

Where a capital carbon assessment has been already undertaken, the results in tCO_2e should be reported.

Method 2: High-level assessment

This method should be used where no previous capital carbon quantification exists. To obtain a high-level estimate of the carbon associated with construction activities and materials, a relevant benchmark should be applied.

Suggested benchmarks based on lengths of scheme are provided in Table 7-5[34]. The carbon emissions in tCO_2e should be reported.

Table 7-5: Capital carbon benchmarks

Asset/ facility type	Capital carbon (tCO_2e/metre)	Source
Footpaths	0.5	Little Black Book (2010)
Cycleways	0.3	

Method 3: Detailed quantification

If the high-level assessment indicates that capital carbon emissions account for more than 5% of total emissions, then construction emissions should be assessed as per Method 3 if project-specific data is available.

The Highways England Carbon Tool[35] should be used to calculate the carbon emissions associated with construction activities.

To navigate back to scheme descriptions, click here.

[34] Little Black Book (2010). *Construction benchmarks: Highways construction and asset management 2010 – 2011*.

[35] Highways England (2019). *Carbon emissions calculation tool*. Available online: https://www.gov.uk/government/publications/carbon-tool.

8 Transport (bus priority) schemes

This section provides guidance for schemes which contain a bus priority component such as traffic signal improvements or the construction of new bus lanes.

8.1 Assessment threshold

An operational carbon assessment should be undertaken where it is required under the DfT TAG guidance. Carbon emissions from induced demand effects should already be accounted for in the operational/in-use carbon assessment. However, care should be taken to ensure the scope and coverage of these multi-modal assessments is representative of the entire journey. Capital carbon should also be accounted for as per Section 4, unless there is evidence that construction is very minimal such as where the bus priority scheme consists of traffic signal improvements only.

8.2 Sources of emissions

Operational/in-use carbon emissions and savings result from changes in vehicle use over the road network. Capital carbon emissions associated with construction activities and materials used in the creation of an asset should be assessed. The impacts of refurbishment, and end-of-life can be excluded if there is a lack of project-specific data at OBC and FBC design stages.

Table 8-1: Carbon emission sources which require assessment

Emission source	Assessment required
Operational/in-use	Yes
Capital	Yes, unless minimal construction

8.3 Data required

8.3.1 Operational/in-use carbon

Carbon assessments using traffic modelling (for example calculated using a TUBA[36] assessment) should be used to account for the change in operational/in-use carbon emissions. See section 6.3.1 for more information on TUBA assessments and alternative options.

Table 8-2: Data required for operational/in-use carbon assessment

Data type	Units	Example source
GHG outputs from traffic modelling	tCO_2e	TUBA assessment*

**The annual and total carbon values (in tCO_2e) can be extracted from the TUBA output file. The results are under the headings "CO2_EMISSIONS_UNTRADED" and "CO2_EMISSIONS_TRADED."*

8.3.2 Capital carbon

Refer to Section 4 for detailed guidance on capital carbon. To perform a high-level estimate (Method 2 in the capital carbon methodology), Table 8-3 indicates the data that would be required:

[36] For further information on TUBA, refer to the definitions section of this guidance or visit Transport users benefit appraisal: software and user manuals - GOV.UK (www.gov.uk).

Table 8-3: Data required for capital carbon assessment

Data type	Units	Example source
Scheme length	Metres	Project data
Asset/ facility type	N/A (description)	Project description

8.4 Assessment methodology

8.4.1 Operational/in-use carbon

DfT Transport Analysis Guidance (TAG) UNIT A3[37] for environmental impact appraisal should be followed to calculate the carbon impact of the scheme intervention. Scheme promoters should ensure to use the methodology, software and assumptions outlined in the guidance to ensure the carbon impact of proposed highways schemes are reported and incorporated within the appraisal in a consistent and transparent way. This can allow for comparisons to be made across schemes. The assessment principles listed in Table 2-1 are consistent with TAG UNIT A3 however, for a greater level of detail refer to the TAG guidance document itself. These results should be presented in units of tCO_2e as a total over the appraisal period and on an annual basis where possible.

8.4.2 Capital carbon

See Section 4 for detailed instructions on undertaking a capital carbon assessment.

A capital carbon assessment should be undertaken for all projects unless minimal construction is involved. A tiered approach to assessment has been developed:

Method 1: Pre-existing assessment

Where a capital carbon assessment has been already undertaken, the results in tCO_2e should be reported.

Method 2: High-level assessment

This method should be used where no previous capital carbon quantification exists. To obtain a high-level estimate of the carbon associated with construction activities and materials, a relevant benchmark should be applied.

Suggested benchmarks based on lengths and types of road are provided in Table 8-4.[38] The carbon emissions in tCO_2e should be reported.

Table 8-4: Capital carbon benchmarks

Asset/ facility type	Capital carbon (tCO_2e/metre)	Source
Bus lane	0.8	Little Black Book (2010)
Wide single carriageway	1.8	
Single carriageway	1.3	
Single lane slip road	1	
Single lane link road	0.8	

Method 3: Detailed quantification

[37] DfT (2021). TAG unit A3 environmental impact appraisal. Available online: TAG UNIT A3 Environmental Impact Appraisal (publishing.service.gov.uk).

[38] Little Black Book (2010). *Construction benchmarks: Highways construction and asset management 2010 – 2011*.

If the high-level assessment indicates that capital carbon emissions account for more than 5% of total emissions, then construction emissions should be assessed as per Method 3 if project-specific data is available.

The Highways England Carbon Tool[39] should be used to calculate the carbon emissions associated with construction activities.

To navigate back to scheme descriptions, click here.

[39] Highways England (2019). *Carbon emissions calculation tool*. Available at: https://www.gov.uk/government/publications/carbon-tool.

9 Transport (bus interchange) schemes

This section provides guidance for schemes with a bus interchange component. Bus interchange scheme components are typically focussed on facilities which host multiple bus routes.

9.1 Assessment threshold

An operational carbon assessment should be undertaken for all bus interchange scheme components. Carbon emissions from induced demand effects should already be accounted for in the operational/in-use carbon assessment. However, care should be taken However, care should be taken to ensure the scope and coverage of these multi-modal assessments is representative of the entire journey. In addition, capital carbon emissions should be assessed following the methodology outlined in Section 4. For schemes involving the construction of buildings, refer to Sections 12 and 13 for these aspects.

9.2 Sources of emissions

Operational/in-use carbon emissions and savings result from changes in vehicle use over the road network and should be assessed for all bus interchange schemes where required under the DfT TAG guidance. Capital carbon emissions associated with construction activities and materials used in the creation of an asset should be assessed. The impacts of refurbishment, and end-of-life can be excluded if there is a lack of project-specific data at OBC and FBC design stages.

Table 9-1: Carbon emission sources which require assessment

Emission source	Assessment required
Operational/in-use	Yes
Capital	Yes

9.3 Data required

9.3.1 Operational/in-use carbon

Carbon assessments using traffic modelling (for example calculated using a TUBA[40] assessment) should be used to account for the change in operational/in-use carbon emissions. See section 6.3.1 for more information on TUBA assessments and alternative options.

For operational emissions associated with the heating and/or lighting of a bus station or other associated buildings refer to Section 12 and 13.

Table 9-2: Data required for operational/in-use carbon assessment

Data type	Units	Example source
GHG outputs from traffic modelling	tCO_2e	TUBA assessment*

**The annual and total carbon values (in tCO_2e) can be extracted from the TUBA output file. The results are under the headings "CO2_EMISSIONS_UNTRADED" and "CO2_EMISSIONS_TRADED."*

[40] For further information on TUBA, refer to the definitions section of this guidance or visit Transport users benefit appraisal: software and user manuals - GOV.UK (www.gov.uk).

9.3.2 Capital carbon

Refer to Section 4 for a detailed guide on capital carbon. Bus interchange schemes can take different forms but to perform a high-level estimate (Method 2 in the capital carbon methodology), the data outlined in Table 9-3 will be required:

Table 9-3: Data required for a capital carbon assessment

Data type	Units	Example source
Scheme dimensions	m/m^2	Project data
Asset/ facility type	N/A (description)	Project description

9.4 Assessment methodology

9.4.1 Operational/in-use carbon

DfT Transport Analysis Guidance (TAG) UNIT A3[41] for environmental impact appraisal should be followed to calculate the carbon impact of the scheme intervention. Scheme promoters should ensure to use the methodology, software and assumptions outlined within the guidance to ensure the carbon impact of proposed bus interchange schemes are reported and incorporated within the appraisal in a consistent and transparent way. This can allow for comparisons to be made across schemes. The assessment principles listed in Table 2-1 are consistent with TAG UNIT A3 however, for a greater level of detail refer to the TAG guidance document itself. These results should be presented in units of tCO_2e as a total over the appraisal period and on an annual basis where possible.

9.4.2 Capital carbon

See Section 4 for detailed instructions on undertaking a capital carbon assessment.

A capital carbon assessment should be undertaken for all projects. A tiered approach to assessment has been developed:

Method 1: Pre-existing

Where a capital carbon assessment has been already undertaken, the results in tCO_2e should be reported.

Method 2: High-level assessment

This method should be used where no previous capital carbon quantification exists. To obtain a high-level estimate of the carbon associated with construction activities and materials, relevant benchmarks should be applied.

[41] DfT (2021). TAG unit A3 environmental impact appraisal. Available online: TAG UNIT A3 Environmental Impact Appraisal (publishing.service.gov.uk).

A selection of suggested benchmarks for hardstanding[42], station buildings[43] and, bus lanes and footpaths[44] are provided in Table 9-4 for use depending on the exact components of the scheme. The carbon emissions in tCO_2e should be reported.

Table 9-4: Capital carbon benchmarks

Asset/ facility type	Capital carbon (tCO_2e/metre)	Source
Bus Lane	0.8	Little Black Book (2010)
Footpath	0.5	
Hardstanding areas	0.0156 (tCO_2e/m^2)	Moata Carbon Poral
Station Building	1 (tCO_2e/m^2)	GLA (2020)

Method 3: Detailed quantification

If the high-level assessment indicates that capital carbon emissions account for more than 5% of total emissions, then capital emissions should be assessed as per Method 3 if project-specific data is available. Consult Section 4 for further information on how to complete a bottom-up assessment using publicly available databases and industry standards.

To navigate back to scheme descriptions, click here.

[42] This benchmark has been modelled in the Mott MacDonald Moata Carbon Portal using typical materials and types of plant.

[43] GLA (2020). *Whole Life-Cycle Carbon Assessments guidance.* Available online: https://www.london.gov.uk/publications/whole-life-cycle-carbon-assessments-guidance#appendix-2-benchmarks.

[44] Little Black Book (2010). *Construction benchmarks: Highways construction and asset management 2010 – 2011*.

10 Transport (park and ride) schemes

This section provides guidance for schemes which contain a park and ride component. Park and ride schemes are typically a combination of parking facilities and public transport, mostly by bus. They can also incorporate walking and cycling arrangements. To assess the impacts of walking and cycling arrangements, refer to Section 7.

10.1 Assessment threshold

An operational carbon assessment should be undertaken where it is required under the DfT TAG guidance for public transport schemes. Carbon emissions from induced demand effects should already be accounted for in the operational/in-use carbon assessment. However, care should be taken However, care should be taken to ensure the scope and coverage of these multi-modal assessments is representative of the entire journey. Capital carbon should be assessed for all projects of this type as outlined in Section 4.

10.2 Sources of emissions

Operational/in-use carbon emissions and savings that result from changes in vehicle use over the road network and changes in congestion should be assessed for park and ride schemes if required under the DfT TAG guidance. If the scheme comprises provision of charging facilities, this could influence emissions by increasing the uptake of electric vehicles, altering the vehicle split. This change should be accounted for in the traffic modelling and will be part of reported operational emissions

Capital carbon emissions associated with construction activities and materials used in the creation of an asset should be assessed. The impacts of refurbishment, and end-of-life can be excluded if there is a lack of project-specific data at OBC and FBC design stages.

Table 10-1: Carbon emission sources which require assessment

Emission source	Assessment required
Operational/in-use	Yes
Capital	Yes

10.3 Data required

10.3.1 Operational/in-use carbon

Carbon assessments using traffic modelling (for example calculated using a TUBA[45] assessment) should be used to account for the change in operational/in-use carbon emissions. See section 6.3.1 for more information on TUBA assessments and alternative options.

Table 10-2: Data required for operational/in-use carbon assessment

Data type	Units	Example source
GHG outputs from traffic modelling	tCO_2e	TUBA assessment*

[45] For further information on TUBA, refer to the definitions section of this guidance or visit Transport users benefit appraisal: software and user manuals - GOV.UK (www.gov.uk).

**The annual and total carbon values (in tCO_2e) can be extracted from the TUBA output file. The results are under the headings “CO2_EMISSIONS_UNTRADED” and “CO2_EMISSIONS_TRADED.”*

10.3.2 Capital carbon

Refer to Section 4 for detailed guidance on capital carbon. To perform a high-level estimate (Method 2 in the capital carbon methodology), the data shown in Table 10-3 will be required.

Table 10-3: Data required for capital carbon assessment

Data type	Units	Example source
Scheme dimensions	m/m^2	Project data
Asset/ facility type	N/A (description)	Project description

10.4 Assessment methodology

10.4.1 Operational/in-use carbon

DfT Transport Analysis Guidance (TAG) UNIT A3[46] for environmental impact appraisal should be followed to calculate the carbon impact of the scheme intervention. Scheme promoters should ensure to use the methodology, software and assumptions outlined within the guidance to ensure the carbon impact of proposed park and ride schemes are reported and incorporated within the appraisal in a consistent and transparent way. This can allow for comparisons to be made across schemes. The assessment principles listed in Table 2-1 are consistent with TAG UNIT A3 however, for a greater level of detail refer to the TAG guidance document itself. These results should be presented in units of tCO_2e as a total over the appraisal period and on an annual basis where possible.

10.4.2 Capital carbon

See Section 4 for detailed instructions on undertaking a capital carbon assessment. A capital carbon assessment should be undertaken for all projects. A tiered approach to assessment has been developed:

Method 1: **Pre-existing assessment**

Where a capital carbon assessment has been already undertaken, the results in tCO_2e should be reported.

Method 2: High-level assessment

This method should be used where no previous capital carbon quantification exists. To obtain a high-level estimate of the carbon associated with construction activities and materials, a relevant benchmark should be applied.

Suggested benchmarks based are provided in Table 10-4 below[47]. The carbon emissions in tCO_2e should be reported.

[46] DfT (2021). TAG unit A3 environmental impact appraisal. Available online: TAG UNIT A3 Environmental Impact Appraisal (publishing.service.gov.uk).

[47] Little Black Book (2010). *Construction benchmarks: Highways construction and asset management 2010 – 2011*.

Table 10-4: Capital carbon benchmarks

Asset/ facility type	Capital carbon (tCO_2e/metre)	Source
Station building	1 (tCO_2e/m^2)	Little Black Book (2010)
Footpath	0.5	
Bus lane	0.8	

For areas of car parking, it is suggested the following benchmark is used:

Table 10-5: Capital carbon benchmark

Data type	Capital carbon (tCO_2e/m^2)
Car parking spaces	0.0156

This benchmark has been modelled in the Mott MacDonald Moata Carbon Portal using typical materials and types of plant.

Method 3: Detailed quantification

If the high-level assessment indicates that capital carbon emissions account for more than 5% of total emissions, then construction emissions should be assessed as per Method 3 if project-specific data is available. Consult Section 4 for further information on how to complete a bottom-up assessment using publicly available databases and industry standards.

To navigate back to scheme descriptions, click here.

11 Transport (railway station) schemes

This section provides guidance for schemes which contain a railway station. Railway station schemes involve the construction/refurbishment of a new station building and/or platforms.

Railway station schemes, such as station gateways, could also include elements of other scheme components. In this case, the applicable sections of this guidance should be referred to. Some examples are below:

- Access improvements and urban realm (see Section 7 for cycling and walking or Section 6 if this involves roads)
- New station building, operational energy impacts (see Section 13)
- Station refurbishment or energy efficiency improvements (see Section 14)

11.1 Assessment Threshold

For all railway station schemes an operational carbon assessment should be undertaken. It should be noted that this section will only cover operational/in use transport emissions. Carbon emissions from induced demand effects should already be accounted for in the operational/in-use carbon assessment. However, care should be taken However, care should be taken to ensure the scope and coverage of these multi-modal assessments is representative of the entire journey.

