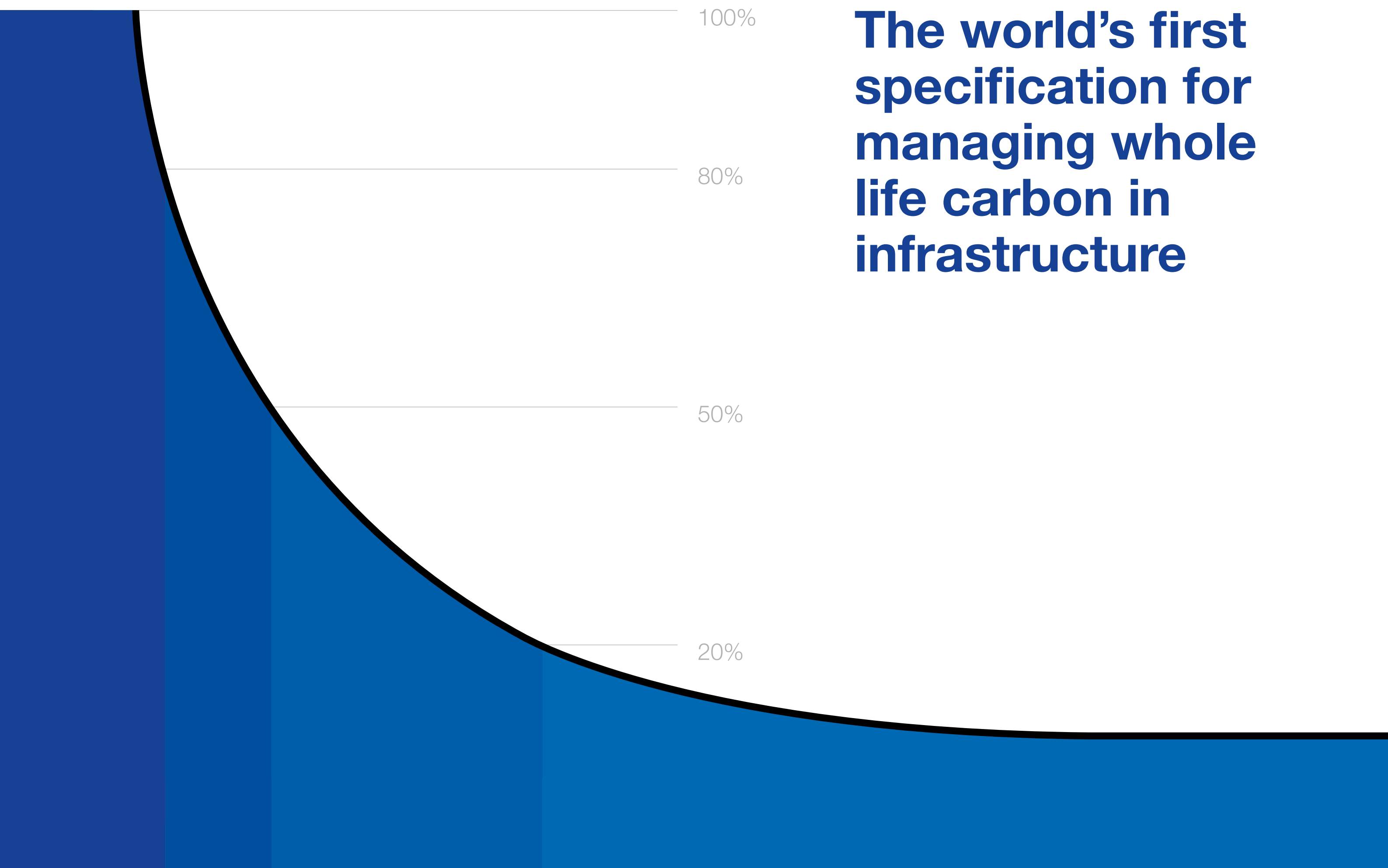
Guidance Document for PAS 2080

Construction Leadership Council

The Green Construction Board



The world's first specification for managing whole life carbon in infrastructure

Foreword

"PAS 2080 has the power to transform the benefits that the UK gains from its infrastructure assets. If all parties involved across the value chain work collaboratively and towards a common goal to reduce carbon, the following outcomes can be achieved:

- A reduction in the costs of delivering and maintaining our infrastructure – driving more efficient ways of working and helping us to have an even greater impact on society and the communities that we serve.
- Effective carbon management – an important contribution to tackling climate change and leaving a positive legacy for future generations.
- Delivering more sustainable solutions at lower cost – enhancing the reputation of the industry, generating pride for those who work in it and attracting new people and skills to strengthen our capabilities.
- A platform for innovation to thrive – leading to more vibrant and rewarding workplaces.

The Infrastructure Carbon Review recognized the opportunity. PAS 2080 helps us all turn this into reality."

Thomas Faulkner, Executive Vice President,
Skanska UK, Green Construction Board and Infrastructure Working Group

The UK's Green Construction Board (GCB) and Department for Business, Innovation and Skills (BIS) formed a team from Mott MacDonald and Arup to write a new Publicly Available Specification (PAS) to show how carbon in infrastructure can be managed more rationally and strategically.

This Guidance Document has been developed by the same technical authorship team as for PAS 2080, namely Maria Manidaki, Priyesh Depala and Terry Ellis from Mott MacDonald, and Kristian Steele and Daniel Roe from Arup. Peer review support was provided by The Carbon Trust.

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Introduction

PAS 2080 shows a more systematic way for managing whole life carbon in infrastructure delivery. By joining up the value chain, a new culture of challenge and innovation is encouraged to help drive down carbon and cost. Making use of this Guidance Document for PAS 2080 will accelerate the understanding and use of the PAS.

“The industry has been calling for a clear and consistent approach to delivering low carbon infrastructure for the 21st century. PAS 2080 provides just that – using a structured carbon management process which encourages full participation from all members of the value chain across the different work stages. It is now up to us all to use it to make a quantum leap forward in carbon reduction.”

Adrian Johnson, Technical Director, MWH and Green Construction Board, Infrastructure Working Group

This PAS includes requirements for all leaders and practitioner-level individuals in all value chain members (asset owners/managers, designers, constructors and product/material suppliers), to show the right leadership and to establish effective governance systems for reducing whole life carbon through the use of a carbon management process.

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

- Setting appropriate carbon reduction targets;
- 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.

In adopting PAS 2080, a more integrated value chain will form, communicating in a common language and working in a culture of genuine collaboration and innovation.

Value chain members will be comfortable proactively challenging the status quo – resulting in reduced carbon, reduced costs and increased value.

For more information on PAS 2080 please refer to **www.bsigroup.com**

The benefits of PAS 2080

Defining good carbon management
The PAS will provide clarity to value chain organizations on what constitutes good carbon management and the key enablers to drive whole life carbon reduction. Businesses that can demonstrate they are 'PAS 2080: Asset Owners/Managers' will have a good carbon management framework in their organization which fosters innovation, carbon and cost reduction.

Providing consistency
The PAS will ensure carbon is consistently and transparently quantified at key points in infrastructure delivery, enabling carbon data to be shared transparently along the value chain.

Increasing competitiveness in the UK
Businesses that can demonstrate they are 'PAS 2080: Designers', 'PAS 2080:Constructors' and 'PAS 2080: Product/Material suppliers' – and hence able to deliver low carbon infrastructure – will gain more work, while international clients who want to succeed in the UK infrastructure sector, will favour companies with a proven ability to cut cost by cutting carbon.

Competitive Advantage
Experience of the carbon management principles and components of PAS 2080 – with its positive message of improved carbon management and cost reduction – will be viewed favourably when bidding for work overseas, especially in economies aiming to meet their international carbon reduction commitments, but unsure of the best approach.

Towards a common understanding and approach

The requirements of PAS 2080 will help establish a common understanding and approach for managing whole life carbon among infrastructure sectors (defined as water, energy, transport, communications and waste) and value chain members.

This Guidance Document has been developed to support practitioners with practical guidance to support the implementation of the PAS through selected examples and case studies and insight on the underpinning components of the PAS 2080 carbon management process.

In this Guidance Document the word 'carbon' is used as shorthand for all greenhouse gas (GHG) emissions in the same way that it is used within PAS 2080.

Role of this Guidance Document
Table 1 below clarifies the roles of this Guidance Document, highlighting how it should be used to support the effective use of PAS 2080.

Document element	PAS 2080	Guidance
Specification for infrastructure carbon management	✓	×
Specification of value chain member responsibilities for carbon management in infrastructure delivery	✓	×
Practical guidance on implementing a carbon management process by asset owners/managers and other value chain members when delivering assets and programmes of work	×	✓
Case studies and worked examples of carbon management process components.	×	✓

Table 1: Content covered by PAS 2080 and Guidance Document

References to PAS 2080
Where specific guidance is given, relevant clauses in PAS 2080 are referred to within the text. The style for this is as follows where the guidance references **Clause 6.1.1** of PAS 2080, as an example: All value chain members shall implement an organizational carbon management process to help them meet their requirements when delivering assets and/or programmes of work (**Clause 6.1.1**).

1. Target Setting
2. Baselines
3. Quantification
4. Continual Improvement
5. Reporting
6. Monitoring

Responsibilities of value chain members for implementing PAS 2080

“PAS 2080 will liberate dedicated professionals throughout the supply chain to do the right thing – together.”

Tim Chapman, Leader – Infrastructure London Group, Arup and member of Green Construction Board

Infrastructure is delivered, operated and maintained by a wide range of value chain member organizations. PAS 2080 is targeted at practitioner-level individuals in these organizations who are responsible for different aspects of infrastructure delivery and carbon management.

The value chain members for whom PAS 2080 is relevant to include:

- Asset owners and managers;
- Designers;
- Constructors; and
- Product/Material suppliers.

It is acknowledged that more than one value chain member may reside within a single organization. For example, the asset owner/manager or constructor may also undertake some of the design work. It is therefore important to see the value chain as a set of roles to be fulfilled rather than specific organizations.

Engagement profile of the value chain members and their practitioners

The guidance shows where the key points of involvement for the value chain members will be. This includes which practitioner role in each value chain member is involved during infrastructure delivery – delineated by the work stages for infrastructure delivery (**PAS 2080 – Figure 4**).

As required in the PAS, value chain members also need to implement the components of the Carbon Management Process in their organizations (**Clause 6.1.1**). Doing so will help them build relevant capability for delivering low carbon assets and programmes of work under the Carbon Management Process of the asset owner/manager (as detailed in Section 2 of this document).

Key roles and responsibilities for the successful implementation of PAS 2080

Every member of the value chain is responsible for contributing to the successful implementation of a PAS 2080 compliant Carbon Management Process. The responsibilities of individual practitioners are identified in *Table 2*. Note: roles may vary depending on different value chains and organizational structures.

Practitioner	Responsibilities
Everyone	Understand the carbon management objectives of the organization are and how these affect their role.
	Take ownership of carbon management within their team to transfer organizational policy to day-to-day working practice.
	Engage with those in similar roles in value chain organizations to help share best practice and streamline processes.
	Engage with other internal practitioners to ensure alignment between working practices in terms of carbon management.

Table 2: Practitioner responsibilities

Asset Owner/Manager

Practitioner	Responsibilities
Leadership Team	Setting the overall carbon management direction including targets and governance systems.
	Ensuring staff have adequate carbon management skills through training or recruitment.
Strategy Planner	Ensure strategic plans for new and existing assets incorporate clear carbon objectives and targets.
Procurement Manager	Procure products/materials/services using the criteria agreed to achieve the organization's carbon objectives.
	Involvement from the strategy stage through to operation/end of life depends on the procurement strategy of the organization, e.g. whether procurement of construction materials is responsibility of constructors.
Infrastructure delivery manager	Engage across the value chain to ensure that technologies and solutions proposed and implemented are in line with carbon targets.
Operator/Operations Manager	Ensure assets are operated to achieve carbon targets.
	Ensure asset maintenance and replacement strategies incorporate carbon objectives.
	Managing carbon throughout the life of an asset.

Designers

Practitioner	Responsibilities
Leadership Team	Understand the carbon objectives of asset owner/managers and ensure own organizational targets are aligned.
	Promoting a carbon reduction culture through the organization, ensuring carbon management principles are fully integrated into existing design systems.
	Ensure technical teams have the appropriate training and skills to facilitate the development of low carbon solutions.
Designer/Technical Advisor	Assess low carbon solutions (strategically, in outline and in detailed design) using appropriate tools and understanding the impacts of specific design decisions around materials and process suggested.
Designer/Technical Advisor	Support the asset owner/manager's carbon management approach during strategy, brief, concept, definition and design.

Constructors

Practitioner	Responsibilities
Leadership Team	Understand the carbon objectives of asset owner/managers and ensure own organizational targets are aligned.
	Promote a carbon reduction culture through the organization, instigate appropriate training and implement best practice approaches to realise low carbon objectives.
	Ensure carbon management principles are integrated into delivery systems.
Procurement Manager	Ensure that low carbon selection criteria are aligned with those of the asset owner/manager, and are embedded in procurement processes and are communicated clearly to suppliers.
Construction Manager	Employ low carbon construction techniques/products/materials, challenge design decisions, as required, to deliver low carbon outcomes.
	Quantify, monitor and report emissions during construction.

Suppliers

Practitioner	Responsibilities
Leadership Team	Understand the carbon objectives of asset owner/managers and ensure own organizational targets are aligned.
	Promote a carbon reduction culture through the organization and ensure technical teams have the appropriate training to develop low carbon solutions.
	Showcase their low carbon products/materials through the value chain.
	Ensure carbon management principles are integrated into delivery systems.
Procurement Manager	Embrace low carbon procurement criteria and cascade them to lower tiers of the value chain.
Material/Product Developer	Propose low carbon products/materials to the rest of the value chain for the best whole life carbon performance.
	Ensuring quantification methods are aligned with value chain requirements.

Table 2: Practitioner responsibilities

Benefits of early engagement

It is important that all organizations involved in infrastructure delivery engage with each other at the earliest possible stage and ideally – to drive positive change in the industry – engage outside of specific infrastructure projects.

This early engagement will allow the organizations fulfilling the different value chain roles to better understand the services and products required in the infrastructure sector and to proactively develop these.

2 How to implement the Carbon Management Process

"Where the ICR established the case for reducing carbon and reducing cost in infrastructure, PAS 2080 provides the practical guidance to make it a reality."

Mark Enzer, Water Sector Leader, Mott MacDonald and member of Green Construction Board, Infrastructure Working Group

This section provides guidance for all value chain practitioners on how to develop and implement the PAS 2080 Carbon Management Process (Figure 5 in PAS 2080). It focuses on how the Carbon Management Process is implemented to enable value chain members to work together when delivering an asset or programme of work (**Clause 6.2.1**), instead of focusing on their own organizational Carbon Management Processes (**Clause 6.1.1a**).

Although the asset owner/manager is a pivotal member of the value chain when delivering infrastructure, the greatest carbon reduction potential occurs when all value chain members are fully engaged and implementing together the asset owner/manager's Carbon Management Process to deliver assets and programmes of work.

Figure 1 below summarises how whole life carbon emissions can be managed by integrating different carbon management process components into existing infrastructure work stages.

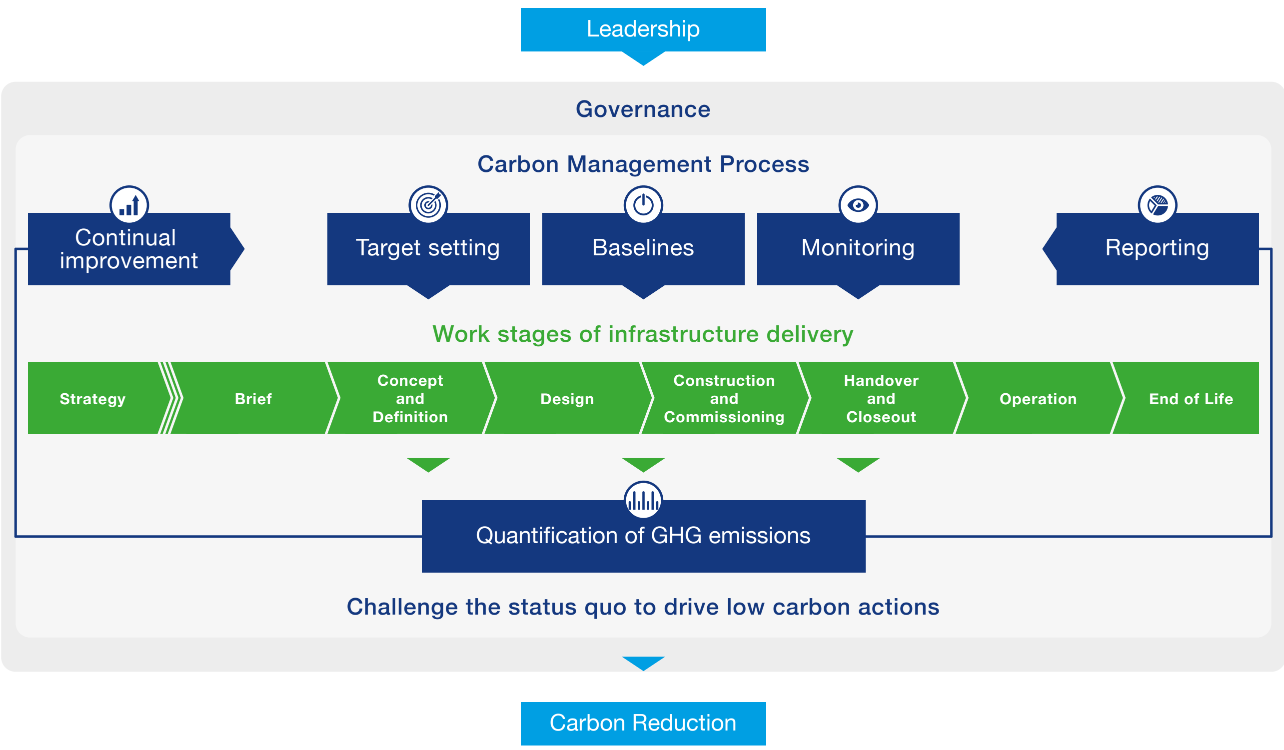


Figure 1: PAS 2080 Carbon Management Process
Source: PAS 2080:2016 – Carbon Management in Infrastructure

The objective is to reduce whole life carbon emissions in infrastructure assets and programmes of work across each of the eight different work stages of infrastructure delivery.

