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# Carbon Accounting and Management in Infrastructure

## Literature Review

NGED Project Alpaca

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## Quality information

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# 1. Introduction

This literature review provides an overview of the current and available information, guidance and legislation surrounding carbon accounting in infrastructure. It is presented in a way that can inform and support the development of an effective whole-life carbon management process for National Grid Electricity Distribution (NGED). However, it is intended that this whole-life carbon management process can be used by all Distribution Network Operators (DNOs) in Great Britain. This review is split into four main headings:

- Existing government legislation, regulations and policy;
- Standards and specifications governing carbon accounting and reporting;
- Standard emission factor data sets; and
- Existing whole-life carbon reporting tools.

# 2. Existing government legislation, regulations and policy

For over 200 years we have largely built our economy on carbon-based infrastructure, as such, meeting our net zero targets will mean resetting a lot of the current infrastructure within the power sector. This section provides an overview of what regulations, policies and market-based instruments are in place to support the UK's power sector transition to net zero carbon emissions, and therefore should be taken into consideration when developing a whole-life carbon management tool for NGED.

## 2.1 The Climate Change Act 2008 and Carbon Budgets

The Climate Change Act came into force in 2008 and formalised the UK's approach towards tackling climate change in terms of both mitigation and adaptation. The Act originally stated that the UK net carbon emissions account for all six Kyoto Greenhouse Gas (GHG) emissions (carbon dioxide, methane, nitrous oxide, sulphur hexafluoride, hydrofluorocarbons and perfluorocarbons) and needed to be at least 80% lower than the 1990 baseline by 2050. However, in 2019, this target was updated to a 100% reduction[1]. With this updated target, the UK became one of the first countries to pass a law that mandates net zero by 2050. By net zero, the government mean: "*Any emissions would be balanced by schemes to offset an equivalent amount of greenhouse gases from the atmosphere, such as planting trees or using technology like carbon capture and storage*"[2].

To achieve the 2050 target, the Act created the independent Committee on Climate Change (CCC), whose focus is to work towards the target and remain separate from political fluctuations. The Act has cemented the UK's position as an international leader in tackling climate change.

This Act required that the UK government set legally binding carbon budgets, with the aim of creating a smooth and practical pathway towards meeting the 2050 target. Therefore, since 2008, six carbon budgets have been approved by parliament based on the CCC's advice. These carbon budgets set a cap on the amount of greenhouse gases emitted in the UK over a five-year period and must be set at least 12 years in advance to allow policymakers, businesses and individuals enough time to prepare[3]. Table 1 below summarises the six carbon budgets that have been set to date. The first carbon budget was met, as was the second, and the UK is on track to outperform the third. However, this outperformance includes the impact COVID-19 had on emissions in 2020, much of which is not expected to be permanent. As detailed in the table, the UK is not on track to meet the fourth or the fifth targets, and therefore to meet the future carbon budgets and the net zero target for 2050, the government will have to introduce more challenging measures.

**Table 1. Carbon budgets**

| Budget | Carbon budget level | Reduction below 1990 levels | Met? |
|---|---|---|---|
| 1st Carbon Budget (2008 to 2012) | 3,018 $MtCO_2e$ | 25% | Yes |
| 2nd Carbon Budget (2013 to 2017) | 2,782 $MtCO_2e$ | 31% | Yes |
| 3rd Carbon Budget (2018 to 2022) | 2,544 $MtCO_2e$ | 37% by 2020 | On track |

| Budget | Carbon budget level | Reduction below 1990 levels | Met? |
|---|---|---|---|
| 4th Carbon Budget (2023 to 2027) | 1,950 $MtCO_2e$ | 51% by 2025 | Off track |
| 5th Carbon Budget (2028 to 2032) | 1,725 $MtCO_2e$ | 57% by 2030 | Off track |
| 6th Carbon Budget (2033 to 2037) | 965 $MtCO_2e$ | 78% by 2035 | Off track |

## 2.2 Net Zero Strategy: Build Back Greener

The UK Government's Net Zero Strategy, published in October 2021, set out policies and proposals for decarbonising all sectors of the UK economy to meet the net zero target by 2050[4].

One of the key messages that the strategy outlined was the requirement for sector-specific polices to implement credible mechanisms to achieve the UK's net zero ambitions. With regards to the power sector, the strategy set a target to decarbonise the entire sector, including electricity and distribution networks, by 2035[4]. It is stated that a clean and reliable power system will be the foundation of a productive net zero economy; this is not limited to, but it is linked to the fact that the demand of electricity is expected to significantly increase as alternatives to gas are sought. NGED's ambition of achieving net zero for their business carbon footprint (BCF) by 2028, is therefore aligned with the goals set out in this strategy[5].

The strategy details that to fully decarbonise the power sector at the required pace, whilst still meeting increasing demand, a total public and private investment of £280-400 billion is needed in generation capacity and flexible assets – around £150-270 billion of this reflects increased ambition from the Sixth Carbon Budget[4]. The electricity transmission and distribution networks will also both require significant expenditures, with an additional £20-30 billion required by 2037, to maintain and reinforce Great Britain's electricity network[4]. Furthermore, it is added that the Government will continue to work with Ofgem, distribution network operators, and other local actors on the approach to upgrade the network in Great Britain and deliver smart, secure, cost-effective solutions.

## 2.3 The Infrastructure Carbon Review

The Infrastructure Carbon Review was published by the UK Government in 2013, and sets out a series of actions for government, clients, and suppliers to reduce carbon from the construction and operation of the UK's infrastructure assets, in line with the UK's climate change commitments[6]. This review was developed jointly by the government and industry, and not only presents practical steps to reduce carbon within an organisation and its supply chain, but also recommends actions for wider change across the infrastructure sector. Its recommendations have the potential to reduce up to 24 million tonnes of carbon and save the UK £1.46 billion a year by 2050[6].

The Review identifies five main enablers for implementing carbon reduction within an organisation and its supply chain[6]:

- Effective leadership - provide the highest-level of sponsorship in embedding carbon reduction as a core organisational value, by delivering clear and consistent policies on carbon reduction;
- Communication and culture - effectively provide training, share carbon knowledge and ensure that carbon reduction behaviours are encouraged by the organisation;
- Metrics and governance - establish a baseline against which to measure performance, set carbon reduction targets, and build effective carbon control;
- Innovation and standards - promote new thinking across the supply chain and allow existing standards to be challenged, whilst also setting new standards for carbon best practice; and
- Commercial solutions - align supply chain objectives with reducing carbon and take carbon reductions into commercial and contractual solutions.

The overarching recommendation of this review is that government and industry work together to make carbon reduction a requirement on all infrastructure projects.

## 2.4 Ofgem

The Office of Gas and Electricity Markets (Ofgem) regulates much of the energy sector, including the monopoly companies which run the gas and electricity networks. They make decisions on price controls and enforcement, acting in the interests of consumers and helping the industries to achieve environmental improvements[7]. Therefore, following the commitment made by the UK government in 2019 for a net zero greenhouse gas emissions target by 2050, in early 2020, Ofgem published their decarbonisation action plan[8] where it highlights the need for increased investment in renewable and low-carbon electricity. This will include the expansion of the electrical infrastructure that NGED and other DNOs provide in order to continue to reliably supply energy when and where consumers need it. The decarbonisation plan sets out nine actions that detail how they will support the government to meet the net zero goal[8]:

1. Regulate to ensure network companies invest efficiently to deliver affordable clean energy;
2. Set up a fund to unlock investment in innovative solutions to tackle climate change;
3. Explore regulatory options to support development of an offshore grid to enable a four-fold increase in offshore wind generation by 2030;
4. Encourage more options in the way people use electricity, for example, charging electric vehicles at night and selling the power stored in car batteries back at peak times;
5. Review the way the energy system is managed to ensure it is fit for a net zero future;
6. Support government and industry to develop affordable low carbon heating options;
7. Enable drivers to go electric by supporting an energy network that can power 10 million electric vehicles by 2030;
8. Kick start innovation by supporting energy suppliers to create low carbon products and services for consumers;
9. Take big decisions in a fast-changing environment by being more adaptive in their approach to regulation.

Ofgem recognises that energy networks will sit at the heart of the race to cut harmful carbon emissions from power, heat and transport by 2050, highlighting that local electricity networks run by DNOs will play a central role in greening the system[9]. The increasing electrification of transport (via a nationwide EV charging network) and heat (through the use of heat pumps to replace fossil-fuelled water and space heating), and a large-scale expansion in embedded generation solutions will need a coordinated upgrade of electricity transmission and distribution networks. Ofgem has held consultations with DNOs regarding the plans to modernise the local electricity grids and have also asked network companies to come forward with proposals to accelerate green investment[8].

However, modernising local grids will not simply be about installing more infrastructure. Ofgem's analysis has demonstrated that if owners use flexible 'smart charging' – where users only charge vehicles outside peak demand times on the grid – at least 60% more electric vehicles could be charged up using existing grid capacity, compared with vehicles charged only at peak time[8]. Therefore, Ofgem is asking that network companies use data and the best modern technology to cope with new demand and smooth peaks, which will present much quicker solutions, and could save billions of pounds compared to building new network capacity. In order to assist network companies, Ofgem has recently unlocked a £450 million[10] network technology innovation fund; the fund is to be used by network companies, system operators, and global businesses and researchers to build innovative ideas on how to accelerate the transition to an emissions-free energy system.

## 2.5 Market-based Instruments and Regulatory Requirements

Over the years the government has introduced several market-based instruments, which will help the UK to meet its net zero target by 2050; these include[2]:

- Fuel duty tax on the road; fuel burnt by UK car drivers;
- Contract for Difference (CFD) guarantee a fixed price per unit of low-carbon power generation for large-scale power operations;
- Energy Company Obligation, on large energy firms in Britain, requires companies to boost the efficiency of homes, with the costs passed to consumers via energy bills; and

- Climate Change Levy (CCL) is paid by polluters in the business sector on every unit of energy consumed. CCLs can be opted out of if the user agrees to a Climate Change Agreement to boost their efficiency.

In addition to these instruments, the UK government has also established regulatory requirements, with the same aim of assisting the country meeting its net zero target by 2050, including:

- UK Emission Trading Scheme (UK ETS);
- Streamlined Energy and Carbon Reporting (SECR); and
- Energy Savings Opportunity Scheme (ESOS)

### UK Emission Trading Scheme (UK ETS)

The UK Emission Trading Scheme[11] is a mandatory cap and trade scheme for energy-intensive industries, the power sector and the aviation sector, with the aim of incentivising them to lower emissions and save money. This scheme replaced the UK's participation in the EU ETS post Brexit on January 1st 2021.

The UK ETS Regulators (Environment Agency in England) are responsible for enforcing compliance with the UK ETS Regulations, including operational functions such as issuing and ensuring compliance with permits[11].

Under this Scheme, installations receive an allocation of free allowances to emit greenhouse gases; one allowance under the UK ETS is called a UK allowance, and one UK allowance gives permission to emit one tonne of carbon dioxide equivalent. These allowances can be traded at the going market rate.

### Streamlined Energy and Carbon Reporting (SECR)

The SECR is a mandatory UK government framework that replaced the Carbon Reduction Commitment (CRC) Energy Efficiency Scheme in 2019[12]. The aim was to simplify the reporting process for companies and to reduce emissions from business and industry by 80% by 2050. SECR also extended the reporting requirements for quoted companies and mandated new annual disclosures for large unquoted and limited liability partnerships. This regulatory framework applies to[12]:

- Quoted companies of any size that are required to prepare a Directors' Report; and
- UK registered, unquoted large companies as defined in the Companies Act 2006 - this refers to companies that fulfil at least two of the following three conditions in the financial year for which they are reporting:
  - at least 250 employees;
  - an annual turnover of £36m or more and/or; and
  - an annual balance sheet total greater than £18m.