For guidance on accounting for operational/in-use energy from the station building refer to Sections 12 and 13. Capital carbon emissions should also be included following the guidance and tiered methodology approach found in Section 4.

11.2 Source of emissions

Transport operational/In-use carbon results from a change in vehicle use across the transport network and should be assessed for all railway station schemes. Capital carbon emissions associated with construction activities and materials used in the creation of an asset should be assessed. The impacts of refurbishment, and end-of-life can be excluded if there is a lack of project-specific data at OBC and FBC design stages.

Table 11-1:Carbon emission sources which require assessment

Emission source	Assessment required
Operational/in-use	Yes
Capital	Yes

11.3 Data Required

11.3.1 Operational/In-use Carbon

Carbon assessments using traffic modelling (for example calculated using a TUBA[48] assessment) should be used to account for the change in operational/in-use carbon emissions. See section 6.3.1 for more information on TUBA assessments and alternative options. If a TUBA assessment is not available, carbon outputs can be extracted from an assessment using

[48] For further information on TUBA, refer to the definitions section of this guidance or visit Transport users benefit appraisal: software and user manuals - GOV.UK (www.gov.uk).

demand modelling and Marginal External Costs (MEC), further information is available in Section 11.4.1.

Table 11-2: Data required for operational/in-use carbon assessment

Data type	Units	Example source
GHG outputs from traffic modelling	tCO_2e	TUBA assessment*, MEC outputs

**The annual and total carbon values (in tCO_2e) can be extracted from the TUBA output file. The results are under the headings "CO2_EMISSIONS_UNTRADED" and "CO2_EMISSIONS_TRADED."*

11.3.2 Capital carbon

Refer to Section 4 for detailed guidance on capital carbon. Railway station schemes can take different forms, but to perform a high-level estimate (Method 2 in the capital carbon methodology), the data in Table 11-3 may be required:

Table 11-3: Data required for capital carbon assessment

Asset/ facility type	Units	Source
Platform and track – construction spend	£	Project data
Station building – floor area	m^2	Project data
Roads and footpaths - length	Meters	Project Data
Hardstanding - area	m^2	Project Data

11.4 Assessment Methodology

11.4.1 Operational/In-use Carbon

DfT Transport Analysis Guidance (TAG) UNIT A3[49] for environmental impact appraisal should be followed to calculate the carbon impact of the scheme intervention. Scheme promoters should ensure to use the methodology, software and assumptions outlined within the guidance to ensure the carbon impact of proposed railway station schemes are reported and incorporated within the appraisal in a consistent and transparent way. This can allow for comparisons to be made across schemes. The assessment principles listed in Table 2-1 are consistent with TAG UNIT A3 however, for a greater level of detail refer to the TAG guidance document itself. These results should be presented in units of tCO_2e as a total over the appraisal period and on an annual basis where possible.

11.4.2 Capital carbon

See Section 4 for detailed instructions on undertaking a capital carbon assessment.

A capital carbon assessment should be undertaken for all projects. A tiered approach to assessment has been developed:

Method 1: Pre-existing

[49] DfT (2021). TAG unit A3 environmental impact appraisal. Available online: TAG UNIT A3 Environmental Impact Appraisal (publishing.service.gov.uk).

Where a capital carbon assessment has been already undertaken, the results in tCO_2e should be reported.

Method 2: High-level assessment

This method should be used where no previous capital carbon quantification exists. To obtain a high-level estimate of the carbon associated with construction activities and materials, a relevant benchmark should be applied.

A selection of suggested benchmarks for railway stations[50] and their platforms[51], roads[52] and hardstanding components [53] are provided in Table 11-4 for use depending on the exact components of the scheme. The carbon emissions in tCO_2e should be reported. Note, if the scheme consists of significant road construction, this should be accounted for using the methodology in Section 6 (Transport (highways) schemes).

Table 11-4: Capital carbon benchmarks

Asset/ facility type	Capital carbon	Source
Platform and track	0.00032 (tCO2e/£)	Institution of Civil Engineers (2020)
Station building	1 (tCO_2e/m^2)	GLA (2020)
Wide single carriageway	1.8 (tCO_2e/m)	Little Black Book (2010)
Single carriageway	1.3 (tCO_2e/m)	
Single lane slip road	1 (tCO_2e/m)	
Single lane link road	0.8 (tCO_2e/m)	
Bus Lane	0.8 (tCO_2e/m)	
Footpath	0.5 (tCO_2e/m)	
Hardstanding Areas	0.0156 (tCO_2e/m^2)	Moata Carbon Portal

A specific capital carbon benchmark for platform and track is not currently available. Instead, the suggested benchmark is an industry average across a range of infrastructure sectors. Only the capital spend associated with platform and track construction should be used when calculating the associated capital carbon emissions.

The capital carbon benchmark for the station building is a conservative value based upon the guidance provided in Section 12.

Method 3: High-level assessment

If the high-level assessment indicates that capital carbon emissions account for more than 5% of total emissions, then capital emissions should be assessed as per Method 3 if project-specific data is available.

[50] GLA (2020). *Whole Life-Cycle Carbon Assessments guidance.* Available online: https://www.london.gov.uk/publications/whole-life-cycle-carbon-assessments-guidance#appendix-2-benchmarks.

[51] Institution of Civil Engineers (2020). *Infrastructure Carbon Review 2020 Data Update.* Available online: https://www.ice.org.uk/news-and-insight/the-civil-engineer/november-2020/carbon-in-infrastructure-where-and-how-much.

[52] Little Black Book (2010). *Construction benchmarks: Highways construction and asset management 2010 – 2011*.

[53] This benchmark has been modelled in the Mott MacDonald Moata Carbon Portal using typical materials and types of plant.

The RSSB Rail Carbon Tool[54] should be used to calculate emissions associated with construction activities.

To navigate back to scheme descriptions, click here.

[54] RSSB (2021). *Rail Carbon Tool.* Available online: https://www.rssb.co.uk/sustainability/Rail-Carbon-Tool.

12 Buildings schemes – new

This section provides guidance for projects which involve the construction of **new** buildings.

For projects that involve demolition and rebuilding, the capital carbon of the buildings to be demolished should be accounted for when estimating the total capital carbon of the scheme. For guidance, see Section 4. Operational carbon emissions from any new build portion of the scheme can then be estimated using the approach described below.

12.1 Assessment threshold

All new buildings are required to undergo an energy use and carbon emissions assessment to demonstrate compliance with Part L of the UK Building Regulations. However, the Part L calculation procedure only addresses a portion of the total lifecycle carbon emissions from buildings (see Box 1 below). In the interest of transparency, it is recommended that both operational and capital carbon emissions for all building schemes be assessed. However, this is not a legislative requirement, and there is no industry standard approach for Local Authorities to undertake such assessments.

Obtaining a robust assessment of operational and capital carbon requires large amounts of detailed information that is typically only available once the project reaches an advanced stage (post-planning). Where it is financially feasible to do so, all building projects should undergo a whole life-cycle carbon assessment at key RIBA stages.[55] At minimum, this should be carried out for 'major developments' which are defined by the Town and Country Planning Act (2015) as:

- Residential developments consisting of 10 or more dwellings;
- Developments where the total area of the building(s) will be 1,000 square meters or more; or
- Developments carried out on sites of 1 hectare or more.

Some projects may not meet the threshold described above, but might be replicated across the Combined Authority's estate, and therefore collectively represent a significant source of carbon emissions. An example of this would be refurbishment of houses and offices. It may therefore be necessary to undertake a dedicated carbon assessment that considers these effects in aggregate, recognising that the projects may not be brought forth at the same time.

Box 1: A note on terminology in the buildings sector

'Operational' fuel consumption and carbon emissions are those that occur during the operation of the building. This is different from capital carbon, which refers to fuel consumption and carbon emissions associated with the manufacture of building products or materials, and the construction or demolition of the building.

Some operational fuel consumption is 'regulated', i.e., covered within the scope of UK Building Regulations, and some is 'unregulated'. Regulated fuel consumption is associated with fixed building services and fittings i.e., space heating, hot water, lighting, pumps, fans,

[55] RIBA (2017). *Embodied and whole life carbon assessment for architects*. Available online: https://www.architecture.com/-/media/gathercontent/whole-life-carbon-assessment-for-architects/additional-documents/11241wholelifecarbonguidancev7pdf.pdf.

and ventilation systems. Unregulated fuel consumption is associated with other systems or processes such as IT equipment and other electrical appliances, which may be installed by the building user.

Because Building Regulations compliance assessments are somewhat limited in scope, they tend to underestimate the total operational energy use and carbon emissions. For this guidance, the aim is to understand the total operational fuel consumption, and the associated carbon emissions:

Total operational energy use = Regulated energy use + Unregulated energy use

12.2 Sources of emissions

Operational carbon emissions are due to the fuel required to power and heat the building when it is in use. Capital carbon emissions are associated with construction activities and materials when the scheme is built. In some cases, end-of-life emissions (i.e., demolition and material reclamation / waste management) are included in capital carbon benchmarks; this is clearly stated when required.

Some schemes will involve demolition of existing buildings (known as ‘demolish and rebuild’). The capital carbon emissions of those buildings is not typically considered part of the carbon impact of the new development, as defined in PAS2080 or the RICS whole life carbon assessment methodology. However, this carbon is essentially ‘wasted’ if the material is not beneficially reused. In order to promote consideration of how demolition waste can be minimised and materials can be kept in use for as long as possible, the capital carbon of demolished buildings should be assessed using benchmarks and reported separately, with consideration given to whether demolished buildings have reached the end of their intended design life. Induced effects, such as changes in transport emissions from new development, are assumed to be covered by other chapters of this report and are therefore assessed separately.

Table 12-1: Carbon emission sources which require assessment

Emission source	Assessment required
Operational	Yes
Capital	Yes
Capital (buildings demolished, if applicable)	Yes - reported separately

The relative contribution of these sources of emissions is illustrated in Figure 12-1 below. Figure 12-2 provides a similar analysis, broken down for different building types. As can be seen, both operational and capital emissions are important, but their relative contribution varies considerably depending on the project in question.

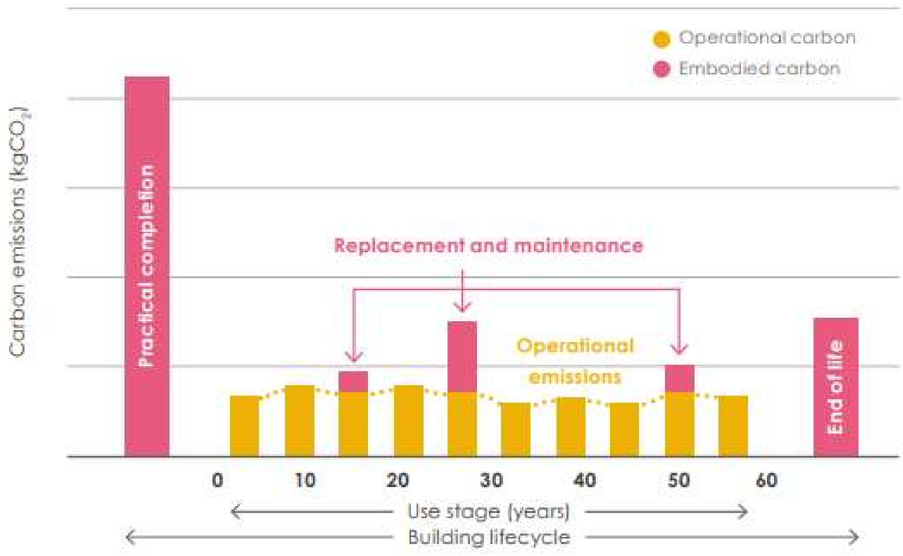

Figure 12-1: Emission breakdown of a building's lifecycle (Source: LETI, 2020[56])

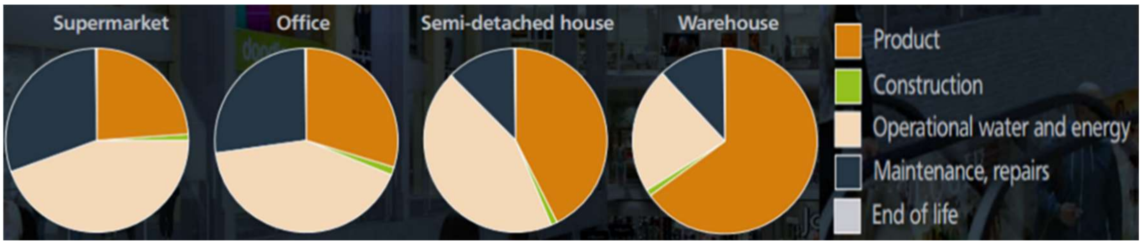

Figure 12-2: Diagram showing operational energy and water use as a proportion of whole lifecycle carbon emissions for a range of sample buildings (Source: UK GBC, 2017[57])

Recognising that the Government plans to update UK Building Regulations to minimise operational energy demands in buildings, and that the Combined Authority has adopted a target for the Leeds City Region to achieve Net Zero annual emissions by 2038, it is anticipated that the operational emissions from new buildings will decrease significantly in the coming years. This means that capital carbon emissions will represent a higher proportion of the total, potentially resulting in more scrutiny from designers, building users, project promoters and other stakeholders.

12.3 Data required

12.3.1 Operational carbon

If an assessment of the *total* operational emissions (from both regulated and unregulated energy use) has already been undertaken, results of that analysis can be used. If metered energy data for comparable projects is available (for example, if the building forms part of a

[56] LETI (2020). *LETI Embodied carbon Primer.* Available online: https://www.leti.london/ecp.

[57] UKGBC (2017) . *Embodied carbon: developing a client brief.* Available online: https://www.ukgbc.org/sites/default/files/UK-GBC%20EC%20Developing%20Client%20Brief.pdf.

housing development for which identical units are already in occupation), then that could be used as a proxy. Otherwise, it is possible to obtain an estimate of operational carbon emissions using benchmarks.

Table 12-2: Data required for operational carbon assessment

Data type	Units	Example source
Method 1: If an operational carbon assessment has been undertaken:		
Operational energy consumption or carbon emissions	kWh or tCO_2e (either per year or over the assessment period)	Non-domestic buildings: Examples include CIBSE TM54 assessment, BREEAM In-use calculator, or similar. Domestic buildings: Examples include PHPP modelling results, monitored data from comparable case study properties, or similar.
Method 2/3: If an operational carbon assessment has not been undertaken:		
Building usage	e.g., residential, retail, office, healthcare, education	Project data
Floor area	m^2	Project data
(Residential projects only) Size of development	# of dwellings	Project data
If known, operational energy intensity of the proposed development	kWh/m^2 or kWh/dwelling	Project data
If known, target carbon emissions reduction for the project	Typically expressed as % reduction (compared with standard practice)	Project data

Some metrics, such as energy or fuel consumption, are often reported as annual figures. These will need to be converted into cumulative totals depending on the intended lifecycle of the scheme. For typical buildings, the lifespan is assumed to be 60 years, but this may differ for some temporary buildings such as pavilions. Guidance on selecting an appropriate analysis period (number of years) is provided by the RICS: Practice Standards (rics.org)

12.3.2 Capital carbon

Table 12-3, adapted from the RICS 'Methodology to calculate capital carbon of materials', gives an overview of the suggested capital carbon assessment method, based on the relevant RIBA work stage[58]. It shows that the approach to estimating capital carbon emissions will depend on the project stage and level of information that is available.

Table 12-3: Capital carbon assessment method

RIBA work stage	How to estimate capital carbon depending on the stage of the project?
0 - 2	Multiply floor area of the development by a benchmark value. This is usually done until the point in the project when the specification and quantities of materials are confirmed.
3 and beyond	Calculate mass of construction materials and multiply the results by the relevant embodied carbon factors. If more specific factors (e.g., from the manufacturer) become available, then they can replace the generic factors, if/when applicable.

In line with the above RICS guidance, if a capital carbon analysis of the project has already

[58] RICS (2013) *Methodology to calculate embodied carbon of materials.*. Available online: https://www.igbc.ie/wp-content/uploads/2015/02/RICS-Methodology_embodied_carbon_materials_final-1st-edition.pdf.

been carried out, those results can be used. Otherwise, the floor area of the building can be used to estimate the capital carbon associated with construction of the scheme using benchmarks. As with operational energy use, it is difficult to obtain accurate predictions without detailed project information and the use of specialist software, so the latter approach is intended only for projects with limited information available.

The capital carbon emissions from a newly constructed building over the appraisal period should be calculated. As noted previously, this is typically assumed to be 60 years.

