# Meaningful measurement for whole-life carbon in infrastructure

## A methodology for measuring carbon impacts from infrastructure



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Some 70% of carbon emissions worldwide can be linked to infrastructure. Civil engineers, as the designers, builders and maintainers of this infrastructure, have a duty to minimise the harmful impacts on our climate by understanding and reducing the whole-life carbon in infrastructure.

To support designers of infrastructure in fulfilling this obligation, this paper examines the measuring, sharing and benchmarking of carbon impacts in infrastructure delivery. The three chapters highlight:

- The data sources for carbon that are currently available to engineers
- How engineers can create crucial carbon benchmarks in their work
- A new capital carbon reporting protocol for engineers and project teams to use[1]

[1] Reference is made throughout this document to PAS 2080: Carbon Management in Infrastructure, a publicly available UK specification for managing infrastructure carbon.

# Introduction

The Infrastructure Carbon Review (2013)[2] showed that infrastructure was associated with more than half of UK greenhouse gas (GHG) emissions. Measuring, sharing and benchmarking of carbon impacts – covering all stages of the infrastructure lifecycle – is integral to facilitating carbon management as a routine aspect of infrastructure design. This paper, which has been devised and produced by a panel of industry experts as part of the Institution of Civil Engineers' The Carbon Project[3], seeks to demonstrate to designers of our infrastructure assets a consistent methodology for how they can successfully measure, share and benchmark carbon impacts.

## Reaching net zero

The net zero challenge, in all of its scale and complexity, requires a cross-industry response with collaboration at its heart. An open approach to carbon reporting will hasten industry transformation and bolster collaborative efforts. The whole value chain – including asset owners/managers, designers, constructors and product/material suppliers – should be able to contribute to and benefit from these developments.

Consideration of carbon impacts covering capital, operational and user GHG emissions (see box on the next page for explanations of these terms) will allow management of the carbon that is within both the control and influence of infrastructure. Taking a whole-life approach will maximise opportunities for joint carbon and cost reductions. The scope of capital carbon impact considerations will need to include materials, products, design solutions and construction techniques.

## The value of measuring and monitoring

Measuring and monitoring is critical to reducing our carbon impacts – otherwise we will not know if our interventions are delivering the desired change or if we are focusing efforts in the most important areas. Considering carbon impacts – and understanding them in the context of the Paris Agreement[4] – will allow the value chain to better understand a project's impact. This can have a motivational effect and link to a broader appraisal of project outcomes, for example based on the UN Sustainable Development Goals (SDGs).

Sharing is important because it helps engagement and enables benchmarking. Benchmarking and having sound data in the public domain changes attitudes and priorities.

## How to use this document

This paper is divided into three chapters:

- Chapter 1 highlights the challenges engineers can face in achieving accurate carbon data capture.
- Chapter 2 examines how carbon benchmarks could be better used in infrastructure.
- Chapter 3 provides a consistent methodology and reporting protocol for use across the project lifecycle.

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[2] UK Government's Infrastructure Carbon Review (2013)
[3] ICE's The Carbon Project is a series of blogs and technical papers that arms engineers with everything they need to know about the journey to net zero infrastructure.
[4] UN Paris Agreement on climate change (2015)

# Chapter 1: The challenges of achieving accurate cradle-to-grave carbon data capture, measurement and reporting

**Development of a robust carbon assessment is highly dependent on the data used for the analysis. This section highlights challenges with quality and consistency of data and how engineers can compile, measure and use data on projects.**

Having complete data sets of sufficient granularity and transferability between projects or assets will allow for consistent and transparent reporting on carbon. Given the urgent need for accurate reporting on carbon in infrastructure to meet the UK government's target of net zero by 2050, organisations should gather and manage data using appropriate, rigorous and interoperable systems, validate it through benchmarking, and share it. Increased granularity and transferability will also allow for lessons to be learnt across projects or assets and between phases using sector agnostic metrics.

***Carbon*** *is used in this report as shorthand for the carbon dioxide equivalent of all greenhouse gases.*
***Capital carbon*** *refers to emissions associated with the creation of an asset.*
***Operational carbon*** *describes emissions associated with the operation and maintenance of an asset.*
***Whole-life carbon*** *combines both capital and operational carbon.*

## Key challenges

Fundamental areas that must be addressed to achieve consistency and quality of data include the following:

- It is essential that the infrastructure sector can not only capture and compare 'like with like' but that the data is of high enough quality and completeness to allow accurate and meaningful interpretation throughout a project's lifecycle.
- Carbon data capture must be rigorously considered and iteratively improved upon from the earliest stages of a project rather than as an afterthought. This is a necessity, regardless of the fact that carbon measurements will generally become increasingly accurate with the certainty of as-built data as projects move through the design and construction phases.
- There should be a planned and timely handover of data from one project stage to the next – for example, from consultant to contractor – to show that monitoring data is reflective of design data.
- Carbon data should be integrated into existing technologies such as BIM and carbon calculators, with consistency and improved compatibility, and with the ambition to move from manual data collation to digital automation.
- Siloed collation and management of data needs to be overcome as it prevents integration with other engineering functions.
- Uncertainty around data ownership and tracking responsibilities during the various lifecycle stages of an asset has to be addressed.