The SECR report must be included in Directors' Reports for all financial years starting on or after the 1st April 2019. Therefore, the deadline will depend on a company's financial year.

Quoted companies need to report their global energy use, Scope 1 and 2 GHG emissions, and one emissions intensity metric for the current and previous financial years. Unquoted companies need to report their global energy use, Scope 1 and 2 GHG emissions, Scope 3 grey fleet (rental cars or employee-owned vehicles) business travel, and one emissions intensity metric for the current and previous financial years.

Both quoted and unquoted companies are encouraged to go beyond the minimum requirements and voluntarily report on Scope 3 emissions[13]. The relevant report must also include a description of measures taken to improve the businesses' energy efficiency in that year and, where possible, resulting energy savings from the actions reported should also be stated. Even though no specific methodology is prescribed, the methodology used must be disclosed and considered to be robust, transparent and widely accepted[12].

The Department for Environment, Food and Rural Affairs (DEFRA) provide guidance to help companies comply with the Streamlined Energy and Carbon Reporting regulations (SECR), including GHG reporting[14]. The document includes the benefits of reporting, the legal framework for reporting, principles of accounting and reporting, and guidance on reporting environmental impact, SECR, and voluntary GHG reporting.

### Energy Savings Opportunity Scheme (ESOS)

ESOS is a mandatory piece of EU legislation (EU Energy Efficiency Directive (2012/27/EU)[15]) requiring large companies to submit an energy report to the Environment Agency (the England's scheme administrator) every four years[16]. Companies which qualify for ESOS are required to submit an ESOS report to the Environment Agency every four years (Table 2).

**Table 2 ESOS compliance periods**

| Compliance Period | Qualification Date | Compliance Period | Compliance Date |
|---|---|---|---|
| **1** | 31 December 2014 | From 17 July 2014 to 5 December 2015 | 5 December 2015 |
| **2** | 31 December 2018 | From 6 December 2015 to 5 December 2019 | 5 December 2019 |
| **3** | 31 December 2022 | From 6 December 2019 to 5 December 2023 | 5 December 2023 |
| **4** | 31 December 2026 | From 6 December 2023 to 5 December 2027 | 5 December 2027 |

During the second compliance period (31 December 2018) a large undertaking was defined as any UK company that either[16]:

- employed 250 or more people; and
- had an annual turnover in excess of €50 million (£44,845,000), and an annual balance sheet total in excess of €43 million (£38,566,700).

For the qualification date for the third compliance period (31 December 2022), a large undertaking is any UK company that either[16]:

- employs 250 or more people; and
- has an annual turnover in excess of £44 million, and an annual balance sheet total in excess of £38 million.

If a company qualifies for ESOS, they are required to carry out an ESOS assessment, unless already compliant with ISO 50001. An ESOS assessment includes the calculation of their total energy consumption (buildings, processes and transport activities) and an audit of areas of significant energy consumption, in order to presented costed energy saving opportunities [16]. ESOS reports must be verified by a qualified ESOS Lead Assessor and the organisation then needs to submit their declaration of compliance to the Environment Agency.

# 3. Standards and specifications governing carbon accounting and reporting

The overall reliability and usefulness of a carbon accounting and reporting strategy is reliant on the integrity of the standards and methodologies used, and the completeness of the reporting. For credibility and consistency, it will be important that the standards and specifications used in the whole-life carbon management tool are relevant for the NGED and other DNOs. This section reviews and summarises the relevant standards for reporting GHG emissions.

## 3.1 2006 IPCC Guidelines for National Greenhouse Gas Inventories

The 2006 Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories provide methodologies for estimating national inventories of anthropogenic emissions by sources and removals by sinks of greenhouse gases[17]. The guidelines were prepared to provide guidance in fulfilling commitments under the United National Framework Convention on Climate Change (UNFCCC), on reporting inventories of anthropogenic emissions by sources and removals by sinks of greenhouse gases not controlled by the Montreal Protocol[17].

The series consists of five volumes:

- Volume 1: General Guidance and Reporting;
- Volume 2: Energy;
- Volume 3: Industrial Processes and Product Use;
- Volume 4: Agriculture, Forestry and Other Land Use; and
- Volume 5: Waste.

Volume 1 describes the basic steps to be followed when developing a GHG inventory and offers general guidance in the estimation of GHG emissions and removals. This is based on the authors' understanding of accumulated experiences of countries over the period since the late 1980s, when national greenhouse gas inventories started to appear in significant numbers[18]. Volumes 2 to 5 offer detailed guidance for GHG estimates in different sectors of the economy, with Volumes 2 and 3 being of particular relevance to NGED. Volume 2 covers GHG emissions from stationary combustion, mobile combustion, including exploration of primary energy sources, conversion of the primary energy sources into more usable energy forms, transmissions and distribution, and fugitive emissions[19]. Volume 3 covers GHG emissions occurring from industrial processes, from the use of greenhouse gases in products, and from non-energy uses of fossil fuel carbon[20].

In 2019, the Task Force on National Greenhouse Gas Inventories (TFI) prepared the *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. This 2019 Refinement does not revise the 2006 IPCC Guidelines, but updates, supplements and/or elaborates the 2006 IPCC Guidelines where there are gaps or out-of-date science has been identified. Therefore, it will not replace the 2006 IPCC Guidelines, but should be used in conjunction with the 2006 IPCC Guidelines[21].

## 3.2 Greenhous Gas Protocol

The original GHG Protocol Corporate Accounting standard was first developed in the late 90s, and it currently builds on a 20-year partnership between World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD)[22]. As one of the most widely used GHG accounting standards, the GHG Protocol has been used by governments, industry associations, NGOs, business and other oganisations[22]. Currently the GHG Protocol has several standards (Corporate Standard, GHG Protocol for Cities, Mitigation Goal Standard, Corporate Value Chain (Scope 3) Standard, etc.)[23]. For the purposes of NGED and other DNOs, the relevant standards are the Corporate Standard, which provides guidance in the preparation of a corporate-level GHG inventory, the Product Standard, which is used to understand the fully life cycle emissions of a product, and the Scope 3 Standard, which provides guidance for companies to assess their entire value chain emissions.

The GHG Protocol Corporate Standard focuses only on developing a verifiable accounting and reporting emissions inventory. It does not require emissions information to be reported, or provide a standard for the verification[24]. In accordance with this standard, there are five core principles that should be followed when developing an inventory[24]:

- Relevance - Ensure the GHG inventory appropriately reflects the GHG emissions of the reporting company and serves the decision-making needs of users;
- Completeness - Account for and report on all GHG emission sources and activities within the chosen inventory boundary, disclosing and justifying any specific exclusions;
- Consistency - Use consistent methodologies to allow for meaningful comparisons of emissions over time;
- Transparency - Address all relevant issues in a factual and coherent manner, based on a clear audit trail, disclosing relevant assumptions, and making appropriate references to the accounting and calculation methodologies and data sources used; and
- Accuracy - Ensure that the quantification of GHG emissions is systematically neither over nor under actual emissions, as far as can be judged, and that uncertainties are reduced as far as practicable.

This standard introduced the categorisation of carbon emissions into three scopes, which are now widely accepted as the three scopes for carbon accounting (Figure 1)[24]:

- Scope 1 accounts for direct GHG emissions, which are emissions that occur from sources that are owned or controlled by the company (e.g. fuel burnt);
- Scope 2 accounts for GHG emissions from the consumption of imported services (grid electricity, steam, heating and cooling etc.) by the company; and
- Scope 3 emissions are a consequence of the activities of the company's supply chain but occur from sources not owned or controlled by the company (e.g., extraction and production of purchased materials; transportation of purchased fuels; and use of sold products and services).

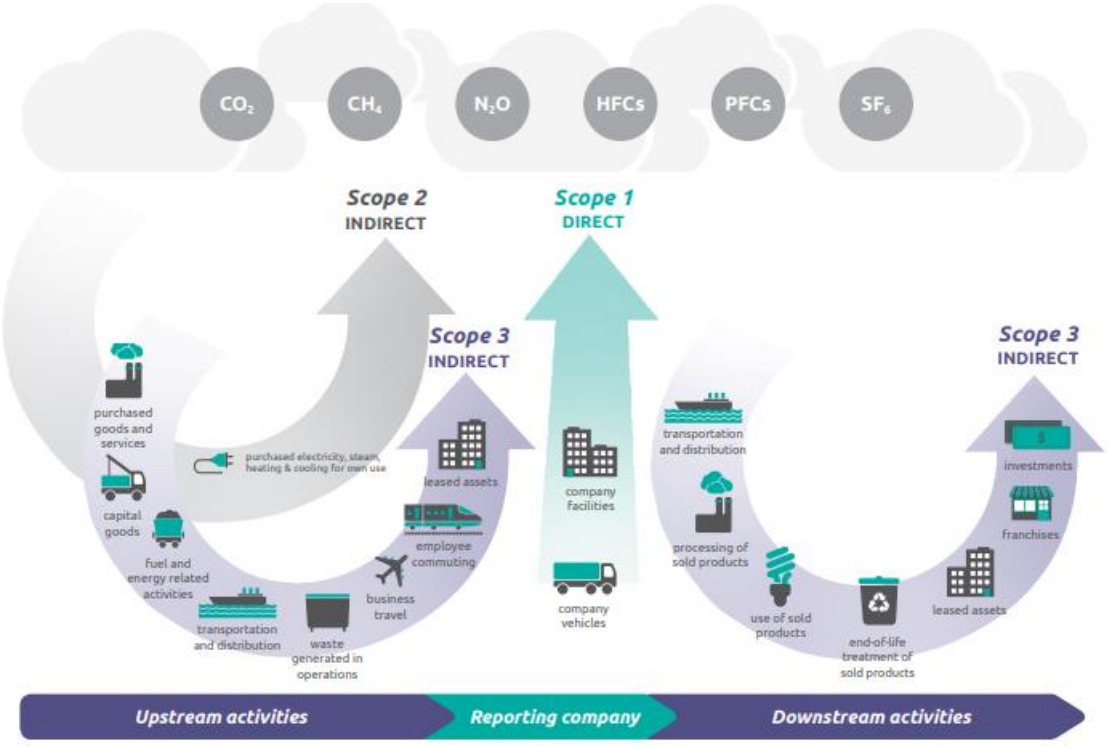


**Figure 1. Overview of GHG Protocol scopes and emissions across the value chain[25]**

The Scope 3 Standard provides the requirements and guidance for companies to prepare and report a GHG emissions inventory that includes indirect emissions resulting from value chain activities (i.e., Scope 3 emissions). The primary goal of this standard is to provide a standardised step-by-step approach to help companies understand their full value chain emissions impact and to focus company efforts on the greatest GHG reduction opportunities, leading to more sustainable decisions about companies' activities[25]. Scope 3 emissions can represent the largest source of emissions for companies and present the most significant opportunities to influence GHG reductions and achieve a variety of GHG-related business objectives. This Standard complements and builds upon the Corporate Standard to promote additional completeness and consistency in the way companies account for and report on indirect emissions from value chain activities[26]. Figure 1 above depicts the 15 distinct reporting categories in Scope 3 and shows how Scope 3 relates to Scope 1 and Scope 2.