Guidance on the Carbon Management Process requirements (as described in PAS 2080) is provided for each work stage, to help practitioners understand when such requirements need to be addressed and which organization from the value chain is best placed to address them.

Some components of the process can be considered or undertaken earlier or later in the work stages than is documented in this section. The timings presented here are for guidance purposes only. The timing of specific actions, e.g. when and how a baseline is developed, should be determined by the individual practitioner to fit with the way individual assets or programmes of work are developed.

For programmes of work, some activities may be undertaken outside of the development of a specific project (e.g. during the initial "Strategy" stage). Where there are differences in the guidance for delivering single assets and programmes of work, this has been highlighted. Guidance is illustrated through a number of worked examples and case studies from different infrastructure sectors.

Responsibility charting

The implementation of an effective PAS 2080 carbon management process when delivering assets and programmes of work requires the engagement and involvement of a number of different value chain roles. To align all stakeholders, a Responsibility Chart (RACI) is provided for each work stage to inform as to the responsibilities of each value chain member and the activities to be completed.

The levels of responsibility for each activity are defined as follows:

- **Responsible** – The doer of the activity.
- **Accountable** – The value chain member accountable for ensuring the activity is completed to the level required.
- **Consulted** – Value chain member who is actively engaged and contributes input to the doer of the activity.
- **Informed** – Value chain member who is kept aware of how and when the activity is being completed and ready to provide inputs if necessary.

The RACI charts summarise how responsibilities are commonly split in infrastructure delivery but it is acknowledged that these can differ, depending on contractual and organizational agreements.

As per the requirements of PAS 2080, the Asset Owner/Manager is ultimately responsible for clarifying the responsibilities for each activity and for communicating these to their value chain. Nevertheless, it is acknowledged that all value chain members need to show leadership and proactively take specific responsibilities in the different infrastructure work stages, as described in this Section. *Table 3* below illustrates an example RACI chart, colour coded to show the different levels of responsibility for each activity.

Carbon Management Process activities during work stage	Asset Owner/ Manager	Designer	Constructor	Product/ Material Supplier
Activity 1	RA	R	R	R
Activity 2	RA	C	C	C
Activity 3	RA	C	I	I
Activity 4	A	C	R	I
Activity 5	R	A	C	C

R Responsible A Accountable C Consult I Inform

Table 3: Example RACI chart

Strategy

The Strategy work stage is where the asset owner/manager defines the outcomes expected and functional units for the infrastructure asset. Designers are often also involved during this stage and other value chain members have the opportunity to challenge the asset owner/manager's decisions.

Key actions in this work stage to maximise carbon reduction opportunities are to:

- Show clear leadership;
- Set bold targets and clear outcomes;
- Engage the value chain early to share carbon objectives;
- Remove any constraints to collaboration;
- Define corporate governance;
- Embrace a culture of challenge and change; and
- Encourage and incentivise innovation throughout the value chain.

Responsibility Chart

The elements of the Carbon Management Process to be addressed during the Strategy work stage, together with the specific responsibilities of the key value chain members, are summarised in *Table 4* below.

Carbon Management Process activities during Strategy work stage	Asset Owner/ Manager	Designer	Constructor	Product/ Material Supplier
Demonstrate **leadership** to **reduce carbon**	RA	R	R	R
Define infrastructure service outcomes including statement of need (define functional unit)	RA	C	I	I
Set up corporate **governance** that will include a continual improvement process	RA	C	I	I
Set **carbon reduction targets**; or other relevant ambitions related to carbon management	RA	C	I	I
Early engagement with value chain partners	RA	R	R	R

Table 4: RACI chart summarising the activities in the Strategy work stage

Leadership

Value chain members should demonstrate effective leadership and commitment at the highest level within their organizations to embed a low carbon culture. This commitment should cascade from the board, down to the manager and practitioner.

Each value chain member is expected to develop a clear vision and goals for reducing carbon in their organizational activities. In addition, Asset Owners/Managers need to set specific carbon goals to the infrastructure asset/programme of work they need to deliver (**Clause 5**) which should be documented and used for claims of conformity (**Clause 12**).

Value chain members should promote a carbon reduction culture across their organization encouraging everyone to constructively challenge the status quo and deliver low carbon infrastructure (**Clause 0.2, Clause 5**).

Empowering and upskilling early adopters

Leaders, at all levels (**Clause 5**), and practitioners need to empower delivery teams in their organization and the value chain who are naturally enthusiastic about carbon reduction and encourage them to influence others. This can be supported by developing the carbon management knowledge and skills in their organization and across the value chain, sharing the PAS 2080 principles in the process.

TARGET SETTING

The organization's board should set ambitious carbon reduction targets to enable a step change in the asset/programme of work delivery process and ensure significant movement away from business as usual (**Clause 8**). Carbon reduction targets need to reflect whole life carbon reduction aspirations. The practitioner can choose to set separate targets for Capital, Operational or User Carbon, or a single whole life carbon target.

Carbon reduction targets can reflect the total emissions of an asset/programme of work, i.e. 20% reduction in total whole life carbon emissions from a baseline, or a carbon intensity figure, e.g. tCO_2e Capital carbon /£'000 spend (**Clause 8.2.1**).

The asset owner/manager should set targets for the asset/programme of work being delivered and the remaining value chain members should at least meet these targets whilst delivering this infrastructure. However, the value chain should also set targets relating to their own involvement in infrastructure delivery and challenge asset owner/managers to improve targets. The value chain should also encourage asset owner/managers who have not set targets to do so.

Targets should be set relative to a baseline value, e.g. a proportion of the baseline set, which will need to be quantified. Targets can reflect individual assets/programmes and then aggregated to provide an overall reduction target for the organization as a whole. The continual improvement process should support periodic updates to the targets which become increasingly ambitious (**Clause 10**).

Practitioners in designers, constructors and material supplier organizations are encouraged to actively challenge the targets set for delivering the asset or programme of work.

Strategy (demonstrating leadership, governance)

CASE STUDY A1

OLYMPIC PARK

The Olympic Park is a 2.5 square-km site featuring a number of waterways and links to surrounding areas via highway, cycleway and rail networks. The bridges and highways provide the backbone to the park's infrastructure. The North and South Park consist of 20 km of roads, 13 footbridges, 11 km of retaining walls, 7 highways bridges and 6 underpasses. The North Park infrastructure included retaining walls, highways, secondary roads, one land bridge, one highway bridge, six existing bridges and two underpasses.

In the support of the Olympic Delivery Authorities (ODA) aspiration to create the most sustainable Olympic and Paralympics Games ever, several guidance documents were provided to the design and construction team to ensure priority themes were embedded in the design and construction of the project. Environmental assurance procedures were in place to track performance against a range of Key Performance Indicators (KPI), including the requirement to achieve at least a CEEQUAL Whole Project rating of 'Very Good'. This governance structure included targets for:

- Materials and Waste
- Energy and Carbon
- Transport

Under Energy and Carbon an embodied energy statement demonstrated the actions that had been taken to reduce the energy and carbon consumption associated with the key building materials – aggregates, concrete and steel for the infrastructure design at key stages during the whole life cycle. Case studies carried out during the design determined a:

- 50% carbon reduction, from concept to final design, of underpass U01
- 90% carbon reduction of the kerb selection from concept to final design.

Under Transport, biodiesel was identified as a cost effective solution to reducing carbon emissions when: the fuel is from a sustainable source; the quality is to European standard; and the project team accept the financial implications of the vehicle warranties being void. As a result, direct carbon dioxide (CO_2) emissions were reduced by 50% and cost savings of 12% were achieved.

Governance

The asset owner/manager practitioner should challenge existing governance systems to ensure a carbon reduction culture is encouraged and at the heart of infrastructure delivery. A good governance system should clearly define the key stages where carbon needs to be quantified and reported so that carbon hotspots are identified early to inform reduction and progress against targets is visible.

This should tie in with existing governance processes for cost and quality management. Carbon (and cost) quantification, and reporting should be more frequent during the initial concept design stages, where the opportunity to reduce carbon is greatest.

Practitioners in asset owner/manager organizations need to allow sufficient flexibility in the governance processes to allow designers, constructors and product/material suppliers to demonstrate their capabilities and proactively put forward innovative ideas (**Clause 5.2**).

As part of the corporate governance, practitioners should encourage delivery teams to challenge existing asset standards/specifications (where applicable) so as to allow reductions to follow the carbon reduction hierarchy (**Clause 6.1.4**). The practitioner should embed in the governance system procedures to ensure innovations are given proper consideration, even if they are in tension with existing asset standards.

Overseeing the activity

Each value chain member may choose to appoint a single person to oversee all of the required actions in this work stage within their organization and report these back to the asset owner/manager, especially for single projects. For programmes of work, responsibility for the tasks may be shared and built in to standard business procedures which will ensure consistency of approach.

Incentives

Practitioners should consider the use of incentives with their value chain partners and within their organizations to encourage whole life carbon and cost reduction. They should consider how to incorporate whole life carbon management in contracts and suitable metrics for acknowledging and rewarding good performance in the delivery teams.

Examples include incorporating carbon reduction and progress against targets as a KPI, with links to financial rewards. Rewarding carbon reduction behaviours could be achieved by establishing and promoting (internal and external) award schemes which recognise project/programme related achievements related to carbon reduction.

> "Leadership has been critically important all the way along the low carbon journey, and now that same leadership will be needed to drive the adoption of PAS 2080 and to unlock the value that it promises."
>
> Mark Enzer, Water Sector Leader, Mott MacDonald and member of Green Construction Board, Infrastructure Working Group

QUANTIFICATION

The asset owner/manager practitioner should identify at the earliest opportunity what the specific 'outcome' of the proposed/existing infrastructure is and quantify carbon emissions in those terms, as well as the total carbon emissions for an asset or programme of works. An outcome-focused approach is more likely to follow the carbon reduction decision-making hierarchy required in the PAS (**Clause 6.1.4**) and encourage no build and refurbishment options.

The outcome should be directly related to the functional unit for GHG quantification. The functional unit is a measure of the useful product or service that the infrastructure delivers (**Clause 7.1.2**). For certain organizations more than one functional unit may be required. Where possible, the assessment of carbon emissions should use the same metrics already adopted within a business or sector, e.g. for financial or performance related reasons.

Value chain members should be in dialogue with asset owners/managers to understand the functional units to be used (**Clause 7.1.2**).

Brief

The Brief work stage is where the asset owner/manager undertakes initial scoping of the infrastructure asset and programme of work. During this stage the asset owner/manager is encouraged to consult designers and constructors.

Key actions in this work stage to maximise carbon reduction opportunities are to:

- Engage designers early to focus on service outcomes and challenge the need for new assets;
- Allow time in the programme for designers to challenge the initial brief and review opportunities to further utilise existing assets;
- Clearly communicate desired service outcomes but allow value chain freedom in how these outcomes are achieved to allow maximum scope for innovation;
- Select procurement routes (for other organizations in the value chain) that address whole life performance and incentivise low carbon;
- Engage constructors early to assess innovative construction techniques and materials;
- Engage product/material suppliers early to showcase low carbon alternatives to be considered during the concept and design work stages; and
- Define the quantification methodology scope and cut-off rules.

Responsibility Chart

The elements of the Carbon Management Process to be addressed during the Brief work stage, together with the specific responsibilities of the key value chain members, are summarised in *Table 5* below:

Carbon Management Process activities during Brief work stage	Asset Owner/ Manager	Designer	Constructor	Product/ Material Supplier
Define the asset/programme **baseline** based on a notional solution	RA	C	I	I
GHG Quantification – Decide on carbon emissions quantification methodology;	RA	C	C	C
Decide on project **data quality** requirements	RA	C	C	C
Decide on carbon emissions **quantification tools** to use throughout the different work stages	RA	C	C	C
Develop brief following initial **engagement with the value chain**	RA	C	C	C

Table 5: RACI chart summarising the activities during the Brief work stage 2

BASELINES

Baselines can be created at different levels depending on the type of asset/programme being delivered and the targets set. The baseline should refer to the functional unit defined for the infrastructure being developed:

- Asset owners/managers are likely to set baselines against assets, programmes of works or service provision; whereas
- Constructors are most likely to measure their performance against baselines for activities (**Clauses 8.1.2 and 8.4.2**). These may be defined in time, referencing a particular investment period or previous programme of work.

Baselines for single assets are relatively simple to calculate as they are built up from the materials and activities required to construct them and for smaller assets these are not too onerous to collect. For programmes of works with numerous assets being delivered, the asset owner/manager may decide to use higher level quantification methodologies such as an input-output approach.

Data should be collected for all the relevant GHG life cycle stages to inform the baseline. Where possible, baselines should be created using in-house data from previous projects. This may take the form of drawings, bills of quantities or models. Baselines should be established for a notional solution, based on previous 'business as usual' practices implemented to achieve the desired outcome. The baseline can also indicate what key carbon hotspots should be for the subsequent design stage.

A practical worked example, which includes how a baseline can be set, is included in Section 4.

It is important the asset owner/manager gives the value chain the opportunity and sufficient time to challenge the baseline and then agrees a baseline which is realistic. Baselines which are set artificially high carbon emissions (because they are not defined carefully), risk making the task of carbon reduction look too easy and prevent maximising further carbon reduction opportunities. On the other hand, setting unreasonably low baselines may be too onerous for the value chain and misrepresent the carbon savings made in subsequent work stages.

The methodology used to quantify baselines is influenced by data availability, time constraints and the level of accuracy required. The asset owner/manager should consult their value chain members and determine what data are available and what needs to be captured throughout the delivery process. Accordingly, value chain members should proactively collect activity data to improve baselines and share these with the asset owner/manager. An appropriate methodology can then be chosen (**Clause 7.1.4**).

Practitioners should be encouraged to set baselines even if very limited data are available at the initial work stages but acknowledge that the accuracy of those may be limited.

Once initial baselines are created these can remain unaltered for the duration an asset or programme is delivered before updates are incorporated as part of the continual improvement process (**Clause 10.2.1**). Baselines only need to be modified during the delivery of an asset/programme of works if significantly improved data becomes available or errors have been found in original assumptions. This may be different for single large infrastructure assets where asset owners/managers may choose to re-baseline several times over the course of a very long construction period (see Component 2).

The governance system should enable activity data to be captured to allow continual improvement of baselines (**Clause 10.2.1**).

Development of Baselines

CASE STUDY | A2

BALFOUR BEATTY RAIL CARBON BASELINE

As part of the £6.5 billion Thameslink Rail Programme Balfour Beatty Rail are responsible for the track and minor civil works both inside and outside the main station at London Bridge. This includes the installation of 158 S&C units and renewal of circa 38,000 meters of track.

An important element in calculating the baseline was to determine what was 'business as usual,' what data was available and what needed to be captured throughout the delivery process. An outline baseline was calculated based on high level data available from the tendering process. This highlighted gaps in data relating to certain packages of work. To address this a workshop was held with key members of the client, design and construction teams in order to raise awareness of carbon management and the practicalities of how to improve the accuracy of the initial baseline based on what data was available. A further meeting was chaired by the Project Director in order to allocate responsibility for providing data for input in to the baseline.

The material data was built up based on outline designs for each of the work packages. Fuel, gas and electricity used in the first two years of the project was normalised against the Net Sales Value (NSV) and multiplied by the value (NSV) of the remaining work.

The Rail Industry Carbon Tool was then used to calculate the carbon baseline. Where possible calculations were based on material totals for each work package instead of completing individual calculations for every structure within that particular work package (for which there was 100's). Using the tool ensured transparency of the baseline calculation and traceability back to the exact carbon factors and calculation methodologies used.

A key lesson learnt was the benefit of spending time planning the most efficient method of calculating the baseline. It was also evident that raising awareness and gaining buy in from key individuals from the very start was key to calculating the baseline and to the whole carbon management process.