Table 12-4: Data required for capital carbon assessment

Data type	Units	Example source
Method 1: If a capital carbon assessment has already been undertaken…		
Capital carbon emissions	tCO_2e	Project data could be found in a stand-alone capital carbon assessment, if available. These may be referred to as a Life Cycle Assessment (LCA) Whole Life Carbon (WLC) carbon assessment.
Method 2: If a capital carbon assessment has not already been undertaken, and limited design or material information is available…		
Building usage	e.g., residential, retail, office, healthcare, education	Project data
Floor area	m^2	Project data
Method 3: If a capital carbon assessment has not already been undertaken, and sufficient information is available to support a detailed assessment…		
Building usage	e.g., residential, retail, office, healthcare, education	Project data
Floor area	m^2	Project data
Construction materials (e.g., concrete, cement, bricks, steel, glass, wood)	e.g., metric tonnes, m^3, number	Project data e.g., financial documents, building specification documents or Quantity Surveyor reports

If detailed information regarding the design, quantity and type of construction materials is available, then it is recommended that a detailed lifecycle carbon assessment should be commissioned (where possible), as mentioned in Section 12.1. This is a time-intensive process that requires specialist knowledge and the use of dedicated software.

12.4 Assessment methodology

12.4.1 Operational carbon

If an operational carbon assessment has already been undertaken for the project, operational carbon emissions in tCO_2e should be reported for the appraisal period.

For most projects, it is unlikely that such an assessment will have been undertaken as these are not routine within the construction industry. If this is the case, it will be necessary to first estimate the operational fuel consumption, and then convert this to carbon emissions.

To convert operational fuel consumption into CO_2e emissions, multiply the annual fuel consumption for each fuel type (kWh) by the appropriate carbon emissions factor for that fuel ($kgCO_2e$/kWh) (see Appendix A for relevant emission factors) to find the total carbon emissions ($kgCO_2e$) for a given year. This should be repeated for each year of the project's anticipated lifespan using carbon factors that account for future emission factors for grid electricity (and other fuels where applicable). The results can then be summed to obtain the total estimated operational carbon emissions for the appraisal period.

For projects that are at a more advanced stage of design, where predicted energy assessments (PEAs) or energy performance certificates (EPCs) are available, these can be used to tailor the estimates. However, because they only consider regulated energy use and carbon emissions, they are likely to underestimate total operational CO_2 emissions so cannot be used directly. They are also likely to use outdated emission factors. It is recommended that the design team should be consulted to advise on how best to utilise EPC or PEA results and assess the potential scale of unregulated CO_2 emissions.

Suggested benchmarks are provided in Table 12-4 below. These are based on the typical performance of existing and new buildings in the UK and will need to be reviewed subject to future changes in Part L of the UK Building Regulations. Note that these benchmarks assume the building uses a gas heating system.

If the project is targeting improvements in energy use and/or carbon emissions compared with Building Regulations or other policy requirements, then it will be necessary to apply a reduction to the figures below. This will vary on a project-by-project basis. Such targets are frequently expressed as an overall percent (%) reduction figure which can be applied directly.

Table 12-5: Operational carbon benchmarks

Type of building	Suggested source of benchmarks
Non-residential, new or refurbished	CIBSE TM46 'best practice' benchmarks[59] for the relevant building use category
Non-residential, existing	CIBSE TM46 'standard practice' benchmarks for the relevant building use category
Residential, new or refurbished	The National Energy Efficiency Database provides typical consumption figures for new domestic buildings that meet current Part L (2013) standards as follows: [60] • Electricity: 3,100 kWh per dwelling per year • Gas: 9,300 kWh per dwelling per year
Residential, existing	Median domestic gas and electricity consumption figures for each Local Authority are published annually by BEIS[61,62]

If the scheme promoter or design team is aware of alternative benchmarks that are more suitable, these can be used instead. This would be the case, for example, if new benchmarks are published that better reflect the performance of buildings constructed to meet future Building Regulations. It would also be the case if modelled or metered energy data from similar buildings is available.

To summarise:

1. Identify the appropriate annual fuel consumption benchmarks: kWh/m^2 or kWh/dwelling

[59] A consolidated list of industry standard benchmarks can be found in Appendix C of the Cundall publication, *'What Colour is Your Building?'* Available online: What Colour Is Your Building? - Cundall

[60] These benchmarks are taken from the National Energy Efficiency Database. They represent annual fuel consumption for new buildings where the first year of metered data is from 2017. In other words, these figures represent typical performance for homes constructed to current (Part L 2013) Building Regulations. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/853067/energy-consumption-new-domestic-buildings-2015-2017-england-wales.pdf

[61] BEIS (2020) *Sub-national gas consumption data.* Available online: Sub-national gas consumption data - GOV.UK (www.gov.uk).

[62] BEIS (2020) *Sub-national electricity consumption data*. Available online: Sub-national electricity consumption data - GOV.UK (www.gov.uk).

2. Estimate annual fuel consumption: kWh/m^2 x m^2 = kWh or kWh/dwelling x number of dwellings = kWh
3. Convert fuel consumption to annual carbon emissions: kWh x kgCO_2e/kWh = kgCO_2e
4. If necessary, repeat these steps for different fuels (e.g., gas, electricity, etc.) to find the total operational carbon emissions per year: kgCO_2e [gas] + kgCO_2e [electricity] = kgCO_2e [total annual emissions]
5. Repeat for each year of the lifecycle of the scheme, using carbon emission factors that account for future decarbonisation.
6. Add these together to find the total operational emissions.
7. If necessary (for example, if the project is targeting a specific % reduction in carbon emissions), reduce the estimates accordingly.

12.4.2 Capital carbon

If a capital carbon assessment has already been undertaken for the project, emissions in tCO_2e should be reported for the appraisal period. This should incorporate future energy decarbonisation trajectories.

Alternatively, to estimate the capital carbon emissions associated with construction activities and materials, a relevant benchmark should be applied based on the building use and floor area. Suggested benchmarks are provided for residential, and commercial/public buildings in Table 12-6 below. Where a benchmark for a specific building type is not available, a comparable building type should be selected. Where there are no comparable building types, the most conservative value of 1 tCO_2e/m^2 should be used. Capital carbon emissions in tCO_2e should be reported.

The benchmark for residential buildings in Table 12-6 reflects a 'typical' building and a 'best practice' building for each building type. A 'best practice' building assumes that 30% of construction materials come from re-used sources, and 50% of material is to be re-used at end of life. The 'aspirational' capital carbon benchmarks for other public and commercial buildings are based on a 40% reduction in emissions compared to a 'typical' building; this assumption is based on the World Green Building Council's target to achieve a 40% reduction in whole life cycle emissions by 2030.

Table 12-6: Capital carbon benchmarks

Building type	Building specification	Stage	Capital carbon (tCO_2e/m^2)	Source
Residential	Typical practice	Construction (and assumed to include use and end of life)	0.8	LETI (2020)[63]
	Best practice		0.5	
Office	Typical practice ('benchmark')	Construction	1	GLA (2020)[64] *
		Use and end of life	0.5	
	Best practice ('aspirational')	Construction	0.6	
		Use and end of life	0.3	
Retail	Typical practice	Construction	1	
		Use and end of life	0.2	
	Best practice	Construction	0.6	
		Use and end of life	0.12	

[63] LETI (2020). *LETI Embodied carbon Primer.* Available online: https://www.leti.london/ecp.

[64] GLA (2020). *Whole Life-Cycle Carbon Assessments guidance.* Available online: https://www.london.gov.uk/publications/whole-life-cycle-carbon-assessments-guidance#appendix-2-benchmarks.

Building type	Building specification	Stage	Capital carbon (tCO_2e/m^2)	Source
Education	Typical practice	Construction	0.8	
		Use and end of life	0.3	
	Best practice	Construction	0.5	
		Use and end of life	0.18	
Apartment/hotel	Typical practice	Construction	0.85	
		Use and end of life	0.4	
	Best practice	Construction	0.5	
		Use and end of life	0.24	

* Note, at the time of writing, the benchmarks in this table are from a consultation draft of the 'Whole Life-Cycle Carbon Assessments guidance' and therefore may be subject to amendments.

To navigate back to scheme descriptions, click here.

13 Buildings schemes - refurbishment and energy efficiency

This section provides guidance for projects which involve building refurbishment or energy efficiency improvements.

13.1 Assessment threshold

Any refurbishment or energy efficiency projects that are required to demonstrate compliance with Part L of the Building Regulations should be subject to an operational carbon assessment to establish the scale of any carbon savings associated with the scheme.

13.2 Sources of emissions

Potential sources of carbon emissions are the same as those for new buildings. As is the case when assessing new buildings, if there is any demolition work or material being removed as part of the scheme, the capital carbon of those buildings and the demolition process itself should be assessed and reported separately, with consideration given to whether demolished buildings have reached the end of their intended design life.

Potential *reductions* in emissions (i.e., operational energy savings) may be achieved once the energy efficiency measures are installed, for instance, after the fitting of insulation, or a change to lower carbon heating technologies.

Operational carbon emissions for the building both before and after refurbishment should be assessed; this will indicate the scale of carbon emissions savings that is achieved, if any. Capital carbon should be assessed when a significant amount of construction activity is required (see Section 12 for discussion of potential thresholds). However, note that because the structure and sub-structure of the building are not likely to be substantially altered, it may be difficult or impossible to carry out a capital carbon assessment until details of the material quantities are known. Induced effects are assumed to be negligible and do not require assessment.

Table 13-1: Carbon emission sources which require assessment

Emission source	Assessment required
Operational	Yes – compare emissions before and after refurbishment
Capital	Yes

13.3 Data required

13.3.1 Operational carbon

The operational carbon emissions for the building should be calculated for the scheme appraisal period. If annual figures are used, then these should be multiplied by the number of years that the scheme is assumed to be in operation. If only one element of the building is being upgraded, refer to the RICS guidance to establish a suitable analysis period.

Table 13-2: Data required for operational carbon assessment (Method 2)

Data type	Units	Example source
Pre-refurbishment operational energy consumption or carbon emissions	kWh or tCO_2e (either per year or over the assessment period)	Ideally this would be taken from metered energy data or Display Energy Certificates (where available). Otherwise, use the benchmarks for 'existing' buildings described in Section 12 to generate an estimate.
Post-refurbishment operational energy consumption or carbon emissions	kWh or tCO_2e (either per year or over the assessment period) *Note: Some projects may state a percent (%) energy or carbon emissions reduction target in which case this should be applied instead.*	Use project calculations if available. Otherwise, use the benchmarks for 'new or refurbished' buildings described in Section 12 to generate an estimate. If the building use is also changing, then the post-refurbishment benchmarks should reflect the new use.
Operational carbon savings	tCO_2e	Project calculations – This will typically be the difference between operational emissions pre- and post-refurbishment, calculated over the lifecycle of the scheme.

13.3.2 Capital carbon

Unless there are significant new build components of the scheme it is unlikely that industry standard benchmarks will be suitable for use in refurbishment projects. This is because the benchmarks typically include parts of the building such as the foundations, structure, façade, and internal finishes that may or may not be replaced during refurbishment. Some forms of refurbishment may only affect the building services (heating, ventilation, etc.) and there is very little peer-reviewed research on the capital carbon impacts of those individual technologies.

Therefore, it may not be possible to estimate the capital carbon emissions of such schemes until details of the design, materials and quantities are known. At that stage it may be necessary to commission a detailed carbon assessment. This is likely to take place after FBC stage in WYCA's assurance process, during RIBA work stages 3 onwards, as explained in Section 12.3.2. See Section 4 for further details of capital carbon assessments in general.

13.4 Assessment methodology

The approach to estimating emissions from refurbishment and energy efficiency schemes is similar to the approach for new buildings. The key differences are:

1. It is necessary to estimate the carbon emissions of the DM scenario (current building) in addition to the carbon emissions of the DS scenario (building post-refurbishment) to find the scale of operational carbon savings.
2. Metered energy data may already be available. If so, this should be used instead of benchmarks to quantify the DM operational carbon emissions.

Sense-checking results

The level of improvement that can be achieved varies depending on the project, but it may nonetheless be helpful to sense-check the results. There has been a considerable amount of research on the actual impact of energy saving measures undertaken in the last decade which can be used for reference.

For domestic buildings, typical reductions in annual heat demand following common measures such as loft or wall insulation and boiler replacement are in the range of 2-10%.[65] Much higher savings can be achieved for projects that involve a whole-house retrofit, with some Passivhaus and Energiesprong projects reporting heat demand reductions of 70-80% or more.[66,67] Research by the Building Research Establishment found reductions more commonly in the range of 40% for whole-house refurbishments.[68]

For non-domestic buildings, where heat demand often comprises a smaller portion of the operational emissions, there may be more of a focus on the energy management/control system and the use of efficient appliances. The net effect depends on many variables, but overall operational carbon savings may be in the 5-20% range whereas more ambitious retrofitting schemes may reduce operational carbon emissions by 30% or more.[69]

To navigate back to scheme descriptions, click here.

[65] For example, see BEIS, *'National Energy Efficiency Database: Impact of Measures Data Tables'* (2019). Available at: National Energy Efficiency Data-Framework (NEED): impact of measures data tables 2019 - GOV.UK (www.gov.uk)

[66] For examples, refer to the Passivhaus Trust website: Passivhaus News (passivhaustrust.org.uk)

[67] CIBSE Journal, *'Energiesprong – the Dutch system that could rescue Britain's social housing'* (2018). Available at: https://www.cibsejournal.com/case-studies/a-forward-leap-how-dutch-housing-process-energiesprong-guarantees-performance/

[68] As cited in UK-GBC, *'Regeneration and Retrofit: Task Group Report'* (2017). Available at: https://www.ukgbc.org/wp-content/uploads/2017/09/171027-Regen-Retrofit-Report_Final.pdf

[69] Based on various sources including research by the Carbon Trust and Better Building Partnership (BBP) and case study evidence (see below). This scale of emissions reduction also aligns with national and regional Government policies, such as the Clean Growth Strategy which aspires to a 20% reduction in business energy use by 2030, and the GLA London Plan which requires major non-domestic developments to achieve a minimum 15% reduction in regulated CO_2 emissions compared with Part L 2013 of the UK Building Regulations.

Carbon Trust, *'Building the Future, Today'* (2009). Available at: https://www.ukgbc.org/sites/default/files/Carbon%20Trust%20-%20Building%20the%20Future%20Today.pdf

BBP, *'Real Estate Environmental Benchmark: 2019 Energy Snapshot – Chart 6'* (2020). Available at: https://www.betterbuildingspartnership.co.uk/sites/default/files/media/attachment/BBP_REEB%202019%20Energy%20Snapshot.pdf

BBP, 'Helping Businesses to Improve the Way they Use Energy – Call for Evidence' (2018). Available at: https://www.betterbuildingspartnership.co.uk/sites/default/files/media/attachment/Better%20Buildings%20Partnership%20-%20Call%20for%20evidence%20-%20helping%20businesses%20to%20improve%20the%20way%20they%20use%20energy.pdf

14 Buildings schemes – Demolition and land remediation

This section provides guidance for projects which involve the demolition of existing buildings and land remediation, in preparation for further development of the land.

14.1 Assessment threshold

14.1.1 Building demolition

14.1.2 Emissions from demolition should be assessed for any projects that involve demolition of buildings. Land remediation

Land remediation is the process to restore land to its former state; this may occur in preparation for land being developed. The remediation of land is often considered to be a sustainable practice as it allows the reuse and redevelopment of previously developed land. However, most remediation methods involve a wide range of activities that result in environmental, social, and economic impacts. Certain remediation methods may result in significant carbon emissions. It is suggested that a carbon assessment is only undertaken where the remediation method used involves soil stabilisation/solidification.

NB: It should be noted that, despite soil stabilisation/solidification producing more carbon emissions than other remediation methods, it may still be the most suitable method given the circumstances and wider benefits or impacts to be considered.

14.2 Sources of emissions

When a building is demolished, energy is used to deconstruct the building and remove waste. There are also capital carbon emissions from disposal of the waste. Carbon emissions from the demolition process itself are small in comparison to the full life cycle of a building, as shown in Figure 14-1 (a repeat of Figure 12-2).