For NGED and other DNOs, examples of emissions by scope are shown in Table 3.

**Table 3: Examples of DNO emissions by Scope**

| Scope | Emissions sources |
|---|---|
| 1 | Natural gas and other fuels consumed in company buildings and installations |
| | Petrol and diesel consumed in vehicles controlled by the company |
| 2 | Consumption of grid electricity, including network losses* |
| 3 | Embodied carbon from capital goods, including new and replacement assets |
| | Transport of capital goods |
| | Disposal of waste |
| | Business travel |
| | Staff commuting |
| | All outsourced activities (e.g., by contractors) |

Building on the Corporate Standard and Scope 3 Standard, the GHG Protocol is currently developing new guidance specifically aimed at the land sector and on how organisations should account for GHG emissions and carbon removals from land use, land use change, bioenergy, and related topics in their inventories[27]. The guidance will be available for public consultation in June 2022 and is currently undergoing pilot testing by selected companies. Final publication is expected in early 2023[27].

## 3.3 ISO 14064:2019

ISO 14064 was initially developed and published in 2006[28].The ISO 14064 standards provides government, businesses, and other organisations with an integrated set of tools for programs aimed at measuring, quantifying and reducing greenhouse gas emissions, allowing them to take part in emissions trading schemes using a globally recognised standard. ISO 14064 is comprised of three standards, respectively detailing specifications and guidance for the organisational and project levels, and for validation and verification[28]:

- ISO 14064-1 Part 1: Specification with guidance at the organisational level for quantification and reporting of GHG emissions and removals. Part 1 includes requirements for the design, development, management, reporting and verification of an organisation's GHG inventory[29].
- ISO 14064-2 Part 2: Specification with guidance at the project level for quantification, monitoring and reporting of GHG emission reductions or removal enhancements. Part 2 focuses on GHG project-based activities specifically designed to reduce GHG emissions and/ or enhance GHG removals, providing the basis for GHG projects to be verified and validated[30].
- ISO 14064-3 Part 3: Specification with guidance for the validation and verification of GHG claims. Part 3 provides principles, requirements, and guidance for individuals conducting or managing verification or validation of organisational carbon inventory reports or project-level assertions[31].

Figure 2 below illustrates the relationship between the ISO 14060 standards.

* For end consumers of grid electricity, associated transmission and distribution losses are categorised under Scope 3, but for DNOs network losses fall under Scope 2

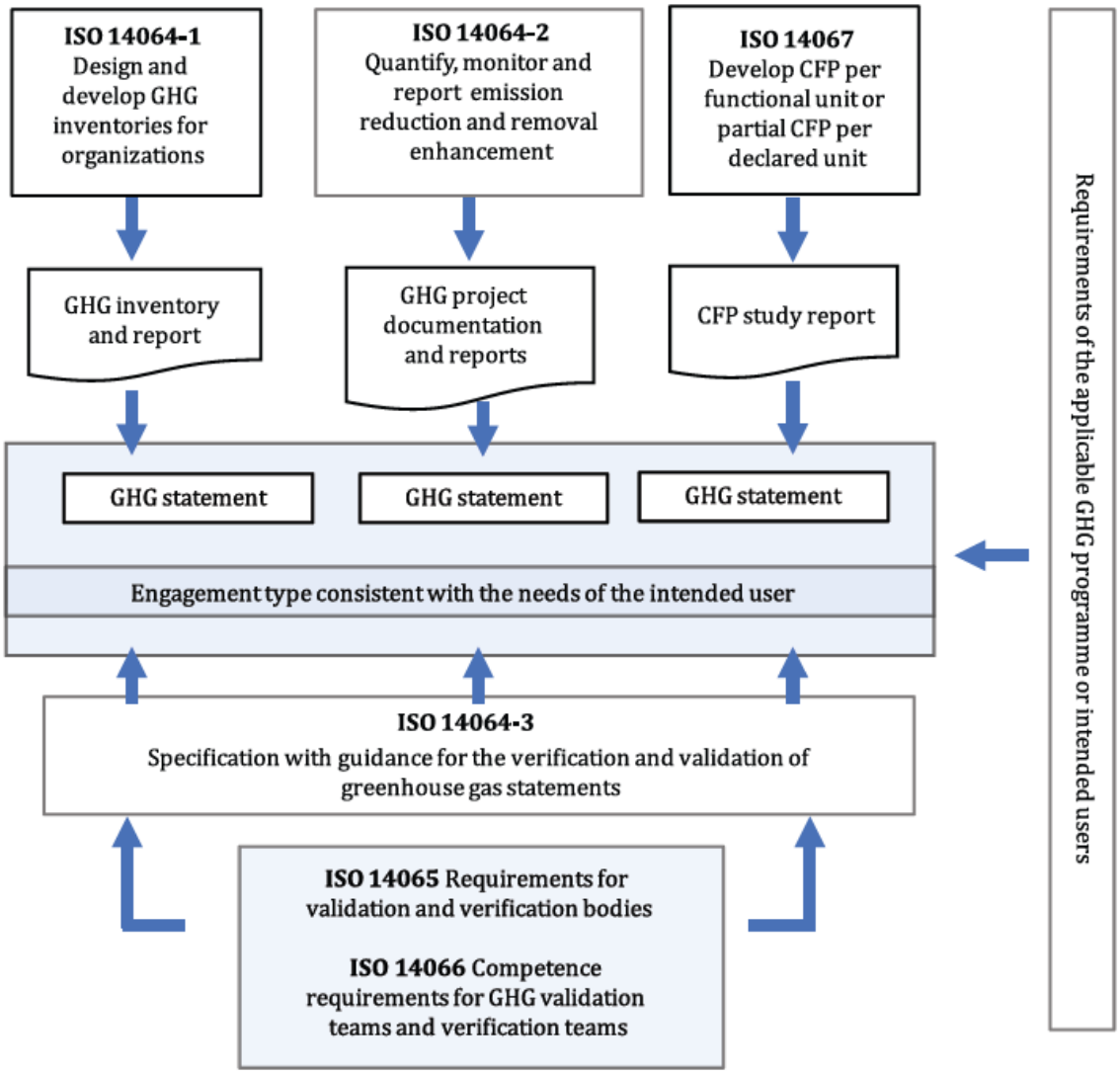


**Figure 2. Relationship between the ISO 14060 family of GHG standards**

## 3.4 PAS 2080:2016 – Carbon Management in Infrastructure

Following the publication of the Infrastructure Carbon Review in 2013, it was recognised that infrastructure is responsible for over 50% of the UK's carbon emissions. As such PAS 2080 was designed to specifically address the management of carbon in infrastructure (defined as the transport, energy, water, waste and communications sectors)[32]. The framework looks at the whole value chain, aiming to reduce carbon and reduce cost through more intelligent design, construction, and use, while also ensuring that carbon is consistently and transparently quantified at key points in infrastructure delivery[33]. Furthermore, this framework highlights the importance of ensuring that all value chain members (including asset manager, designers, constructors and suppliers) are involved in the delivery of a carbon management plan, because only with a fully integrated value chain contribution it is possible to realise all the potential carbon reductions (Figure 3)[32]. It recommends that all value chain members engage with each other as early as possible in a collaborative working manner to identify whole-life low carbon solutions.

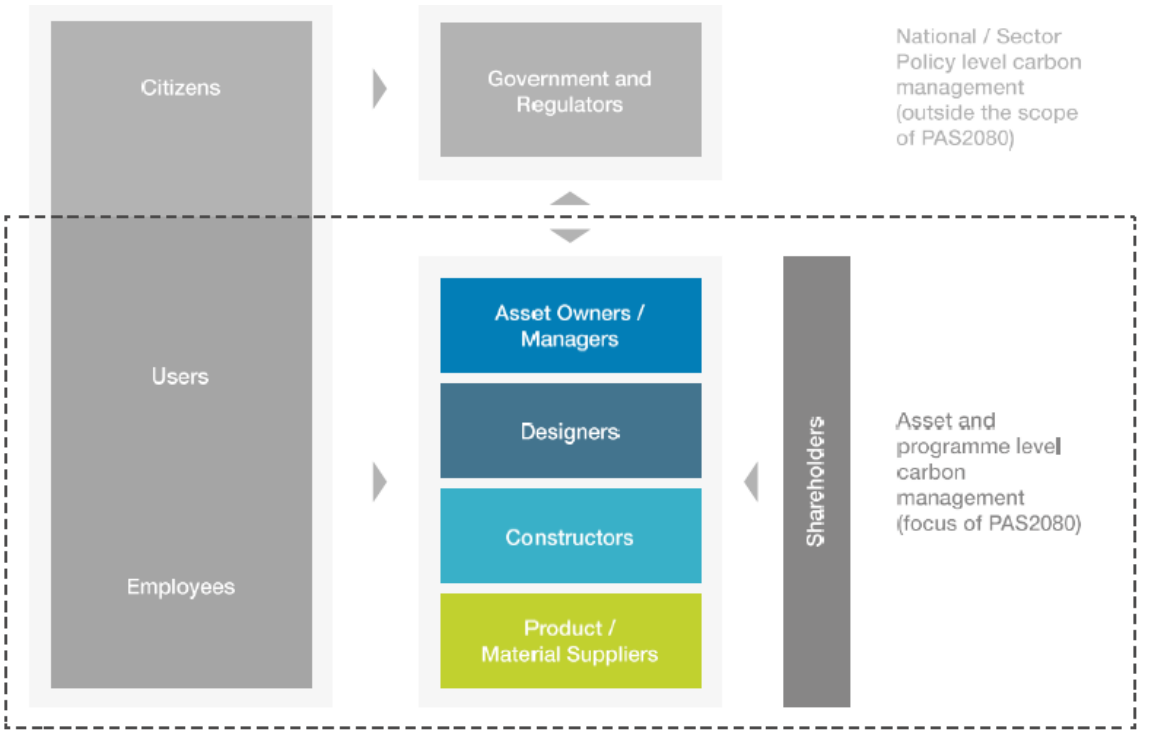


**Figure 3. Infrastructure value chain members responsible for carbon management**

The individual value chain requirements in the carbon management process are structured around the following components[34]:

- Setting appropriate carbon reduction targets - effective target setting for the carbon management process is a key component which underpins successful carbon reduction;
- Determining baselines against which to assess carbon reduction performance;
- Establishing metrics, e.g., key performance indicators for credible carbon emissions quantification and reporting;
- Selecting carbon emissions quantification methodologies to include defining boundaries and cut-off rules;
- Reporting at appropriate stages in the infrastructure work stages to enable visibility of performance; and
- Continual improvement of carbon management and performance.

Figure 4 below illustrates how PAS 2080 manages whole-life carbon emissions by integrating different carbon management process components into existing infrastructure work stages. Furthermore, Figure 5 presents the system boundaries, and lifecycle stages for infrastructure GHG emissions quantification.