Examples of baseline calculation methodologies

Top down / input-output analysis (IOA) type
This approach uses high level sector or industry average data to estimate carbon emissions. This approach is often best used when a high level estimate is required and only limited data is available. This methodology provides an insight to overall emissions but won't necessarily help identify where emissions are concentrated and where reduction efforts should be focused. This approach may be suitable for organizations starting their carbon reduction journey before improved data is captured; or when a first outline understanding of carbon emissions of an asset or programme of works is needed.

Example calculation

A = Estimated cost of bridge = £5 million
B = Industry average of GHG emissions per £ spent = 0.224 kgCO_2e per £
A x B = 1,120 tCO_2e for delivery of the bridge.

Bottom up / life cycle assessment (LCA) type
This approach collates and analyses all materials and activities to be completed to deliver the required infrastructure. This methodology provides opportunities to conduct more in depth analysis to determine where carbon emissions are concentrated and think about what appropriate project responses might be. This approach is suitable for organizations which have captured detailed activity and associated carbon factor data for construction works.

Combining top down and bottom up methods
Most organizations will take a bit of a hybrid approach and use detailed data when available and make use of general industry data and assumptions when data and time constraints require. Over time with appropriate governance in place, it is expected that organizations will capture company specific data and reduce their use of generic industry and similar top down data.

QUANTIFICATION – ESTABLISHING AND COMMUNICATING A QUANTIFICATION METHODOLOGY

It should be determined at the earliest opportunity how and when GHG emissions will be quantified throughout the infrastructure delivery process (**Clause 7**). PAS 2080 sets requirements for designers, constructors and product/material suppliers to have the capability for quantifying GHG emissions at the asset owner/manager's request.

The quantification of GHG emissions of different design options in the brief stage may be high-level and primarily focused on long-list type option selection. In these cases, practitioners should identify an appropriate methodology based on available data (**Clause 7.1.4**); see Case study A3 (i) and (ii) and the worked example in Section 4.

Quantification of Baselines

CASE STUDY | **A3 i**

ATKINS – EDINBURGH-GLASGOW IMPROVEMENT PROJECT (EGIP)

The Edinburgh-Glasgow Improvement Project (EGIP) is a comprehensive programme of improvements to Scotland's railway infrastructure, rolling stock and service provision. The carbon work Atkins carried out on this project focused on the overhead line electrification infrastructure and route clearance works for electrification of the existing line between Glasgow and Edinburgh.

Atkins' approach to the carbon modelling for this project was to move significantly beyond pure carbon quantification and to work closely with engineers and the client to identify viable low carbon intervention options.

The principal step was to calculate a baseline carbon footprint of the OLE infrastructure and route clearance works using the Atkins Carbon Knowledgebase.

The carbon model this produced could then be analysed to identify carbon 'hot spots'.

This information, the primary carbon model, and Knowledgebase analysis functionality were then used to facilitate a series of innovation workshops with engineers and the client to identify potential alternative low carbon intervention options, and importantly the strengths, weaknesses, opportunities and threats (SWOT) of each. Following the workshop, the identified options were modelled in the Knowledgebase to quantify their actual carbon value. The model for each option was then compared to the relevant component of the primary carbon model to determine what the envisaged carbon benefits actually were. Those options confirmed to provide carbon reduction over the primary design and which had acceptable, or better, SWOT balances were put forwards as the final recommendations.

The project was very successful in the identification of different carbon reduction options. The sum of the identified options indicated a potential carbon impact reduction of more than 40%.

Quantification Tools

Practitioners in value chain organizations should examine existing tools for GHG emissions quantification (**Clause 7.1.8**) and decide whether they are adequate in terms of the requirements of **Clause 7** in PAS 2080, or whether new tools need to be developed.

A good quantification tool, with clear outputs for visualising performance, helps delivery teams to understand where the high-carbon hotspots are and where to focus reduction efforts. Section 3 provides guidance on what constitutes a good tool.

A bespoke tool is often not necessary and asset specific reporting templates may be developed and used for communicating progress against targets or during the concepts evaluation.

A good quantification tool, with clear outputs for visualising performance, helps delivery teams to understand where the high-carbon hotspots are and where to focus reduction efforts.

Quantification of Baselines

CASE STUDY | **A3 ii**

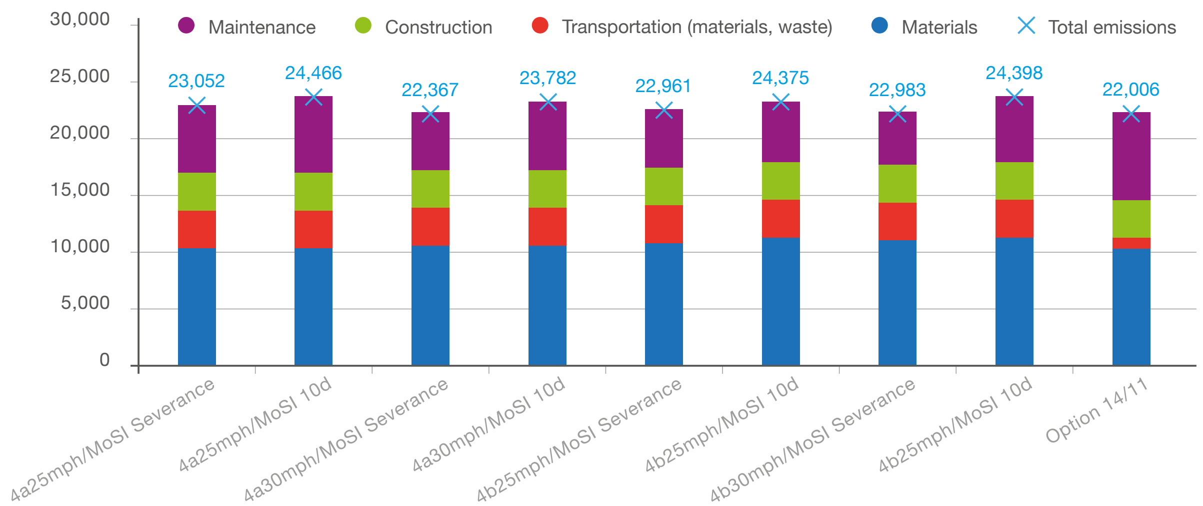
WSP PARSONS BRINCKERHOFF, ORDSALL CHORD FOR NETWORK RAIL

Within the Northern Hub programme of improvements, the Ordsall Chord scheme includes plans for a new section of track connecting Manchester's three main stations for the very first time. As part of the plan, Network Rail needed to build a new viaduct to connect Manchester's Victoria, Oxford Road and Piccadilly stations.

As part of the Network Rail GRIP 3 Option Selection Process, whole life carbon modelling was used for the structure's anticipated 120-year life, using Transport Scotland's prototype carbon tool.

A baseline study was conducted, covering all stages of the projects' life: construction materials (embodied emissions), transportation of materials and waste; construction; and replacement of materials. This baseline was undertaken, which allowed for a series of design options to be developed for the project, considering all stages of the projects' life.

The results indicated there was little difference between the design options in terms of carbon emissions (*Figure below*). However, hotspots were identified which helped focus efforts of a cross-disciplinary team during a "carbon challenge workshop" run by Parsons Brinckerhoff to identify emissions reduction opportunities.



The key learning points from conducting the exercise included the understanding that a whole life cycle approach to the carbon analysis was needed in order to develop a complete picture of emissions and related hotspots.

In addition, although estimations of construction-related emissions were not possible using the tool, Transport Scotland's prototype 'carbon tool', provided an excellent means of developing a baseline by estimating the emissions associated with materials and transportation; it could also be manipulated to help estimate maintenance emissions associated with materials replacement.

Concept and Definition

The Concept and Definition work stages involve the initial evaluations of options for an asset and/or programme of work, followed by the selection of the preferred option before detailed design.

At the concept stage, there is still a large opportunity for achieving significant carbon reduction, which may still include building nothing options (**Clause 6.1.4**). The asset owner/manager should encourage designers, constructors and product/material suppliers to challenge the brief and develop options to achieve the lowest carbon solution possible for the project. This should be informed by the quantification, so that the maximum opportunity to intervene is provided.

Key actions in these work stages to maximise carbon reduction opportunities are to:

- Inform optioneering with whole life carbon performance;
- Consider optimum balance between Capital carbon and Operational carbon;
- Reduce Capital carbon by building less and opting for lower carbon materials;
- Reduce Operational carbon by reducing operational energy and resource use, and through integration of renewable energy systems;
- Consider UseCarb to understand which option could reduce whole life carbon;
- Influence end user behaviour to further reduce UseCarb;
- Consider early engagement findings (from Brief stage) from designers, constructors and product/material suppliers on ways to reduce carbon (innovative products/materials and construction techniques, low energy processes, renewable energy systems); and
- Consider end of life scenarios and carbon emissions to inform asset layout and materials used.

Responsibility Chart

The elements of the Carbon Management Process to be addressed during the Concept and Definition work stage, together with the specific responsibilities of the key value chain members, are summarised in *Table 6*.

Carbon Management Process activities during Concept and Definition work stages	Asset Owner/ Manager	Designer	Constructor	Product/ Material Supplier
High level **quantification of all options** (and use of tools, where appropriate) against baselines	RA	R	C	C
Challenge the need for a new asset. Set and refine objectives for subsequent work stages	R	RA	R	R
Report on project activities, materials/components and carbon categories where the greatest emissions occur and where reductions can be made	I	RA	C	C
Engagement with value chain for carbon reduction of design options, focus on preferred solution and its identified **hotspots** (follow the carbon reduction hierarchy)	R	RA	C	C
Report and monitor progress against targets	R	RA	I	I

Table 6: RACI chart summarising the responsibilities during Concept and Definition work stage

BASELINES

A baseline may already exist for the project or have been developed for a programme of work. If it does not exist then a baseline should be created following the guidance set out in the Brief work stage. The asset owner/manager should check with the rest of the value chain that the baseline is relevant throughout this work stage and update it if not (**Clause 8**).

'Relevance' of the baseline includes making sure that the same scope of activities in terms of the GHG life cycle stages and Capital, Operational and User carbon emissions are captured. The methodology used to calculate the baseline must be compatible and provide comparable outputs with that used to make a quantification of the design.

Where multiple options are to be assessed, these can all be compared to the baseline using the functional unit. In the case that no baseline has been pre-determined, one of the assessed options could be the 'business as usual' approach which then becomes the baseline against which other projects are assessed. In this case, practitioners should take care to ensure that the business as usual option is realistic and not designed to make other options appear better in relative terms.

QUANTIFICATION

Based on the agreed GHG emissions quantification method, the designer or other relevant practitioner should determine the emissions of potential infrastructure service delivery options. The level of detail should be appropriate to this stage of the project, and rely on project-based information where possible, such as outline strategy descriptions, concept drawings, estimates for bills of materials plus information from past similar projects (**Clause 7.1.5.4**).

The practitioner should ensure that all requirements of **Clause 7** have been fully addressed including:

- Inclusion of emission sources for all relevant GHG life cycle stages. Where the practitioner identifies potential exclusions, these should be documented. (**Clause 7.1.3.2** and Appendix A in PAS 2080);
- The activity data used in the assessment is relevant and accurate (**Clause 7.1.5.3**); and
- The emission factors are appropriate for the location and time of the project (**Clause 7.1.5.3**).

MONITORING

Outputs from the GHG quantifications of different options should be reported and reviewed with the asset owner/manager and constructors at key decision points, with quantifications presented in the agreed functional units.

Practitioners should present data that also allows the value chain to understand where the key hotspots have been identified, e.g. by presenting the component breakdown and the GHG life cycle stages of Figure 7 in PAS 2080 as necessary.

The practitioner should consider the most relevant way of doing this; information about the performance of projects could be presented as a report, graphically or as part of a dashboard to relevant members of the value chain. In any case, the reporting should facilitate challenge and discussion of the solutions and/or options for further improvement.

Standardised quantification tools may make this kind of reporting straightforward. Practitioners are encouraged to integrate this reporting as part of normal project reporting/deliverables.

The underpinning assumptions and evidence for a given assessment may be reported separately to the specific results in order to keep the focus on relevant issues (**Clause 9**).

Early engagement and collaboration between Costain and Tarmac driving sustainability

CASE STUDY | A4

The £104m Heysham to M6 link road project was one of Lancashire's highest priority transport projects. Costain and Tarmac set out to realise the full potential of genuine collaboration, enabled by early engagement, to deliver complete transparency and informed specification decisions based on whole-life performance.

Working together two years ahead of the project being spade-ready provided a unique opportunity to gain a deeper understanding of each other's operations. This helped identify potential logistical, cost and sustainability benefits. Collaborative working was embedded in the approach of both businesses from the outset, as teams worked together to understand each other's operations.

Tarmac provided strategic information on the impact of site decisions on quarrying, deliveries and routes to site. As a result, the team could aim for zero wastage at the quarry supplying the project. This would ensure that all materials produced would be used on the scheme or by planning in advance, where excess could go to avoid landfill. In addition, a logistics plan was put in place that provided an optimal route to site and minimised the impact on local traffic.

This working relationship model is having a marked impact on the project. The overall new design produced at ECI stage has reduced the aggregate tonnage by nearly 25%, saving over 200,000 tonnes of raw materials, and enabled a reduction of nearly 9,000m^3 of readymix concrete, just over 26%. This translates into a 21% saving of CO_2e from the original design, exceeding the 20% KPI.

CONTINUAL IMPROVEMENT

The asset owner/manager should record any actions or outcomes from the solutions review with the constructor(s). These will contribute to the continual improvement process for future projects and inform the subsequent stages of work for the current project (**Clause 10**). These can be captured in a project register both for ‘designed in’ carbon reductions and for opportunities that have been identified but not yet included.

Early Engagement

The asset owner/manager and designer should engage relevant value chain members early to help identify all potential carbon reduction opportunities. This can be done through briefings and workshops or by integrating carbon management in to existing project meetings.

Information from the quantification stage and past projects can help identify the potential hotspots and direct the value chains focus on the most valuable areas.

Early engagement with material suppliers, CEMEX

CASE STUDY | A5

Early engagement with material suppliers in the value chain is important to consider innovative and potential carbon reduction initiatives.

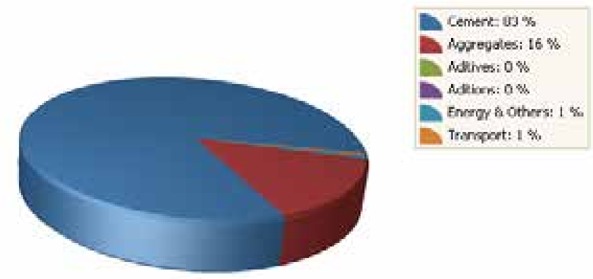
For example, as a material supplier of concrete, CEMEX UK has developed a Carbon Footprint Tool (CO_2 Tool) which allows CEMEX to accurately estimate the embodied carbon of its concrete. The tool follows the principles of PAS2050 and the cement input data, the key contributor of embodied carbon in concrete, being externally verified to PAS2050.

CEMEX can use the output of the tool to support asset managers on alternative solutions and methods to deliver carbon reduction targets to support low carbon solutions.

In the example shown, a standard concrete mix could have an embodied carbon figure of 338 $kgCO_2e/m^3$. However, with early engagement the embodied carbon figure could be reduced using alternative concrete mix designs to support low carbon solutions, in this example to 248 $kgCO_2e/m^3$.

CO2 FOOTPRINT RESULTS

Name	tCO2 eq/m3	%
Cement	0.280632	83.0
Aggregates	0.052845	15.6
Aditives	0.000000	0.0
Aditions	0.000000	0.0
Energy & Others	0.002548	0.8
Transport	0.001895	0.6
TOTAL	0.337920	
Density (ton/m3):		2.305000
Total (tCO2 eq/ton):		0.146603

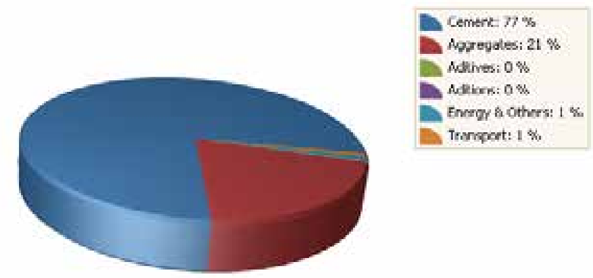


CO_2 Footprint

0.338 tCO_2 eq/m^3

CO2 FOOTPRINT RESULTS

Name	tCO2 eq/m3	%
Cement	0.190259	76.9
Aggregates	0.052597	21.2
Aditives	0.000289	0.1
Aditions	0.000000	0.0
Energy & Others	0.002548	1.0
Transport	0.001864	0.8
TOTAL	0.247558	
Density (ton/m3):		2.268200
Total (tCO2 eq/ton):		0.109143



CO_2 Footprint

0.248 tCO_2 eq/m^3

Figure 2: Difference between standard concrete mix and alternative concrete mix – achieved through early engagement with value chain

Design

The Design work stage involves the detailed design of the preferred option. During this work stage, further opportunities for carbon reduction should be considered and the relevant construction activities should be planned.