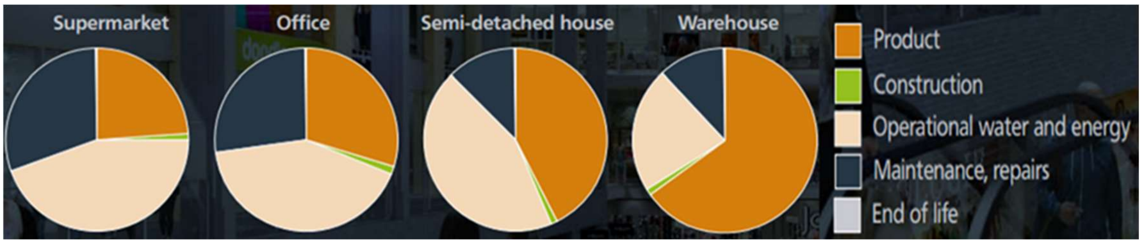

Figure 14-1: Diagram showing operational energy and water use as a proportion of whole lifecycle carbon emissions for a range of sample buildings (Source: UK GBC, 2017[70])

The capital carbon emissions of the buildings that are demolished are not typically considered part of the carbon impact of the new development, as defined in PAS2080 or the RICS whole life carbon assessment methodology. However, this carbon is essentially 'wasted' if the material is not beneficially reused. In order to promote consideration of how demolition waste can be minimised and materials can be kept in use for as long as possible, it is recommended that the

[70] UKGBC (2017). *Embodied carbon: developing a client brief.* Available online: https://www.ukgbc.org/sites/default/files/UK-GBC%20EC%20Developing%20Client%20Brief.pdf.

capital carbon of demolished buildings is assessed using benchmarks and reported separately, with consideration given to whether demolished buildings have reached the end of their intended design life.

Care needs to be taken with demolition carbon emissions to avoid double counting as some capital carbon emission factors include end of life emissions. At the moment, as total life cycle assessments are not routinely undertaken for buildings, this is likely not an issue, but should be flagged to avoid double counting of future emissions.

Carbon emissions associated with land remediation come from the process itself (i.e., use of machinery or plant), from the disposal of materials (i.e., landfilling of materials) and from the capital carbon in materials (for example, cement used to stabilise or support ground).

Table 14-1: Carbon emission sources which require assessment

Emission source	Assessment required
Operational	Yes (dependent on scheme methods and size)
Capital	Yes (dependent on scheme methods and size)
Capital (buildings demolished, if applicable)	Yes – reported separately

14.3 Data required

The data outlined in Table 14-2 is required for a Method 2 carbon assessment of demolition or land remediation projects.

Table 14-2: Data required for land remediation carbon assessment (Method 2)

Data type	Units	Example source
Remediation method used	Type	Project data
Tonnes of soil remediated	Metric tonnes	Project data
Area of building to be demolished	m^2 gross internal area (GIA)	Project data

14.4 Assessment methodology

For demolition projects, in the absence of more detailed information, project promoters can use the benchmarks set out in the RICS methodology for whole life carbon assessment of buildings.[71] This assumes an average of 3.4 $kgCO_2e/m^2$ GIA.

There are no industry standard benchmarks to apply to land remediation projects. Benchmarks have therefore been selected from an Institution of Civil Engineers report[72] which compares the sustainability, including carbon emissions, of five land remediation projects each using different remediation techniques and methods. When applying these benchmarks, it should be noted that they **include both operational and capital carbon**.

Project promoters can utilise alternative benchmarks e.g., based on internal data of real construction projects, if these are available.

[71] RICS, *'Whole life carbon assessment for the built environment'* (2017). Available online: whole-life-carbon-assessment-for-the--built-environment-november-2017.pdf (rics.org)

[72] Institution of Civil Engineers (2007). *Sustainability of land remediation. Part I: Overall analysis*. Available online: https://core.ac.uk/download/pdf/8799352.pdf.

Table 14-3: Benchmarks for land remediation methods

Remediation method	Tonnes CO_2e per metric tonne soil remediated	Source
Stabilisation/solidification	0.15 (during) and 0.004 (absorption after)	Institution of Civil Engineers (2007)
Soil washing	0.014	
Ex situ bioremediation	0.016	
Cover system	0.009	
Landfilling	0.018	

A more detailed Method 3 assessment could be undertaken but would likely require the expertise of a carbon assessment specialist. Data requirements would include: the amounts and types of materials used, the types of machinery and plant used and for how long, disposal routes and volume of soil remediated, and any transport-related activity.

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15 Renewable energy schemes

This section provides guidance for projects which involve the installation of renewable energy generation. This includes standalone renewable projects (i.e., the development of a wind or solar farm) or small-scale renewable projects on existing buildings and structures (i.e., retrofitting rooftop solar to an existing building). If renewables are included in the design of a new building, this will be taken into account when assessing the carbon of the new building (as part of the building regulation calculations) and should therefore not be calculated separately as this would result in a double counting of carbon emission savings.

15.1 Assessment threshold

In terms of operational emissions, renewable energy projects will reduce carbon emissions compared to a more carbon-intensive electricity source in the DM scenario, for example grid-supplied electricity. It is therefore recommended that all standalone and retrofitted renewables projects are assessed in order to show these savings. Capital carbon can be significant so should also be assessed where data allows.

15.2 Sources of emissions

Operational carbon emission savings come from replacing electricity consumed from DM sources (i.e., the national grid) with renewable alternatives (i.e., wind, solar, hydropower, etc.). To show these savings, project emissions will need to be compared to a scenario where no renewables are installed. Capital emissions will result from the production and installation of renewable energy technologies.

Table 15-1: Carbon emission sources which require assessment

Emission source	Assessment required
Operational	Yes – reported as emission savings compared to using baseline sources (e.g., grid supplied electricity)
Capital	Yes

15.3 Data required

15.3.1 Operational carbon

Given that the main purpose of a renewable energy scheme will likely be to reduce carbon emissions, it is probable that this will have already been calculated in a detailed way for a renewable energy project. If an operational carbon assessment has already been undertaken for the project, operational carbon emissions in tCO_2e should be reported for the scheme appraisal period.

If no assessment has been undertaken, a simple Method 2 approach can be used to estimate the operational carbon emissions of the renewable energy project for the scheme appraisal period. The data outlined in Table 15-2 is required for the operational carbon assessment of renewable energy projects.

Table 15-2: Data required for operational carbon assessment of renewable energy projects (Method 2)

Data type	Units	Example source
DM scenario energy type	Type	Project data
Renewable energy type	Type	Project data
Amount of renewable energy to be generated*	kWh/year	Project data
Lifespan of technology	Years	Project data. If not available, a lifespan of 25 years can be used; this is the typical warranty period.

*The amount of renewable energy generated is naturally dependant on the location and how the technology has been installed (for example, orientation, pitch, shading, etc.). A specialist may be required to provide an accurate estimation of the amount of renewable energy that will likely be generated as a result of the project.

15.3.2 Capital carbon

If a capital carbon assessment has already been undertaken for the project, carbon emissions in tCO_2e should be reported for the project.

If no assessment has been undertaken, a Method 2 approach should be used to estimate the capital carbon emissions of the renewable energy project. Table 15-3 outlines the data required for undertaking a capital carbon assessment for renewable energy projects.

Table 15-3: Data required for capital carbon assessment of renewable energy projects (Method 2)

Data type	Units	Example source
Renewable energy type	Type	Project data
Amount of renewable energy to be generated*	kWh/year	Project data
Capacity of installation	kWp	Project data
Lifespan of technology	Years	Project data. If not available, a lifespan of 25 years can be used; this is the typical warranty period.

15.4 Assessment methodology

15.4.1 Operational carbon

If no operational carbon assessment has already been undertaken for the project, a simple Method 2 approach is outlined below. This method will estimate the carbon emission savings from switching to renewable energy over the scheme appraisal period.

Carbon savings will be equal to the carbon emissions offset by switching from the DM electricity source (i.e., grid-supplied electricity) to renewable electricity. To calculate this, multiply the amount of renewable energy to be generated per year (kWh) by the appropriate emission factor ($kgCO_2e/kWh$) (see Appendix A for relevant emission factors) to find the total carbon emissions ($kgCO_2e$) for a given year. This should be repeated for each year of the project's anticipated lifespan, where the DM is grid electricity, carbon factors that account for future decarbonisation should be used (and for other fuels where data allows) Examples are provided in Appendix A. The results can then be summed to obtain the total estimated operational carbon emissions for the appraisal period.

15.4.2 Capital carbon

If a capital carbon assessment has already been undertaken for the project, emissions in tCO_2e should be reported.

Alternatively, to estimate the capital carbon emissions associated with construction activities and materials, a Method 2 approach involving applying a relevant benchmark based on the renewable energy type and system capacity should be used. Suggested benchmarks are provided in Table 15-4 for solar PV and wind turbines as these are the most likely renewable energy options given the context.

Table 15-4: Capital carbon benchmarks for solar and wind energy

Renewable energy type	Capital carbon	Unit	Source
Solar (average mon-crystalline PV)	2.56	tCO_2e / kWp	Circular Ecology[73] (based on data from International Energy Association, Ecoinvent and others)
Solar (cadmium-telluride PV)	0.867	tCO_2e / kWp	
Wind	0.000008 to 0.00002 (suggest to used midpoint of 0.000014)	tCO_2e / kWh	IPCC[74]

To apply the benchmarks, simply multiply the capacity of the installation (kWp) or amount of electricity generated (kWh) by the appropriate benchmark.

To navigate back to scheme descriptions, click here.

[73] Circular Ecology (no date). *Embodied Carbon of Solar PV: Here's Why It Must Be Included In Net Zero Carbon Buildings*. Available online: https://circularecology.com/solar-pv-embodied-carbon.html.

[74] IPCC (2012). *Special Report on renewable energy sources and climate change mitigation*. Available online: https://www.ipcc.ch/site/assets/uploads/2018/03/SRREN_Full_Report-1.pdf.

16 Woodland schemes

This section provides guidance for projects which involve the creation or removal of areas of woodland. It refers to the Woodland Carbon Code (WCC) Carbon Calculation Spreadsheet V2.4 which is available here and is accompanied by a detailed supporting guidance document (WCC Carbon Calculation Guidance V2.4 March 2021, available here). It is important to note that this assessment should only be used for woodland schemes that have a long-term maintenance plan in place to ensure that either the woodland is unmanaged or that any wood harvested is used in construction rather than being burned or allowed to decay. If biomass burning or decay occurs this will result in the stored carbon dioxide being released back into the atmosphere. Thus, long-term maintenance plans will provide assurance that the woodland will act as a carbon sink over a specific period of time.

16.1 Assessment threshold

The carbon impact of planting individual trees does not require assessment as part of the Combined Authority Assurance Process. Although tree planting generally provides benefits, the carbon impact of planting individual trees is negligible, and hence not recommended for assessment. Where areas of woodland are created, projects may use either the WCC 'Small Project Carbon Calculator' (for projects equal to or less than 5 hectares) or the 'Standard Project Carbon Calculator' (projects greater than 5 hectares).

The removal of areas of woodland of any size may be accounted for using this methodology. It is recommended that where removal is of a scale greater than individual trees, these impacts are accounted for.

16.2 Sources of emissions

As trees grow, they sequester carbon from the atmosphere. Conversely, the removal of woodland can result in emissions to the atmosphere as previously sequestered carbon is released. The planting or removal of vegetation that is not defined as trees or woodland does not require assessment as part of the Combined Authority Assurance Process as it can be assumed to be minimal; the WCC guidance states "in most cases in the UK, the project area will not sequester a significant amount without implementing the project".

An additional source of carbon emissions is the carbon associated with establishing a woodland. This is analogous to the 'capital carbon' of construction projects and can occur due to factors such as soil disturbance, machinery, the use of fertilisers and construction of access roads. These variables will be addressed by the WCC calculator.

Project promoters should also consider whether the scheme will result in more intensive use of another area of land under the same ownership. If so, then any significant carbon emissions through changes in land use or management of the area of land should be accounted for over the project duration. For example, if the proposed land is currently used for agriculture activity, this may result in the farmer buying a new plot of and changing the land-use elsewhere, this then results in activity-shifting carbon leakage. The WCC calculator includes a carbon leakage assessment.

Table 16-1: Carbon emission sources which require assessment

Emission source	Assessment required	
	Woodland/trees	Other vegetation
Sequestration	Yes	No
Loss of previously sequestered carbon	Yes	No

16.3 Data required

If an assessment has already been undertaken, this should be used (Method 1).

Guidance is provided on the WCC website as to the exact requirements to complete the carbon calculation spreadsheet. As a minimum, the data outlined in Table 16-2 are required for the assessment of carbon sequestration and any loss of previously sequestered carbon (e.g., tree removal).

Table 16-2: Data required for carbon sequestration assessment

Data type	Units	Example source
Project area	Ha	Project data
Tree species	Type	Project data
Planting spacing	M	Project data
Thinning regime	e.g., thinned/no-thin	Project data

16.4 Assessment methodology

16.4.1 Carbon sequestration

The WCC is a voluntary standard for woodland creation projects in the UK. It is not suggested that Combined Authority schemes must be registered under the standard; however, the publicly available spreadsheet tool can be used to calculate carbon emissions and sequestration over the appraisal period. It also accounts for the emissions from establishing the woodland such as ground preparation, fuel use and fencing.

The spreadsheet tool presents the carbon sequestration from woodland creation as a carbon unit where one unit is 1 tonne of CO_2e removed from the atmosphere. The instructions to complete the Woodland Carbon Code Calculation Tool should be followed, and can be found here. This involves inputting appropriate planting densities, species and thinning regimes. Where exact project data is not available, a relevant approximation should be made. The results from the column 'PIUs to Project' (converted into tCO_2e) will show the carbon sequestration resulting from the project.

The WCC 'small project' tool can be used with very limited project knowledge. However, if a suitable assumption cannot be made, and data is too limited to allow for the use of the WCC Calculation Tool, a simple benchmarking approach can be used to calculate the annual average carbon sequestration over the first 100 years of a scheme (refer to Box 2). This benchmark is highly uncertain and project teams should endeavour to complete a more detailed assessment using the WCC Calculation Tool, especially if the project progresses through the assurance process. Where carbon sequestration is quantified, the value should be reported as a negative carbon value within the proforma, and assumptions clearly stated.

Box 2: Suggested benchmark (and calculation) for sequestered carbon

Benchmark: 3.77 tCO_2e/ha per year, on average, during the first 100 years

This has been calculated from the WCC to illustrate the scale and magnitude of a scheme's carbon sequestration.

***Calculation**: Validated site area: 14,867 ha*

Validated CO_2 sequestration (cumulative, over 100 years): 5.6 MtCO_2e

5,600,000 tCO_2e / 14,867 ha = 377 tCO_2e/ha, cumulative, over 100 years

377 tCO_2e/ha / 100 years = 3.77 tCO_2e/ha per year, on average, during the first 100 years.

To navigate back to scheme descriptions, click here.

17 Peatland restoration

This section provides guidance for projects aimed at restoring peatlands. Typically, this involves raising the water table by restoring gullies and blocking drains, and/or protecting bare peat by reintroducing vegetation.

17.1 Assessment threshold

An assessment of carbon impacts should be undertaken for all peatland restoration schemes.

17.2 Sources of emissions

Peat is organic material which acts as a large store of carbon captured from the atmosphere. When peatlands are damaged, the stored carbon can be re-emitted to the atmosphere as carbon dioxide (CO_2), changing peatlands from a carbon sink to a carbon source. This can occur due to a range of factors, including pollution, drainage, conversion of peatland to agriculture, peat extraction and burning. Restoring damaged peatland can help to both avoid CO_2 emissions, and improve the rate of carbon sequestration.

Unlike woodland creation, where the rate of sequestration is high during the growth period but tapers off once the woodland reaches maturity, in certain conditions peatland is capable of continuing to sequester CO_2 over a longer time period.

It should be noted that re-wetting peatlands can increase emissions of other greenhouse gases such as methane and nitrous oxide. However, evidence from Natural England suggests that, overall, peatland restoration delivers net benefits by protecting stored carbon and drastically reducing the amount of CO_2 emitted, even after accounting for the increased emissions of methane and nitrous oxide following re-wetting.[75]

Emissions from each of these gases are expressed in units of CO_2 equivalent and therefore they are not listed as separate sources in the table below.

Table 17-1: Carbon emission sources which require assessment

Emission source	Assessment required
Peatland restoration	Yes

17.3 Data required

The data outlined in Table 17-2 is based on the inputs required to carry out an assessment using the Peatland Carbon Calculator.

[75] Natural England (2010). *England's peatlands: carbon storage and greenhouse gases (NE257)*. Available online: http://publications.naturalengland.org.uk/publication/30021.