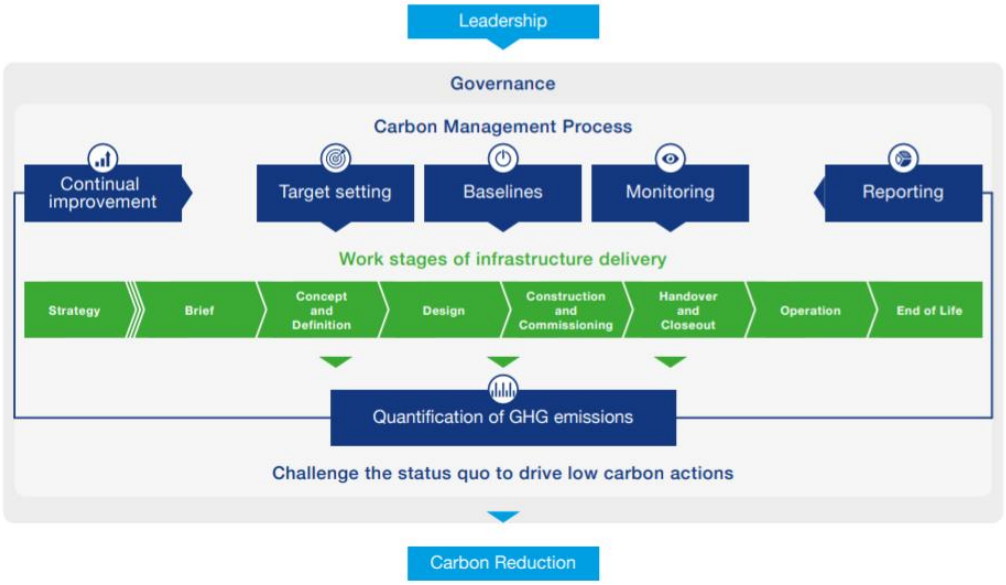


**Figure 4. PAS 2080 Carbon Management Process**

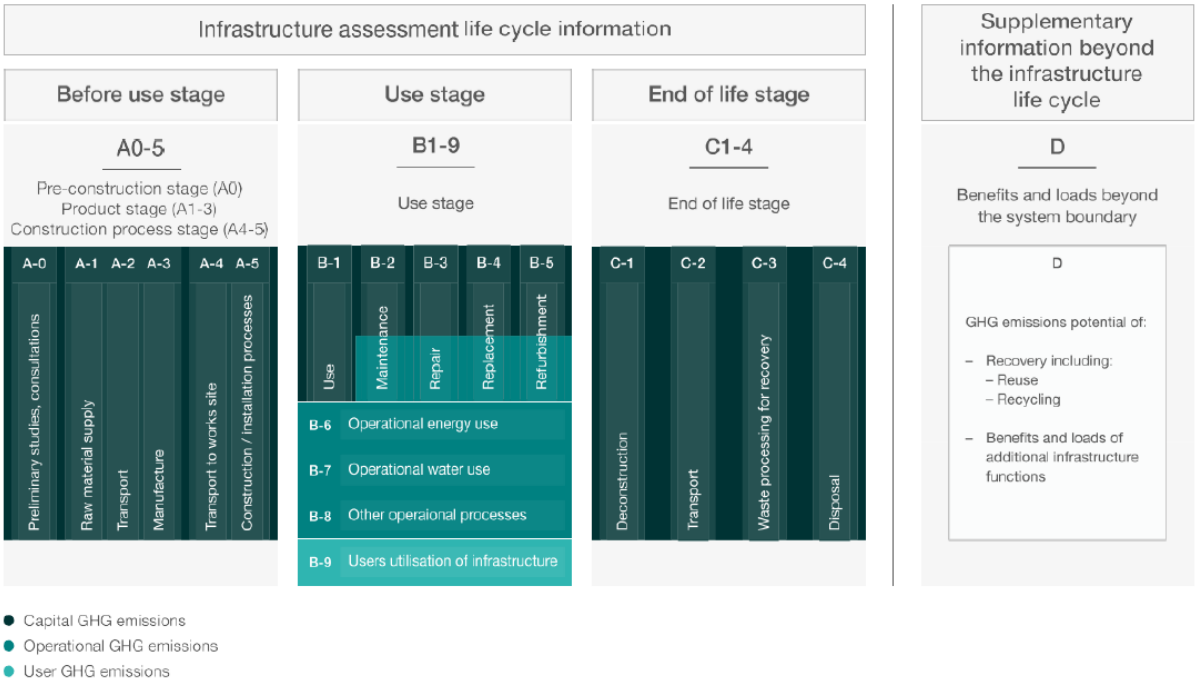


**Figure 5 Modular approach showing the life cycle stages and individual modules for infrastructure GHG emissions quantification**

With support from the Green Construction Board and Institution of Civil Engineers, PAS2080 is currently being updated, due to the recognised momentum that is building around the development of zero carbon infrastructure and incorporating nature-based solutions[35]. The main aim of this review is to improve clarity and accessibility for all, in that way encouraging more organisations to adopt PAS2080 as the norm for delivering low carbon, sustainable infrastructure fit for a net zero future. The revision is expected to be published before the end of the year.

## 3.5 Environmental Product Declarations

An Environmental Product Declaration (EPD) is an independently verified and registered document that communicates transparent and comparable information about the life-cycle environmental impact of products in a credible way[36]. They report a manufacturer's commitment to measuring and reducing the environmental impact of its products and services.

EPDs are based on international standards (ISO 14025; Environmental Labels and Declarations) and can be used for all types of goods and services allowing comparable and robust information[36]. EPDs are verified by an approved independent verifier before being registered and published at the International EPD System. In addition, EPD climate declarations are adapted to ISO 14067 for the calculation of carbon footprint; the emissions are measured in terms of Global Warming Potential (GWP) as measurable carbon dioxide equivalents ($CO_2e$)[37].

EPDs would be a useful tool for NGED going forward, because as a standardised document across all sectors, they are a good indicator of best practice and a reliable and comparable source of data. In physical terms, the EPDs consist of two keys documents: a background project report (comprehensive summary of the life-cycle assessment to support the verification of the EPD), and a public EPD document that provides the results from the life-cycle analysis[36] (see example below, Figure 6). Therefore, the use of EPDs in NGED's supply chain can provide an invaluable source of data and ongoing active engagement to drive decarbonisation, as NGED would have accurate information about the life-cycle environmental impact of products they purchase.

Sample EPD generated with One Click LCA Pre-Verified EPD Generator

### ENVIRONMENTAL IMPACT DATA

#### ENVIRONMENTAL IMPACTS - EN 15804+A1, CML

| Impact category | Unit | A1 | A2 | A3 | A1-A3 | A4 | A5 | B1-B7 | C1 | C2 | C3 | C4 | D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Global warming potential | kg CO2e | 6,26E1 | 3,92E0 | 4,1E0 | 7,06E1 | 4,97E0 | MND | MND | 1,6E0 | 3,09E0 | 2,42E0 | 5,07E−1 | −1,28E1 |
| Depletion of stratospheric ozone | kg CFC11e | 1,64E−6 | 7,16E−7 | 4,92E−7 | 2,76E−6 | 9,07E−7 | MND | MND | 2,73E−7 | 5,64E−7 | 4,13E−7 | 1,66E−7 | −7,66E−7 |
| Photochemical ozone formation | kg C2H4e | 8,04E−3 | 5,16E−4 | 1,03E−3 | 9,69E−3 | 6,55E−4 | MND | MND | 2,43E−4 | 4,07E−4 | 3,67E−4 | 1,47E−4 | −6,71E−3 |
| Acidification | kg SO2e | 1,24E−1 | 7,98E−3 | 2,04E−2 | 1,62E−1 | 1,01E−2 | MND | MND | 2,36E−3 | 6,3E−3 | 3,57E−3 | 2,01E−3 | −4,68E−2 |
| Eutrophication | kg PO4 3e | 3,67E−2 | 1,66E−3 | 4,32E−3 | 4,17E−2 | 2,11E−3 | MND | MND | 4,16E−4 | 1,31E−3 | 6,28E−4 | 3,88E−4 | −2,71E−2 |
| Abiotic depletion of non-fossil | kg Sbe | 2,3E−5 | 9,78E−5 | 9,21E−6 | 1,3E−4 | 1,24E−4 | MND | MND | 2,44E−6 | 7,71E−5 | 3,69E−6 | 4,63E−6 | −4,29E−4 |
| Abiotic depletion of fossil | MJ | 2,07E2 | 5,91E1 | 4,43E1 | 3,11E2 | 7,5E1 | MND | MND | 2,17E1 | 4,66E1 | 3,29E1 | 1,41E1 | −1,78E2 |

*MND abbreviation stands for Module Not Declared*

#### CORE ENVIRONMENTAL IMPACT INDICATORS – EN 15804+A2, PEF

| Impact category | Unit | A1 | A2 | A3 | A1-A3 | A4 | A5 | B1-B7 | C1 | C2 | C3 | C4 | D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Climate change – total | kg CO2e | 9.75E+01 | 3.90E+00 | 6.13E+00 | 1.06E+02 | 4.96E+00 | MND | MND | 1.59E+00 | 3.08E+00 | 2.40E+00 | 5.01E-01 | -1.26E+01 |
| Climate change – fossil | kg CO2e | 9.65E+01 | 3.88E+00 | 2.73E+00 | 1.03E+02 | 4.93E+00 | MND | MND | 1.59E+00 | 3.06E+00 | 2.40E+00 | 4.98E-01 | -1.24E+01 |
| Climate change – biogenic | kg CO2e | 9.39E-01 | 2.31E-02 | 2.39E+00 | 3.35E+00 | 2.93E-02 | MND | MND | 2.69E-03 | 1.82E-02 | 4.06E-03 | 3.16E-03 | -2.27E-01 |
| Climate change – LULUC | kg CO2e | 1.95E-02 | 1.38E-03 | 1.46E-02 | 3.53E-02 | 1.75E-03 | MND | MND | 1.35E-04 | 1.09E-03 | 2.04E-04 | 1.51E-04 | -9.13E-03 |
| Ozone depletion | kg CFC11e | 3.85E-06 | 8.98E-07 | 4.31E-07 | 5.18E-06 | 1.14E-06 | MND | MND | 3.45E-07 | 7.08E-07 | 5.22E-07 | 2.09E-07 | -8.42E-07 |
| Acidification | mol H+e | 3.31E-01 | 9.18E-03 | 9.97E-03 | 3.51E-01 | 1.17E-02 | MND | MND | 2.73E-03 | 7.24E-03 | 4.13E-03 | 2.39E-03 | -5.42E-02 |
| Eutrophication, aquatic freshwater | kg PO4e | 2.11E-02 | 2.98E-04 | 5.22E-04 | 2.19E-02 | 3.79E-04 | MND | MND | 5.80E-05 | 2.35E-04 | 8.77E-05 | 5.25E-05 | -7.16E-03 |
| Eutrophication, aquatic marine | kg Ne | 5.77E-02 | 1.29E-03 | 2.58E-03 | 6.16E-02 | 1.63E-03 | MND | MND | 3.68E-04 | 1.01E-03 | 5.56E-04 | 4.69E-04 | -1.04E-02 |
| Eutrophication, terrestrial | mol Ne | 6.59E-01 | 1.37E-02 | 2.86E-02 | 7.02E-01 | 1.73E-02 | MND | MND | 3.93E-03 | 1.08E-02 | 5.95E-03 | 5.09E-03 | -1.06E-01 |
| Photochemical ozone formation | kg NMVOCe | 1.89E-01 | 7.09E-03 | 8.27E-03 | 2.05E-01 | 9.01E-03 | MND | MND | 3.91E-03 | 5.60E-03 | 5.92E-03 | 2.09E-03 | -4.32E-02 |
| Abiotic depletion, minerals & metals | kg Sbe | 5.69E-04 | 9.78E-05 | 1.01E-05 | 6.76E-04 | 1.24E-04 | MND | MND | 2.44E-06 | 7.71E-05 | 3.69E-06 | 4.63E-06 | -4.29E-04 |
| Abiotic depletion of fossil resources | MJ | 7.13E+02 | 5.91E+01 | 4.16E+01 | 8.14E+02 | 7.50E+01 | MND | MND | 2.17E+01 | 4.66E+01 | 3.29E+01 | 1.41E+01 | -1.78E+02 |
| Water use | m3e depr. | 1.88E+03 | 9.25E+01 | 2.02E+03 | 3.99E+03 | 1.17E+02 | MND | MND | 1.23E+01 | 7.30E+01 | 1.86E+01 | 1.25E+01 | -7.98E+02 |

EN 15804+A2 disclaimer for Abiotic depletion and Water use indicators and all optional indicators except Particulate matter and Ionizing radiation, human health. The results of these environmental impact indicators shall be used with care as the uncertainties on these results are high or as there is limited experienced with the indicator.