## What is required and areas for action

There are numerous actions that the infrastructure industry could take to improve its use of data for consistent and transparent whole-life carbon reporting. Areas that could encourage the development or adoption of meaningful whole-life carbon measurement are:

1. A comprehensive list of the specific data required to inform whole-life carbon methodology data in its most granular form (from areas such as material, waste, volume, site of origin and end-disposal location).
2. A single source of truth for that data for whole-life carbon estimation and actual reporting.
3. Behavioural change – considering data earlier and handing it over appropriately throughout a project's lifecycle.
4. Consideration of design and construction alterations from a whole-life carbon impact perspective.
5. Endorsement of a best practice in benchmarking, such as the Infrastructure and Projects Authority (IPA)'s Best Practice in Benchmarking document, or a standard for complete, consistent data formats and qualities.
6. Encouraging data service providers to enable data integration and compatibility, to improve efficiency and technology take up.
7. Encouraging and endorsing procurement best practices that establish who owns the data and the responsibilities for collecting it at each stage of the lifecycle.

*A new Built Environment Carbon Database (BECD) is under development as the result of a collaboration between ICE and other built environment stakeholders (for more information see Chapter 2). It will collect and supply product data and entity-level data to the industry through its own portal and by interacting with existing databases and software solutions. This builds upon and supports the existing Inventory of Carbon and Energy embodied carbon database.*

## How could the collection and generation of this data be supported?

There is an opportunity for professional engineering institutions and other organisations to set guidelines for the types, structure and shareability of data to establish baselines and clear and consistent reporting.

Appendix A shows part of the research carried out by The Carbon Project workstream that has informed the above statements. *Appendix A: Validation and challenges of data sources at different stages of a project or asset's lifecycle* outlines the various data sources at design, construction and operation stages, how they are validated, the challenges with obtaining them and ensuring the consistency of the compiled data. It also provides references to show how each data area maps to the requirements of PAS 2080.

*PAS 2080 is a UK specification for managing infrastructure carbon, looking at the whole value chain. It aims to reduce carbon and cost through intelligent design, construction and use.*

# Chapter 2: Comparing carbon data against reliable benchmarks

This chapter examines better use of carbon benchmarking for infrastructure, recommends how this could be achieved and presents examples of progress within the industry.

## Benchmarking and whole-life carbon management

Benchmarking is the process of measuring key metrics and practices and comparing them. Lifecycle carbon metrics are often at an asset level, with linked functional units, captured at different work stages (e.g. for a rail asset, a functional unit might be 1km of rail with 60 equivalent million gross tonnes per annum and a service life of 60 years).

Effective whole-life carbon management of infrastructure can be accelerated through the development, sharing and use of benchmarks, which provide a point of reference. The use of these whole-life carbon benchmarks can be coupled with the infrastructure cost benchmarking process. This process works well when managed and incentivised at an industry level, and led by infrastructure clients.

There is a lack of openly available asset-level benchmarks for whole-life carbon data in infrastructure. Efforts to encourage the sharing of benchmarks at an industry level (i.e outside of the value chain for a particular project) have thus far relied on voluntary contributions by the value chain. This has not been successful. There are examples of more mature benchmarking practice for particular sectors or by individual organisations, but rarely covering all infrastructure types. Practical, ambitious actions are required to enable this step change, coupled with the need for continuous improvement as maturity in data collection and benchmarking develops.

As described in PAS 2080:2016, whole-life carbon management requires all supply chain members to capture and share carbon emissions information, but also to share good practice at a sector level. Infrastructure benchmarks are of significant value at project creation stage, for example in determining the best type of asset to achieve the desired outcomes. Benchmarks are also critical for whole-life carbon management through the infrastructure lifecycle, for example in target setting and baselining at design stage.

## Recommendations

Those who are developing benchmarks should ensure that:

- They are initially developed at an asset level, aggregating components. A programme of works would therefore report multiple benchmarks, one for each asset. It should be for each infrastructure sector to advise on the form of functional units.
- The whole infrastructure value chain is involved in providing the data to support the production of benchmarks, as they will be reproduced at different work stages.
- In future, requirements for data used at different work stages should be developed – for example, the use of spend data or actual construction data in the post-construction phase.
- Benchmarks should be developed for: the work stage; the functional unit, including function, quality, time and quantity aspects; capital GHG emissions; operational GHG emissions; user GHG emissions; and GHG emissions potential beyond the infrastructure boundary (see Table 1, next page).