Table 17-2: Data required for carbon assessment of peatland

Data type	Units	Example source
Project duration	Years	Project data
Pre-restoration condition category	(Select from options in tool)	Project data*
Post-restoration condition category	(Select from options in tool)	Project data*
Site area	hectares	Project data

* May require a more detailed environmental / condition survey to be carried out.

17.4 Assessment methodology

Assessments of peatland restoration can be undertaken using the publicly available spreadsheet tool used for the Peatland Code. The Peatland Code is a voluntary standard for peatland restoration projects in the UK.

The instructions to complete the Peatland Code Emissions Calculator, along with the spreadsheet, can be found here. This involves inputting information about the site area, project duration, pre- and post-restoration conditions.

If there is insufficient information to carry out an assessment using the Peatland Code Calculator (for instance, where projects are at a very early stage), as a rough rule of thumb estimate, the IUCN Peatland Programme suggests that peatland restoration projects save, on average, between 2 and 19 tCO_2e/ha.[76] More detailed assessments should be carried out at a later stage once information becomes available.

To navigate back to scheme descriptions, click here.

[76] IUCN (no date). *Peatland Code FAQs*. Available online: 160930 FAQs.pdf (iucn-uk-peatlandprogramme.org).

18 Heat networks

This section provides guidance for projects which involve the construction of district heat networks (DHNs) or communal heating, where this is carried out as a standalone project. For schemes that involve new construction or other energy efficiency refurbishments, refer to Sections 12 and 13 respectively. For schemes that involve other fuel switching, apply the same methodology as described in Section 15, substituting “renewable energy” for the DS fuel type.

18.1 Assessment threshold

An operational carbon assessment should be undertaken for all DHN schemes. If detailed information about material quantities and construction activities is available, then a capital/embodied carbon assessment should also be carried out; however, this is usually not the case until much later stages of a project.

18.2 Sources of emissions

Heat networks can be used to provide space heating or hot water to multiple properties from a centralised heat source. The heat can be provided by a range of technologies such as gas boilers, biomass boilers, gas-fired combined heat and power (CHP) systems, heat pumps, energy recovery from waste (EfW), etc. This can be particularly beneficial where there is a source of waste heat that would otherwise not be utilised, as is the case with some forms of industrial facilities and waste processing plants.

Heat networks are not a renewable technology per se but can potentially offer operational carbon savings compared with individual heating systems, due to (a) improvements in plant efficiency or (b) enabling the use of fuels with a lower carbon intensity (that is, less CO_2 emitted per unit of fuel consumed). For the purpose of this assessment, as a rule of thumb it is assumed that fuel consumption would be 10% lower as a result of better plant efficiency. However, they are not guaranteed to provide carbon savings. For example, the energy efficiency improvements from the heating system may be offset by heat losses from the distribution pipes. Operational carbon emissions could also increase if the new fuel is more carbon-intensive, as when switching from electric heating to communal gas boilers.

There will be some capital carbon emissions associated with the construction activities and materials (e.g., steel pipework), new heating systems (e.g., removal of old boilers and installation of new plant), and construction of a new energy centre (where applicable).

There is assumed to be minimal induced demand from heat networks. There is some evidence to suggest that building occupants may increase their heating use if they believe that their bills will be lower or that the new heating system is more efficient, but this is expected to be minimal.

Table 18-1: Carbon emission sources which require assessment

Emission source	Assessment required
Operational/in-use	Yes
Capital	Yes, if information is available

18.3 Data required

18.3.1 Operational carbon

Carbon impacts from heat networks are estimated in relation to the DM carbon emissions, based on the DM heating demand.

Table 18-2: Data required for operational carbon assessment of DHNs (Method 2)

Data type	Units	Example source
DM scenario annual energy use for heating	kWh/year	Metered energy data should be used if available. Otherwise, the heating demand can be estimated by reference to sources such as: • Median gas consumption figures for the Local Authority, published by BEIS[77] • CIBSE energy benchmarks[78] • Energy Performance Certificate (EPC) or Display Energy Certificate (DEC) data[79] • Typical Domestic Consumption Values (TDCVs), published by Ofgem[80]
DS scenario annual energy use for heating (once the heat network is complete)	kWh/year	Calculated (see methodology in Section 18.4)
Type and efficiency of the DM heating system	Type and efficiency (%)	If the efficiency is not known, use the assumptions listed in Table 18-3.
Type and efficiency of the DS heating system	Type and efficiency (%)	If the efficiency is not known, use the assumptions listed in Table 18-3.
Anticipated losses from the distribution network (distribution loss factor or DLF)	#	Project data. If this is not known, assume a distribution loss factor (DLF) of 1.15.[81]
Carbon emission factors (CEFs) for the DM and DS fuel types	$kgCO_2e/kWh$	Refer to the UK Government's carbon emissions factors for company reporting of greenhouse gas emissions.[82]

[77] BEIS (2020). *Regional and local authority gas consumption statistics*. Available online: https://www.gov.uk/government/statistical-data-sets/gas-sales-and-numbers-of-customers-by-region-and-local-authority.

[78] CIBSE (no date). *Energy benchmarking tool dashboard*. Available online: https://www.cibse.org/Knowledge/Benchmarking.

[79] Ministry of Housing, Communities & Local Government (2021). *Energy Performance of Buildings Data: England and Wales*. Available online: https://epc.opendatacommunities.org/. It is important to note that EPCs report the ***estimated*** annual space and water heating demands based on assumptions, whereas DECs report the actual energy use. DECs are only available for public buildings.

[80] Note that these are reviewed annually and may be revised. The most recent figures at the time of writing (August 2021) are available here: Decision on revised Typical Domestic Consumption Values for gas and electricity and Economy 7 consumption split (ofgem.gov.uk)

[81] The Government's Standard Assessment Procedure (SAP) methodology assumes that standard values for heat networks installed after 1990 are 1.05-1.1, but research indicates that the actual values are often much higher. 1.15 is used as a cautious estimate.

[82] BEIS (2021). *Government conversion factors for company reporting of greenhouse gas emissions*. Available online: Government conversion factors for company reporting of greenhouse gas emissions - GOV.UK (www.gov.uk).

Data type	Units	Example source
Lifespan of technology	Years	Project data. If not available, assume 15 years.

Table 18-3. Assumed heating system efficiency

System type	Efficiency*
Gas, oil or biomass boilers	80% (90% if installed in the last ~2 years)
Electric heating	100%
Air source heat pump	250%
Ground source heat pump	350%

** Note that these are simple rules of thumb and reflect the fact that in-use performance is often not as good as the theoretical performance.*

18.3.2 Capital carbon

Refer to Section 4 for detailed guidance on capital carbon.

18.4 Assessment methodology

18.4.1 Operational carbon

If an operational carbon assessment has already been undertaken for the project, operational carbon emissions in tCO_2e should be reported for the appraisal period.

Otherwise, for a Method 2 assessment, the annual operational carbon impacts can be estimated as follows:

1. **Calculate the DM scenario annual carbon emissions:**

   DM fuel consumption (kWh per year) x CEF for DM fuel ($kgCO_2e$/kWh) = DM CO_2 emissions ($kgCO_2e$ per year)

2. **Calculate the DS scenario annual fuel consumption for heating, accounting for 10% better plant efficiency, distribution losses, and changing the heating system:**

   DM fuel consumption x 0.9 x DLF x ([efficiency of DM heating system]/ [efficiency of DS heating system]) = DS annual fuel consumption (kWh per year)

3. **Calculate the DS scenario annual carbon emissions:**

   DS annual fuel consumption (kWh) x CEF for DS fuel ($kgCO_2e$/kWh) = DS CO_2 emissions ($kgCO_2e$ per year)

4. **Find the difference between the DS scenario and DM scenario annual carbon emissions:**

   DS CO_2 emissions ($kgCO_2e$ per year) – DM CO_2 emissions ($kgCO_2e$ per year) = CO_2 impact ($kgCO_2e$ per year)

   Divide by 1000 to obtain results in tCO_2e per year

   Note: If this is a negative number then there is a saving, however a positive number would indicate the annual emissions have increased.

5. **Estimate the total carbon savings over the lifespan of the project.**

   If the carbon intensity (CEF) of the fuels used within the DM and DS scenarios are expected to remain the same over time, then simply multiply the result from Step 4 by the number of years that the project will be in operation. If the fuel used within the DM or DS scenario is grid electricity, or if the heat network will use a mixture of fuels[83] then a different approach is needed. In that case, repeat the calculation for each year of the project lifespan, using appropriate CEFs, and sum the results to find the total carbon impact.

18.4.2 Capital carbon

Refer to Section 4 for detailed guidance on capital carbon.

To navigate back to scheme descriptions, click here.

[83] For example, if the heat network initially uses gas boilers, but there is the intention of switching to biofuel or hydrogen in future.

19 Other schemes

It is unlikely that all schemes will align with the categories outlined in the previous sections. As an example, other schemes might include those that provide training opportunities for skills and qualifications or provide businesses with financial support.

19.1 Assessment threshold

As other schemes are varied in their nature, there is no clearly defined threshold above which the carbon emissions for the scheme should be calculated. The scheme promoter should use their best judgement to identify the likely important sources of carbon emissions which will require assessment. It is up to the scheme promoter to identify situations where the project is likely to create carbon emissions and undertake a carbon assessment in these circumstances. Using the guidance below, and the guidance provided for the other scheme types, the major emissions sources should be quantified.

19.2 Operational/in-use carbon

For transport projects, DFT guidance and/or aspects of the approaches outlined for highways, public transport and active travel schemes in this document should be followed.

For non-transport schemes, calculating the operational emissions may involve, for example, estimating the annual energy consumption and applying a relevant carbon emissions factor from a reputable source such as the UK Government GHG Conversion Factors for Company Reporting.[84] These are often updated on an annual basis so care should be taken to ensure the most relevant database is being referenced.

Induced effects may be assumed to be negligible for most projects and do not require assessment unless there is a strong reason to believe that behavioural responses are likely to be significant and quantifiable. However, it is important to ensure that the boundary for carbon assessment aligns with the scheme benefits being claimed in the economic assessment.

19.3 Capital carbon

In the absence of detailed project data such as material quantities, benchmarks should be used to estimate the capital carbon impact where significant construction activity is required. For two different scenarios, suggested benchmarks are provided in Table 19-1 and Table 19-2. Use the most relevant to the construction associated with the scheme.

Table 19-1: Significant construction activity (e.g., plant use) but limited use of materials (especially concrete and steel)

Scope	tCO_2e/£m	Source
This includes any energy consumption for site accommodation, plant use and the impacts associated with any waste generated through the construction process, its treatment and disposal. Lifecycle stages A4 and A5.	14	RICS (2017) [85]

[84] BEIS (2021). *Greenhouse Gas Reporting: Conversion factors 2021*. Available online: Greenhouse gas reporting: conversion factors 2021 - GOV.UK (www.gov.uk).

[85] RICS (2017). *Whole life carbon assessment for the built environment. Available* online: whole-life-carbon-assessment-for-the--built-environment-november-2017.pdf (rics.org).

Table 19-2: Significant construction activity including plant use and widespread use of materials such as concrete and steel

Scope	tCO_2e/£m	Source
Similar to the scale of construction associated with a new highways scheme. Includes capital carbon associated with the use of materials. Lifecycle stages A1-A5.	126	Mott MacDonald derived[86]

To navigate back to scheme descriptions, click here.

[86] Benchmark based upon emerging research conducted by the Mott MacDonald Net Zero Coalition.

A. Appendix A – Fuel and energy emission factors

Emission factors per unit of electricity or fuel consumed are often required for carbon assessments on any scheme. For consistency and comparability, Table A 1 provides suggested BEIS (2021) emission factors for electricity and some common fuels. A new set of conversion factors are produced each year, so the project promoter should ensure the most up-to-date factors are used by following the source link provided in Table A 2. There are also conversion factors available for many other fuels and activities, if required.

Table A 1: Conversion factors for electricity and common fuels[87]

Fuel/activity	Unit	kg CO_2e / unit
Electricity generated (renewable sources)	kWh	0[88]
Electricity generated (grid)	kWh	0.21233
Electricity transmission and distribution	kWh	0.01860
Natural gas	kWh (gross CV)	0.18316
Diesel	kWh (gross CV)	0.23686
Gas oil	kWh (gross CV)	0.25679
Natural gas	m^3	2.02135
Diesel	Litres	2.51233
Petrol	Litres	2.19352

For electricity in particular, it is important to consider the potential longer-term decarbonisation of the electricity grid (particularly for buildings projects) using the electricity factors in Table A 2. These factors are based on the projected decarbonisation of the UK electricity grid and can be used over the lifetime of a scheme (i.e., 60 years for a buildings project). Note that these emission factors include transmission and distribution losses.

Table A 2: Consumption based grid average electricity emission factors to 2100 (unit: $kgCO_2e/kWh$)[89]

Year	Sector		
	Domestic	Commercial/public	Industrial
2010	0.501	0.492	0.483
2011	0.485	0.476	0.467
2012	0.532	0.523	0.513
2013	0.495	0.486	0.477
2014	0.441	0.433	0.425
2015	0.369	0.363	0.356
2016	0.291	0.285	0.280
2017	0.247	0.243	0.238

[87] BEIS (2021). *Greenhouse Gas Reporting: Conversion factors 2021*. Available online: Greenhouse gas reporting: conversion factors 2021 - GOV.UK (www.gov.uk).

[88] This value is not reported in the BEIS emission factors, but is aligned with guidance on electricity market based emissions reporting, as per the GHG Protocol (https://ghgprotocol.org/sites/default/files/standards/ghg-protocol-revised.pdf).

[89] BEIS (2021). *Green Book supplementary Guidance: Data table 1*. Available online: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/793632/data-tables-1-19.xlsx.

Year	Sector		
	Domestic	Commercial/public	Industrial
2018	0.180	0.177	0.174
2019	0.146	0.143	0.141
2020	0.141	0.138	0.135
2021	0.115	0.113	0.111
2022	0.107	0.105	0.103
2023	0.112	0.110	0.108
2024	0.104	0.102	0.100
2025	0.105	0.103	0.101
2026	0.099	0.097	0.095
2027	0.105	0.103	0.101
2028	0.100	0.098	0.096
2029	0.092	0.090	0.088
2030	0.083	0.081	0.080
2031	0.073	0.072	0.070
2032	0.061	0.060	0.059
2033	0.057	0.056	0.055
2034	0.049	0.048	0.048
2035	0.041	0.040	0.039
2036	0.041	0.040	0.039
2037	0.041	0.040	0.039
2038	0.041	0.040	0.039
2039	0.041	0.040	0.039
2040	0.041	0.040	0.039
2041	0.040	0.039	0.038
2042	0.038	0.038	0.037
2043	0.037	0.036	0.036
2044	0.036	0.035	0.034
2045	0.034	0.034	0.033
2046	0.033	0.032	0.032
2047	0.032	0.031	0.030
2048	0.030	0.030	0.029
2049	0.029	0.028	0.028
2050-2100	0.028	0.027	0.027

The electricity factors given in Table A 1 and Table A 2 do not fully align (likely due to the discrepancies in the year of publication). It is therefore important for project promoters to note which factors are being used, and to ensure they are consistently applied throughout the assessment.

B. Appendix B – Guide for the application of induced demand calculation

B.1 New induced traffic assessment

This section is intended to be used by scheme promoters who are adopting the induced travel assessment i.e., schemes where a quantified journey time change has been predicted for general traffic. It details the application of the methodology discussed in the induced demand technical note (Appendix C). A supporting 'WYCA Induced Travel Calculation' workbook will be provided alongside this guidance; an extensive list of references is provided within this document.

B.1.1 Elasticity Calculation

This section of the spreadsheet calculates the time-based elasticity using the relationship between travel time and traffic demand.

- Mandatory inputs:
  - **Assessment year (number):** The assessment year is the scheme year that is currently being assessed. This impacts all the future year lookups such as the value of time and fuel cost. Assessment years should match the economic assessment and would be expected to include the opening year and 15 years after the opening year for a 60-year assessment.
  - **Location (Urban/Rural/Scheme):** The location of the scheme determines the speed assumptions used in the elasticity calculation. The urban and rural speeds come from the 12-month rolling average from December 2020 in CGN501a TAG data table[90]. The scheme option allows you to use a custom speed where scheme data is available. The default urban speed is 33 kph and the default rural speed is 60 kph.
- Customisable inputs:
  - **Fuel price elasticity (number):** The fuel price elasticity should be a value between -0.1 and -0.5 based on values published in research. -0.13 was chosen as the default value as it is the most common value published across different literature even though it is on the lower end of the spectrum.
- Derived inputs:
  - **Value of time (number):** A lookup based on the assessment year in the TAG data book A1.3.2[91].
  - **Travel time (number):** Calculated from the speed in the Urban/Rural/Scheme section using the assumption of an average trip distance of 10.98 km from the NTS0101[92] data table.
  - **Fuel cost (number):** Copied from the Car Costs (CPI) using the 10.98 km trip length and the yearly fuel cost per km. See C.8 for methodology and assumptions.