7

One Click LCA Environmental Product Declaration created with One Click LCA Rearden Metal manufactured by Rearden Steel

**Figure 6 Extract from sample EPD**

Since this is currently a voluntary process, it is unlikely that all of NGED's suppliers will have EPDs for their products; however, the uptake on EPDs has been increasing and is likely to keep on the same trajectory. For example, regarding construction products, at the start of 2021 there were 360 EPDs for UK produced products, from over 60 manufacturers, and at the start of 2022, there were over 450 EPDs from over 90 manufacturers[38]

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# 4. Standard emission factor data sets

This section outlines the standard emission factor datasets which are available for use in carbon accounting. Emission factors can be used to populate carbon accounting tools or a suitable methodology to provide figures on carbon emissions for organisations, products, supply chains and other assets.

## 4.1 Government conversion factors

Since 2013, the UK Government (initially the Department for Environment, Food and Rural Affairs, more recently the Department for Business, Energy and Industrial Strategy) has released a database of conversion factors for company reporting of GHG emissions for UK and international organisations[39]. The conversion factors are updated annually along with a document outlining the methodology used, guidance on how to use the data, a summary of major changes made since the previous update, and a statement of voluntary compliance with the Code of Practise for Statistics.

The spreadsheet is divided into activities/emission sources. Each year a condensed set, a condensed set (for most users) and a full set (for advanced users) of conversion factors are published. To report the GHG emissions associated with an organisation's activity such as energy use, water consumption, waste disposal etc., 'activity data' such as distance travelled, litres of fuel used, or tonnes of waste disposed can be converted in GHG emissions using the appropriate emissions factors for that activity.

**Table 4. Summary of main features of Government conversion factors**

| Feature | Inclusion |
|---|---|
| **Scope** | Cradle to grave |
| **Latest update** | 2021 (and annual updates expected) |
| **Number of datasets** | 300+ |
| **Main emission sources** | Fuels, electricity, transport and travel, and waste. |
| **Compliance** | Defra/DECC; GHG Protocol; Possible to use in product footprints |
| **Licensing** | Free |

### Relevance

Government emissions factors are updated annually based on UK data enabling them to be highly relevant and accurate. The database is useful for annual reporting of organisations emissions based on activity data in line with government Environmental Reporting Guidelines. While the government emission factor dataset is well suited for operational GHG reporting, this dataset is not designed for reporting emissions associated with capital investment, such as the embodied emissions associated with materials and products.

## 4.2 The Inventory of Carbon and Energy

The Inventory of Carbon and Energy (ICE)[40] database is a free database, originally developed by the University of Bath in 2005, providing embodied carbon values for a wide range of materials. The database contains the embodied carbon of various materials such as concrete, bitumen, and steel, along with the original references used to provide the information. While the database focuses on construction materials, the emission factors for them are relevant to a diverse range of sectors. Three ICE databases are available, with the most up to date versions shown below:

- ICE Database V3.0 – 10 Nov 2019
- ICE Cement, Mortar and Concrete Model – V1.1 Beta – 28 Nov 2019
- ICE Database Machine Readable V3.0 Beta – 10 Nov 2019

An additional background database stores metadata referring to the methodology and boundaries of the data provided in the databases, although it is not publicly available. Notedly, variations in the methodologies do exist in the background database, depending on the material considered.

The ICE database implements data quality indicators (DQIs), whereby the carbon footprint method is scrutinized. The results are published alongside each datapoint as a percentage and correlating traffic light colour detailing the quality of data, allowing users to make judgements on consistency. The DQI score is based on a matrix taking into account method compatibility, assurance, temporal correlation, geographic compatibility, and transparency.

**Table 5. Summary of main features of The Inventory of Carbon and Energy**

| Feature | Inclusion |
|---|---|
| **Scope** | Cradle-to-Gate |
| **Latest update** | 2019 |
| **Number of datasets** | 400+ |
| **Main emission sources** | Construction |
| **Compliance** | - |
| **Licensing** | Free |

### Relevance

The ICE database contains average or generic embodied carbon factors for many materials and the most recently updated database ICE V3.0 can be used. The database is useful for providing accurate and transparent data and is considered the industry standard for emissions factors for materials used in construction and the built environment. Due to the database being material focused, its use when considering fabricated components and equipment is limited and this presents challenges when accounting for whole-life carbon of differing assets. In addition, when trying to differentiate between materials coming from different suppliers, the ICE database can be limited. Supplier-specific information such as that provided in EPDs is needed for this.

It is also worth noting that the emission factors from the ICE database are often used in external carbon accounting and integrated database tools, however the emission factors provided are not always updated with V3.0 data.

## 4.3 Civil Engineering Standard Method of Measurement Carbon and Price book

The Civil Engineering Standard Method of Measurement, fourth edition (CESMM4) Carbon and Price Book [41] (2013) provides guides in the standard for the preparation of bills of quantities in civil engineering and is developed by the Institute of Civil Engineers (ICE) [42]. Alongside cost, the CESMM4 Carbon and Price Book includes estimates of carbon values for a wide range of civil engineering materials and activities, allowing users to estimate carbon and cost at the same time.

Along with purchase of the book, users are entitled to a 12-month period of access to CapIT, an online estimating tool with comprehensive $CO_2e$ data for civil engineering works. This enables users to build on the cost and carbon estimates in the book along with their own items, carbon values, unit rates and plant or material costs. This data is updated quarterly, and specific regional context can be selected, as well as past and future dates for greater accuracy.

**Table 6. Summary of main features of Civil Engineering Standard Method of Measurement Carbon and Price book**

| Feature | Inclusion |
|---|---|
| **Scope** | Carbon from civil engineering materials and activities |
| **Latest update** | 2013 |
| **Number of datasets** | - |
| **Main emission sources** | Civil engineering |

| Feature | Inclusion |
|---|---|
| Compliance | - |
| Licensing | Purchase required (< £500) |

### Relevance

The CESMM4 carbon and price book is a simple method to collate data on price and emission factors relevant to civil engineering. Data is provided at a unit level, i.e., factors are often provided for the supply and installation of civil engineering structures meaning that it is challenging to separate embodied emissions in materials from the emissions resulting in the construction process. However, the data is now several years old (carbon emission data utilises emission factors sourced from ICE (v2.0) and DEFRA 2012), so in some cases may no longer be relevant to modern materials and practices.

## 4.4 National Grid Carbon Asset Database

The Carbon Asset Database is an excel spreadsheet that provides embodied carbon data values for a range of equipment, materials and activities used in the electricity transmission sector. Upgraded for the T2 period in December 2020, the database contains 534 items, with embodied carbon values provided for each of the product stages: A1 – raw material supply, A2 – transport of raw materials, A3 – manufacturing (see Figure 5 above for more detail on the different lifecycle stages). A small number of items also have carbon data for transportation to site (A4) and for the construction/installation process (A5). Items are categorised by Group, Asset Group, Family, Parent, Class, Supplier and Code. For each item, units (number, m, $m^2$, $m^3$ etc.) and the mass of each unit are provided. A guidance tab provides some background information on the structure of the database and relevant lifecycle stages (Figure 5), but there is very little information describing how the carbon values have been derived, or what source data or tools might have been used to generate them. The spreadsheet-based nature of the database means that it is difficult to include an image or graphic to illustrate its structure or operation.

**Table 7 Summary of main features of National Grid Carbon Asset Database**

| Feature | Inclusion |
|---|---|
| Scope | Embodied carbon (Product stage A1-3). Limited data for transport to site (A4) and construction activities (A5) |
| Latest update | 2020 |
| Number of datasets | 1 |
| Main emission sources | Civil engineering |
| Compliance | PAS2080, in terms of lifecycle stages |
| Licensing | Available to transmission system operators; it is not clear if it is more widely available than this. |

### Relevance

This database is of great relevance to NGED and other DNOs. Although it is oriented towards the electricity transmission sector, the overall database structure would also lend itself to electricity distribution. The main critique of the database is that there is very little transparency around how the data has been generated, but it is possible that this information exists in documentation that was not available during the drafting of this literature review.

## 4.5 ecoinvent Database

The ecoinvent database is a Life Cycle Inventory (LCI) database[43] that supports various types of sustainability assessments. A license is required to use the database. The database contains around 18,000 LCI datasets[44]. The datasets include a range of sectors such as building and construction, chemicals and plastics, energy, forestry and wood, metals, transport, waste treatments and recycling, and water supply, among other industrial sectors.

Emission factors can either be exported or used within the tool to generate assessments. Each activity is attributed to a geographic context, either individual country, region or global, allowing the most relevant to be selected. For global data location context, the activity data represents the average global production process and outcome. Data can be further classified by technology level, time period and special activity type such as ordinary transforming activity, market activity, import activity, or market group. Documentation for all aspects of the dataset is available, and the database itself includes details about the properties of products, access to parameters and mathematical formulas behind datapoints and clarity about their uncertainty. Data quality guidelines[45] are available and describe the methodology behind the modelling of the database and the applied LCA methodology.

**Table 8. Summary of main features of ecoinvent Database**

| Feature | Inclusion |
|---|---|
| **Scope** | Cradle to grave |
| **Latest update** | 2020 |
| **Number of datasets** | 4000+ |
| **Main emission sources** | Energy carriers and technologies; production; systems; end-of-life treatment; transport services; other Services; use and consumption; wastes. |
| **Compliance** | ISO 14040; ISO 14044; ISO/TS 14048 |
| **Licensing** | Licence required – prices vary between 3,500€ (commercial license for a single user) and 9,000€/year (enterprise license for multiple unnamed users) |

### Relevance

ecoinvent databases are used in other software tools such as the carbon calculations over the life cycle of industrial activities (CCaLC). ecoinvent is updated annually, at the end of summer, and most databases integrating the whole ecoinvent database are also updated. The database provides not only emissions factors for a huge variety of materials in different sectors, but it also provides a tool to input emission factors and generate outputs. The ability to increase accuracy with market and geographic scales also increases the accuracy of data where available.

## 4.6 International Panel on Climate Change (IPCC) Emission Factor Database

The IPCC has published a library of emission factors and other parameters with reference background documents and technical references[46], which is free to use. The data sources have been obtained from industry statistics, government publications and other LCA databases and includes cradle to grave data. The data is compliant with the GHG Protocol.

The databases include energy; industrial processes and product use; agriculture, forestry, and other land use; waste; and other. The activity data is split by greenhouse gas (e.g. methane, carbon dioxide, nitrous oxide, etc.). Each activity states any region/regional conditions, the specific technology or practices used, information about the source of data, and the units of activity providing context of the data e.g. tonne $CO_2$/tonne produced, or tonne $CO_2$/tonne used.