Key actions in the Design work stage to maximise carbon reduction opportunities are to:

- Optimise resource use and energy efficiency of the preferred design option through low carbon materials, leaner design methods, smart communication (Instrumentation Control and Automation – ICA) systems for operational efficiency;
- Consider end of life carbon during materials selection; and
- Design for disassembly and material re-use at end of life.

Responsibility Chart

The elements of the Carbon Management Process to be addressed during the Design work stage, together with the specific responsibilities of the key value chain members are summarised in *Table 7* below.

Carbon Management Process activities during Design work stage	Asset Owner/ Manager	Designer	Constructor	Product/ Material Supplier
Detailed **quantification** of anticipated project carbon emissions **against the baseline and target**	R	A	C	I
Engage with the value chain to seek innovation and cost efficiencies for reducing carbon and to use specific information where it is available in the quantification	C	RA	C	C
Report carbon hotspots to focus efforts for further reduction and **record carbon reductions** in pursuit of the targets	R	A	I	I
Set out **specification requirements** relating to carbon emissions and **set challenges for procurement and construction**	A	R	C	C

Table 7: RACI chart summarising responsibilities during the Design work stage

BASELINES

Following the concept design stage a preferred option will have been identified. At the design stage, the baseline can be maintained from the previous stage where the accuracy and method of baseline determination allows this.

For example, if the baseline was determined using a top-down input output method, it may be more appropriate to recalculate the baseline using a bottom-up approach, as the amount of information available is likely to have increased (**Clause 10.2.1**).

The practitioner should consider whether a specific target for the design work stage should be set and assessed separately to the overall project target. This may help focus the assessment and make the outcomes of the assessment clearer.

QUANTIFICATION

Based on the agreed quantification approach, the designer or other relevant practitioner should determine the emissions of potential infrastructure design options. The level of detail should be appropriate to this stage of the project and is expected to be more detailed than at earlier work stages (**Clause 7.1.5.4** – Table 2).

The designer and asset owner/manager should engage with the value chain to identify whether any generic information contained in the GHG emissions quantification could be replaced with more specific information on the products and materials and construction approach that is anticipated (**Clause 7.1.5.4** – Table 2). This will improve the overall accuracy of the assessment and also act as a mechanism to explore ideas and options with other value chain partners.

The practitioner should assess the information provided by the value chain to make sure it is compatible with the quantification method and of reasonable quality. This will involve checking the GHG life cycle elements of the information, its accuracy and representativeness (**Clause 7.1.5.3**).

REPORTING

The designer should report and communicate outputs from the quantification to the Asset owner/manager and other value chain members in the agreed functional unit (**Clause 7.1.2**). The reporting need not be complicated and should be focussed on the relevant carbon hotspots of the design and performance against the targets set.

The information should be used by practitioners to set meaningful objectives for contractors and suppliers in procurement events by focusing on the key areas.

Reporting on specific designs can feed back into earlier design stages for other projects by providing additional data points in the development of baselines and targets (**Clause 10.2.1**).

Practitioners should implement mechanisms to make sure that learning is shared and incorporated into all projects (**Clause 10**). This could be presented in a 'Good Practice' guide with examples communicated to the value chain.

Reporting on HS2

CASE STUDY | A6

HS2 Ltd is responsible for developing and promoting the UK's new high speed rail network. The proposed network is set to be delivered in two phases:

- Phase One between London and the West Midlands; and
- Phase Two between the West Midlands and Manchester and Leeds.

Development consent for Phase One of HS2 is being sought by primary legislation – an Act of Parliament. An Environmental Statement (ES), reporting the results of the Environmental Impact Assessment (EIA), was submitted to Parliament in November 2013.

The ES reported the carbon emissions implications associated with the construction and operation of Phase One of HS2. The assessment in the ES updated and refined an earlier carbon assessment reported in the Appraisal of Sustainability, which was published to support public consultation for the proposed scheme for Phase One. The ES reported:

1. A construction carbon footprint
2. An operational carbon footprint which included the following benefits and loads beyond the system boundary:
   a. Modal shift of passenger journeys onto Phase One of HS2 and associated surface access journeys;
   b. Modal shift of passenger and freight journeys onto capacity released on the classic rail network; and
   c. Carbon sequestration from tree planting.
3. A total carbon footprint, the carbon emissions from construction and operation minus the carbon benefits.

The carbon footprints were reported in the context of international (Kyoto Protocol), European (EU ETS) and national (UK Climate Change Act) policies.
The total carbon footprint was reported for a 60 year assessment period (to align with the economic appraisal) and a 120 year assessment period (to reflect the infrastructures design life).

In each instance, the carbon footprints were reported as a range based on scenarios adopting different projections of external variables, e.g. the carbon intensity of grid electricity in future years influencing future carbon performance. The scenarios were adopted to place the carbon performance of HS2 within the wider UK context and to show how it may be influenced by policies and measures outside of HS2 Ltd.'s own operational and construction activities.

Benchmarking against other significant transport modes, comparable infrastructure projects, the construction sector and the UK's overall carbon footprint was also used to provide context for the carbon footprint. The assumptions, emission factors and methodology used for the carbon assessment were reported in the appendices of the ES.

Collaboration
The Asset owner/manager should formally allow time and space in the programme to encourage designers, constructors and suppliers to collaborate and challenge the design and the options that achieve the required outcome (**Clause 5.2**). This should happen in parallel with and be informed by the quantification, so that the maximum opportunity to intervene is provided. The use of an inclusive workshop approach may help promote this.

Reporting Carbon Emissions Quantification

CASE STUDY | A7

PARSONS BRINCKERHOFF – GREAT WESTERN ELECTRIFICATION PROGRAMME (GWEP) FOR NETWORK RAIL

GWEP is Network Rail's programme to electrify the main line from London to Oxford, Bristol and South Wales. WSP | Parsons Brinckerhoff Rail and Atkins made up the programme's Lead Design Organisation (LDO). The carbon study was undertaken at GRIP Stage 5 (Detailed Design).

The scope of this carbon study covered embodied carbon associated with construction materials for all Route Sections for which the LDO had design responsibility. Transportation and construction emissions were estimated by other contractors reporting to Network Rail.

The UK Sustainability Team undertook a detailed analysis of the quantities of materials involved in a single Route Section (RS3), summing the number of piles and OLE structures in each Construction Unit. The resulting material quantities were passed to Atkins who entered them into the RSSB's Rail Carbon Tool.

The footprint for RS3 was then extrapolated to provide an estimate of the total footprint of all LDO-led Route Sections.

The RSSB Tool's outputs identified the embodied carbon hotspots. Carbon reduction opportunities fell into two categories:

1. Reducing the quantity of materials: Work had already been undertaken to reduce the depth of piles across the project, and the carbon savings associated with the materials savings were estimated. A thinner OLE mast option was also introduced which, where selected, reduced the steel and associated capital carbon emissions.
2. Changing the specification of materials: Steel and concrete were the two materials which represented the largest associated carbon. The concrete specified in the design allowed for a range of concrete mixes to be applied; the range included different levels of GGBS and PFA. Work is on-going to ensure that concrete with higher levels of GGBS are adopted where possible. A large quantity of steel has already been procured for the programme, so the opportunity to identify sources of reclaimed steel or steel suppliers with lower levels of embodied carbon appears to have been largely missed.

Asset standards

Practitioners in asset owners/managers should have reviewed technical specifications and procedures to allow the formal design as much flexibility as possible. Practitioners should consider the extent to which asset standards and specifications are influencing (or constraining) design decisions and whether they are being appropriately challenged. This challenge process should be made as efficient as possible to give the greatest chance of integrating innovations into projects (**Clause 5**).

Influencing procurement

The outcome of the challenge process should also identify specific objectives for the construction work stage, informed through procurement. It is vital that the targets for carbon reduction are discussed with procurement teams during the design stage, since this is where key decisions are made to lock-in (or not) low carbon opportunities. Design practitioners should work with procurement teams to develop specific questions and objectives for tender events that are relevant to and based on the specific assessment of the project.

Construction and Commissioning, Handover and Close out

The Construction and Commissioning, Handover and Close out work stages include the procurement and physical delivery of infrastructure.

By the end of this stage, the capital carbon emissions will no longer be predicted but will have occurred.

Key actions during the Construction and Handover work stages, to maximise carbon reduction opportunities are to:

- Embrace innovative construction techniques to minimise waste and plant fuel use;
- Optimise construction energy use to reduce capital carbon from construction/commissioning activity;
- Capture as built carbon emissions and feedback as part of the continual improvement process.

Responsibility Chart

The elements of the Carbon Management Process to be addressed during the Construction (including procurement) and Handover work stages, together with the specific responsibilities of the key value chain members, are summarised in *Table 8* below.

Carbon Management Process activities during Construction and Handover work stages	Asset Owner/ Manager	Designer	Constructor	Product/ Material Supplier
Use procurement to help embed the identified carbon reductions and **challenge the value chain** to seek **innovation** and cost efficiencies over and above design intent for reducing carbon	R	C	A	C
Detailed quantification and record of project carbon emissions based on as built information	I	I	RA	C
Engage with the value chain to use specific information where it is available (this might be on materials manufacture from the supplier; material quantity from the QS; etc.)	C	C	RA	C
Monitor progress to ensure project design aspirations for carbon emissions are delivered	A	I	R	C
Report back to Asset Owner/Manager as part of the continual improvement process	I	C	RA	I

Table 8: RACI chart summarising activities during Construction and Handover work stages

M5 Junction 27–28 (Willand) Resurfacing Scheme (2014), Skanska

CASE STUDY | A8

The road surface and markings on this stretch of the M5 were in poor condition and an original full reconstruction was projected to cost over £4.5million.

Skanska's smart re-design involved re-laying the surface course, halving the cost and reducing the environmental impact of the project. 50mm of the existing surface was planed off and re-laid, road markings and road studs were replaced, and vehicle detection loops were replaced.

Carbon footprint reduced by 23%
A carbon footprint was conducted for the project which calculated that construction materials resulted in over 70% of the project's carbon footprint. This was reduced by:

- laying the asphalt in the summer at a more optimal temperature and optimising the amount of asphalt laid per shift to reduce waste;
- planning truck movements to allow the continuous production of asphalt, rather than stop-start production that requires equipment re-heating;
- introduction of a new 'hot box' technique to keep the equipment hot when batching asphalt to save energy; and
- storing equipment and vehicles close to the site rather than returning them daily to the depot which reduced the number of shifts from 42 to 33.

Engagement with the value chain

Procurement practitioners – within asset owners/managers and the rest of the value chain – should be engaged early to help unlock potential carbon reduction benefits. The role of procurement may vary depending on the structure of the project or programme (**Clause 5.1**).

A collaborative delivery model between value chain members should be encouraged. Practitioners should ensure that project targets are clearly communicated throughout the value chain (**Clause 8.1.1**) and that there are ample opportunities for all to add value to decision.

Asset owners/managers can use procurement events to directly challenge product/material suppliers to deliver carbon targets in respect of specific projects. Asset owners/managers, designers and constructors should all engage with suppliers outside of tender events to ensure the whole value chain understands the carbon objectives and the way it will be managed through delivery (**Clause 5.5**).

BASELINES

For single large infrastructure assets with extended construction periods the asset owner/manager may decide to re-baseline at fixed points during the construction phase or following a procurement event (see component 2). This may be done to ensure the focus is maintained on activities within this work stage which can be controlled for maximum carbon reduction.

Worked Example – Monitoring carbon emissions against baselines/targets set during construction

The practitioner engages with the value chain to improve the emission factor associated with concrete in the quantification. Potential suppliers are asked to provide information.

Supplier A provides an Environmental Product Declaration (EPD). The practitioner reviews the EPD and is comfortable that is has been undertaken to the same scope of the project and is of high quality – the values within can be directly used in the quantification.

Supplier B has not undertaken a quantification of their product but is willing to provide information on the concrete mix and specification. The practitioner notes that Supplier B cannot provide information and notes this as a potential requirement for the tender event for the project.

In the concept phase of a project, potential carbon savings of 15% were identified through the development of no-build solutions in relation to a 20% target.

In the procurement for the project, this information was shared with bidders who were challenged to find additional carbon savings, each bidder providing carbon information as part of the event.

The asset owner/manager considered the response of each bidder as part of its evaluation criteria and used the information to select the preferred bidder. Monitoring actions were agreed between the asset owner/manager and the winning bidder as part of the construction phase.

QUANTIFICATION

During procurement, potential suppliers should be asked to provide either complete quantifications for a project or product-based quantifications in order to support the asset owner/manager and other stakeholders in their decision-making process. This will help encourage competition and innovation within the value chain.

The practitioners should set out clearly to the value chain the parameters within which quantification should take place, including the GHG life cycle stages and types of GHG emissions that should be included (**Clause 7.1.3**).

Practitioners reviewing submissions from various suppliers should check that the assessments have followed the prescribed method and scope (**Clause 7.1.4 and 7.1.1**). Practitioners may find it useful to develop checklists to assist in this process and the study goal and scope description should be widely shared so all parties can see the basis to the study.

During the construction work stage itself, the practitioner should measure the impact on carbon emissions from the use of all relevant sources (**Clause 7.1.3**). Constructors should consider how they can streamline the collection of activity data (**Clause 7.1.5**) during construction. This may include using bills of materials, delivery notes or other systems for monitoring works.

It may be possible to use this data to calculate carbon emissions directly (as a tool) or to extract information to undertake a separate quantification. Constructors should also use supplier specific data as far as possible and integrate this in to their quantification process (**Clause 7.1.5.4**).

MONITORING

If carbon emissions are monitored during construction works, this provides the opportunity to identify potential good practice and improve the accuracy of earlier quantifications. Asset owners/managers and constructors should agree how this monitoring can be done efficiently and in a way that provides useful information (**Clause 8**). This may be achieved by monitoring specific packages or elements of a project as they are delivered, building up in to the total project for which specific KPIs can be set. An example of how capital carbon emissions monitoring could be achieved during construction, especially in projects with long construction periods, is shown below.

Worked Example – Capital carbon monitoring during construction for long duration projects

Step 1: Whole life carbon emissions are quantified using existing/new carbon models for different options. Designers identify the lowest whole life carbon solution.
Step 2: Design teams to further challenge whole life carbon in selected option and identify the key carbon hotspots.
Step 3: Design teams and asset owners/managers share with constructors all assumptions behind the design carbon calculation for the top hotspots. This is done by converting the carbon calculation into activity data that a constructor can relate to the construction programme for the selected activities.
Step 4: Constructors can then compare as built carbon data with the design carbon activity data to monitor whether capital carbon in these activities can be further reduced or whether it is likely to be increased.
Step 5: Constructors can produce as-built capital carbon data for the selected activities which can be used for future improvement of the asset owner/manager's carbon models.

REPORTING

At the end of construction, results of the assessment should be shared with the value chain. Practitioners can use this information to communicate the outcome of construction projects and carbon reductions achieved against the defined targets (**Clause 8**). This information can also be used to refine and improve underlying assumptions in baselines (**Clause 10.2**). Constructors should report and monitor capital carbon during construction (**Clause 8.4.3**). This may be particularly useful in longer duration construction projects and should help constructors find ways to reduce carbon as well as to validate and improve the assumptions made quantifying carbon emissions during this stage.

Operation

Infrastructure is operational during this work stage. The primary focus will be on optimising its performance to reduce carbon emissions as far as possible, or to extend its function.

Quantification should be based on measured activity or use data although some predictive modelling may be undertaken. Key actions during the Operation work stage to maximise carbon reduction opportunities, which should be structured around the same carbon reduction hierarchy as for new infrastructure and be focused on the functional outputs of the system (**Clause 6.1.4 and Clause 7.1.2**), include:

- Reduce further operational and maintenance carbon emissions through measures such as real-time control optimisation and proactive condition monitoring and maintenance regimes;
- Identify improvements to existing assets through optimisations and refurbishment – noting that in some cases new infrastructure might be required to deliver better performance; and
- Identify alternative consumable projects which have lower impacts than from existing suppliers.

Practitioners should make sure that governance procedures allow these kinds of challenges to be made (**Clause 5**).

Responsibility Chart
The elements of the Carbon Management Process to be addressed during the Operation work stage, together with the specific responsibilities of the key value chain members are summarised in *Table 9* below.

Carbon Management Process activities during Operation work stage	Asset Owner/ Manager	Designer	Constructor	Product/ Material Supplier
Develop a **monitoring** system that quantifies GHG emissions during operation	RA	C	I	I
Monitor progress against targets, **report progress** at life cycle milestones to detect any changes in assets	RA	I	I	I
Engage with the value chain to identify low-carbon asset maintenance schedules	RA	R	C	C
For any design and construction works (e.g. maintenance and refurbishment, repeat **carbon management process**	RA	C	C	C
Report on performance to inform the continual improvement process	RA	I	I	I

Table 9: RACI chart summarising activities during Operation work stage

Optimising performance and delivering reductions

CASE STUDY | A9

BALFOUR BEATTY RAIL UK – THAMESLINK SIGNAL STRUCTURES

Balfour Beatty Rail (BBR) is the main contractor for the civil and track works on the Key Output 2 project, which is part of Network Rail's £6.5bn Thameslink programme.