Industry initiatives to improve benchmarking and whole-life carbon management should:

- Incorporate the carbon metrics described above into any cost benchmarking database
- Encourage project sponsor or delivery bodies to develop and share these carbon metrics
- Validate the metrics provided against the recommendations provided here
- Share the carbon benchmarks with parties that are willing to contribute to the database
- Take forward continuous improvement of this process

*Table 1: Recommended infrastructure asset benchmarks*

| BENCHMARK ASPECT | NOTES |
|---|---|
| **Work stage** | **E.g. post-design, post-construction, during operation** |
| **Functional unit, including function, quality, time and quantity aspects** | **E.g. for a rail asset: 1km of rail with 60 equivalent million gross tonnes per annum and a service life of 60 years. For a solar PV asset: solar electric plant with a generating capacity of 250MWh per year including all ancillary equipment and with a peak power output of 50kWp and a project service life of 50 years.** |
| **Capital GHG emissions** | ***X* $tCO_2e$** |
| **Operational GHG emissions** | ***Y* $tCO_2e$** |
| **User GHG emissions** | ***Z* $tCO_2e$** |
| **GHG emissions potential beyond infrastructure boundary** | ***A* $tCO_2e$ savings at a system level, for example because of modal shift or displacement of carbon-intensive power generation.** |

## Built Environment Carbon Database

The Carbon Project has made the above recommendations to the cross-industry consortium developing the BECD. As set out in its recent white paper, the consortium is designing and developing two sections for the database, to be made available in 2022: “The first section contains data at entity level, providing benchmark-type data points to support the feasibility, early design and end of life stages. The second one contains data at product level to support the evolving and detailed design, construction and operational stages, and provide good-quality product data to conduct reliable assessments.”[5] Experts from The Carbon Project continue to feed into the BECD’s overarching steering group.

## IPA Best Practice in Benchmarking

The recommendations made here have also informed a 2021 update to the Best Practice in Benchmarking guidance document published by the Infrastructure and Projects Authority.

[5] https://becd-cms.uksouth.cloudapp.azure.com/uploads/BECD_white_paper_85cc064670.pdf

# Chapter 3: Consistent methodology and reporting protocol across the project lifecycle

This section sets out a proposed standard protocol to help progress towards consistent reporting of project whole-life carbon emissions using lifecycle stages, and to help the industry to objectively report carbon reduction progress. This is made in reference to – and to aid in working with – PAS 2080.

## Context and objectives

The protocol presented in this chapter can serve as an industry standard for delivering consistent reporting outputs from infrastructure projects and clients, to estimate capital carbon that allows meaningful comparison of results to help inform and drive carbon reductions. Its adoption will enable carbon reductions to be collated to determine the infrastructure sector's contribution to delivering the net zero national target.

The opportunity to reduce emissions is by far at its greatest early in the project delivery lifecycle (see Fig 1, below). This protocol should therefore be used to support early decision-making. The emphasis is on measuring capital carbon and identifying carbon hotspots that can be prioritised for reduction efforts. It is acknowledged that any reduction opportunities should be assessed in terms of whole-life benefit, considering both operational and user carbon.

Recognising organisational maturity, the carbon reduction elements of the protocol have been written to remain accessible to all engineering organisations, regardless of where they are on their carbon journey.

It has been written to target the greater area of inconsistency in current whole-life carbon assessments. It therefore focuses on capital carbon assessments from early strategy stage through to design (see lifecycle stages in Fig 1), while acknowledging that any reduction opportunities should be considered in the context of whole-life benefits.

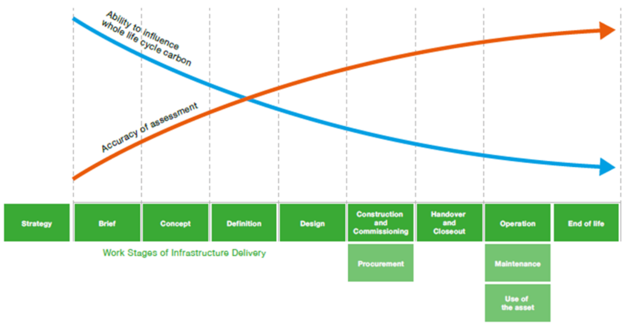


*Fig 1: Ability to influence infrastructure delivery carbon (PAS 2080:2016 Carbon Management in Infrastructure)*

## Carbon in decision-making throughout the infrastructure lifecycle

*From strategy to concept stage (asset planning organisation lead):*
At this stage, project-specific data is limited and it is acceptable to use industry benchmarks or previously delivered projects to help understand the carbon impact of different options.

*From project definition stage to construction and commissioning stage (designer lead):*
While the emphasis is on optimising whole-life carbon, the greatest uncertainty in measurement of carbon impact remains in capital carbon assessment; therefore, this is where the main focus of this protocol lies. With a greater focus on delivering net zero rather than just lower carbon infrastructure, it will be important to consider the broader carbon impact of the infrastructure delivered – for example, how the infrastructure affects user carbon and emissions across system boundaries. At this stage the aim would be to use as much verified and, where available, supplier-specific carbon emissions data as possible.