**Table 9. Summary of main features of IPCC Emission Factor Database**

| Feature | Inclusion |
|---|---|
| **Scope** | Cradle to grave |
| **Latest update** | 2020 |
| **Number of datasets** | - |
| **Main emission sources** | Energy carriers and technologies. |
| **Compliance** | GHG Protocol |
| **Licensing** | Free |

**Relevance**

Provides data on an international basis.

## 4.7 OpenLCA Nexus database search engine

OpenLCA Nexus is a search engine for emission factors, providing a "mildly harmonised" set of data[47]. It allows users to find appropriate and suitable data, locate a database that contains the correct information, and import datasets into LCA software. The software aims to overcome methodological differences, for example, concerning the modelling of waste, or flow categories.

The database includes data from free and licensed databases. Purchased databases include ecoinvent, Federal LCA commons, Idemat, Carbon Minds, IDEA (Inventory Database for Environmental Analysis), and more. Free databases include IMPACT world+, Product Environmental Footprints, exiobase, NEW Energy Externalities Developments for Sustainability, European Reference Life Cycle Database (ELCD), and more. The website allows searches to be filtered by database, year, geographical location, industrial sector, product, and/or price.

**Relevance**

This search engine is useful for identifying the databases with the relevant materials and coverage needed for a whole-life assessment. This could be useful when choosing an emission factor database or integration of databases. The search engine allows a comparison of databases/LCA method used, the date the emission factor for a material was generated, information on the reliability of the source, and case studies where possible.

## 4.8 Material-specific carbon tools and databases

In addition to the above emission factor databases, there are many separate, individual databases for specific materials. These mainly apply to the built environment sector and include, but are not limited to, the databases listed below:

- **Asphalt Pavement Embodied Carbon Tool (asPECT)**[48]: A downloadable spreadsheet-based calculator guides the user through the methodology of the protocol and makes the necessary calculations using up-to-date emissions factors.
- **European Federation of Corrugated Board Manufacturers (FEFCO)**[49]: Cradle to grave data sets for paper and corrugated board products.
- **International Iron and Steel Institute (IISI)**[50]: A life cycle inventory (LCI) study to quantify resources use, energy and environmental emissions associated with the processing of fourteen steel industry products from extraction of raw materials to the steel factory gate.
- **International Stainless Steel Federation (ISSF)**[51]: A life cycle inventory (LCI) study quantifying resources use, energy and environmental emissions associated with the processing of cold roll and white hot rolled steel.

## 4.9 Summary

Below a summary table is presented to highlight the key emission factor data sets that might be of particular use to NGED and other DNOs based on their activities.

**Table 10 Key emission factor data sets suitable for NGED's activities**

| DNO Activity | Key sources of emissions factors |
|---|---|
| Civil engineering | CESMM4 Carbon and Price Book |
| Raw Materials | Inventory of Carbon and Energy v3.0 |
| Fabricated components | National Grid Carbon Asset Database<br>EPDs (if available)<br>OpenLCA Nexus<br>Inventory of Carbon and Energy v3.0 |
| Transportation of materials | UK Government conversion factors for company reporting |
| Operation | UK Government conversion factors for company reporting |
| Disposal of waste/ End-of-life | UK Government conversion factors for company reporting |

# 5. Existing whole-life carbon reporting tools

There are many whole-life carbon reporting tools in use across the infrastructure and built environment sector in the UK. This section describes a sample of the tools that are available for whole-life carbon assessments, primarily in the UK infrastructure sector, including highways, rail, water, the built environment, and construction. There are other carbon accounting tools developed for specific applications and sectors, and this section cannot hope to provide a comprehensive list of them all.

Carbon accounting can be done using a variety of different tools which usually align with recommended reporting standards, guidelines and frameworks. It is possible to perform carbon accounting without a tool, however the methodology should align with recognised standards, guidelines and frameworks, as discussed in Section 3.

## 5.1 UK Transmission Operator Carbon Product Calculator

The three Great Britain Electricity Transmission Owners: Scottish Power Energy Networks (SPEN), Scottish and Southern Electricity Networks Transmission (SSEN Transmission) and National Grid Electricity Transmission (NGET) have formed a collaborative group called UK ROCCIT (Reduction of Capital Carbon in Infrastructure: Transmission)[52], in order to address and manage the capital carbon emissions associated with developing and maintaining their networks.

To support their aim of developing a consistent approach and common methodology to managing capital carbon emissions and collaboratively working with their common supply chain in a consistent way, UK ROCCIT has developed the UK Transmission Operator Carbon Product Calculator to be used by electrical equipment suppliers. The calculator should provide an easy way for suppliers to quantify the carbon emissions associated with the transmission losses, and the manufacture and supply of electrical equipment used within the UK Transmission Network.

**Table 11. Summary of main features of UK Transmission Operator Carbon Product Calculator**

| Feature | Inclusion |
|---|---|
| **Scope** | • Embodied carbon in materials<br>• Transportation of materials to manufacturing site<br>• Energy used in manufacturing process<br>• Transportation of finished product to site<br>• Operational emissions from leakage of f-gases |
| **Latest update** | 2020/21 |
| **Databases** | ICE V3.0, BEIS carbon factors 2020, IEA 2015 (for international grid carbon intensity) |
| **Main sectors** | Electricity transmission |
| **Compliance** | PAS2080 |
| **Licensing** | Login to Supply Chain Sustainability School required (free) |

### Relevance

The UK Transmission Operator Carbon Product Calculator is aimed at transmission operators, but given the significant similarities between the equipment required in transmission and distribution, the calculator is likely to be of great relevance to NGED and other UK DNOs.

The calculator is designed to be used by the suppliers of electrical equipment, and allows them to input various activity data relating to materials, transport and energy content. Standard emissions factors are used to convert this activity data to generate an overall carbon emission value for each unit of equipment supplied.

There does not appear to be any requirement for suppliers to have their use of the calculator independently verified, but its use could provide unverified carbon data until Environmental Product Declarations can be provided. Where EPDs are available, the calculator does allow for this information to be recorded.

The operational impact of equipment as reported by the calculator includes fugitive emissions of $SF_6$ and other f-gases, and electrical losses from transformers and some switchgear.

A minor critique of the tool is that the calculator provides carbon data per unit of supply; but there is no opportunity to specify the unit of supply, e.g. per length (as may be the case with cables and other conductors), volume, area or any other metric.

## 5.2 Highways England (National Highways) Carbon Tool

National Highways has developed a carbon emissions calculator, the Highways England Carbon Tool, to estimate emissions for operational, construction and maintenance activities undertaken on behalf of National Highways[53]. Suppliers must report on the carbon associated with activities undertaken on behalf of National Highways by downloading and completing the National Highways carbon tool on a quarterly basis, with an option of submitting monthly. National Highways have collated data on carbon emissions from their supply chain construction and maintenance contractors since 2008-09 to establish a specific database of carbon emissions undertaken on the road network.

**Table 12. Summary of main features of Highways England Carbon Tool**

| Feature | Inclusion |
|---|---|
| **Scope** | Operational, construction and maintenance activities |
| **Latest update** | 2019 |
| **Databases** | ICE V3.0, BEIS carbon factors 2020 |
| **Main sectors** | Highways, transport |
| **Compliance** | - |
| **Licensing** | Free |

### Relevance

While the Highways England Carbon tool is specific to the highways sector, the tool and methodology both provide a useful framework. The specificity to the sector allows for accurate accounting. For example, the material specificity (e.g., recycled content, end use, etc.) and material categories allow a simple and accurate calculation. The tool is up to date with ICE V3.0.

The highways sector does not have a lot of overlap with the distribution of electricity. Emissions associated with highways projects are predominately from consumption of fuel and bulk materials in construction, for which there is reliable emissions data available for assessments. NGED and other DNOs have a large amount of GHG emissions associated with highly technical equipment for which reliable emissions data is not readily available and is not captured or covered in the Highways England tool. This could lead to gaps in whole-life carbon assessments and result in assumptions and omissions being made and increasing uncertainty within the carbon accounting process.

## 5.3 Rail Safety and Standards Board (RSSB) Carbon Tool

The Rail Carbon Tool has been developed to assist the UK rail industry with carbon footprinting, and therefore it is available for all organisations in the rail industry[54]. The tool is a web-based calculator and carbon reduction tool provided by RSSB for UK rail industry organisations and companies to enable them to:

- Calculate and analyse the carbon footprints of UK rail projects and activities;
- Identify and assess alternative low carbon options;
- Select low carbon solutions;
- Monitor performance and compare design with as-built.

RSSB offers Rail Carbon Tool Training in the form of tutorial videos, user guides, a Practitioner's introduction document, and demonstrations.

The tool has many features that allow detailed carbon assessments. There is a library of carbon factors and a library of templates. The tool allows users to import previously established templates from items that have already been calculated. Materials in the carbon library have many carbon factor values and multiple calculation formulas which allows specific engineering data to be used to increase specificity. Each user also has a project

library, allowing for easy storage and sorting of projects for carbon calculation. Within here, a project can be copied. The copy can be sent to other users, as well as allowing use as a template for further carbon calculations. There is also a 'sandbox' allowing for offline carbon calculations. Users can add notes and upload documents associated to materials e.g., dataset, image or drawing. This is a useful feature as it allows users to pinpoint where information is from, how recent/relevant the data used is. Further details can be added such as costs of materials, specific construction plant, asset owner etc.

**Table 13. Summary of main features of RSSB Carbon Tool**

| Feature | Inclusion |
|---|---|
| **Scope** | Cradle-to-completed construction, use optional |
| **Latest update** | - |
| **Databases** | Various |
| **Main sectors** | Rail, transport |
| **Compliance** | - |
| **Licensing** | Free |

### Relevance

Although not highly relevant for NGED or the other DNOs, the RSSB tool demonstrates a method of adding a considerable level of detail and specificity to assessments. Similar to electricity distribution, the rail sector has a large amount of highly specific systems, equipment and materials which must be accounted for. In addition, the tool is able to be applied for a wide range of projects and assets within the sectors realm. For example, the RSSB Carbon tool encompasses a wide range of railway works from station refurbishments, platform extensions, new footbridges, etc., all of which have a varying range of emissions associated.

While the RSSB carbon tool allows good estimates for carbon associated with projects in the rail sector, there are still some data gaps. Carbon factors are not available for all materials and some materials have not been updated with ICE 3.0 emission factors. In addition, the tool can be difficult to navigate due to high level of detail required.

## 5.4 UK Water Industry Research Carbon Accounting Workbook (CAW)

UK Water Industry Research (UKWIR) has developed a carbon accounting tool for use by individual water companies in the UK[55]. The Carbon Accounting Workbook (CAW) allows users to estimate operational GHG emissions. The CAW is updated annually and costs £200 to purchase. The latest version of the workbook is V15, released in 2021 and new amendments include alignment with the ISO14064 standards.

The tool addresses emissions from UK water and sewage operations, under the following 'activity areas':

- Drinking water treatment and pumping;
- Sewage treatment and pumping;
- Sludge treatment and disposal;
- Administrative activities; and
- Transport.

Along with the annual workbook, UKWIR publishes a user guide and methodology report relating to the CAW.