Network Rail has implemented a BS11000 accredited collaborative working approach with its contractors BBR, Costain and Siemens.

The civil engineering works include 15 signal gantries, 10 cantilever supports for signals and 69 single posts or canopy structures for signals. The cantilever structures can be particularly expensive and disruptive, requiring a slab to be cast beneath the track bed in most instances.

On their appointment at the end of Grip Stage 4 (outline design), BBR carried out a review of the design for the scheme with a view to reducing cost and carbon and enhancing buildability.

They identified that three of the new cantilever structures were directly adjacent to existing gantry structures. A survey of the existing structures revealed that, with certain strengthening measures, they could be utilised to support the new signals.

Modifying the existing structures was more demanding in terms of survey and subsequent design work, and in terms of the authorisations that were needed to enable work to be undertaken on an existing 'live' structure. However the benefits were considerable.

The initiative contributed directly to Network Rail's Thameslink sustainability objective #17 – to reduce the environmental impact of the materials deployed in the works. Specifically:

- The carbon footprint of the adopted solution was some 60% less than represented by the Grip Stage 4 proposal.
- Installation was less intrusive – labour time on site, lighting and noise were all reduced.
- There was a cost saving similar to the carbon saving.

It also addressed Network Rail's objective #18 to reduce waste:

- There was no excavated soil to be removed from site.
- The Stage 4 proposal would have involved part demolishing the parapet wall, which would have created both waste and associated safety risks. These were avoided in the adopted solution.

TARGETS

Asset owner/managers should adopt targets during operation which reflect those set during the development of the infrastructure in previous work stages. Project-level targets should be maintained and measured against in order to measure specific performance of an asset and to corroborate data and target setting approaches used during the earlier work stages as part of a continual improvement process.

Wider operational-based targets may also be set and applied to assets once they are in operation. New targets may be defined at this stage which focus on specific elements of the assets' operation, e.g. energy use or maintenance regimes (**Clause 8.2.1**).

Practitioners should consider which targets may be required to drive the intended behaviours that will support ongoing efforts to reduce carbon emissions (**Clause 8**).

QUANTIFICATION

As far as is practicable for operating assets, measured activity data should be used in order to make ongoing quantifications of the asset. Before the asset begins operation, a monitoring system should be developed to capture activity data and inform the ongoing quantification of emissions (**Clause 8, Clause 7.1.5.4**). This might notionally be focused on operational or user carbon elements as capital carbon becomes less of a priority during infrastructure operation.

Practitioners should evaluate the sources of GHG emissions that might occur during this phase and revisit the inclusion and exclusions identified at previous work stages to make sure that these still apply. Where relevant these should be included with the quantification and monitoring regime, as well as the baseline and targets (**Clause 8**).

MONITORING

Monitoring should be developed in line with the functional unit of the asset, as developed in earlier work stages (**Clause 8**). In the case that the assessment of carbon emissions begins with an asset already in operation, then the appropriate functional units should be identified for that asset in line with the guidance set out in the Strategy work stage. Depending on the asset in question, this may be based on direct measurements from instruments, from purchase orders/invoices or derived from modelling.

The monitoring system should document the appropriate sources of data, relevant data holders and how the information is to be assimilated. Practitioners should consider whether existing management systems can be used to help collect and maintain such information. At the End of Life stage, quantification approaches similar to those set out in the Construction work stage should be followed.

REPORTING

The quantification should be reported periodically in line with other regular reporting that may occur within an organization, but at least as frequently as required to be able to take timely action in the event that the asset does not achieve its expected performance level (**Clause 9**).

Practitioners should consider whether reporting of carbon emissions should be included in standard reporting already undertaken in the organization or whether a separate report is made – either way may have more impact in any organization.

In the case that targets are not met, then the Practitioner should engage the value chain at the earliest practicable time in order to identify potential solutions and to record specific learning points that may inform other projects and improve the quality of assumptions made for assessments undertaken at earlier design stages (**Clause 10**).

End of Life

The End of Life stage of existing assets should be considered with the same mind-set as if dealing with a new asset.

Key actions during this work stage to maximise carbon reduction opportunities, are to:

- Explore possibilities for extending the asset life and re-using or recycling assets for the same or different uses.
- Assess the possibility of “build nothing solutions” and look to re-use existing assets.
- Assess beneficial asset re-use potential in any assets about to be made redundant – can these be re-used on site and/or can any resources be recovered to use in other assets or markets; and
- Adopt collaborative approaches to identify the best options for re-using/recovering materials and equipment.

The carbon reduction opportunities at the End of Life stage of individual assets should be incorporated into the consideration of new schemes.

End of Life work stage Responsibility Chart

The elements of the Carbon Management Process to be addressed during the End of Life work stage, together with the specific responsibilities of the key value chain members, are summarised in *Table 10* below.

Carbon Management Process activities during End of Life work stage	Asset Owner/ Manager	Designer	Constructor	Product/ Material Supplier
Explore opportunities for **beneficial re-use of materials** from existing assets to be decommissioned to be used in new asset design	A	R	I	I
Collect data from assets to be decommissioned to improve future designs on useful **material recovery** for future assets	A	I	R	I
Look for **collaboration** opportunities across sectors to identify opportunities to re-use assets or demolition material to avoid landfill or other disposal methods	RA	C	C	C

Table 10: RACI chart summarising responsibilities during End of Life work stage

Innovating at End of Life

Practitioners should follow the carbon reduction hierarchy (**Clause 6.1.4**) when it has been decided an asset has reached its end of life to identify innovative solutions which can either extend the life of the existing asset within its current function, extend its life with a new function or be incorporated within a new programme of works to reduce the requirement for new assets.

Designing for End of Life

The major challenge practitioners face when considering end of life carbon impacts is that it is often difficult, if not impossible, to accurately predict how the asset will fair over its designed life and what context the asset will or will not be required once it does reach the end of life stage.

However, it is important practitioners learn what they can from decommissioning of existing assets to learn how to make asset re-use, material recovery and disposal a more efficient and lower carbon impact process and incorporate this learning into designs for new assets.

The key components underpinning the requirements of PAS 2080

3

This section provides guidance on five key components that underpin the Carbon Management Process set out in PAS 2080.

Case study examples are included throughout this section to provide further practical applications of some of the components.

Component 1

Target Setting (**Clause 8**)

Effective target setting for the Carbon Management Process is a key component which underpins successful carbon reduction. Guidance on target setting (**Clause 8**) includes particular focus on the differences between setting targets for Projects and Programme of Works.

Guidance on Key Performance Indicators (KPIs) (**Clause 8.2.3**) supports monitoring the progress of:

- Capital carbon against target during construction works;
- Operational carbon against target during asset operation; and
- User carbon emissions against target during user utilisation of infrastructure.

While the asset owner/manager is responsible for setting targets for the asset or programme of work (**Clause 8.1.1**), value chain practitioners should seek to challenge and exceed targets to drive innovation at all stages of delivery.

Target Setting

CASE STUDY | B1

Allies and Morrison Architects worked with Arup on the delivery of new city district Masterplan for Madinat Al Irfan, a proposed new mixed-use development located close to Muscat International Airport in Oman. The Masterplan is envisaged as being an exemplar urban centre that becomes both a local and global model for city development, a benchmark for a truly sustainable infrastructure.

A key element of the project is the desire to reduce life cycle carbon emissions. Therefore, a carbon study was undertaken to quantify the emissions relating to the proposed development as a base case. This study highlighted that the major infrastructural contributors to carbon emissions were transport, energy and potable water supply.

In order to focus the efforts of the design team it was decided that a series of explicit targets should be set for the performance of these systems. These were established through a close dialogue between the client and design team, through workshops and reviews. The targets took account of baseline conditions in Oman and pushed the design team to achieve significant improvements upon these in order to bring wider sustainability benefits.

Targets were not stated explicitly in terms of carbon, as this was deemed to be inaccessible for the lay person, instead proxies were used with the reduction in carbon emissions associated with achieving these targets calculated separately. For transport, a target was to "Reduce the carbon emissions associated with per km travel by promoting less carbon intensive transport options such as walking and public transport as opposed to the car."

The overall capital carbon emissions of the building and infrastructure elements are approximately equal in the Irfan Case and the Base Case. However, the total forecast carbon emissions over a 20 year lifespan for Madinat Al Irfan were 40% less than the Base Case. Additionally, the total forecast costs associated with the Irfan development over a design period of 20 years reduces by 44% compared to the baseline.

Component 2

Baselines (**Clause 8**)

Baselines should be developed at the earliest opportunity by asset owners/managers once suitable data has been identified and the desired outcomes of the infrastructure asset/programme of work are known (**Clause 8.2.2**). However, all practitioners should support this process by collecting and sharing appropriate data to facilitate the production of robust baselines (**Clause 8.1.2**).

A lack of detailed data should not prevent asset owners/managers from developing initial baselines, generic data can be used as highlighted in Section 2. In addition, data from other parts of the value chain with relevant sectoral experience, may be useful. These initial baselines provide a base point from which organizations can improve over time.

A lack of accuracy in initial baselines can be mitigated by:

- Transparently reporting all data and assumptions used to calculate them (so that users can understand and account for limitations); and
- Establishing a governance system to allow the capture of improved data during infrastructure delivery; and making it available for future studies.

Continual improvement of baselines

How and when baselines are improved depends on the type of infrastructure project being delivered.

- **Single large infrastructure asset/project**

For the delivery of a single large infrastructure asset – where the construction period may run over a number of years – more effort is likely to be needed to produce a detailed baseline before design and construction commence.

However, once these stages do commence, what were new methods (i.e. design or construction solutions) at the outset, may become business as usual, and the team may choose to re-baseline at an appropriate time, to encourage further carbon reductions.

- **Programme of works**

For programmes of works where multiple assets are being delivered, baselines should be established at the earliest possible stage. Minimal incremental improvements can be made if significant errors in original assumptions or new data are found.

During the delivery of a programme of works, data will be captured on a regular basis as determined by the governance system and fed back to the original baseline dataset. This improved data can be used to create a new baseline at the start of the next programme of works. This allows the performance of all solutions to be compared against a stable value.

Component 3

Quantification (**Clause 7**)

This section provides guidance on how to undertake GHG emissions quantification and illustrates this through practical examples of scope and boundary definition, data selection and functional units.

A robust and transparent quantification methodology gives confidence to value chain members of study findings, promotes good decision making for carbon management, facilitates participation and enables consistent practice. It will also support comparability and better understanding for variations between methodologies.

PAS 2080 does not specify a particular methodology for GHG emissions quantification; rather it provides requirements for the key components that need to feature in a methodology.

Define goal and scope (Clause 7.1.1)

When undertaking a GHG emissions quantification it is first important to set out a clear study goal. Careful consideration of the goal will encourage stakeholders to think through the study process so that it is appropriately tailored to meet study requirements. Aspects to consider when defining a study goal include:

- what will results be used for, e.g. baselining, target setting or outturn reporting;
- where will the results be applied, e.g. which work stage will results be used for: strategy, design or procurement; and
- who will be the recipient of the information, e.g. procurement officer, designer, asset manager or product/ material supplier.

However, a properly established goal will go further than this – it will assist in defining the study scope applied in the quantification, i.e. defining study boundary conditions, data requirements, methodology choice, quantification approach, and reporting /communication strategy.

An illustrative example of a study scope for a new bridge is illustrated in *Table 11* below.

Study scope criteria	Example Description
System description	A brick arch bridge of 15m span (8m width) on a local authority managed A-road over a river. The existing structure requires strengthening and refurbishment and will be expected to have a service life of 120 years (with periodic maintenance).
System function	A highway bridge crossing for two way vehicle flow with vehicles up to 41 tonnes gross vehicle mass.
Functional unit	A 15m by 8m highway bridge with two way traffic and 41 tonnes gross vehicle mass limit with a service life of 120 years.
System boundary	Study to cover GHG life cycle modules A, B and C allowing for structural strengthening and refurbishment in the first instance and periodic maintenance over the 120 years. Any input or output exclusions applied to any module shall not be greater than 5% of energy usage and mass.
Applied allocation procedures	No particular allocation requirements are anticipated and the study shall try to avoid the need for allocation. If a need does arise or data is used that incorporates allocation decisions then it shall be dealt with by following the requirements of EN ISO 14044.
Where outcomes will be used	Outcomes will be used by the highway authority management team to inform future structural strengthening strategy with regards to it impacting on climate change.
Data quality requirements	The study shall be conducted using specific or average data from consistent methodologies. It shall be regionally applicable and reflect the technologies used in the supply chain for the project.
Assumptions and limitations	The study is of a single purpose structure with the function of providing a highway carriage way. The future is uncertain and variation of life cycle are possible due to many factors from physical, to economic, technical, safety, etc. The study shall apply a future maintenance regime that reflects current authority practice and which will secure the structure for 120 years.
Review process	Findings will be used to inform strategic direction of the organization and therefore a review process will be applied that shall include two highway authority bridge engineers supported by an external academic with experience of LCA in infrastructure.

Table 11: Example of GHG emissions study scope description

Function and functional equivalence of studied systems (Clause 7.1.2)

Infrastructure GHG emissions quantification should always be based on using the infrastructure's underlying delivered service as a basis for measuring and reporting the GHG emissions (i.e. the utility and function infrastructure provides). This is achieved by using what is called a functional unit as the basis for defining and undertaking the study. A GHG emission quantification study will use a functional unit as a reference base against which study outcomes can be more clearly understood to inform decision making and communication.

It is important to apply a functional unit that is similar or consistent with the way that cost information is being estimated and recorded. A functional unit might be representative of a single discrete component (e.g. a bridge bearing), a discrete infrastructure asset (e.g. a slow sand filter), or even an entire infrastructure system (e.g. a railway system from location A to location B).

Regardless of scale, a good functional unit will incorporate information on a number of key characteristics including the:

1) function of the component, asset or system under assessment;
2) quality that is related to its performance;
3) time period or duration over which functionality will be provided; and finally
4) quantity that defines the physical nature of the item under study.

Some examples of functional units for comparing options during infrastructure development, e.g. strategy work stage, are presented in *Table 12* below.

In working with asset owner/managers, designers and contractors should develop and apply functional units that enhance the understanding of how infrastructure performs from a whole life carbon perspective. This means creating a richly described functional unit reflecting the item under study and its life cycle.

For product suppliers it may be difficult to present carbon information on materials and products because of the many different functional scenarios of where materials will be used. For this reason the format most appropriate will often be to present in terms of a 'CO_2e per physical unit' (e.g. CO_2e/kg, CO_2e/m, CO_2e/m^2, CO_2e/m^3 and CO_2e/material item). When reporting carbon information on materials or products in this way it is commonly referred to as the 'declared unit' as there is no functionality associated with the units.

Sector	Example Functional Unit	Comment
Power	Provision of 1GWh of baseload electricity per year for a service life of 30 years.	For power generation technology comparison at project strategy.
	Solar electric plant with a generating capacity of 250 MWh per year including all ancillary equipment and with a peak power output of 50 kWp and a project service life of 50 years.	For solar technology comparison when considering design options.
Transport	Provision of 10,000 passengers per day between Point A and Point B 20km apart with a journey time of 1hr, over a period of 60 years.	For a comparison of transport modal options.
	1km of rail track with 60 equivalent million gross tonnes per annum and a service life of 60 years.	For comparing different rail track designs.
Waste	The treatment of 5 tonnes municipal waste during the day (24hr period), with a density of waste of 106 kg/m^3.	For the comparison of different waste treatment technology.
	The treatment and disposal in landfill of collected and unsorted municipal solid waste for a 24hr period, in an typical neighbourhood of 1000 inhabitants, with a UK average waste generation of 1.5 kg/inhabitant/day and a density of waste of 106 kg/m^3.	For looking at different landfill technologies.
Communication	Data connection of 1 Tbps bandwidth of 99.9% annual availability between two points in an urban environment 10km apart, over a period of 5 years.	Used to compare types of network data transfer.
Water	1km of portable water main supplying 5ML/day at 2bar pressure, from water treatment works in location A to location B 30km away, over a period of 60 years.	Example for comparing alternative solutions for transferring potable water between two points (e.g. using existing assets, providing new pipes, etc).
	Potable water main of flow rate of 1m^3 per second with a carrying pressure of minimum 3.5 bar/10 metres difference in elevation and a minimum internal roughness coefficient of not less than 100mm, located 2m underground in clay soil, to include necessary supporting trenching and bedding materials and with a service life of 60 years.	For comparing pipe materials and construction techniques.

Table 12: Example functional units for comparing whole life carbon performance

Study boundaries (Clause 7.1.3)

Figure 7 in PAS 2080 sets out a modular approach to GHG emissions life cycle boundaries. This mirrors the approach for presentation of Environmental Product Declaration information according to BS EN 15804 and the wider CEN TC350 standards programme. The structure enables efficient organization and presentation of information modules through the GHG life cycle.

The information modules important to infrastructure GHG quantification all have unique identifiers and are structured around four distinct stages:

- A – Before use stage;
- B – Use stage;
- C – End of life stage; and
- D – Supplementary information beyond the infrastructure life cycle.