*Operational stage (operations organisation lead):*
Here the focus shifts to maintaining and improving efficiency of asset operation and maintenance. Carbon can be influenced through upgrading existing assets with more efficient alternatives or modifying operational philosophies. Decisions on carbon at this stage often consider whether existing assets can be maintained efficiently or whether larger-scale replacement or refurbishment is required to improve overall performance.

For ease of integration with PAS 2080, the protocol shown below aligns with process requirements as set out in Table B1 in PAS 2080:2016, which shows carbon management responsibilities. The following process requirements are centred on ‘quantification’ from the concept-definition stage onwards in PAS 2080 Table B1.

PAS 2080 process requirements:
1. System boundary
2. Scope of carbon assessment
3. Assessment standards and calculation methodology
4. Data and tools
5. Starting point, iterations and frequency
6. Presenting the results
7. Continual improvement

# The Carbon Project capital carbon reporting protocol

## 1. System boundary

Data can be reported in three boundary conditions, as defined using PAS 2080:2016:

- Cradle-to-completed construction, comprising PAS 2080 modules A0-A5
- Cradle-to-grave, comprising PAS 2080 modules A1-C4 (excluding B9) over 10-year reference study periods up to a maximum as defined in the asset standard
- Cradle-to-cradle (whole-life carbon), comprising PAS 2080 modules A1-C4 (excluding B9) and module D over a reference study period as defined in the asset standard

Where possible, this study period should be established in accordance with BS 15686 Buildings and Constructed Assets Service Life Planning. In the absence of specific-sector guidance, a study period should be selected that reasonably reflects the intended function and life expectancy of the infrastructure assets.

> **Guidance *note:*** *Users* should test whether selecti*ng* a certain study period m*ay* lead to a different outcome compared *with* another *study* period. This is *especially* important when balancing the potential *GHG* emissions associated with capital and operational carbon.

## 2. Scope of the carbon assessment

The scope needs to clearly state the description of the project included in the capital carbon assessment and the items within scope. All items outside of scope must also be stated. This will enable independent checking and data to be reproduced and compared at a later date. Table 2 shows an example of the type of information that should be included in a scope list. Exclusions should also clearly be stated. For example, the assessment may exclude emissions from design stage (paper and office consumption) and worker commuting activities.

*Table 2: Scope description example (reproduced from Scottish Water Capital Carbon Accounting Tool)*

| NUMBER | SCOPE ITEMS | SCOPE ITEM SUMMARY |
|---|---|---|
| **Ref no.** | **Standard asset name e.g. pump/pipeline/tank** | **Short description of asset in relation to project, e.g. function, location, sizing** |

*Key exclusions: Highlight any aspects linked to the project that are not included as part of the project, that may reasonably be expected to be included as part of a similar project.*

## 3. Assessment standards and calculation methodology

The methodology for calculation will conform to PAS 2080:2016 and will also use RICS' methodology to calculate embodied carbon. It is recommended that data gathering is aligned to ISO 14025:2010 ("Environmental labels and declarations. Type III environmental declarations. Principles and procedures"). This facilitates and supports an audit trail for whole-life carbon data management.

## 4. Data and tools

The following industry data/databases are preferred for carbon assessment calculations:

- Environmental Product Declarations (EPDs)
- Inventory of Carbon and Energy database
- Proprietary databases

A commentary should be provided as to the rationale of the tools used.

> ***Guidance note:*** *See Appendix B for a list of suitable carbon software tools available.*

The assessment shall include a general commentary on data quality for the project.

The ability to quantify high-level estimates at the early stages of sufficient accuracy to highlight carbon hotspots is crucial i.e. the design and construction elements with the greatest carbon emissions.

> ***Guidance note:*** *For complex products, EPDs conforming to ISO 14025 and EN 15804 will become an important source of product information, particularly where they include a 'climate declaration'. Manufacturers and suppliers are encouraged to provide EPDs and climate declarations for their products to help support the industry's net zero ambition.*

## 5. Starting point, iterations and frequency

Iterations of the design as it progresses should align with standard infrastructure project gateway review outputs, including:

- Brief – baseline developed at outset of project
- Concept design stage – carbon variance of key options known before option selection
- Design stage – carbon reduction assessment, comparing anticipated project carbon achievements against the reference baseline and target (where set)
- As-built – carbon reduction assessment, comparing actual project carbon achievements against the reference baseline and target (where set)

Where the first assessment is to be before product selection, initial calculations should be based on (in order of priority): publicly available company-specific benchmarks, industry benchmarks or estimated quantities and use of the Inventory of Carbon and Energy database

This generic data should be substituted for detailed product data as the design progresses. As subsequent iterations of the assessment are prepared, the scope should be updated accordingly.