**Table 14. Summary of main features of CAW**

| Feature | Inclusion |
|---|---|
| **Scope** | Operational |
| **Latest update** | 2021 |
| **Databases** | Unknown |
| **Main sectors** | Water |
| **Compliance** | ISO14064 |
| **Licensing** | Licence required (< £500) |

### Relevance

While the emissions and associated activities of the water industry are not highly relevant to NGED and wider DNOs, this tool includes accounting for administrative activities as well as treatment and distribution. Despite needing a licence to use this tool, purchasing the rights to use this tool is cheap and provides up-to-date emissions data. However, the CAW only accounts for operational GHG emissions; the construction, capital maintenance and decommissioning of assets are not included. For new assets and capital investments, an alternative strategy would have to be used for whole-life carbon assessments of the projects.

## 5.5 EcoTransIT World

EcoTransIT World is a widely used software worldwide for automatic calculations of energy consumption, carbon emissions, air pollutants, and external costs[56]. The tool allows calculation of global transport chains across all modes of transport (truck, ocean going vessel, airplane, train, inland waterway), including transhipments/warehousing. The tool is complaint with current standards for Global Logistics Emissions Council (GLEC) Framework and EN 16258, as well as the GHG Protocol (Corporate Standard), and preparations for ISO 14083 compliance are currently under development.

EcoTransIT World determines the emissions using an energy-based bottom-up approach. That means the emissions are determined on the basis of the energy consumed and the fuel used, rather than the usual top-down approach, in which $gCO_2e$ / tkm are multiplied by the freight weight and a distance. The tool takes into account differences such as the type of road, vehicle class and corresponding properties, allowing for future adjustments based on technological advancement.

The results of the calculations give emissions, and external costs data and allow split by country, mode of transport or fuel type.

**Table 15. Summary of main features of EcoTransIT World**

| Feature | Inclusion |
|---|---|
| **Scope** | Global transport chains |
| **Latest update** | 2021 |
| **Databases** | - |
| **Main sectors** | Transport |
| **Compliance** | EN 16258, GLEC, ISO14083, GHG Protocol. |
| **Licensing** | Free |

### Relevance

This tool is regularly updated and uses sector-specific data rather than generic or default data where possible. The granularity of the tool is high, using specific factors for many elements which could also be useful when considering electricity distribution, such as using specific emission factors for assets such as switchgear and transformers.

The split of calculations by country is a useful feature, however, NGED only operates within parts of England and Wales, so only UK carbon factors would be relevant. Nevertheless, the global transport chains would be useful to estimate emissions associated with the sourcing of overseas equipment. As this tool only covers transport, its use would mean that calculations for transport would need to be isolated/removed from the carbon assessment in other tools and approaches likely leading to manual data transfer between systems for project wide assessment.

## 5.6 Embodied Carbon in Construction Calculator (EC3) Tool

The EC3 tool is a free-to-use, US-based tool allowing benchmarking, assessment, and carbon reductions in embodied carbon used within the built environment[57]. The tool is focused on the upfront supply chain emissions of construction materials. Each material has a unique lifecycle assessment performance and Environmental Product Declarations (EPDs – see section 3.5 above). The EC3 tool is regularly updated, and users can upgrade to a purchased licence to gain access to an increased number of features.

The tool uses data from inputs of almost 50 industry partners, building material quantities from construction estimates, BIM models and a robust database of digital, third-party verified EPDs. This allows owners, green building certification programs and policymakers to assess supply chain data to create EPD requirements, and set embodied carbon limits and reductions, at both the construction material and project scale.

Key features of the tool include the ability to plan and compare building features, find and compare materials, and declaration of products via a digitized EPD platform. The tool gives outputs showing projects' potential and realised embodied carbon emissions, the ability to see limits and targets, and allows sorting of material supply chains EPD and embodied carbon data, whereby material category baselines and reduction targets can be set.

**Table 16. Summary of main features of EC3 Tool**

| Feature | Inclusion |
|---|---|
| **Scope** | Embodied carbon |
| **Latest update** | 2021 |
| **Databases** | EPD Data |
| **Main sectors** | Construction |
| **Compliance** | Unknown |
| **Licensing** | Free |

### Relevance

The tool allows for specific materials to be searched for and compared. Filters can be applied to increase specificity and an average emission factor of all available materials in the search category is given.

This tool has the valuable quality of requiring suppliers to upload carbon data in the form of EPDs. The use of EPDs as the source of data for emissions factors also incentivises companies to actively engage with the tool, as the company's product will then be visible to potential customers of materials.

Although focused on materials in the construction sector, the use of EPDs is relevant to NGED. Specific equipment and products used by DNOs may have EPDs available which can be used during whole-life carbon accounting. However, one of the downfalls of this tool lies within the fact that it is required that the supply chain gets involved and submits the EPDs to the platform; if this engagement from the supply chain is non-existing, the tool loses its relevance.

## 5.7 The Energy Performance and Carbon Emissions Assessment and Monitoring (ECAM) tool

The Water and Waste Companies for Climate Mitigation has developed a tool to assess and monitor energy performance and carbon emissions[58]. The tool is web-based, based on IPCC Guidelines for National Greenhouse Gas Inventories and is free to use. The tool uses a tiered approach (tier A and B: an initial assessment and detailed assessment, respectively). The ECAM tool can be used to estimate the greenhouse

gas emissions associated with water and wastewater utilities at a system-wide level and identify potentials and opportunities to reduce greenhouse gas emissions, decrease energy consumption and save operational costs.

**Table 17. Summary of main features of ECAM tool**

| Feature | Inclusion |
|---|---|
| **Scope** | Operational |
| **Latest update** | 2021 |
| **Databases** | Unknown |
| **Main sectors** | Water and wastewater |
| **Compliance** | Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories |
| **Licensing** | Free |

### Relevance

The ECAM tool includes some aspects relevant to distribution such as the residential population that the water utility area will service, which is an aspect that could be relevant to NGED for electricity distribution. While the tool is applicable globally, it is only currently implemented in a few countries (Mexico, Jordan, and Peru), and therefore is not highly relevant for NGED.

## 5.8 SmartWaste

SmartWaste[59] is a licensed sustainability and environmental monitoring and reporting tool, developed by BRE. Predominately the tool is designed for the construction sector, to allow contractors to report into a single database and allow tracking across various construction projects.

Originally developed as a waste management tool, but having evolved in line with demand over recent years, it currently has modules for: waste, water, energy transport, materials, biodiversity, reporting, social value, other site impacts, integration and pre-demolition audits.

The materials module tracks embodied carbon for a variety of civil materials. However, the source of emissions factor for this is unclear. Carbon emissions can also be calculated for fuel, transport, water and waste, utilising the latest BEIS carbon conversion factors.

**Table 18. Summary of main features of SmartWaste tool**

| Feature | Inclusion |
|---|---|
| **Scope** | Cradle-to-grave |
| **Latest update** | Version 10, 2021 |
| **Databases** | BEIS Carbon Conversion Factors |
| **Main sectors** | Construction |
| **Compliance** | - |
| **Licensing** | Licensed by BRE |

### Relevance

The SmartWaste tool includes some aspects relevant to distribution for as-built emissions, such as, construction fuel use, transportation, water and waste.

NGED and other DNOs have a large amount of GHG emissions associated with highly technical equipment for which reliable emissions data is not readily available and is not captured or covered in the SmartWaste tool. This could lead to gaps in whole-life carbon assessments and result in assumptions and omissions being made

and increasing uncertainty within the carbon accounting process. SmartWaste also doesn't allow for the capture of operational emissions which would mean NGED needed to capture and report this information separately.

## 5.9 The UK Biomass and Biogas Carbon Calculator (B2C2)

The B2C2 tool allows users to estimate the emissions associated with using different solid and gaseous biomass feedstocks for heat and power[60]. The tool includes GHG emissions default values for a wide range of biomass feedstocks used in the UK for electricity, heat and biogas generation. The calculation method reflects the GHG emissions calculations and savings guidance provided in the EU Renewable Energy Directive and the European Commission's report on sustainability requirements for the use of solid and gaseous biomass sources in electricity, heating and cooling.

The feedstocks for which default carbon intensities have been developed, include different types of cakes and meals (such as wheat DDGS, olive cake and oilseed rape meal), dedicated energy crops, and a series of wastes, all highly specific to the use of biomass for energy production. The tool allows users to build a fuel chain from 'modules' specific to the fuel. Not all modules can be connected to each other and reducing the likelihood of certain simple errors when building new fuel chains. In addition, there are compulsory linkages, for example, if data is input for 'crop yield', the user must also input data for 'nitrogen fertilizer application rate'.

**Table 19. Summary of main features of B2C2**

| Feature | Inclusion |
|---|---|
| Scope | Fuel chain |
| Latest update | 2015 |
| Databases | Unknown |
| Main sectors | Biomass and Biogas |
| Compliance | Renewables Obligation scheme (RO), and the Non-Domestic Renewable Heat Incentive scheme |
| Licensing | Free |

### Relevance

While the calculation of carbon associated with biomass energy production is within the energy and distribution sector, there are many disparities. Biomass energies must account for biogenic carbon sequestration and loss of carbon sink, unlike other energy sources. NGED's emissions scope is focused on the distribution of electricity, rather than generation. Nevertheless, the complexities and differences of electricity sources should be noted, as highlighted by this tool.

The tool was last updated in 2015 and therefore emission factors and data may not provide accurate estimates for current energy production. The tool is based on the fuel chain itself and does not include parameters over the whole supply chain or industry. The tool relies on the use of default emission factors (although it is possible to input actual data where possible) which reduces the accuracy of the calculator.

## 5.10 Carbon Calculations over the Life Cycle of Industrial Activities (CCaLC)

The Carbon Calculations over the Life Cycle of Industrial Activities (CCaLC) database comprises of data from CCaLC, International Reference Life Cycle Data System (ILCD) and ecoinvent databases[61]. No license is required to use CCaLC. The software allows multiple environmental assessments including carbon footprinting, water footprinting, other environmental impacts, economic impacts and optimisation. The tools follow the internationally compliant whole-life cycle methodology as defined by ISO 14044 and PAS2050.

Whole systems approach is to develop a life cycle methodology for integrated environmental and economic analysis of carbon intensity of different industrial systems. This involves both environmental and economic aspects of carbon footprints and embodied carbon, enabling estimation of 'carbon added' and 'valued added' at each stage of the supply chain.

**Table 20. Summary of main features of CCaLC**

| Feature | Inclusion |
|---|---|
| **Scope** | Cradle to gate |
| **Latest update** | 2016 |
| **Databases** | Various: CcaLC, Life Cycle Data System (ILCD) and ecoinvent databases. |
| **Main sectors** | Industrial activities |
| **Compliance** | ISO 14044 and PAS2050 |
| **Licensing** | Free |

### Relevance

Used for industrial activities including in the energy sector such as biofuels and bio-feedstocks. Although the tool has not been updated since 2016, the inclusion of environmental and economic aspects of the tool is a valuable asset and can be used for a wide variety of industrial sectors. The tool includes requirements to specify the data quality for the information of the data set and the data quality for the amount being used in the analysis. Data quality within the tool is always expressed as either high, medium or low quality and measured is based on the data quality standards indicated in ISO14040/44.

Although not very relevant to NGED, the use of tools in the industrial sector highlights how tools and inputs can be adapted to increase relevance. Also, the CCaLC tool is complaint with PAS2050, a product focused standard rather than the PAS2080 which is focused on infrastructure.