[90] DFT (2021). *CGN0501: Average speed on local 'A' roads: monthly and annual averages.* Available online: Average speed, delay and reliability of travel times (CGN) - GOV.UK (www.gov.uk).

[91] DfT (2021). *TAG Data Book.* Available Online: TAG Data Book - GOV.UK (www.gov.uk).

[92] DfT (2019). *Table NTS0101: National Travel Survey.* Available online: National Travel Survey - GOV.UK (www.gov.uk).

These inputs are then used in the calculation for the time-based elasticity which is used in the induced travel calculation.

B.1.2 Induced travel calculation

The induced travel calculation uses inputs from the elasticity calculation to calculate the increase in vehicle kilometres which is used to estimate the carbon impact.

Elements of the induced travel calculation:

- **Base travel demand (number):** The base travel demand is the starting traffic flow without induced effects. This figure should represent an annual traffic flow for the entire time period. This could be a 24-hour flow but typically a transport scheme would not calculate benefits in off peak periods so this could be 12 or 18 hours to match the economic assessment.

Some schemes will have annualised flow figures available such as those which have done the TUBA. This can be entered directly in Section 3 induced travel assessment provided the TUBA assessment only covers the scheme area and does not include flows that don't experience a journey time change. This may require a selection of specific links from a transport model to remove the "model noise" from non-scheme links. Section 1 and 2 contain information and UK data to convert from model data to an annualised flow.

- **Elasticity (number):** Calculated in the previous step for each assessment year. This impacts how many additional trips are calculated.
- **Do minimum (DM) and do something (DS) journey times (JT) (number):** The journey time in minutes should be taken from the do minimum (without scheme) and do something (with scheme) assessment. These journey times should match the geographical area of the base travel demand. This could be taken from a TUBA or transport model.
- **Time of a trip within the model (number):** This figure measures the time taken for an individual trip within the model. This is important for the calculation as the scheme will only benefit a proportion of the whole trip that an individual driver is making. This will factor the induced travel estimate down to reflect the proportion of the trip that receives the journey time benefit. This is most important for schemes such as a junction improvement which could have a large impact in a small geographic area.
- **Location (Urban/Rural/Scheme):** The location is the same as in the elasticity calculation and is used in the speed and journey time assumptions.
- **Total trip time for an average 10.98 km trip (number):** This trip time is calculated using the aforementioned speed assumptions. This is used alongside the time of the trip within the model to proportion the induced calculation to represent how much of a trip experiences a journey time improvement.
- **Proportion of trip modelled (number):** This figure is calculated to represent the proportion of the trip that receives a journey time benefit from the scheme.
- **Induced trips (number):** The number of additional trips calculated by ((DS JT- DM JT)/DM JT) multiplied by the elasticity, base trips and proportion of trip modelled.
- **Average trip length (number):** Assumed to be 10.98 km based on NTS0101[93].
- **Total yearly induced travel (number):** The induced travel is calculated by multiplying the number of new trips by the average trip length.

[93] DFT (2019). *Table NTS0101: National Travel Survey*. Available online: National Travel Survey - GOV.UK (www.gov.uk).

B.1.3 Yearly carbon estimate

The yearly carbon estimate uses the annualised induced travel estimates and accounts for yearly changes over the appraisal period.

Inputs:

- **Vehicle split (TAG A1.3.9/2019 DfT transport statistics/Customisable vehicle fleet mix):** There are three options for the fleet future year assumptions. The 2019 transport statistics assume no change on the 2019 data and will provide a conservative assessment as most data assumes switches to lower carbon fuels. TAG A1.3.9[94] uses the assumed fleet changes in A1.3.9. The third option allows for customisable vehicle split assumptions.
- **First year (number):** This is the first year of the assessment and should be consistent with elasticity and induced travel calculations.
- **Yearly travel (number):** This is calculated in the induced travel calculation.
- **Location (Urban/Rural/Scheme):** This should be consistent with the previous calculations and determines the speed assumptions.

Elements of the Carbon Estimate:

- **Vehicle Split (table):** The vehicle split defines the proportion of kilometres travelled by each vehicle type consisting of cars, LHVs, OGV1, OGV2 and PSVs. The data used for this split has come from TRA0106[95]. and TRA3105[96].
- **Fuel Split (table):** Dependent on the selected future vehicle split assumptions the breakdown in petrol, diesel and electric vehicles is defined here.
- **Yearly fuel consumption (table):** This calculation uses the fuel split and yearly travel to calculate the amount of each fuel consumed. The table needs to be updated for the number of years in the assessment period. See section A for more information. Data from the TAG data book A1.3.8[97]. and A3.3[98]. were used here.
- **Yearly CO_2 (table):** This table uses the fleet change assumptions to convert from fuel consumption to carbon.

B.1.4 Appraisal period

The appraisal period sums up all the previous annual calculations to give results over the whole appraisal period. The appraisal period should be consistent across all assessment aspect e.g., carbon, economic, environmental. It is anticipated that there would be at least 2 sets of calculations for a 60-year appraisal period. This would cover the opening year up to 15 years and 15 years to 60 years after opening. More assessment years can be included to increase the precision of the calculation where data is available. Between multiple assessment years linear interpolation has been assumed. The final assessment year has been assumed to apply for the remainder of the assessment period.

[94] DfT (2021). *TAG Data Book.* Available Online: TAG Data Book - GOV.UK (www.gov.uk).

[95] DfT (2019). *TRA0160: Road traffic (vehicle miles) by vehicle type and region and country in Great Britain, annual 2019.* Available online: www.gov.uk/government/organisations/department-for-transport/series/road-traffic-statistics.

[96] DfT (2019). *TRA3105: Road traffic (vehicle miles) by vehicle type and region and country in Great Britain, annual 2019.* Available online: www.gov.uk/government/organisations/department-for-transport/series/road-traffic-statistics.

[97] DfT (2021). *TAG Data Book.* Available Online: TAG Data Book - GOV.UK (www.gov.uk).

[98] DfT (2021). *TAG Data Book.* Available Online: TAG Data Book - GOV.UK (www.gov.uk).

C. Appendix C – Technical Note detailing the development and basis of the induced travel assessment

C.1 Introduction to induced effects

The phenomenon where provision of new facilities, be they transport or otherwise, leads to behavioural responses such as increased demand is well known, but not consistently allowed for in existing appraisals. Induced demand is a commonly used phrase in the context of transport appraisal and includes changes in mode, destination, time of travel, trip frequency plus generated or new trips caused by the intervention. It is therefore only applicable in the "Do something" scenario.

Induced effects will be important on some schemes and negligible on others. For transport schemes, while there is provision for induced effects to be appraised using TAG methodologies, a review of business cases submitted to the Combined Authority for consideration within a variety of funding programmes suggests that induced effects are rarely allowed for explicitly, and that further guidance and support for project promoters is required. Nevertheless, existing appraisal approaches used by the Combined Authority do allow for some induced effects including, for example, within TAG transport appraisal where traffic models are used with a Variable Trip Matrix to model behavioural responses. The Active Mode Appraisal Toolkit (AMAT) also estimates additional active mode trips such as those switching from different modes.

For some schemes induced effects will already have been well accounted for in the operational transport assessments undertaken by project promoters (for example, where Variable Trip Matrices have been used as part of a transport assessment), whereas in other cases an additional assessment may be required to adequately account for induced effects. For non-transport schemes, additional induced effects would include effects not well accounted for in existing appraisal approaches.

C.2 Why are induced effects important for carbon assessment?

Todd Litman, writing in 2020, references the concept of induced demand for travel in respect of carbon emissions, and its consequent impact on increasing carbon emissions especially in respect of road transport. As noted by Litman "inducing total vehicle travel tends to increase total emissions, particularly over the long run"[99]. Litman quoted research undertaken by the Norwegian Centre for Transport Research (TØI) in 2009, which noted that "road construction, largely speaking, increases greenhouse gas emissions, mainly because an improved quality of the road network will increase the speed level. Emissions also rise due to increased volumes of traffic (each person traveling further and more often) and because the modal split changes in favour of the private car, at the expense of public transport and bicycling." The 2009 Norwegian work concluded that "increased vehicle mileage (induced vehicle travel) in large cities led to significant emission growth, and in smaller cities to moderate emission growth."

[99] Generated Traffic and Induced Travel Implications for Transport Planning 1 July 2020 Todd Litman Victoria Transport Policy Institute p17

This points towards some examination of carbon impacts of induced effects from changed travel behaviour being important in considering investments, especially in respect of investments to improve highway networks, as part of the development of a robust and proportionate approach to assessing carbon emissions in support of improved investment decisions in West Yorkshire.

Behavioural responses to transport investments and policies are not however limited to highway investments. This is amply illustrated by a recent major study for the Department for Transport to evaluate the effects of large-scale Smarter Choice Programmes in the Sustainable Travel Towns[100]. This work gathered and analysed in depth a large body of data "in order to evaluate the effect on car use and travel by other modes, and to understand the likely impacts on carbon emissions", as well as on other benefits including congestion and physical activity. Analysis of trips within the towns and their surrounding sub-regions showed that car driver trips fell by 9% and car driver mileage fell by 5-7%. A specific scoping study evaluated the contribution that smart measures could make to reducing carbon dioxide emissions, and the policy package necessary to make the most of these measures[101]. It found that smart measures offer a highly cost-effective way of reducing carbon emissions, compared to other methods.

The sections that follow therefore consider some of the potential behavioural responses in respect of investments in active travel, public transport, and highways infrastructure. In respect of active travel proposals, it is evident that, for the assessment of carbon impacts to inform the decision making process, such proposals tend to be beneficial in terms of carbon, resulting in a reduction of emissions; for public transport investments it is less clear, with potential for behavioural responses to both increase or decrease vehicle travel distances dependent upon circumstance; and for highways investments, there is more clarity in the evidence around behavioural responses resulting in induced travel. Less helpfully, a recent evidence review on behalf the Department for Transport by WSP & RAND Europe notes that "the evidence base on induced travel is mainly from outside the UK" and that "it was not possible to obtain any qualitative understanding about the composition of induced traffic in terms of new trips, redistributed trips, transfers between modes and trips associated with new developments."[102]

C.3 Active travel schemes

Investment in active travel programmes overtly promotes modal shift from private car use and other motorised forms of travel. This means that a comprehensive carbon assessment must consider behavioural responses. The evidence above from the Smarter Choices evaluation, of which active travel forms part, demonstrates the positive carbon impact of such measures. Furthermore, new research led by Oxford University's Dr Christian Brand[103] found active travel substitutes for motorised travel. The research identified that increases in cycling, e-biking or walking over time independently lower mobility-related lifecycle CO_2 emissions. And swapping the car for a bike or e-bike for just one day a week – or going from 'not cycling' to 'cycling' – drastically lowers mobility-related lifecycle CO_2[104]. Dr Brand notes that 'If just 10% of the population were to change travel behaviour, the emissions savings would be around 4% of lifecycle CO_2 emissions from all car travel' and went on to note that 'Our findings suggest that,

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[100] Impact of the Local Sustainable Transport Fund, Transport for Quality of Life, Arup & TRL, August 2018.

[101] Unpublished research for the Department for Transport by the Smarter Choices team (Transport for Quality of Life, University College London, Eco-Logica and Robert Gordon University).

[102] DfT (2018). *Latest Evidence on Induced Travel Demand: An Evidence Review WSP & Rand Europe*, Executive Summary (p2).

[103] Brand, C., Götschi, T., Dons, E., Gerike, R., Anaya-Boig, E., Avila-Palencia, I., de Nazelle, A., Gascon, M., Gaupp-Berghausen, M., Iacorossi, F., Kahlmeier, S., Int Panis, L., Racioppi, F., Rojas-Rueda, D., Standaert, A., Stigell, E., Sulikova, S., Wegener, S., Nieuwenhuijsen, M.J. (2021) The climate change mitigation impacts of active travel: Evidence from a longitudinal panel study in seven European cities. *Global Environmental Change,* **67**, 102224. https://doi.org/10.1016/j.gloenvcha.2021.102224

[104] University of Oxford (2021). *Get on your bike: Active transport makes a significant impact on carbon emissions*. Available online: Get on your bike: Active transport makes a significant impact on carbon emissions | University of Oxford.

even if not all car trips could be substituted by bicycle trips, the potential for decreasing emissions is huge.'

There is an established Department for Transport approach to the appraisal of active modes investment, the Active Mode Appraisal Toolkit (AMAT). The user guide for AMAT[105] is helpful in providing clarity on the quantification of carbon savings from active travel investment, illustrating how AMAT quantifies a wide range of potential benefits of cycling and walking interventions including:

- Health improvements from increased levels of physical activity in terms of reduced mortality risk and lower work absenteeism;
- Improvements to journey quality as a result of providing the perception of a safer or pleasant journey whilst using walking and cycling infrastructure; and
- Impacts associated with modal shift away from cars and taxis including improvements in traffic congestion, greenhouse gas emissions, air quality, noise, accidents, infrastructure maintenance, and changes to indirect tax revenues as a result of a reduction in distance travelled by these modes.

The AMCB worksheet summarises the quantified costs and benefits of proposed interventions for several benefit categories including:

- Greenhouse gases - in terms of a reduction in emissions of greenhouse gases due to a reduction in car kilometres.

Taken together, the understanding that AMAT quantifies impacts associated with the behavioural effect of modal shift to active travel modes and presents benefits in terms of quantified GHGs indicates that the use of AMAT, an established and recognised tool, can be the recommended approach for assessing the carbon impact of active travel. Promoters are therefore required to provide an assessment for active travel proposals using the Department for Transport's AMAT. There is no further recommended assessment of the behavioural response to these proposals, as it is likely that they will provide a benefit in respect of carbon emissions, and AMAT will provide a proportionate assessment of those benefits as described above.

C.4 Public transport schemes

While active travel investment universally brings carbon benefits in respect of the behavioural response it promotes, the behavioural response to investment in public transport is less clear cut. Behavioural response is specific to the intervention in question, with some investments having the potential to reduce vehicle distances travelled by promoting mode shift from car to public transport (and consequently reduce carbon emissions) whereas others may result in increased demand for travel and longer trip lengths with consequent increases in vehicle distances travelled and a resultant increase in carbon emissions. Each investment should therefore be viewed uniquely.

This potential for public transport to both increase or decrease vehicles distances travelled, and the consequent variety of impacts on carbon emissions, is illustrated by the case of park & ride investments. The work of Professor Graham Parkhurst is prominent in providing evidence of

[105] DfT (2020). *Active Mode Appraisal Toolkit User Guide*. Available online: Active Mode Appraisal Toolkit User Guide (publishing.service.gov.uk).

this, noting in a UWE Bristol video series that “most park and ride schemes increase traffic”[106], instead of working as a means of sustainable transport.

Writing in 1996[107] Parkhurst noted that “the effects of trip generation and abstraction from public transport are shown to have been universal, although varying in extent” and that “traffic reduction in urban areas has not been demonstrated.” He went on to say that “Park & Ride can be characterised as pursuing either economic or transportation goals. However, if employed in a transportation role, Park & Ride is unlikely to achieve satisfactory results outside a carefully constructed and radical package.” He concluded that “No long-term reductions in traffic levels have been attributed to the Park & Ride schemes considered in this review. Implementation can, though, be regarded as having had economic benefits.” This concept of providing economic benefits is linked to the opportunity presented by Park & Ride “to increase the total number of trips made within the urban area without additional congestion or environmental intrusion from more private vehicles”.

More recently Parkhurst and Meek concluded that “the key travel behavioural findings are that only a portion of Park & Ride users’ car trips are shortened. Hence, overall increases in car use occur, combined with overall reductions in public transport use, and in some cases less active travel.”[108]

Conversely, research that studied the effects of Park and Ride systems in Brighton, Cambridge Coventry, Norwich, Plymouth, Reading, Shrewsbury and York concluded that in seven of the eight towns and cities there was an “overall decrease in distances driven by cars”[109]. However, the behavioural effects of Park & Ride are complex, as this study also noted that 16% of those questioned said that they would not have made the journey had the Park and Ride been unavailable.