## 6. Presenting the results

All assumptions must be clearly stated. The results of the assessment shall be presented as follows:

- Total kgCO2e, i.e. the total capital carbon footprint
- Total kgCO2e per material or major scope item
- The results shall include functional intensity metrics appropriate to the asset such as kgCO2e per linear km. Normalisation by cost, tCO2e per £100k cost, should always be reported.

Each breakdown should be expressed as a proportion (%) of the total carbon footprint.

The assessment should also provide a benchmark comparison asset. Any benchmarks used should be as directly comparable as possible; however, it is recognised that this may not always be possible so generic benchmarks are acceptable. Explanation shall be provided on the use of the benchmark and its limitations.

## 7. Continual improvement

The carbon assessment results should be used to promote discussion as standard as part of design workshops, making comparisons with benchmarks to drive improvement.

To support continual improvement at an industry level, detail on carbon quantification and data quality needs to be fed back.

To determine the infrastructure sector's progress for delivering the net zero national target, carbon reduction savings data made through the adoption of this protocol can be collated and reported.

# Summary

This report draws together three areas of carbon emission measurement that are in urgent need of improvement and consistent methodology. Within the theme of measuring and monitoring, recommendations have been made about key considerations, areas for action and best practice. In addition, the report offers insight into initiatives and reports that have been steered by the recommendations in this paper.

Readers of this report should now understand the suggested methodology for successfully measuring, sharing and benchmarking carbon impacts. They should also now better understand the importance of measuring and monitoring to assess the effectiveness of interventions and the impact and value of a project.

The recommendations set out in this paper are critically important as they advise on how to effectively facilitate carbon management as a routine aspect of infrastructure design. Key takeaways from each of the three chapters can be identified as:

### The challenges of achieving accurate cradle-to-grave carbon data capture, measuring and reporting

The infrastructure industry needs to take action to significantly improve its use of data for consistent and transparent whole-life carbon reporting. These actions include, but are not limited to, behavioural change (considering data earlier and handing it over appropriately throughout the lifecycle) and considering design and construction alterations from a whole-life carbon impact perspective. The industry should set guidelines for the types, structure and shareability of data to establish baselines and clear and consistent reporting.

### Comparing carbon data against reliable benchmarks

Effective whole-life carbon management of infrastructure can be accelerated through the development, sharing and use of benchmarks, which provide a point of reference. The industry must accelerate the production of openly available asset-level benchmarks for whole-life carbon data. The recommendations in this report by The Carbon Project Workstream 1 have informed two key external initiatives: the IPA Best Practice in Benchmarking report update and the Built Environment Carbon Database.

### Consistent methodology and reporting protocol across the project lifecycle

This chapter provides a capital carbon reporting protocol that can be utilised by the industry to objectively report carbon reduction progress. The methodology encourages consistent reporting of project whole-life emissions using lifecycle stages. The adoption of this protocol will also enable carbon reductions to be collated to determine the infrastructure sector’s contribution to delivering the national net zero target.

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## Appendix A: Validation and challenges of data sources at different stages of the project or asset lifecycle

Table 1: Design

| Data (reference to PAS 2080) | Key values<br>*What data do we need for carbon accounting?* | Source<br>*Where do we get it from currently?* | Validation<br>*How do we validate this data?* | Quality and challenges<br>*What challenges do we have with this?* |
|---|---|---|---|---|
| **Construction materials (A1-3)** | • Material embodied carbon – kgCO2e/kg<br>• Material quality | • Inventory of Carbon and Energy database<br>• Civil Engineering: CESMM4<br>• Manufacturer's data<br>• Environmental Product Declarations<br>• European Life Cycle Database<br>• Individual company databases | • Ensure assessment conforms to BS EN 15804<br>• EN 15804 also states data must be less than five years old | • Ensuring materials are reported at the same stage e.g. comparing cradle to cradle rather than cradle to grave or gate<br>• If not progressing towards cradle to cradle it can lead to missed data or opportunities |
| | • Wastage | • % allowance on top of design amounts | • No current validation | • Not clear if % allowances are reflective of actual construction amounts |
| **Construction plant (A5)** | • Construction emissions kgCO2<br>• | • Highways: Maintenance Works and Highways: Major Works<br>• Civil Engineering: CESMM4<br>• Environmental Product Declarations (if available)<br>• WRAP net waste tool | • Case studies and company experience | • Sometimes not included in EPDs |
| **Construction transport (A4)** | • Material<br>• Transport distance<br>• Carbon conversion factor | • EeB guidance document, Part B: Buildings – Operational guidance for Life Cycle Assessment studies of the energy-efficient buildings initiative | • Case studies and engineering experience | • Often difficult to reliably predict early on in project with suppliers and material qualities not defined |
| **Operational energy (B6)** | • kWh<br>• Heating<br>• Domestic hot water supply<br>• Air conditioning (cooling and humidification/ de-humidification)<br>• Ventilation<br>• Lighting<br>• Auxiliary energy used for pumps, control and automation | • Evaluation of embodied energy and CO2e for building construction<br>• BS EN 15978:2011<br>• BRUKL submissions, energy modelling results from SBEM and/or dynamic thermal simulation, energy calculations according to CIBSE TM5<br>• BREEAM UK New Construction 2014, Ene 01 Reduction of energy use and carbon emissions | • Including all of Part L of the Building Regulations<br>• Meet EN 15804 standards – deemed quality data | • Wide variability in energy generation<br>• Difficult ensuring energy used offsite is accurately predicted |
| **Operational processes (B7)** | • Operational water use<br>• Maintenance activities<br>• Operational wastage | • BSRIA rules of thumb – guidelines for the building services | • Meet EN 15804 standards – deemed quality data | • Often difficult to reliably predict early on in project |