## 5.11 Moata Carbon Portal

The Moata Carbon Portal is a solution for calculating and reducing embodied carbon in new assets[62]. Developed by Mott Macdonald, it enables designers and engineers to quickly identify carbon hotspots in a project, facilitating low carbon design.

The tool is built on various carbon databases within the infrastructure industry, it offers direct integration with BIM software and Bill of Quantities (BoQ), enabling the carbon impact of designs to be integrated within existing processes and visualised as changes are made. The tool has the ability to offer access to individuals, teams, or company-wide, the Moata Carbon Portal enables collaboration and knowledge sharing.

**Table 21. Summary of main features of Moata Carbon Portal**

| Feature | Inclusion |
|---|---|
| **Scope** | Cradle to grave |
| **Latest update** | 2021 |
| **Databases** | Various: 15 libraries including ICE v2.0 and ICE V3.0. |
| **Main sectors** | The built environment and infrastructure |
| **Compliance** | PAS 2080 |
| **Licensing** | Available to Mott Macdonald clients |

### Relevance

This tool integrates data from multiple libraries and, being complaint with PAS2080, would be applicable to NGED's whole-life carbon accounting methodology. The tool can be used for a variety of project types and project stages which, when considering the variety in NGED's capital investments and projects, is a valuable tool. Although the tool can be used for a variety of projects in the built environment, the range can limit specificity and relevance when considering highly complex and detail-specific assets such as those within NGED's portfolio.

## 5.12 Carbon Intensity API (Application Programming Interface)

National Grid Electricity System Operator's (ESO) Carbon Intensity API provides an indicative trend of regional carbon intensity of the electricity system across Great Britain[63]. The spatial and temporal characteristics of carbon intensity can be observed across 14 regions, the boundaries of which are defined according to DNO boundaries.

The forecast is split by fuel type and projects several days ahead. The forecasts are updated every 30 minutes to adjust the forecasts for a short period ahead. The approach considers the carbon intensity of electricity consumed in each region and uses carbon intensity factors of GB fuel types. The carbon intensity factors used are based on the output-weighted average efficiency of generation in Great Britain and Digest of UK Energy Statistics (DUKES) $CO_2$ emission factors for fuels.

Estimating the carbon intensity of the electricity consumed in each region is modelled using the power flows between importing/exporting regions and the carbon intensity of those power flows. The estimated regional carbon intensity of generation uses metered data for each fuel type. The carbon intensity factors for each fuel type and interconnector are based on GridCarbonUK[64] and Staffell (2017)[65].

The Regional Carbon Intensity forecasts include $CO_2$ emissions related to electricity generation only. The forecasts include $CO_2$ emissions from all large, metered power stations, interconnector imports, transmission and distribution losses, as well as accounting for regional electricity demand, and both regional embedded wind and solar generation.

### Relevance

Carbon Intensity API is not a whole-life carbon tool, rather it is an estimator for carbon intensity. However, due to division of the boundaries according to DNOs the map forecasts the carbon intensity for NGEDs distribution area for the South West, South Wales, and the East and West Midlands.

The carbon intensity for fuel types and the methodology used to calculate the estimates is specific to the energy sector and distribution and therefore provides some context to NGED. Although, the site does not assess whole-life carbon, estimations are made using proxies based on energy source and accounts for regional differences in energy sources.

## 5.13 Additional carbon reporting tools for the built environment

In addition to the carbon accounting tools and systems noted above, there are numerous tools available for use in the built environment and construction sector. Common industry tools are included in, but are not limited to, the list below:

- **Oneclick LCA**[66]: Allows users to calculate and reduce the environmental impacts of buildings and infrastructure projects, products and portfolio. This tool requires a licence. It includes a database of global generic data or manufacturer specific, third-party verified EPDs. The tool is certified for use by BREEAM, CEEQUAL, LEED, HQE and more and is compliant with EN & ISO standards.
- **Build Carbon Neutral Tool**[67]: A simple and free tool which can be used to estimate the embodied carbon of a construction project and carbon amounts released during the process of construction. Initially the tool was produced for projects in the United States, but it can be used as an estimation for other regions.
- **eToolLCD**[68]: Global LCA software for buildings and infrastructure. The tool is free to use for basic calculations and a subscription can be purchased for more features. The tool is complaint with EN 15978 and ISO 14044.
- **DuboCalc**[69]: This tool requires a licence; however, it enables calculating and comparing the sustainability and environmental costs of procurement. DuboCalc calculates all effects of material and energy from cradle to grave, or from extraction to the demolition and recycling phase. Monetary outputs are in euros, the Environmental Cost Indicator (MKI). The method is based on ISO 14040 standard and Environmental Assessment Method Buildings and Construction.

## 5.14 Building Information Modelling (BIM)

Whilst BIM is not in it's nature a whole-life carbon reporting tool, it is included in this section due to its significant potential to be used as a tool to manage and report carbon in infrastructure projects.

BIM is a 3D modelling process that allows for creation and management of information on a construction project throughout its whole-life cycle, from design through to construction, operation and maintenance to demolition. As part of this process, a coordinated digital description of every aspect of the built asset is developed[70]. The main advantage of BIM is that it makes it possible to coordinate data from the different trades working on the same building, enabling collaboration between different teams and early-stage problem solving.[71] There currently are multiple software tools available for BIM (e.g., Autodesk Revit, Autodesk BIM 360).

Even though typically BIM models do not include carbon data, BIM is starting to be used for carbon management. This will allow for buildings to have environmental considerations integrated from the start of the project, which make the environmental and lifecycle comparison of different material and product specifications vastly easier than a manual calculation[72]. It is believed that BIM will have significant role in the construction industry, meeting the 50% reduction in GHG emissions in the built environment target as set out in the UK's construction strategy[73].

Engie Solutions has started to include the amount of carbon of a particular "BIM object" through the ValoBIM© tool, to optimise the potential for reuse of existing building components and to enrich circular economy ecosystems[72]. They have not only used this technology during the design phase, where they were able to precisely determine carbon savings associated with their choice of building materials, but they have also used it during the demolition phase, where the information from the BIM software assisted them in deciding the more appropriate end-of-life treatment for each object/resource[72].

## 5.15 Summary

Below a summary table is presented to highlight the relevance of each tool against the development of the whole-life carbon management process.

**Table 22. Key elements of each of the existing operational, product and whole-life carbon tools**

| Existing whole-life carbon tool | Key elements |
|---|---|
| UK Transmission Operator Carbon Product Calculator | Allows input of various activity data relating to materials, transport, and energy content, and estimates operational impact (fugitive emissions and electrical losses) |
| Highways England Carbon Tool | The material specificity (e.g., recycled content, end use, etc.) and material categories allow a simple and accurate calculation |
| CAW | Includes accounting for administrative activities as well as treatment and distribution |
| RSSB Carbon Tool | Demonstrates a method of adding a considerable level of detail and specificity to assessments |
| EcoTransIT World | The granularity of this tool is high, and the calculations are split by country, which could be an asset when estimating emissions from the global transport chains |
| EC3 Tool | Allows for specific materials to be searched for and compared |
| ECAM Tool | Includes aspects relevant to distribution such as the residential population that the water utility area will service |
| SmartWaste | Allows for capture of as-built emissions through construction |
| B2C2 | Highlights the complexities and differences of electricity sources |
| CCaLC | The inclusion of environmental and economic aspects of the tool is a valuable asset and can be used for a wide variety of industrial sectors |
| Moata Carbon Portal | Integrates data from multiple libraries and is complaint with PAS2080 |
| Carbon Intensity API | The carbon intensity for fuel types and the calculation methodology used is specific to the energy sector and distribution |
| BIM | Allows for coordination of carbon data with other development data from different trades working on the same building, which enables easy identification of potential carbon reductions |

# 6. Conclusion

The main aim of this literature review was to summarise the current and available information, guidance and legislation surrounding carbon accounting in infrastructure, and therefore inform what should be taken into consideration when developing a whole-life carbon management tool for NGED.

The requirement for carbon management in infrastructure is directly associated with the UK's net zero carbon target by 2050, introduced by the Climate Change Act in 2019. This Act also introduced the carbon targets which determine the decline in the amount of GHG emissions the UK can legally emit in the future (see Table 1); meaning that any source of emissions contributing to the UK's carbon inventory are going to have a more significant impact on the UK carbon budgets in the future. Therefore, it is important that NGED monitors and reduces its carbon footprint. NGED's Environmental Action Plan already recognises this and has set a bold target of achieving net zero carbon emissions by 2028, ahead of the UK's 2050 target. This is not only aligned with the UK policy, but also with Ofgem viewpoint which recognises that energy networks will sit at the heart of the race to cut harmful carbon emissions from power, heat and transport by 2050, highlighting that local electricity networks run by DNOs will play a central role in greening the system.

A holistic approach with carbon management integrated into the decision-making process across all stages of projects, as highlighted by PAS2080, will be key to developing a robust whole-life carbon management tool. Furthermore, it will be vital that the tool is developed with a verifiable accounting methodology, following the GHG protocol core principles (relevance, completeness, consistency, transparency, and accuracy), in order for the estimations to be recognised externally. Thus, it is important for NGED to consider whole-life carbon throughout all aspects of the capital investment programme, networks, and assets. This presents an opportunity to develop a tool that assesses a range of elements highly specific to electricity distribution, where barriers and challenges limit the use of alternative tools for the sector.

Multiple emission factor data sets were summarised to inform the development of the whole-life carbon management tool, by providing an understanding of what data is currently available. As detailed throughout Section 4, the range of available data sets bring different advantages to NGED and therefore a combination of them should be considered when developing NGED's carbon management tool. Nevertheless, it is important to note that when considering NGED's requirements and the relevant carbon data and emission factors relating to operating and maintaining electrical distribution networks, there are key elements that are required for data. The emission factors need to be sourced from reliable and accurate sources, where they should preferably be geographically accurate, conform to the relevant standards of accuracy and transparency and embodied carbon calculation methodologies. They should also be updated on a regular basis to reflect any changes in processes, sourcing, etc. and the data should be comparable across industries, as well as across the different DNOs.

The gaps and shortcomings of a range of tools and their relevance to NGED are highlighted in Section 5. Each tool has a different methodology and format and is generally specific to different sectors. Furthermore, they are compliant with different standards, use different databases and have varying levels of data quality standards and availability of metadata. For NGED it is important that the whole-life carbon of the variety of networks and assets can be assessed. These include elements and projects of varying sizes and complexities across the capital investment programme with a range of associated emissions throughout. The importance of reliable and available data, accuracy and specificity, and user experience of the tool are all important factors. Inclusion of carbon in the decision-making process throughout design, procurement, commissioning, construction and operations is needed for accurate whole-life carbon assessments, as this reduces risk of missing data, inaccurate data and increases specificity.

The sections above also raise the challenges that the electricity distribution sector will face. For example, the use of specialist high tech equipment in the DNO sector presents a challenge, as this relies on industry emission factor availability and results in the sector being vulnerable to data gaps. This level of specificity for the DNO sector is not reflected in any of the individual tools or databases reviewed; although many have useful datasets that can be used for certain elements as well as features that may well be of interest to NGED and could be reflected in the design of a DNO focused tool.

NGED requires a tool that can be adapted for use across a variety of project types, sizes, levels of complexity and purpose, assessing emissions associated with construction, maintenance, and operation. By using a carbon accounting tool to assess whole-life carbon of assets, NGED will fulfil its requirements and be able to identify carbon hotspots at the project level aim, to decarbonise accordingly.

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