Within each stage, there are specific modules. For example, stage A is made up of six information modules: A-0 to A-5, which group related activities leading to GHG emissions. In practice an information module is a package of data recording the carbon emissions of the activity it represents. This might represent a single activity or a combination of separate activities, either of which may have single or combined emission factors.

Practitioners should organise their project data (and reporting) according to these modules in order to produce consistent and transparent GHG emission quantifications.

Capital, Operational and User GHG emissions (Appendix A of PAS 2080)

PAS 2080 recognises three different types of GHG emissions in capital, operational and user carbon. These descriptors track across the modular approach to GHG emissions reporting as set out in Figure 7 of PAS 2080.

Appendix A of PAS 2080 provides detailed descriptions of capital, operational and user carbon and should be consulted for further detail.

The expenditure categories widely applied across infrastructure including capital expenditure (CAPEX) and operational expenditure (OPEX) have been used to inform the definitions. The scopes of CAPEX and OPEX are broadly consistent with capital and operational carbon, but may vary based on the precise interpretations that different organizations and sectors apply.

Reflecting these differences, the PAS enables practitioners to choose their interpretations of which activities in the Use stage modules (Figure 7) are allocated to capital or operational carbon emissions. In the interests of transparency, where choices of this nature are made they must be justified and supported with documentation of any assumptions and criteria used to guide the working approach.

Cut off rules (Clause 7.1.3.2)

Study boundaries define the scope of a GHG emissions quantification study and with this the processes and physical aspects included or excluded. Practitioners should use Figure 7 in the PAS to consider all the GHG life cycle stages and modules when identifying potential sources of GHG emissions to include in their study. Detailed guidance describing the boundaries associated with this are documented in BS EN 15804; and this can be used as a guide to inform on where larger or smaller sources of GHG emissions might occur.

PAS 2080 states that activities may be excluded from a GHG emissions study when they do not significantly change the result of the assessment. However, there are a number of rules that shape this requirement. For example sensitivity analysis shall be used to demonstrate that any exclusions do not affect the result of the quantification.

PAS 2080 also states that where exclusions are applied, expert judgement should be used to inform this decision making. In practice this requires the practitioner to have experience in the field of where they are undertaking the study, and apply logical reasoning to their exclusion choices. This can also be achieved by seeking expert advice from others. In setting out cut off rules, the study boundaries that arise from this, the data applied, and the methodology choices should be reasonable given the context of the GHG emissions quantification exercise and the infrastructure under study.

Study period (Clause 7.1.3.3)

PAS 2080 states that a reference study period should be defined for the quantification. Where possible, this study period should be established in accordance within industry norms such as BS 15686. In the absence of any specific sector guidance, a study period should be selected that reasonably reflects the intended function and life expectancy of the infrastructure.

Practitioners should test whether the selection of a certain study period might lead to a different outcome compared to another study period. This is particularly important when balancing the potential GHG emissions associated with capital and operational carbon.

Control and Influence

GHG emissions and their potential for reduction can be categorised as being ‘controlled’ or ‘influenced’ by the asset owner/manager. Controlled emissions will commonly form the focus of most GHG emission quantification studies and this naturally addresses capital and operational carbon.

However, in many instances the value chain and the asset owner/manager in particular also have an influence on user carbon emissions. This comes through creating enablers that have a direct influence on user decisions, and which can lead to change in the carbon emissions profile of users utilising infrastructure.

Figure 2 below sets out the boundaries for control, influence, and direct influence, and how these relate to the carbon emission categories. The concept of direct influence and the ability to change user carbon emissions is very powerful. In some sectors user carbon emissions are significant and relatively small efforts in the area of direct influence can drive significant carbon reductions through changing user actions.

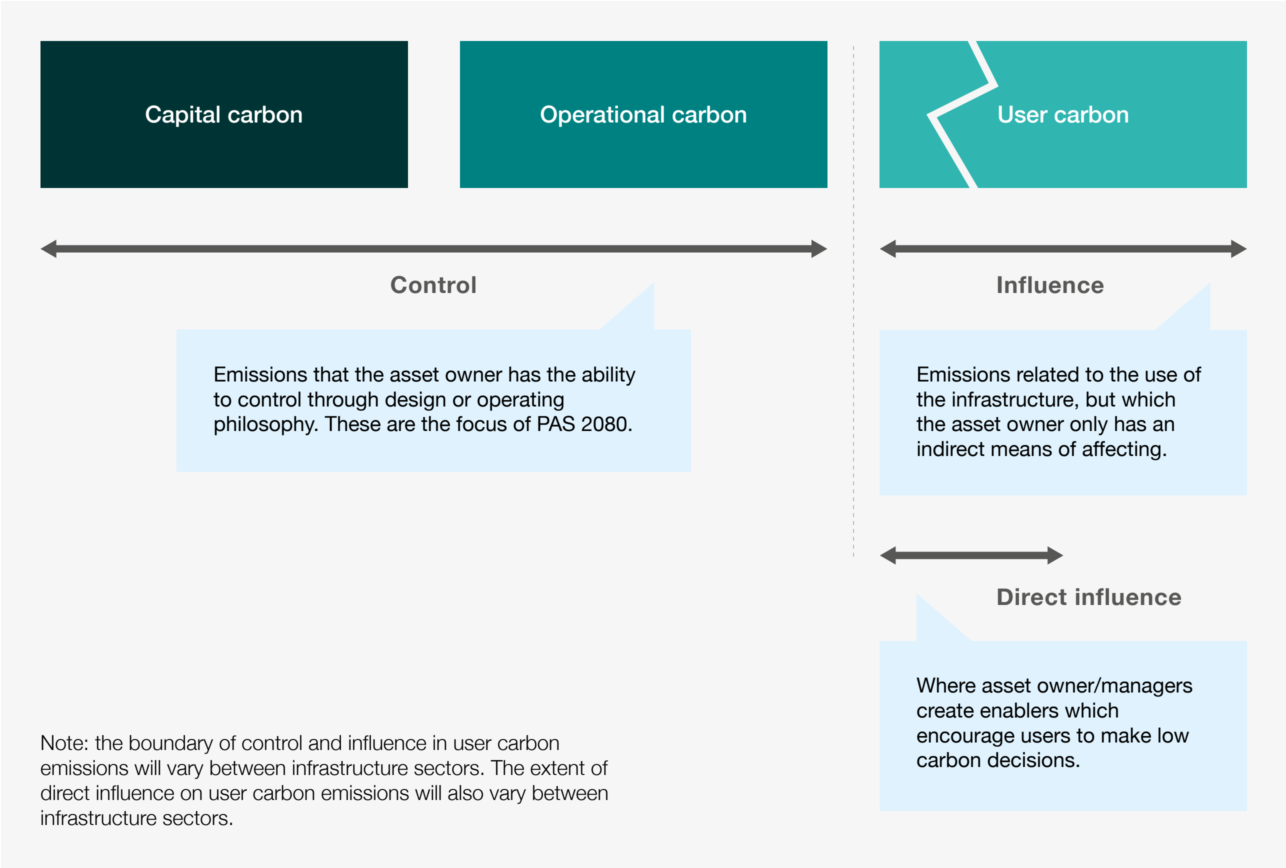


Figure 2: Control and influence and their relationship with carbon emission categories

‘Control’ means those emissions which the asset manager has the ability to directly manage through their decision making. This typically includes capital and operational carbon emissions, e.g. deciding or approving how much concrete is needed, or the specification of a particular piece of equipment, e.g. LED lights. Both these examples have an impact on the outturn capital and operational carbon.

‘Influence’ means those emissions relating to how infrastructure is used, and which cannot be directly controlled by the asset owner. This includes, for example, the way people use roads and the choices they make about when, where and what type of vehicle they drive. However, the asset manager is not always powerless on this issue and they may be able to exert an influence either at a specific point in infrastructure development or on those further up the value chain, e.g. regulators, governments or directly with users in order to change behaviour and the way assets and infrastructure systems are used. The scale of influencing ability will vary across infrastructure types and contexts. Asset owners/managers may have a direct level of influence for reducing user emissions through the development of a new infrastructure asset, e.g. using managed motorway technologies to encourage drivers to stick to specific speed limits. Asset managers in other sectors may have limited levels of influence to reducing user emissions, e.g. a water company may communicate to its customers demand management measures to reduce water use and in turn emissions from heating this water.

Infrastructure work stage definition: when and what type of GHG quantification to undertake

PAS 2080 uses work stages (Figure 3) as the basis around which a carbon management process shall be developed. This structure aligns with PAS 1192-2 which defines work stages for how infrastructure should be developed, from Strategy through to Design, Construction, Commissioning and Handover, and Operation to End of Life. Each of these work stages presents a potential opportunity to undertake an assessment of GHG emissions and to identify potential measures which would reduce GHG emissions.

The PAS does not prescribe that type of quantification of GHG emissions is undertaken at every work stage, but opportunities to reduce emissions do exist at each of these stages as different decisions are made. The asset owner/manager should consider at which stages a GHG quantification would support critical decision making and make provisions for such assessments to be undertaken.

Since the opportunity to reduce emissions is greatest earlier on in the development of infrastructure, it is suggested that asset managers undertake a quantification of GHG emissions at least by the concept stage, and a good asset owner/manager brief will demand this. Design stage assessment should follow. Collectively these efforts through concept and design stages will drive low carbon and cost outcomes.

The construction and commissioning phase can provide useful information in validating assumptions used earlier, i.e. facilitating project-to-project learning. Ongoing measurement in the operational phase can validate that reductions have been achieved on the project.

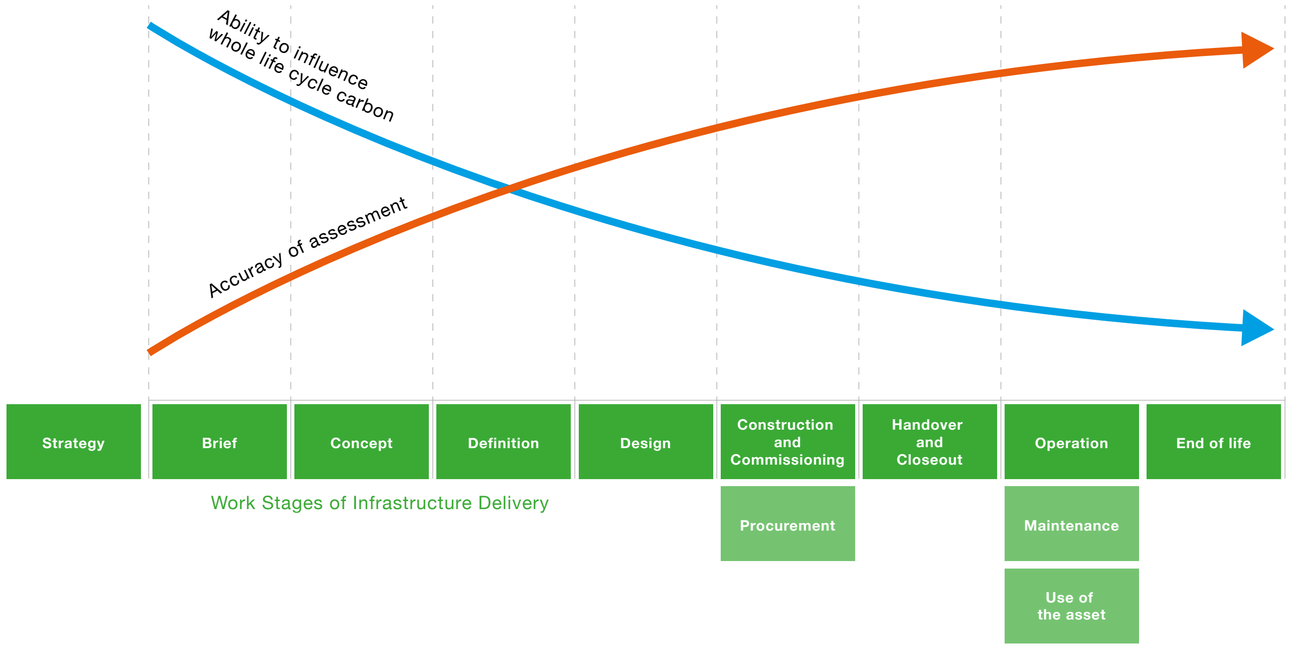


Figure 3: PAS 2080 – Conceptual diagram showing ability to influence carbon reduction across the different work stages of infrastructure delivery
Source: PAS 2080: Carbon Management in Infrastructure

How National Grid integrates carbon management throughout investments

CASE STUDY | B2

The ability to control and influence emissions varies as investment projects progress through infrastructure work stages.

At National Grid, this is illustrated by the way emissions are taken into account throughout their investment process. For example, once a needs case for a new gas compressor station has been established the focus shifts to the investment options assessment. At this Concept stage operational carbon has a higher weighting in the investment decision case alongside a number of other factors including cost and local air quality factors.

Consideration is given to the carbon impact of electric drive compressors versus gas compressor units and the projected carbon emissions of each option; this decision is important for determining the overall impact of the investment since the ongoing carbon emissions from the options can be significantly different.

As a project moves to the Design phase, development engineers work with designers to identify carbon reduction opportunities using an in-house carbon measurement tool. This stage focuses on carbon hotspots such as concrete. With the technology already selected the potential carbon reductions at this stage are more limited, but innovation can still lead to impactful effects on whole life carbon.

Project specific requirements are then set out in the Procurement event, where commercial and technical teams challenge suppliers to reduce whole-life carbon and costs. For major investment projects a 5% carbon weighing is included as part of the tender award criteria.

During Construction, the focus is exclusively on the works including plant, materials and transport, with National Grid's delivery team working in partnership with the winning contractor to identify further opportunities to reduce capital carbon within the scope of works.

Finally, with the asset in place and operational, management of the operational emissions once again becomes the overriding focus.

Selecting a GHG emissions quantification methodology

PAS 2080 requires the selection of a methodology that minimises the amount of uncertainty in GHG emissions quantification. Practitioners have three general choices based around calculation, measurement, and a combination of both.

- **Calculation based** – a rate of activity is combined with an emission factor for the GHG emissions of that activity. There are two main methods of calculation:
  Bottom up/Life cycle assessment (LCA) type – whereby the emission factor is determined by analysing the process and activities of a study system working outwards to a boundary and cut off point; LCA methodologies are commonly applied; and
  Top down/Input-output analysis (IOA) type – whereby activity emission factors are determined based on very broad boundaries (possibly even on a boundary free basis), based on interconnected economic sector information, and macro, e.g. national, regional or sector, emission factors data.

- **Measurement based** – the physical emission of a GHG is measured. This is the most reliable method of quantification, but it can only be used to monitor emissions as they occur. The confidence level of the measured data is dependent on the standards and type of measurement undertaken – for example whether it is continuous or periodic. An example of this would be measuring the concentration and quantity of GHG from a landfill, therefore giving a direct value for the emission.

A calculation based approach is likely to be the main approach used since it has broader applications and can be predictive. Examples of calculation based approaches are those that use activity and quantity data from design models, drawings and bills of quantity and combine this with Environmental Product Declarations and industry carbon factor information.

When selecting the methodology to be used, practitioners should consider the quality of the data that could be used and the work stages at which the information may be applicable. A review of available data may help to inform the choice of approach.

It may be appropriate to use different approaches at different stages, and practitioners should consider whether this leads to comparable outcomes at different stages of delivery or whether different baselines may be required.

Collect and access study inventory data (Clause 7.1.5)

PAS 2080 states that the practitioner shall use study data in the quantification of GHG emissions that are consistent with the stated study goal, scope, and study boundaries. In practice this means data for both the activities that will occur in the studied system and the GHG emission factors associated with them.

Activity data

Activity data will vary depending on the particular infrastructure system under study. It will likely be a combination of material quantity data, energy demand, or other process data covering transport need, waste generation, water demand, or construction works, etc. Activity data may be based on known, predicted/estimated or modelled data. In each case, the practitioner should review the suitability of the data and its representativeness of the subject under study.

The data quality criteria set out in *Table 13* should be used to define the data requirements and these should be recorded in the study scope description.

Activity data may typically be sourced or deduced from measurements of processes, a bill of materials, energy or mass balances, project specifications, scheme reports, drawings, BIM models, or other types of simulation or modelling relating to the infrastructure under study.

GHG emissions factors (Clause 7.1.5.2)

Emission factors assign a rate of GHG emissions to a unit of activity. Emissions factors may be deduced from first-principle calculations, from published sources, and in very rare instances from direct measurement. Practitioners should use emission factors that represent as closely as possible the activity of focus.

Practitioners should be aware that certain activities may lead to more than one type of GHG emission, e.g. fossil fuel combustion leads to CO_2 and N_2O emissions; and may also vary over time, e.g. the GHG emission factor of an electricity grid is likely to lower over time as it decarbonises.

A GHG emission factor may also cover emissions that occur in more than one life cycle module. For example all primary extraction, transportation and manufacturing emissions for the creation and delivery of a product to construction site might be reported in a single GHG emission factor. Practitioners should manage such cases within the quantification, making sure that all activities and GHG life cycle modules are considered (and not double counted) as may be necessary for the defined study goal and scope.