## Table 2: Construction

| Data | Key values<br><br>*What data do we need for carbon accounting?* | Source<br><br>*Where do we get it from currently?* | Validation<br><br>*How do we validate this data?* | Quality and challenges<br><br>*What challenges do we have with it?* |
|---|---|---|---|---|
| **Material** | • Type<br>• Volume/weight/ quantity<br>• Certifications<br>• Source location<br>• End-of-life value | • Delivery tickets<br>• EPDs or similar specifications<br>• Individual supplier material databases | • Auditing<br>• Invoice data | • EPDs hard to source<br>• Many materials do not have EPDs or product specification data inclusive of embodied carbon<br>• Delivery tickets include only limited information<br>• Supplier databases are not accessible |
| **Waste** | • Volume/weight/ quantity<br>• Recovery rates<br>• Transport and destination facilities | • Waste transfer notes | • Audits (both internal and external) | • Largely paper-based, lots of data lost or unreadable<br>• EA database<br>• Unclear where it is going and how it is being reused, to support circularity and transition to cradle to cradle |
| **Energy** | • kWh | • Automatic meter reading (AMR)<br>• Manual meter reading | • Suggest energy provider to validate | • Manual data capture is unreliable<br>• AMRs not widely available<br>• System/transfer losses not taken into account |
| **Water** | • Volume<br>• Quality | • Automatic meter reading (AMR)<br>• Manual meter reading<br>• Spot checks | • Suggest water supplier to validate | • Manual data capture is unreliable<br>• AMRs not widely available<br>• System/transfer losses not taken into account |
| **Fuel (onsite)** | • Volume<br>• Type<br>• Source | • Delivery tickets | • Suggest invoices for fuel are submitted | • Largely paper-based, lots of data lost or unreadable |
| **Supply chain** | • Workforce travel | • Manual data collection in sign-in registers | • None | • Largely paper-based, lots of data missing |

## Table 3: Operation

| Data category | Data sub-category | Data activity | Source | Validation | Quality and challenges |
|---|---|---|---|---|---|
| Energy | Chilled water | **Chilled water** | • Delivery tickets (if water cooler dispenser)<br>• Water meter readings | • Audits<br>• Invoice reconciliation | • Delivery tickets largely paper-based<br>• Manual data capture is unreliable |
| | Co-generation | **Fuel consumed for generating co-gen – liquid (leased site)** | • Fuel invoices/ delivery notes through landlord | • Audits<br>• Invoice reconciliation | • Landlord/building manager reluctance to collate or share data<br>• Delivery tickets/invoices could be paper-based |
| | | **Fuel consumed for generating co-gen – liquid (owned site)** | • Fuel invoices/ delivery notes | • Audits<br>• Invoice reconciliation | N/A |
| | | **Fuel consumed for generating co-gen – solid (leased site)** | • Fuel invoices/ delivery notes through landlord | • Audits<br>• Invoice reconciliation | • Landlord/building manager reluctance to collate or share data<br>• Delivery tickets/invoices could be paper-based |
| | | **Fuel consumed for generating co-gen – solid (owned site)** | • Fuel invoices/ delivery notes | • Audits<br>• Invoice reconciliation | N/A |
| | Electricity | **Electricity purchased from grid (leased site) (Scope 3)** | • Automatic meter reading (AMR)<br>• Manual meter reading<br>• Invoices | • Audits<br>• Invoice reconciliation | • AMRs not widely available<br>• Manual data capture is unreliable<br>• Invoices might be based on estimated reading if actual data not available<br>• Landlord/building manager reluctance to collate or share data |
| | | **Electricity purchased from grid (owned site)** | • Automatic meter reading (AMR)<br>• Manual meter reading<br>• Invoices | • Audits<br>• Invoice reconciliation | • AMRs not widely available<br>• Manual data capture is unreliable<br>• Invoices might be based on estimated reading if actual data not available |
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| | | | | |
|---|---|---|---|---|
| | | | | • Landlord/building manager reluctance to collate or share data |
| | **Fuel consumed for generating electricity – liquid (owned site)** | • Delivery notes/ invoices | • Audits<br>• Invoice reconciliation | • Delivery tickets largely paper-based |
| | **Fuel consumed for generating electricity – liquid (leased site)** | • Delivery notes/ invoices through landlord | • Audits | • Landlord/building manager reluctance to collate or share data |
| | **Fuel consumed for generating electricity – solid (owned site)** | • Delivery notes/ invoices | • Audits<br>• Invoice reconciliation | • Delivery tickets largely paper-based |
| | **Fuel consumed for generating electricity – solid (leased site)** | • Delivery notes/ invoices through landlord | • Audits | • Landlord/building manager reluctance to collate or share data |
| | **Renewable energy** | • Energy bills if through the grid<br>• Onsite meters if own supply | • Audits | • Manual data capture is unreliable |
| | **T&D losses (owned site)** | • Percent provided by literature data<br>• Utility provided info | • Audits | • Data could be regional<br>• Utility not willing to disclose data |
| | **T&D losses (leased site)** | | | |
| **Heat** | **Fuel consumed for generating heat – liquid (owned site)** | • Automatic meter reading (AMR)<br>• Manual meter reading<br>• Invoices | • Audits<br>• Invoice reconciliation | • AMRs not widely available<br>• Manual data capture is unreliable |
| | **Heat purchased – district/grid heat (owned site)** | • Energy bills | • Audits<br>• Invoice reconciliation | |
| | **Fuel consumed for generating heat – liquid (leased site)** | • Energy bills through landlord | • Audits | • Landlord/building manager reluctance to collate or share data |
| | **Heat purchased – district/grid heat (leased site)** | • Energy bills through landlord | • Audits | • Landlord/building manager reluctance to collate or share data |
| | **Fuel consumed for generating heat – solid (owned site)** | • Delivery notes/ invoices | • Audits<br>• Invoice reconciliation | • Delivery tickets largely paper-based |