Similar effects can be seen with rail Park & Ride, which is an important element of the West Yorkshire public transport market. Research in the Netherlands conducted in nine rail-based Park & Rides located around the cities of Rotterdam and The Hague found “a number of additional unintended effects, namely ’abstraction from bike’ and ’Park and walk users’ of Park & Ride facilities, which reinforce the ambiguity surrounding the impact of Park & Ride.”[110]

This evidence illustrates that the behavioural effects of public transport interventions can vary, and therefore scheme promoters are required to ensure that each proposal is appraised using appropriate multi-modal analysis, and that appropriate demand forecasting is provided for each proposal to ensure that the impact of these effects is considered uniquely. Such considerations should inform the operational assessment of carbon impact within any business case presented. Clarity should be provided around the scope and coverage of these multi-modal assessments to ensure that the carbon impact includes assessment of all parts of public transport journeys, including car borne access to rail stations or Park & Ride interchanges.

[106] UWE Bristol (no date). *Transport videos from members of the Centre for Transport and Society*. Available online: Videos - CTS | UWE Bristol.

[107] Parkhurst, G. (1996). The Economic and Modal-split Impacts of Short-range Park and Ride Schemes: Evidence from Nine UK Cities, *ESRC TSU publication 1996/29*.

[108] Parkhurst, G., & Meek, S. (2014). The effectiveness of park-and-ride as a policy measure for more sustainable mobility.

[109] Whitfield, S., & Cooper, B. W.S. (1998). Atkins Planning Consultants on behalf of the UK Department of the Environment, *Transport and the Regions (DETR)*.

[110] Mingardo, G. (2013). Transport and environmental effects of rail-based Park and Ride: evidence from the Netherlands. *Journal of Transport Geography Volume 30*, Pages 7-16.

C.5 Highways schemes

The recent evidence review on behalf the Department for Transport by WSP & RAND Europe noted that “induced demand for road travel can be broadly defined as ‘the increment in new vehicle traffic that would not have occurred without the improvement of the network capacity’.”[111] This review went on to conclude that “induced demand continues to occur and may be significant in some situations.”

In terms of the significance of induced demand this review work for DfT confirmed that “the evidence reviewed in this study supports the findings of the SACTRA (1994) report that induced traffic does exist”. Furthermore, the review concluded that “induced demand is likely to be higher for capacity improvements in urban areas or on highly congested routes.”[112] This reference to SACTRA, The Standing Advisory Committee on Trunk Road Assessment confirms the conclusions in its well-known 1994 report that “Considering all these sources of evidence, we conclude that induced traffic can and does occur, probably quite extensively, though its size and significance is likely to vary widely in different circumstances.”[113]

SACTRA (1994) went on to note that induced traffic is of greatest importance in the following circumstances[114]:

- where the network is operating or is expected to operate close to capacity;
- where traveller responsiveness to changes in travel times or costs is high, as may occur where trips are suppressed by congestion and then released when the network is improved;
- where the implementation of a scheme causes large changes in travel costs.

Looking back to first principles, the WSP & RAND Europe work for DfT also includes some economic background which is helpful in pointing the way to a robust approach for assessing the impacts of induced demand on highways. The review report notes “economic theory tells us that generally if there is a reduction in the price of a good or service, demand for it will increase. This principle also applies to the demand for transport. WSP & RAND Europe go on to say that “in this case, however, the price of transport reflects all costs associated with travelling, such as the time taken, in addition to out-of-pocket costs. This is referred to as the ‘generalised cost’ of travel. If there is a change in this generalised cost of travel, then there should be a change in demand for travel. This applies to any mode of transport.” Note that generalised cost of travel refers to both the monetary (out-of-pocket costs) and non-monetary costs of travel (for example, travel time).

Finally, the WSP & RAND Europe review notes in this respect that “the degree of responsiveness is measured by the elasticity of demand - the percentage change in demand in response to a percentage change in the generalised cost of travel.”[115] This is helpful, and important to note in respect of informing the approach advocated in the assessment of induced demand with respect to highway improvement schemes, pointing the way towards the adoption of a proportionate approach using elasticities based on generalised costs of travel.

Earlier, it was noted that some existing appraisal approaches do allow for some induced effects including within DfT TAG transport appraisal traffic models being used with a Variable Trip Matrix to model behavioural responses. Where such variable demand modelling is used by

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[111] DfT (2018). Latest Evidence on Induced Travel Demand: An Evidence Review WSP & Rand Europe, Executive Summary p1.

[112] DfT (2018). Latest Evidence on Induced Travel Demand: An Evidence Review WSP & Rand Europe, Executive Summary p2.

[113] The Standing Advisory Committee on Trunk Road Assessment (1994). Trunk Roads and the Generation of Traffic, *Chairman Mr D A Wood QC*, p ii, HMSO.

[114] The Standing Advisory Committee on Trunk Road Assessment (1994). Trunk Roads and the Generation of Traffic, *Chairman Mr D A Wood QC*, p iii, HMSO.

[115] DfT (2018). Latest Evidence on Induced Travel Demand: An Evidence Review WSP & Rand Europe, Executive Summary p2.

scheme promoters this should effectively capture induced travel resulting from the proposal, which in turn will form part of the operational assessment of carbon impacts.

However, in cases where the transport model used to inform the scheme appraisal has a fixed demand matrix or is a local area model that doesn't include strategic re-routing, it is likely that the carbon impacts of any induced demand will not be captured within the operational assessment. Here, additional assessment of the carbon resulting from induced traffic will be required as part of the business case for such highway schemes.

In terms of providing a robust and proportionate assessment of carbon resulting from induced demand, the evidence from SACTRA[116] and the more recent WSP & RAND[117] Europe review supports the adoption of a relatively simple approach to capture the quantified carbon impacts of induced demand from highway improvements, based on elasticity of demand.

C.6 Introduction to the methodology

The This section details the methodology for calculating the induced travel demand for road schemes and associated carbon emissions recommended for adoption by WYCA. It is recommended that this methodology is adopted in instances where no suitable modelling has taken place that will account for changes in demand due to a reduction in generalised cost of travel.

For highways schemes the change in demand can be broken down into the following responses:

- modal shift,
- changes in destination choice,
- strategic rerouting outside of the model boundaries,
- departure time changes,

The WSP & RAND Europe review found that "it was not possible to obtain any qualitative understanding about the composition of induced traffic in terms of transfers between modes and trips associated with new developments". Therefore, induced demand from land use changes will not be assessed as part of this approach as sufficient information will either not be available for a small scheme with a fixed demand matrix or will have already been considered in a demand model.

An elasticities approach for calculating induced demand is used to calculate the remaining effects. This expresses the resulting change in travel relative to the fixed flow and the change in the generalised cost of travel (value of time and vehicle operating costs). This aligns with SACTRA's interim recommendations in the 1994 report[118] *Trunk Roads and the Generation of Traffic*:

[116] The Standing Advisory Committee on Trunk Road Assessment (1994). Trunk Roads and the Generation of Traffic, *Chairman Mr D A Wood QC, p iii, HMSO*.

[117] DfT (2018). Latest Evidence on Induced Travel Demand: An Evidence Review WSP & Rand Europe, Executive Summary p2.

[118] The Standing Advisory Committee on Trunk Road Assessment (1994). Trunk Roads and the Generation of Traffic, *Chairman Mr D A Wood QC, p iii, HMSO*.

14.10 *For collections of schemes in rural regions or interurban corridors where area-wide traffic assignment models exist, we recommend that estimates of induced traffic are made using these existing traffic assignment models coupled with a simple elasticity model. We recommend that these estimates are made in addition to the recommendations of paragraph 14.06.*

14.11 *We recommend that the Department undertakes research to determine the most appropriate values of elasticity which should be adopted, but in the interim, we suggest that a range of realistic values, drawn from published work, is used.*

The SACTRA recommendation of using 4-stage transport models to account for demand response is now applied to selected large scale assessments. However, often for smaller scale transport schemes, adopting 4-stage transport models is not considered proportionate. Typically, local authority or combined authority transport investments are assessed using a fixed demand matrix, which will not account for induced demand. It is in these situations where the tool developed for WYCA is intended to be used.

C.7 Scheme information

The assessment approach has been developed to account for a variety of schemes with different levels of detail available. As a minimum, the vehicle flow through the scheme area, opening year, location and number of assessment years are required for the assessment. This is then converted to an annualised flow and then total Vehicle Kilometres Travelled (VKT) using Department for Transport (DfT) statistics. It is intended that where scheme specific information is available this is used to replace regional and national statistics. The minimum scheme information requirements for assessment are summarised in Table C 1.

Table C 1: Summary of the minimum required scheme information for assessment

Scheme information	Assessment use
Opening Year	Used to determine CO_2e based on changing vehicle standards and fuel type
Appraisal Period	CO_2e is calculated for each year of operation
Journey times with and without schemes	Links with improved journey times will need to be assessed for induced travel demand however links that see no change or a longer journey time will not induce additional traffic
Link flows	Induced travel is based on a relative increase in flow, so the link flows are needed to calculate the relative increase
Location	Different speeds are assumed based on whether the scheme is in an urban or rural location. Average speeds are based on national DfT transport statistics.

C.8 Induced travel calculation

Published research on elasticities focuses on the cost of travel and is highly variable depending on the location and method of assessment. Although journey time changes are readily available from scheme information, they are only one aspect of the generalised cost of travel. The equation in Figure C 1 relates the journey time to elasticities.

$$D = f(G) \quad \text{and} \quad G = M + vT$$

Where D is demand, G is generalised cost of travel, M is money cost (fuel price), T is travel time, and v is value of time. The demand elasticities with respect to money E_m and time E_t are:

$$E_m = \partial D/\partial M.M/D$$

$$E_t = \partial D/\partial T.T/D$$

The elasticities are proportional to the relative importance of money and time, as follows:

$$E_m/E_t = M/vT$$

so $$E_t = E_m.vT/M$$

Assume: -0.15 as the elasticity with respect to fuel price; 6 pence per minute as the value of time; average time spent travelling by car per day as 25 minutes; and spending per person per day on fuel costs as 50 pence. Then

$$E_t = -0.15 \times 6 \times 25/50 = -0.45$$

Figure C 1: SACTRA (1994) formula for relating speed and traffic demand[119]

The SACTRA report summarises the logic behind Figure C 1 in section 4.72 quoted below:

"In summary, the observation that fuel prices influence the amount of traffic, together with the established methodology that values of time can be used to convert time savings into a money equivalent, logically requires that travel speed must affect the amount of traffic. Using values accepted by the Department, a simplified calculation suggests that about half the time saved through speed increases might be used additional travel. We interpret this as a short-term effect. The longer-term effect is likely to be greater, with a higher proportion (perhaps all) of the time saved being used for further travel."

The general formula has been updated with values from the DfT transport statistics, TAG data book and academic research for E_m, v, T and M. Where scheme specific information is available it is intended that the default generic values will be replaced with scheme specific values where appropriate.

Table C 2: Methodology and sources for default values

Variable	Symbol	Default value	Source	Methodology
Fuel price elasticity	E_m	-0.13	Road traffic demand elasticities: A rapid evidence assessment RAND 2014[120]	Selected most common value from assessed studies within range of 0.1 to 0.5

[119] The Standing Advisory Committee on Trunk Road Assessment (1994). Trunk Roads and the Generation of Traffic, *Chairman Mr D A Wood QC*, p 46, HMSO.

[120] RAND (2014). Road traffic demand elasticities: *A rapid evidence assessment.* Available online: Road traffic demand elasticities: A rapid evidence assessment | RAND.

Variable	Symbol	Default value	Source	Methodology
Value of time (pence per minute)	v	9.19	Yearly value from TAG data book table A1.3.2[121]	Weighted average between commuting and other market price
Average travel time (minutes)	T	15	DfT transport statistics TRA3105, CGN0409 and CGN0509[122]	Based on a 10.98 km average trip length and an average speed of 33 kph in an urban environment or 60 kph in a rural setting.
Average fuel cost (pence)	M	63.79	Yearly value from TAG databook[123]	Fuel component of vehicle operating cost calculation

The values in the table would give an elasticity of -0.38 for the year 2019. It should be noted that this is a relatively simplistic approach designed to fit the data available in an ordinary scheme assessment. This necessitates assumptions on factors such as future fuel efficiency and fleet mix which can have a significant impact on the final carbon estimate. This assessment is not intended to be the final word on induced carbon but a useful starting point for an often-overlooked impact.

C.9 Carbon Calculation

Once the expected increase in VKT due to induced demand has been calculated the expected carbon emissions can be estimated. This process is split into 4 steps:

1. Define vehicle split
2. Define fuel split
3. Calculate yearly fuel consumption
4. Calculate yearly CO_2 equivalent emissions

The vehicle split considers 5 different user classes: cars, Light Goods Vehicles (LGVs), Ordinary Goods Vehicle (OGV) 1, OGV2 and Public Service Vehicles (PSVs). Each of these user classes has a different prevalence of fuels. The amount of fuel consumed is calculated from the total induced travel in vehicle kilometres travelled (VKT) and then this is converted into a CO_2 equivalent value. This is in line with TAG[124] guidance but uses localised values for West Yorkshire for vehicle splits from DfT transport statistics TRA0106 [125]. Whilst most schemes will not have information on all 4 steps, they have been split out so that if scheme specific information is available it can be included.

Where there are multiple assessment years the change has been interpolated between years and the final assessment year has been assumed to apply for the remainder of the assessment period. It is intended this figure is used to better inform decision makers where existing assessment is limited.

[121] DfT (2021). *TAG Data Book.* Available Online: TAG Data Book - GOV.UK (www.gov.uk).

[122] DfT (2019). *Road traffic (vehicle miles) by vehicle type and region and country in Great Britain, annual 2019.* Available online: www.gov.uk/government/organisations/department-for-transport/series/road-traffic-statistics.

[123] DfT (2021). *TAG Data Book.* Available Online: TAG Data Book - GOV.UK (www.gov.uk).

[124] DfT (2021). *TAG Data Book.* Available Online: TAG Data Book - GOV.UK (www.gov.uk).

[125] DfT (2019). *TRA0160: Road traffic (vehicle miles) by vehicle type and region and country in Great Britain, annual 2019.* Available online: www.gov.uk/government/organisations/department-for-transport/series/road-traffic-statistics.

C.10 Induced demand methodology decision tree

The proposed methodology for assessing induced demand on WYCA schemes at OBC and FCB is shown in the form of a decision tree in Figure C 2.

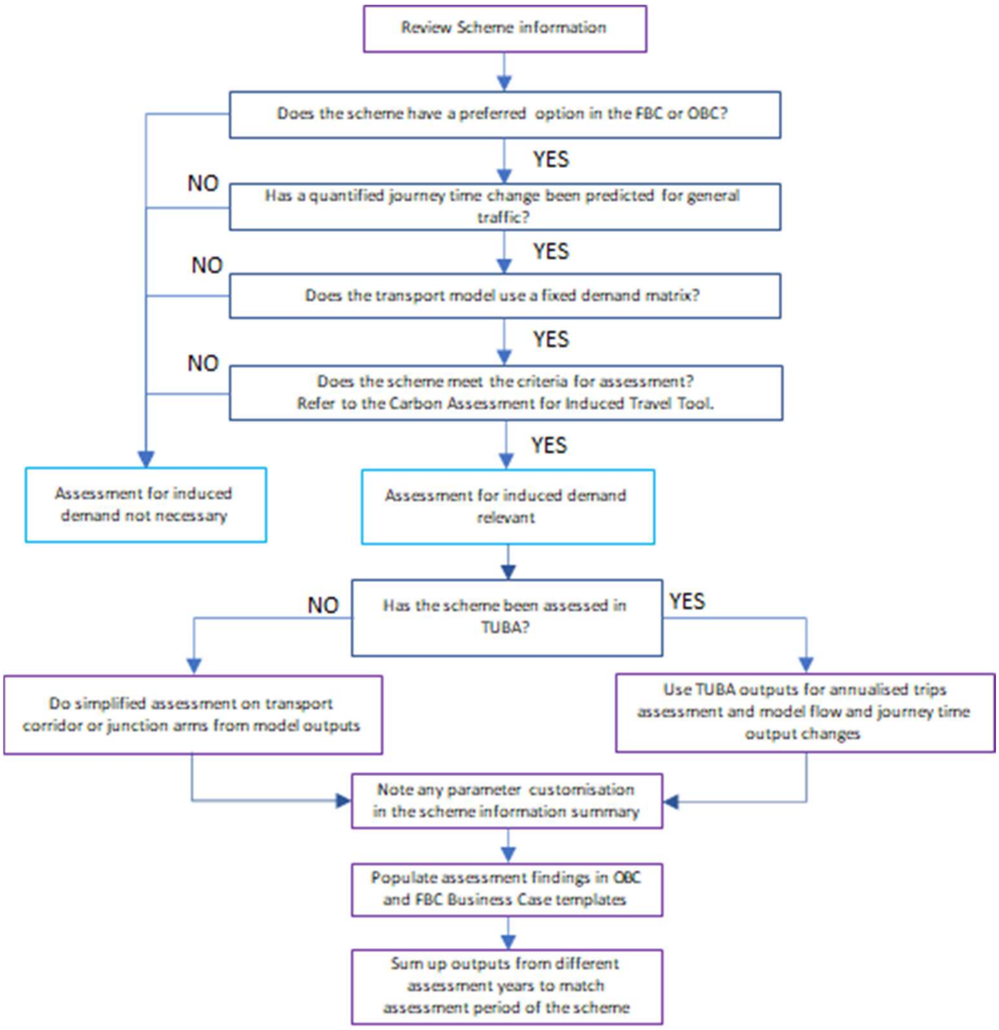


Figure C 2: Induced demand methodology decision tree for transport schemes

The decision tree is designed to filter out schemes where an induced demand assessment is not possible and to determine the assessment methodology.