Data quality rules (Clause 7.1.5.3)

PAS 2080 defines data quality rules for GHG emissions quantification. As far as possible the most accurate data available for the quantification should be used. The rules are set out in *Table 13* below and practitioners should follow the criteria for reviewing and selecting activity or emission factor data for use in quantification.

Given the nature of infrastructure work stage delivery, and the availability of data over a programme, it might be assumed that the data quality requirements for a GHG emissions quantification change and become more rigorous as the study moves from concept or design work through to construction and as built. This evolution reflects the more accurate data that becomes available as the asset or programme of works becomes fixed and is realised.

Quality measure	Issues for the practitioner to consider
Age	Is the data applicable to the time period covered by the quantification? Was the data created before the infrastructure? Is the data applicable to future predictions for the infrastructure?
Geography	Is the data based on assumptions of certain geography? Are there likely to be national or regional variations in the applicability of the data? Does the data represent the likely location the activity will take place?
Technology	Is the data specific to the technology applied in infrastructure and its supply chain? Does it represent a specific or broader category of product or activity?
Methodology	Does the data follow a defined methodology? Is this methodology consistent with the scope, boundaries and methodology applied in the quantification? What are the assumptions and limitations inherent in the data? What is the uncertainty associated with the data?
Competency	Is the source of the data reliable? Is the data widely cited? Has the data been assured or quality checked (for example, through a certification process)?

Table 13: Data quality criteria and supporting descriptions

Quantification Tools (Clause 7.1.8)

The use of quantification tools (**Clause 7.1.8**) to support the Carbon Management Process can deliver significant benefit across the value chain.

A good quantification tool, with clear outputs for visualising performance, can be a good way to engage delivery teams to understand where carbon hotspots are and where the reduction focus should be and can increase the consistency of assessments.

Practitioners should check that the use of proposed tools is consistent with the requirements of the project and are in accordance to **Clause 7**. This includes consideration of the study boundary and data quality.

The attributes of a useful and appropriate tool may include the following characteristics:

- Ability to estimate carbon from high level at early work stages to detailed design at later stages;
- Report quantifications and reductions to facilitate discussions and challenge for improvements;
- Identification of hotspots; and
- Ease of use and transfer and share of data.

Baseline Tools

A number of organizations have developed carbon tools to support and align with their existing cost estimating tools. Such tools can be developed to provide high level models to be used at the early work stages for optioneering. They also often have functionality for detailed quantification when better data becomes available during the later work stages. Tools can also take the form of relationship curves or unit rate data (e.g. rule of thumb curves for the capital carbon of bridge decks over increasing span distances to assist different type of assessments).

BIM Software

GHG quantification can also be undertaken using BIM software as long as the underlying data has been incorporated into the models for different products and materials. This has the potential to allow for rapid identification of carbon hotspots and testing different designs and material options.

Development of in-house tools

Some organizations may choose to develop their own in-house tools, with bespoke benefits including:

- Tailored data to meet specific design requirements/standards and business processes; and
- Include specialist functionality to meet own reporting requirements, e.g. templates.

Sector-specific tools

There is significant scope for sector-specific tools to aid consistency in assessment, knowledge transfer and peer comparison and improvement, e.g. the UK Water Industry Research Carbon Accounting Workbook and the Rail Carbon Tool.

Rail Safety and Standards Board (RSSB): Rail Carbon Tool

CASE STUDY | **B3 i**

The Rail Carbon Tool is provided by the RSSB for UK rail industry organizations and enables the rail industry to measure and reduce its carbon footprint.

The tool is web-based and allows rail organizations and users to calculate, assess, analyse, report and reduce carbon footprints. It facilitates this by evaluating low-carbon options using verified, centrally-available carbon factor data. It accommodates both embodied and operational carbon.

The tool has been specified to accommodate rail industry requirements with speed and flexibility in mind. It replaced traditional spreadsheet-based or domain-specific carbon assessment tools and complements more comprehensive carbon or energy simulation tools.

The Rail Carbon Tool enables rail organizations to; calculate and analyse the carbon footprints of UK rail projects and activities; identify and assess alternative low carbon options, and as a result; inform the development of a low carbon strategy. The overall objective of measuring carbon is to reduce carbon emissions and help improve sustainability performance.

For more information visit:
www.railindustrycarbon.com

Carbon Measurement tools, The Crossrail Scope 1, 2 & 3 predictor tool

CASE STUDY | **B3 ii**

The Crossrail works in formation had a requirement for all contractors to provide energy management plans and identify a target for carbon reduction in scope 1, 2 and 3 emissions.

In discussion with its contractor base, Crossrail quickly identified that there was a lack of confidence in what could be achieved within scope 1 and 2 in particular. Contractors were required to assess the scope of their individual work packages, the plant and equipment used to construct them, then opportunities to reduce emissions and forecast a percentage reduction having implemented these measures.

Using the resultant data, the project set an 8% reduction target for Scope 1 and 2 but had no method of ascertaining if it was on track to achieve this at the end of contract.

This led to the development of an Excel based tool that allows the contractor to input equipment and plant type with energy/fuel usage data. This data was initially extracted from manufacturers' performance datasheets, but amended as real operational data became available.

Using information extracted from Section 61 (Control of Noise and Vibration, CoPA 1974), it has been possible to build up an accurate picture of plant and equipment used for given construction activities including the percentage on time so that this could be related to potential fuel usage.

When all this information is inputted into the tool it produces a predicted energy/carbon usage curve with time, to the end of the project and provides a "do-nothing" output figure. To calculate the do-nothing predicted figure, the contractors were allowed to input default fuel consumption figures based on commonly available and procured equipment within the industry for that particular task. If the contractor then procured a piece of plant or equipment that was more efficient than the industry default equipment, this could be entered as a saving, e.g. Where CFD lighting is still largely standard on construction sites, a contractor procured an entirely LED lighting solution with a forecast saving of 38% on energy. A drop down menu would allow the contractor to include this as an implemented initiative and recalculate the energy sue and carbon emissions from that intervention. Similarly, they may have chosen to procure a hybrid excavator for moving material from a stockpile to a railway wagon, with a 15% fuel saving. Using the drop down menu for excavators the 15% saving can be highlighted. All the interventions are calculated and the graphed curve recalibrates to indicate what the end of contract carbon will be.

Note that all the interventions in the tool use a percentage reduction which relates to a fuel type and its associated carbon intensity so that the output figure is expressed as a carbon reduction.

It is necessary to create the right environment to establish reasonable assumptions around the do-nothing scenario to avoid driving the wrong behaviours. For example, it would be easy for a poorly performing item of equipment to be selected as the default against which the intervention is calculated. For this reason, the user is required to provide a justification for the choice of default equipment. By doing this, we have a more robust baseline, based on what is typically available to the industry rather than a comparison against obsolete or rarely used equipment that is inefficient.

Component 4

Continual improvement (**Clause 10**)

The continual improvement of managing and reducing carbon emissions in infrastructure requires the establishment of procedures and practices that enable the implementation of improvement actions and the review of outcomes. All value chain members should have processes that support continual improvement which includes the sharing of information throughout the value chain.

Addressed in PAS 2080 **Clause 10**, the following steps/activities represent good practice for enabling continual improvement:

a. Determine carbon emissions performance in relation to targets and relevant benchmarks;
b. Identify and establish areas for improvement;
c. Obtain commitment to improve and define the improvement objective;
d. Assess the reasons for current performance;
e. Define and test changes that can achieve the improvement objective;
f. Produce improvement plans which specify how and by whom the change(s) will be implemented;
g. Identify and overcome any resistance to the change(s);
h. Implement the change(s);
i. Establish controls to maintain new levels of performance and repeat step a).

Knowledge on improvements should be used to inform target setting and baselines in order to support ongoing process of carbon reduction (**Clause 10.2.1 and 10.2.2**).

Alignment with existing management systems

The steps listed above align with the Plan Do Check Act (PDCA) methodology which is reflected in both ISO 9001 (Quality) and ISO14001 (Environmental Management).

Where asset managers have an existing management system in place, procedures for the continual improvement of processes to manage carbon emissions can be integrated. Organisations certified to ISO14001 or with a similar EMS in place are likely to already have procedures established.

Facilitating continual improvement at a sector level

Knowledge sharing of best practice is the quickest way to help the infrastructure sector towards low carbon solutions and help realise benefits for all value chain members.

Examples of platforms for knowledge sharing

Value chain members should be encouraged to share best practice and develop their own forums to share knowledge at different levels of their organizations e.g. throughout the leadership team and the different practitioners roles highlighted in section 1.

The Green Construction Board itself has an extensive resource of case studies covering water, rail, utilities and other infrastructure sectors available online and free to all at:
www.greenconstructionboard.org/index.php/resources/promotion/case-studies

Continual Improvement: London South Area Highway Maintenance

CASE STUDY | **B4**

In 2007, EnterpriseMouchel (EM) was tasked with providing maintenance activities and ad-hoc improvements works for the southern Highways and Maintenance Works Contract (HMWC) area of the TfL Road Network (TLRN). The TfL brief included a requirement for EM to take part in piloting CEEQUAL Term Contract – Assessment.

EM was appointed following a competitive tendering process in 2007. EM's environmental credentials were assessed by disclosing any past breach in environmental legislation. The contract was then written to include a number of challenging requirements, which included:

- Environmental Service Performance Indicators (SPIs)
- The formulation of an annual Sustainability Plan
- ISO14001 accreditation
- EM's voluntary but nonetheless binding Environmental Quality Promises.

The aim of these requirements was to establish a framework whereby the environmental impacts and opportunities for environmental enhancements were identified, assessed, managed and monitored. Additionally the requirements ensured reductions in CO_2, NOX and PM10 emissions, reductions in transport related noise and vibration, protection and enhancement of London's built and natural environment, reduction in resource consumption and commitment to green procurement.

The requirements of this contract, to develop a governance structure, resulted in carbon reductions, which include:

- 100% of EM's fleet and their principal subcontractor's fleet meet Euro 4 and 5 emission standards;
- 99.7% of EM's excavated and 96.4% of non-excavated construction and demolition waste was re-used or recycled;
- EM has achieved annual carbon footprint scope 1 and 2 reductions;
- In 2009 and 2010, EM received the platinum award from the Mayor of London's Green500 scheme for reductions in CO_2 emissions and was the first highways contractor in the country to be awarded the Carbon Trust Standard.

In 2011, TfL and EM (together with the other two HMWCs), were awarded the Transport Partnership of the Year at the London Transport Awards (not a TfL event). This award recognised that the partnership between otherwise commercially competitive companies resulted in collaborative working that produced real benefits for London.

Component 5

Reporting (Clause 9)

PAS 2080 reporting is the communication of summary information related to carbon emissions performance for a specific carbon emissions assessment or an aggregation of assessments undertaken as part of a Carbon Management Process.

Reporting of carbon information is undertaken for a number of reasons, including to:

- Share information within the value chain to enable assessment of carbon emissions, e.g. reporting of product emissions to support an asset-level assessment;
- Enable a review of performance against targets and benchmarks and the identification of improvement actions as part of a continuous improvement process;
- Ensure transparency and accountability through communicating performance; and
- Share best practice within and between infrastructure sectors.

Further detail is set out in Appendix 2.

HS2 Environmental Statement

CASE STUDY | **B5**

The Environmental Statement (ES) for HS2, submitted as part of the Environmental Impact Assessment process, reported the carbon emissions implications associated with the construction and operation of Phase One of HS2.

The assessment in the ES updated and refined an earlier carbon assessment reported in the Appraisal of Sustainability which was published to support public consultation for the proposed scheme for Phase One. The ES reported:

1. A construction carbon footprint
2. An operational carbon footprint, including the following benefits and loads beyond the system boundary:
   a. Modal shift of passenger journeys onto Phase One of HS2 and associated surface access journeys;
   b. Modal shift of passenger and freight journeys onto capacity released on the classic rail network; and,
   c. Carbon sequestration from tree planting.
3. A total carbon footprint, the carbon emissions from construction and operation minus the carbon benefits.

The carbon footprints were reported in the context of international (Kyoto Protocol), European (EU ETS) and national (UK Climate Change Act) policies.

The total carbon footprint was reported for a 60 year assessment period (to align with the economic appraisal) and a 120 year assessment period (to reflect the infrastructures design life).

Benchmarking against other significant transport modes, comparable infrastructure projects, the construction sector and the UK's overall carbon footprint was also used to provide context for the carbon footprint.

Quantification Worked Example

4

Calculation of carbon emissions during the Design stage to review the need for an asset to meet the needs of a growing population.

This worked example demonstrates how through work stages Strategy to Design, carbon emissions can be calculated and reductions achieved.

The example concentrates on life cycle emissions stages A1-5 (Pre-construction to Construction) as presented in Figure 7 of PAS 2080.

Work stages Strategy to Concept: Calculating the baseline of standard solution

The brief for the project, provided by the asset owner/manager to the designer, was to provide potable water over the next 15 years to a town with a projected population increase of 20,000 residents. The asset owner/manager provided a target for reducing the capital carbon for achieving this brief by 35% from baseline figures.

The designer challenged the brief, to confirm the growth of 20,000, to determine the extent of potential new infrastructure. This figure was verified, and the original brief remained.

The baseline against which the target reduction is to be measured for the standard solution will usually be carried out by the designers; however, in some cases the asset owner/manager may provide some bespoke tools to aid the designer in quantifying baselines and designs.

Step 1 – Identify the sources of emissions
A review of the potential emissions sources should be undertaken to identify the various sources of emissions that might occur to help define the scope. In this example, the project would lead to capital carbon emissions in Stage A and later in Stage C. There would be some emissions that occur in Stage B associated with maintenance. The asset manager/owner is in control of all these emissions so they are all included in the quantification.

Note: For brevity, this worked example only presents Stage A emissions (A1–A5).

Step 2 – Gather required material/activity data
The relevant material/activity data associated with emissions in Stage A1-5 to achieve the notional solution of installing a new pumping station and laying pipe in a verge needs to be gathered. This can be collated from bills of materials and drawings from previous projects undertaken by the asset owner/manager – or if this is not possible – then by other organizations. At the end of this step, a list of activities grouped by modules would be assembled for use in the quantification.

Step 3 – Gather associated emissions factors
Once the relevant material/activity data has been completed, appropriate emission factors relating to these activities and materials will need to be collected whilst following the data quality rules provided in **Clause 7.1.5.3** of PAS 2080.

In this example the emission factors are based on averaged data as the exact supplier is not known at this work stage, which have been provided by the asset owner/manager in the form of a tool. The practitioner should step through the data quality criteria to check that the emission factor is appropriate for use with the defined activity data.

Step 4 – Calculate Baseline
The material/activity data and emission factors can now be used to calculate the baseline for each material and activity using the quantification formula set out in **Clause 7.1.6** of PAS 2080. These can then be built up to form a baseline for the notional solution.

The baseline will be calculated against a service outcome as stated in **Clause 8** of PAS 2080. In this example the service outcome is the delivery of 15 megalitres per day (ML/day) of water to the service zone, based on the projected population growth. However the designer or constructor may calculate their baseline on the activity they will be completing, e.g. tCO_2e per 100m of pipe laid in a road. This is acceptable as long as this can be later built up to provide overall carbon emissions in the asset managers' functional unit of tCO_2e per XML/day of water supplied.

Baselines have been calculated using a tool provided by the asset owner/manager based on the provision of:

- 15kW pumping station (77 tCO_2e)
- 8km of open cut (in verge) 90mm HDPE SDR17 pipeline (143 tCO_2e, including pipe, cut and reinstatement)

This results in a total baseline figure of 220 tCO_2e, with an affordability of £850,000 (gross).

An example of one of the equations is presented below.

GHG emissions quantification equation (Clause 7.1.7 of PAS 2080)

B x A = F
Where B = Material/Activity quantity, A = Emissions Factor, F = Total GHG emissions per activity

Example calculation for laying 8km of open cut pipeline:

Total emissions for installation of HDPE pipe: 17.85 $kgCO_2e$/m x 8,000m = 142,770 $kgCO_2e$ = 143 tCO_2e

Appendix 3 provides the overall summary table of activities and materials required for establishing this baseline along with the relevant emissions factors and sources. Note that the above values are combined for GHG life cycle stages A1-5. Further detail is presented in Appendix 3.

Work Stages Definition – Early Design Phase Challenge

The designers now have a baseline, against which they must target the required 35% capital carbon reduction.

Step 5 – Determine where the carbon is
The designer should carry out an assessment of the baseline to identify hotspots in the standard solution as stated in **Clause 8.2** of PAS 2080.

Of the two activities to take place, the installation of a pumping station and 8km of new pipeline, the installation on the pipeline presents a significantly higher carbon impact, 65% of total emissions. This is therefore where designers should focus their initial efforts.

This information can be communicated to designers and suppliers to help focus on carbon reduction opportunities.

Step 6 – Challenge design of asset (Clause 6.1.4 of PAS 2080)
From this analysis the designer assesses the asset owners/managers' existing assets to try to find opportunities to re-use existing elements to reduce the need or demand of the new asset.

The designer identified an opportunity to re-use part of the existing pipe infrastructure, reducing the need for new construction.