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|---|---|---|---|---|---|
| | | **Fuel consumed for generating heat – solid (leased site)** | • Delivery notes/ invoices through landlord | • Audits | • Landlord/building manager reluctance to collate or share data |
| | **Steam** | **Fuel consumed for generating steam – liquid (owned site)** | • Delivery notes/ invoices | • Audits<br>• Invoice reconciliation | • Delivery tickets largely paper-based |
| | **Steam** | **Steam purchased – district/grid steam (owned site)** | • Energy bills | • Audits<br>• Invoice reconciliation | |
| | **Steam** | **Fuel consumed for generating steam – liquid (leased site)** | • Delivery notes/ invoices | • Audits<br>• Invoice reconciliation | • Delivery tickets largely paper-based |
| | **Steam** | **Steam purchased – district/grid steam (leased site)** | • Energy bills through landlord | • Audits | • Landlord/building manager reluctance to collate or share data |
| | **Steam** | **Fuel consumed for generating steam – solid (owned site)** | • Delivery notes/ invoices | • Audits<br>• Invoice reconciliation | • Delivery tickets largely paper-based |
| | **Steam** | **Fuel consumed for generating steam – solid (leased site)** | • Delivery notes/ invoices through landlord | • Audits | • Landlord/building manager reluctance to collate or share data |
| **Non-fuel Impacts** | **End of life** | **End of life – liquid** | • Waste transfer notes<br>• Consignment notes | • Audits | • Reliable internal data capture systems required to consolidate information |
| **Non-fuel Impacts** | **End of life** | **End of life – solid** | • Waste transfer notes<br>• Consignment notes | • Audits | • Reliable internal data capture systems required to consolidate information |
| **Non-fuel Impacts** | **Fertilisers** | **Fertilisers** | • Purchase records | • Audits | |
| **Non-fuel Impacts** | **Materials used** | **Materials used – liquid** | • Purchase records | • Audits | |
| **Non-fuel Impacts** | **Materials used** | **Materials used – solid** | • Purchase records | • Audits | |
| **Non-fuel Impacts** | **Refrigerants/halocarbons** | **Refrigerants/ halocarbons** | • F-gas log | • Invoice reconciliation | |
| **Non-fuel Impacts** | **SF6** | **SF6** | • F-gas log | • Invoice reconciliation | |