The screening criteria in the induced travel tool consists of two questions designed to filter out schemes with minor induced effects.

- Does the scheme improve an area of high congestion or one approaching capacity?
- Does the scheme cover an area with a high volume of traffic?

A scheme that is not in an area of high capacity or a high volume of traffic will likely have a minor induced effect and calculating induced demand would not be consistent with a proportional assessment approach.

D. Appendix D - Cycling and walking schemes methodology data

As described within Section 7, the avoided vehicle-km extracted from the AMAT assessment can be applied to DfT TAG[126] assumptions on future fleet mix and the corresponding BEIS[127] emission factors. Table D 1 provides the DfT data, and an example of what the weighted emission factors would be using the BEIS (2021) emission factors. Note that the BEIS emission factors require annual updates.

Given that DfT TAG only provides fleet mix predictions to 2050, any year following 2050 within the appraisal period should assume the fleet mix remains the same.

Table D 1: Weighted emission factors using DfT TAG (sheet A1.3.9) and BEIS (2021) emission factors.

	Proportion of cars using petrol, diesel or electricity			Weighted Carbon Emission Factor (tCO_2e)		
Year	**Petrol**	**Diesel**	**Electric**	**Petrol**	**Diesel**	**Electric**
2021	51%	48%	1%	0.000089112	0.000080026	0.000000747
2022	52%	46%	2%	0.000090415	0.000077839	0.000001049
2023	53%	45%	3%	0.000091606	0.000075469	0.000001445
2024	53%	43%	4%	0.000092504	0.000072813	0.000002027
2025	53%	41%	5%	0.000092770	0.000069695	0.000002957
2026	53%	39%	7%	0.000092748	0.000066439	0.000004023
2027	53%	38%	9%	0.000092565	0.000063230	0.000005124
2028	53%	36%	11%	0.000092201	0.000060121	0.000006249
2029	53%	34%	13%	0.000091635	0.000057152	0.000007393
2030	52%	32%	16%	0.000090793	0.000054374	0.000008560
2031	51%	31%	18%	0.000089758	0.000051881	0.000009696
2032	51%	29%	20%	0.000088538	0.000049669	0.000010799
2033	50%	28%	22%	0.000087162	0.000047727	0.000011863
2034	49%	27%	24%	0.000085671	0.000046004	0.000012892
2035	48%	26%	25%	0.000084114	0.000044486	0.000013875
2036	47%	26%	27%	0.000082542	0.000043136	0.000014807
2037	46%	25%	29%	0.000080979	0.000041922	0.000015693
2038	46%	24%	30%	0.000079466	0.000040848	0.000016518
2039	45%	24%	32%	0.000078015	0.000039902	0.000017282
2040	44%	23%	33%	0.000076428	0.000038914	0.000018102
2041	43%	23%	34%	0.000074945	0.000037999	0.000018865
2042	42%	22%	36%	0.000073550	0.000037150	0.000019579
2043	41%	22%	37%	0.000072227	0.000036371	0.000020248
2044	41%	21%	38%	0.000070923	0.000035621	0.000020902

[126] DfT (2021). *TAG Data Book.* Available Online: TAG Data Book - GOV.UK (www.gov.uk).

[127] BEIS (2021). *Greenhouse Gas Reporting: Conversion factors 2021*. Available online: Greenhouse gas reporting: conversion factors 2021 - GOV.UK (www.gov.uk).

2045	40%	21%	39%	0.000069707	0.000034942	0.000021505
2046	39%	20%	40%	0.000068529	0.000034289	0.000022087
2047	39%	20%	41%	0.000067373	0.000033655	0.000022657
2048	38%	20%	42%	0.000066255	0.000033049	0.000023205
2049	37%	19%	43%	0.000065194	0.000032480	0.000023724
2050	37%	19%	44%	0.000064155	0.000031926	0.000024230

E. Appendix E – Technical note on the carbon impact of greenfield and brownfield development sites

E.1 Introduction

WYCA is undertaking a carbon assessment of all their funded projects and programmes. Among these are several projects aimed at encouraging development of brownfield sites in preference to greenfield sites. This note summarises the key reasons why the choice of site would be expected to make a difference in total carbon impacts of a scheme.

E.2 Why would carbon emissions differ on brownfield sites vs. greenfield sites?

Assuming that the design of the development itself is the same, there are several sources of carbon emissions that differ for brownfield versus greenfield sites. These include site remediation, demolition works, infrastructure provision, travel to/from the site, and emissions from land use changes, as summarised in the chart on the right. The chart also indicates whether the emissions would be considered part of the capital carbon emissions for a new development, or part of the operational carbon emissions.[128] Further information is provided below, based on published research and case studies.

	Greenfield	Brownfield	
Source of emissions	***Emissions tend to be…***		***Category***
Site remediation	Lower	Higher	Capital
Demolition works	Lower	Higher	Capital
Infrastructure	Higher	Lower	Capital
Land use change	Higher	Lower	Capital
Travel to/from site	Higher	Lower	Operational

E.2.1 Site remediation

Carbon emissions from site remediation vary significantly depending on the condition of the site, the amount of remediation that is required, and the methods used. A study of US cities showed the average (median) carbon emissions for brownfield developments to be 1,495 tCO_2e/ha, with a range of 188 to 4,324 tCO_2/ha.[129] As greenfield developments do not typically require remediation, carbon emissions for this were assumed as nil. However, the lack of infrastructure and sustainable transport access on greenfield sites, as well as carbon release from land use

[128] Definitions of capital carbon (a.k.a. embodied carbon) in relation to the built environment are presented in the UK-GBC report, Embodied carbon: Developing a client brief (2017). Available online: UK-GBC-EC-Developing-Client-Brief.pdf (ukgbc.org).

[129] Hendrickson et al. (2013) *Estimation of Comparative File Cycle Costs and Greenhouse Gas Emissions of Residential Brownfield and Greenfield Developments.* Available online: Brownfield-Greenfield Life Cycle Comparison Tool (cmu.edu).

change, can easily exceed carbon emissions from remediation. It is also worth noting that emissions from site remediation are small compared with the operational emissions from most developments.

E.2.2 Demolition works

As with site remediation, the amount of demolition required on brownfield sites varies, but where this occurs, there will be carbon emissions from vehicles and machinery, as well as the need to process and dispose of material. Again, this is likely to make a small difference over the course of the development's life cycle, but it is still worth considering in the context of a fully net zero carbon future.

E.2.3 Infrastructure provision

Brownfield developments tend to benefit from markedly lower infrastructure costs since they are usually already connected to the necessary roadways and pipelines. Costs and carbon emissions from building utilities such as electricity, gas and water are therefore typically also lower in urban areas.[129]

E.2.4 Land use change

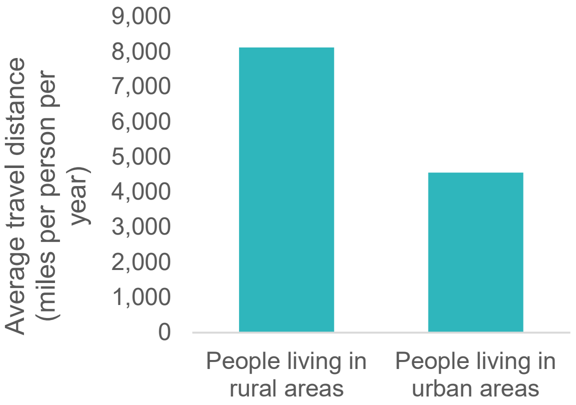
A large amount of carbon is stored in soil. Different land uses, such as forestry, agriculture, pasture, and settlement, result in carbon being stored or released at different rates, and *changes* in land use can therefore cause a net increase or decrease in carbon emissions. [130] For example, conversion of agricultural land or pasture to new settlements will release CO_2 to the atmosphere.

According to the UK Greenhouse Gas Emissions Inventory, around 16.6 kha of land (166 km^2) was converted to settlements in 2019, and this resulted in emissions of roughly 3.5 MtCO_2e.[131,132] On a national scale, therefore, the average emissions from converting land to settlements were around 213 tCO_2e/ha (21.3 tCO_2e/km^2), although this metric cannot be directly applied to individual sites due to the number of variables involved.

E.2.5 Travel to/from site

As brownfield sites are generally located in more urban areas, low-carbon transport options are often already established or can be easily created, e.g., public transport links or cycling routes. Greenfield sites, on the other hand, are associated with greater reliance on cars.

According to the Department for Transport, people living in urban areas in the UK travel, on average, 44% fewer miles by car and private transport each year compared those in rural areas.[133]



[130] Defra (2009), *Safeguarding our Soils*. Available online: Safeguarding our Soils - A Strategy for England (publishing.service.gov.uk).

[131] BEIS (2012). *UK Greenhouse Gas Inventory: Annual Report for Submission under the Framework Convention on Climate Change, Table 6.3*. Available online: UK Greenhouse Gas Inventory, 1990 to 2019 (defra.gov.uk).

[132] BEIS (2021). *Final UK greenhouse gas emissions national statistics*. Available online: Final UK greenhouse gas emissions national statistics: 1990 to 2019 - GOV.UK (www.gov.uk).

[133] DfT (2020). *National Travel Survey 2018/19 data, Table NTS9904. 'Urban' is the weighted average of the two urban classifications and 'Rural' is the weighted average of the two rural classifications*. Available online: Region and Rural-Urban Classification - GOV.UK (www.gov.uk).

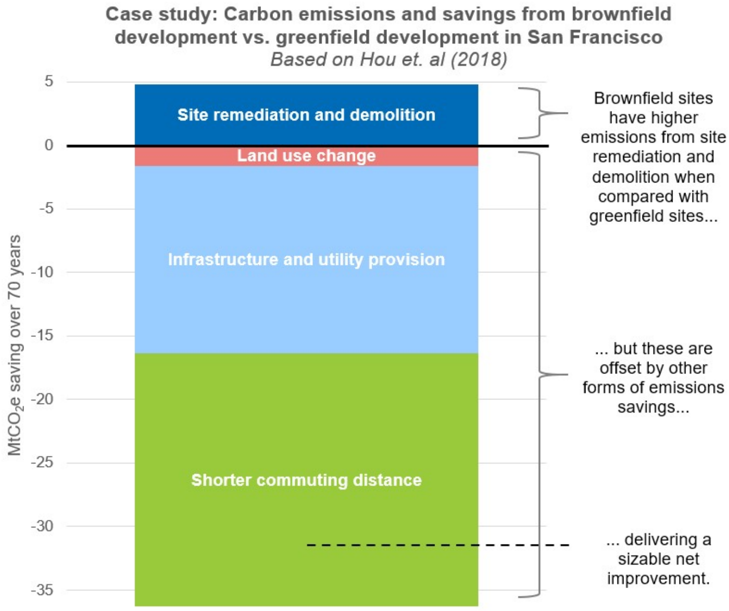
This broadly aligns with data from numerous US cities, indicating that developments on brownfield sites resulted in a 52% reduction of vehicle kilometres travelled and a 66% reduction of GHG emissions and pollutants from personal travel.[134]

"Creating new developments in large towns or redeveloping existing urban sites (brownfield land) makes it easy for new residents to travel sustainably, as the homes are already sited in close proximity to education, shops, businesses and entertainment." – Committee on Climate Change[135]

E.3 How big is the difference?

To give a sense of the relative scale of differences in carbon emissions from these sources, the figure on the right presents data from a research paper that examined the net lifecycle carbon impacts of prioritising brownfield development instead of greenfield development across San Francisco.

The authors concluded that the slightly higher emissions from site remediation and demolition works were more than offset by emissions savings associated with less need for infrastructure and utility provision and shortened commuting distances for residents.



As people switch to zero-emission vehicles, the carbon savings from shorter commute distances would be expected to diminish. However, reducing trips is another key measure for decreasing emissions from transport, and (referring back to the DfT data presented above) this is more likely to happen if development takes place on brownfield sites. It is also worth noting that the magnitude of carbon savings from shorter commute distances will depend on the appraisal period, i.e. the assumed lifespan of the development.

When considered in the context of San Francisco's net carbon emissions, the authors suggested that focusing development on brownfield sites was one of the single most impactful carbon mitigation measures that could be adopted. This is a key finding with implications for other cities and regions, including West Yorkshire.

[134] Mashayekh et al. (2012). *Role of Brownfield Developments*. Available online: Role of Brownfield Developments in Reducing Household Vehicle Travel (cmu.edu).

[135] CCC (2019). *UK Housing*. Available online: UK-housing-Fit-for-the-future-CCC-2019.pdf (theccc.org.uk).

E.4 Capital vs. operational carbon emissions

Most of the sources of emissions described above would be classed as capital (or embodied) carbon emissions of a new development. The exception is travel to and from the site post-completion, which would be classed as part of the operational carbon emissions of a new development. All of these are outside the remit of current Building Regulations and are typically excluded from net zero targets for new developments. However, as shown above, these emissions are not negligible. In the context of combatting global climate change, every gram of CO_2 emitted to the atmosphere counts, and a truly net zero future would require all sources of CO_2 to be addressed.

E.5 Additional points to consider

Carbon is not the only important consideration when selecting a brownfield versus greenfield site. There are a wide range of other environmental, economic, and social factors to consider, such as:

Land use pressures: The Committee on Climate Change estimates that, if housing pressures and farming practices continue, “the available land will not be able to support these basic needs and maintain the current level of per capita food production.”[136] Prioritising previously developed (brownfield) sites can aid in alleviating this pressure.

Biodiversity and habitats: Developments for housing as well as industry and infrastructure have accelerated the country’s habitat and biodiversity loss. Defra estimates the biodiversity unit loss per hectare of greenfield development in Yorkshire and The Humber is 8.0, compared with 2.1 units for brownfield sites.[137]

Economic implications for town/city centres: Development of disused urban sites can boost local economies through job creation, alleviate pressures on the urban housing market, and enhance neighbourhoods through site remediation. Additionally, a focus on brownfield developments reduces urban sprawl, thereby preventing additional loss of green belt and amenity spaces. [138]

E.6 Conclusion

This note highlights the long-term benefits of repurposing previously developed land. It is difficult to quantify the average or typical carbon savings that can be achieved when comparing greenfield sites and brownfield sites. Each of the factors listed above are highly variable; it is not possible to provide a precise figure without detailed information about all of the scheme options under consideration, which is usually not available until the site is selected and the design has progressed to a much later stage. Furthermore, depending on WYCA’s role in delivering a project, some of the carbon emissions or savings might fall outside the scope of what WYCA can claim responsibility for. Nonetheless, the points outlined above can provide a starting point for more

[136] CCC (2018). *Land Use: Reducing emissions and preparing for climate change.* Available online: Land use: Reducing emissions and preparing for climate change - Climate Change Committee (theccc.org.uk).

[137] Defra (2019). *Biodiversity net gain and local recovery strategies*. Available online: Net gain impact assessment (publishing.service.gov.uk).

[138] European Commission (2013). *Science for Environment Policy, Brownfield Generation*. Available online: Thematic Issue: Brownfield Regeneration (europa.eu).

detailed assessments and help to inform discussions about how to reduce carbon emissions from new developments.

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