The designer challenged the asset manager on the requirement to construct all new pipeline, proposing a solution to reuse 2km of pipe, reducing the new pipe installation to 6km.

Step 7 – Calculate GHG emissions in new design
The designer should follow Steps 1–3 again and activity data should be gathered either from previous projects and/or estimated by constructors for the project in question:

Example calculation for laying a 6km of open cut pipeline in a road:

Total emissions for installation of HDPE pipe: 17.85 $kgCO_2e$/m x 6,000m = 107,070 $kgCO_2e$ = 107 tCO_2e.

Pumping station impact remains the same: 184 tCO_2e.

The new design therefore has total estimated GHG emissions of 389 tCO_2e, a reduction of 16.2% versus the baseline figure.

Appendix 3 provides the overall summary table of activities and materials along with the relevant emissions factors and sources required to quantify the emissions of this design. Note that the above values are combined for GHG life cycle stages A1-5. Further detail is presented in Appendix 3.

Work stage Design – Design and Early Constructor Involvement

The new design has already achieved a reduction of 16.2%, however the asset manager is striving to beat its target.

The constructor is now involved and has challenged the assumed construction method to use an open cut technique whilst reviewing the design.

Figure 4 highlights where emissions are in the pipeline design and construction, and shows that 59% of emissions are life cycle stage A5 when using an open cut technique (construction and installation process).

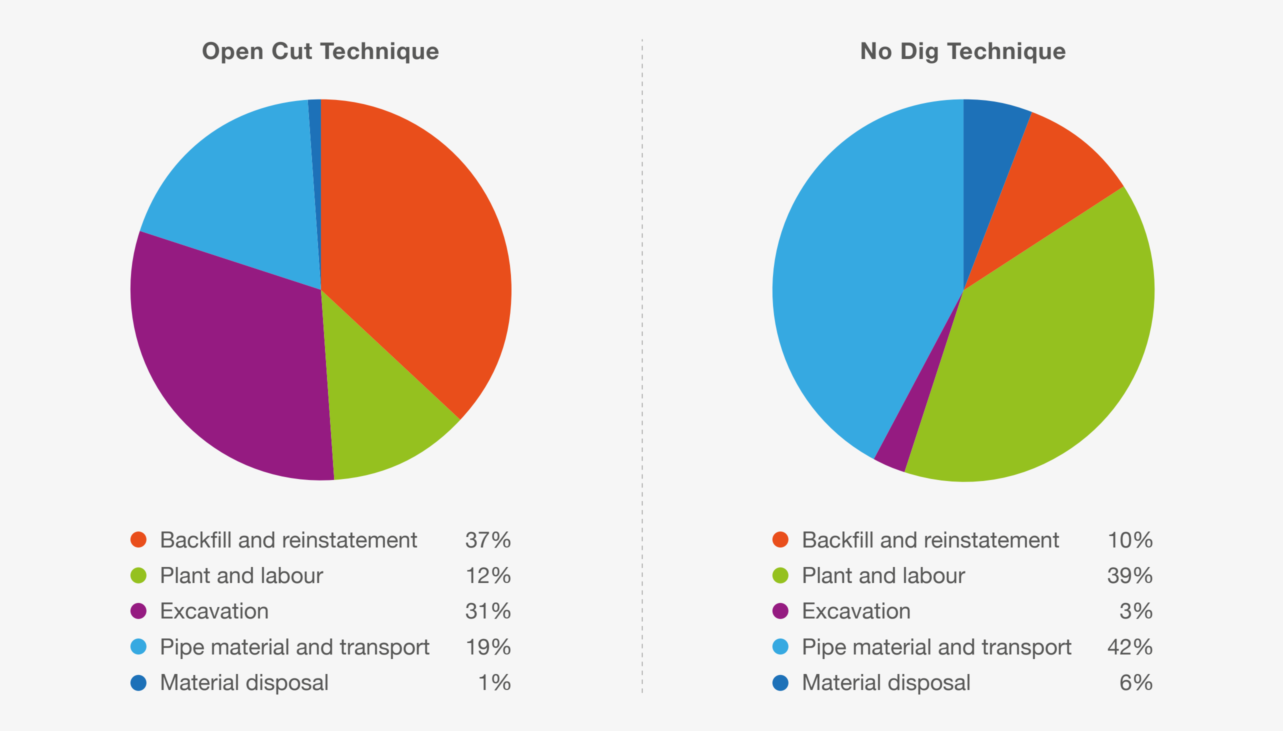


Figure 4: GHG emissions breakdown (A1-A5) – HDPE pipe in road, open cut technique vs. no dig technique
Source: PAS 2080: 2016

The constructor has suggested it would reduce programme to lay the pipe using a trenchless directional drilling technique. This would also reduce carbon emissions by reducing the need for excavation and reinstatement of the road.

Step 8 – Re-calculate emissions based on new construction technique
The designer should follow Steps 1–3 again and activity data should be gathered either from previous projects and/or estimated by constructors.

Trenchless directional drilling technique has a carbon impact of 8.82 $kgCO_2e/m$, a 51% reduction over the open trench technique included in the baseline.

The impact of the pipe is therefore: 8.82 $kgCO_2e/m$ x 6000m = 52,920 $kgCO_2e$ = 53 tCO_2e.

This challenge by the contractor to change the construction technique to trenchless directional drilling, reduces the overall impact to 130 tCO_2e, a saving of 41% over the original baseline.

Appendix 3 provides the overall summary table of activities and materials along with the relevant emissions factors and sources required to quantify the emissions of this design. Note that the above values are combined for GHG life cycle stages A1-5. Further detail is presented in Appendix 3.

Step 9 – Engage with suppliers to embed the saving
With potential savings identified during design, the asset owner/manager should include the design within any tender or procurement events and challenge suppliers to further reduce emissions associated with the infrastructure asset. This may include defining the works information clearly and including incentives for suppliers. The asset owner/manager should facilitate discussions between all value chain members to ensure that all the possible opportunities are explored.

The material supplier challenged the baseline emissions source of the pipe material, claiming a reduction can be made through new, efficient, manufacturing process.

Step 10 – Re-calculate emissions based on new material impact
The designer should follow Steps 1–3 again and activity data should be gathered from material suppliers.

Efficient manufacturing processes result in a 5% reduction in HDPE pipe.

Current impact of pipe material: 3.4 $kgCO_2e/m$ (of the 8.8 $kgCO_2e/m$ impact of trenchless directional drilling).

Accounting for a 15% reduction: 3.4 x 0.85 = 2.8 $kgCO_2e/m$.

The entire construction of trenchless directional drilling with new pipe impact is therefore: 8.65 $kgCO_2e/m$.

Impact of 6km of installation: 8.2 $kgCO_2e/m$ x 6000m = 48,990 $kgCO_2e$ = 49 tCO_2e.

The challenge by the material supplier, to include their new efficiently made material, reduces the overall impact to 125.99 tCO_2e, a 43% saving over the baseline.

Appendices

Appendix 1

Example data sources, quality applicability and content

Category[1]	Example LCI data	Benefits	Drawbacks
Generic	Bath Inventory of Carbon and Energy[2]	Freely available.	Only carbon and energy, not other environmental impacts.
		A lot of common construction materials.	Typically data is for raw materials therefore process emissions and wastage are likely to be missed.
Specific	Manufacturer specific Environmental Product Declarations	Freely available.	Not suitable for early design unless definitely limiting to that specific supply route.
		Reports information for exactly the products used.	Could be slight differences in interpretation of EN 15804.
		Has full environmental impacts.	Availability is currently limited but growing.
		Typically will include in-use and end of life impacts.	
		Specific to construction industry.	
		All (will be) compliant to same standard, EN 15804.	
	Supplier data (example)	Freely available.	Not suitable for early design unless definitely limiting to that specific supply route.
		Specific to construction industry.	Not all data in compliance with EN 15804

Category[1]	Example LCI data	Benefits	Drawbacks
Average	Industry average Environmental Product Declarations	Freely available.	Could be slight differences in interpretation of EN 15804.
		Ideal for early stage design comparisons before more specific information known.	Availability is currently limited but growing.
		Has full environmental impacts.	
		Typically will include in-use and end of life impacts.	
		Specific to construction industry.	
		All (will be) compliant to same standard, EN 15804.	
	Operational carbon data, such as: DEFRA[3], GHG Protocol[4] and IPCC data[5]	Freely available.	
		Regularly updated.	
Collective	Proprietary LCI databases, such as; GaBi/PE data[6], SimpaPro data[7], Ecoinvent[8]	Contain full environmental impacts.	Cost to use/access data.
		Some data has been aggregated to industry/ country level.	A lot of the data is not UK specific.
		A high level of credibility of the data.	There are limited construction specific products.
		Data is in one place and searchable.	Do not typically include other additional information that would be in EPDs such as in-use or end of life or descriptions of product and use.
		Freely available.	Not all data in compliance with EN 15804.
			Potentially too much/too detailed information for our requirements. (Perhaps a simplified/filtered dataset could be requested).
	Construction specific LCI databases such as IMPACT[9]	Full environmental impacts. (Can also be used for costs.)	Cannot access data without using licensed tools.
		Data is in one place and searchable.	Cost to use/access data through licensed tools.
		Specific to construction industry.	
		All data compliant to same standard, EN 15804 using the same interpretation.	
		Includes in-use and end of life impacts.	
Measured	Previous Project example	Actual representative data	Potentially only applicable to a unique scenario

Table A1: Sources of carbon emissions factors

Appendix 2

Carbon Emissions Reports

To drive sector consistency and to ensure that stakeholders have sufficient information to interpret its contents, it is recommended that carbon emissions reports include the following elements:

i. The purpose of the carbon management process or assessment;

ii. A description of the boundary for the carbon management process or assessment (including spatial and temporal scales and life cycle boundaries);

iii. Sources of information and data used;

iv. Methodologies used to calculate carbon emissions and a reference for any calculation tools used;

v. Assumptions and limitations including any exclusions and reasons for exclusion;

vi. A description of the baseline, including how it has been chosen/defined;

vii. A description of the functional unit(s) (i.e. means of comparison) and justification for selection;

viii. If applicable, a description of any alternative options considered (e.g. material choices, fuel types) and reasons for the selection of a preferred option;

ix. A description of actions that have been implemented (or proposed future actions) to reduce emissions; and

x. Emissions data in metric tonnes of CO_2 equivalent, separately for each GHG life cycle stage, as defined in **Clause 7**; and of performance in relation to the baseline, targets and KPIs set in accordance with **Clause 8**.

Appendix 3

Worked example supporting information

Table A1 and A2 below provide background calculations used for the worked example presented in Section 4. It should be noted that the data provided in the tables is subject to change and a made up example so should not be used to undertake any further calculations.

Material and Activities	GHG Life Cycle Stage	Nr	Unit	Emissions Factor	Unit	Total carbon $kgCO_2$/unit	Emissions factor (EF) source
Pipe material (used) – HDPE SDR 17	A1–3	1.3	kg mass per m	2.53	$kgCO_2e$/kg	3.40	ICE Version 2.0, High Density Polyethylene (HDPE) Resin – Pipe
Pipe material (wastage, assumed 2%) – HDPE SDR 17	A1–3	0.03	kg wastage per m	2.53	$kgCO_2e$/kg	0.07	ICE Version 2.0, High Density Polyethylene (HDPE) Resin – Pipe
Pipe transport to site	A4	0.01	t.km (assumed 65km distance)	1.888	$kgCO_2e$/km	0.02	EF from WI_GHG_Estimator_CAWv7.xls, March 2013 – value calculated from supplier transport data
Excavation of:							
Top soil	A5	2.00	m^3/m	2.43	$kgCO_2e/m^3$	4.86	CESMM4 2013 database, updated July 2013

Material and Activities	GHG Life Cycle Stage	Nr	Unit	Emissions Factor	Unit	Total carbon $kgCO_2$/unit	Emissions factor (EF) source
Excavation of:							
Sub-base (excavation and storing of material on site)	A5	0.22	m^3/m	2.76	$kgCO_2e/m^3$	0.60	CESMM4 2013 database, updated July 2013
Pipe installation – Labour							
Manhours	A5	0.20	Hrs/m	1.06	$kgCO_2e$/hr	0.21	EF from WI_GHG_Estimator_CAWv7.xls, March 2013 – value calculated from supplier installation estimate
Pipe installation – Plant							
Diesel Consumption	A5	0.60	L/m	2.67	$kgCO_2e$/l	1.60	WI_GHG_Estimator_CAWv7.xls, March 2013
Petrol Consumption	A5	0.15	L/m	2.30	$kgCO_2e$/l	0.34	WI_GHG_Estimator_CAWv7.xls, March 2013

Material and Activities	GHG Life Cycle Stage	Nr	Unit	Emissions Factor	Unit	Total carbon $kgCO_2$/unit	Emissions factor (EF) source
Backfill and re-instatement of:							
Sub-base – from stockpile	A5	0.15	m^3/m	2.47	$kgCO_2e/m^3$	0.37	CESMM4 2013 database, updated July 2013
Sub-base – imported natural material type 1	A1–3	0.06	m^3/m	33.34	$kgCO_2e/m^3$	2.01	CESMM4 2013 database, updated July 2013 + DEFRA transport
Excavated topsoil taken from temporary stockpile	A5	2.00	m^3/m	2.12	$kgCO_2e/m^3$	4.24	CESMM4 2013 database, updated July 2013
Material disposal of:							
Excavated Material other than topsoil, rock or artificial hard material removed from site – transported to tip 15km away	A5	0.01	m^3/m	8.49	$kgCO_2e/m^3$	0.11	CESMM4 2013 database, updated July 2013
						Total $kgCO_2e$ per m	17.85
						Total $kgCO_2e$ per 8km	142.77
						Total $kgCO_2e$ per 6km	107.07

Table A2: Supporting information for worked example in section 4 – open cut technique

Material and Activities	GHG Life Cycle Stage	Nr	Unit	Emissions Factor	Unit	Total carbon $kgCO_2$/ unit	Emissions factor (EF) source
Pipe material (used) – HDPE SDR 17	A1–3	1.3	kg mass per m	2.53	$kgCO_2e/kg$	3.40	ICE Version 2.0, High Density Polyethylene (HDPE) Resin – Pipe
Pipe material (wastage, assumed 2%) – HDPE SDR 17	A1–3	0.03	kg wastage per m	2.53	$kgCO_2e/kg$	0.07	ICE Version 2.0, High Density Polyethylene (HDPE) Resin – Pipe
Pipe transport to site	A4	0.01	t.km (assumed 65km distance)	1.888	$kgCO_2e$/ km	0.02	EF from WI_ GHG_Estimator_ CAWv7.xls, March 2013 – value calculated from supplier transport data
Excavation of:							
Top soil	A5	0.07	m^3m	2.76	$kgCO_2e/m^3$	0.19	CESMM4 2013 database, updated July 2013
Sub-base (excavation and storing of material on site)	A5	0.02	m^3m	2.43	$kgCO_2e/m^3$	0.04	CESMM4 2013 database, updated July 2013

Material and Activities	GHG Life Cycle Stage	Nr	Unit	Emissions Factor	Unit	Total carbon $kgCO_2$/ unit	Emissions factor (EF) source
Pipe installation – Labour							
Manhours	A5	0.44	Hrs/m	1.06	$kgCO_2e/hr$	0.47	EF from WI_ GHG_Estimator_ CAWv7.xls, March 2013 – value calculated from supplier installation estimate
Pipe installation – Plant							
Diesel Consumption	A5	1.00	L/m	2.67	$kgCO_2e/l$	2.67	WI_GHG_ Estimator_ CAWv7.xls, March 2013
Petrol Consumption	A5	0.25	L/m	2.30	$kgCO_2e/l$	0.57	WI_GHG_ Estimator_ CAWv7.xls, March 2013
Backfill and re-instatement of:							
Sub-base – from stockpile	A5	0.05	m^3/m	2.47	$kgCO_2e/m^3$	0.12	CESMM4 2013 database, updated July 2013
Sub-base – imported natural material type 1	A1–3	0.02	m^3/m	33.34	$kgCO_2e/m^3$	0.71	CESMM4 2013 database, updated July 2013 + DEFRA transport

Material and Activities	GHG Life Cycle Stage	Nr	Unit	Emissions Factor	Unit	Total carbon $kgCO_2$/unit	Emissions factor (EF) source
Backfill and re-instatement of:							
Excavated topsoil taken from temporary stockpile	A5	0.02	m^3/m	2.12	$kgCO_2e/m^3$	0.04	CESMM4 2013 database, updated July 2013
Material disposal of:							
Disposal of drilling fluid	A5	5.96	t.km	0.09	$kgCO_2e$/t.km	0.52	–
Excavated Material other than topsoil, rock or artificial hard material removed from site – transported to tip 15km away	A5	0.00	m^3/m	8.49	$kgCO_2e/m^3$	–	CESMM4 2013 database, updated July 2013
						Total $kgCO_2e$ per m	8.82
						Total $kgCO_2e$ per 8km	70.56
						Total $kgCO_2e$ per 6km	52.92

Table A3: Supporting information for worked example in Section 4 – no-dig technique

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