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|---|---|---|---|---|---|
| | **VOCs** | **VOCs** | • F-gas log | • Invoice reconciliation | |
| **Transport** | **Air** | **Aviation (by distance) – owned and operated** | • Internal travel records | • Audits | • Reliable internal data capture systems required |
| | | **Aviation (by distance) – not owned and operated** | • Mileage data from travel management companies (TMCs)<br>• Expenses data | • Audits<br>• Invoices | • TMCs do not always track data |
| | | **Aviation (by destination) – owned and operated** | • Internal travel records | • Audits | • Reliable internal data capture systems required |
| | | **Aviation (by destination) – not owned and operated** | • Travel records from travel management companies<br>• Expenses data | • Audits | • TMCs do not always track data in useful format (e.g. departure and destination airport codes against each ticket) |
| | **Air by fuel** | **Aviation (by fuel) – owned and operated** | • Fuel purchase records/invoices | • Audits | • Reliable internal data capture systems required |
| | | **Aviation (by fuel) – not owned and operated** | • Fuel data from travel management companies | • Audits | • TMCs are unlikely to be able to collect fuel data from the aviation providers |
| | **Air freight** | **Air freight** | • Shipping records (business expenses) | • Audits | • TMCs do not always track data In useful format (e.g. departure and destination airport codes against each ticket) |
| | **Public** | **Public transport** | • Mileage data from travel management companies<br>• Expenses data<br>• Employee surveys | • Audits | • TMCs typically do not track this data |
| | **Rail** | **Rail** | • Mileage data from travel management companies<br>• Expenses data | • Audits | • TMCs typically do not track this data |
| | **Road** | **Road (by fuel) – owned and operated vehicles** | • Fuel card invoices | • Audits | • Fuel card records are not always 100% correct |
| | | **Road (by fuel) – Not owned and operated vehicles** | • Fuel receipts (expenses data) | • Audits | • Reliable internal data capture systems required |

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| | | **Road (by distance) – owned and operated vehicles** | • Mileage data | • Audits | • Reliable internal data capture systems required |
| | | **Road (by distance) – not owned and operated vehicles** | • Mileage data | • Audits | • Reliable internal data capture systems required |
| | | **Road freight** | • Shipping records (business expenses) | • Audits | • Reliable internal data capture systems required |
| | **Water borne** | **Waterborne** | • Shipping records (business expenses) if freight<br>• TMCs if passenger travel | • Audits | • Reliable internal data capture systems required |
| **Waste** | **Waste** | **Waste – solid** | • Waste transfer notes<br>• Consignment notes | • Audits | • Reliable internal data capture systems required to consolidate information |
| | | **Waste – liquid** | • Waste transfer notes<br>• Consignment notes | • Audits | • Reliable internal data capture systems required to consolidate information |
| | | **Waste – gas** | • Waste transfer notes<br>• Consignment notes | • Audits | • Reliable internal data capture systems required to consolidate information |
| | **Waste water** | **Wastewater DOC – solid** | • Water bills | • Audits | • Often based on estimated readings |
| | | **Wastewater BOD** | • Water bills | • Audits | • Often based on estimated readings |
| | | **Wastewater DOC – liquid** | • Water bills | • Audits | • Often based on estimated readings |
| | | **Number of heads** | | | |
| **Water** | **Water** | **Water** | • Water meter readings | • Audits | • AMRs for water are not widely available<br>• Manual data capture is unreliable (water meters often difficult to reach)<br>• Bills are often based on estimated readings |

# Appendix B: Carbon software tools

There are a number of tools available to measure the carbon impact of built assets. General data about the design is entered by the user, which then generates Life Cycle Assessment (LCA) results. Examples of these tools are listed below.

| | Country of origin | Applicable to UK? | Project type | Online/offline | Scope based on BS EN 15978 | PAS 2080 compliant | Whole value chain design access | Input cost data | Transparency[2] | Robust database | Ability to update database |
|---|---|---|---|---|---|---|---|---|---|---|---|
| One Click LCA | Finland | Yes | Buildings and civils | Offline software | Modules A-C | | | | | | |
| eTool | Australia | Yes | Buildings, civils and rail | Online software | Modules A-C (+D) | | | | | | |
| CITT | UK | Yes | Building and civils | Online software | Modules A-C | | | | | | |
| SimaPro | Netherlands | Yes | Building and civils | Online software | Modules A-C | | | | | | |
| BREEAM LCA tool | UK | Yes | Buildings | | Modules A-C | | | | | | |
| RSSB Rail Carbon Tool | UK | Yes | Rail | Online software | Modules A-C | | | | | | |
| Environment Agency ERIC | UK | Yes | Buildings and civils | Online | Modules A-C (+D) | | | | | | |
| Highways England | UK | Yes | Highways | | Modules A-C | | | | | | |
| National Grid Carbon Interface Tool | UK | Yes | Power | Offline software | Modules A-C | | | | | | |
| H\B:ERT | UK | Yes | Buildings | Online | Modules A-C | | | | | | |
| Rapiere ECCOlab | UK | Yes | Buildings | Online | Modules A-C | | | | | | |

Users can identify which input data and emissions factors have been used and how the calculations have been done. Any assumptions or estimates are clearly stated.

It is likely that carbon assessors in the industry will have their own bespoke tools. Clients should discuss the use of these on a case-by-case basis. When considering alternative tools, assessors should ensure that they are following BS EN 15978 and that the scope covers modules A-C. Module D must still be assessed, but as the majority of available tools do not include module D by default at the moment, this can be done outside the software.