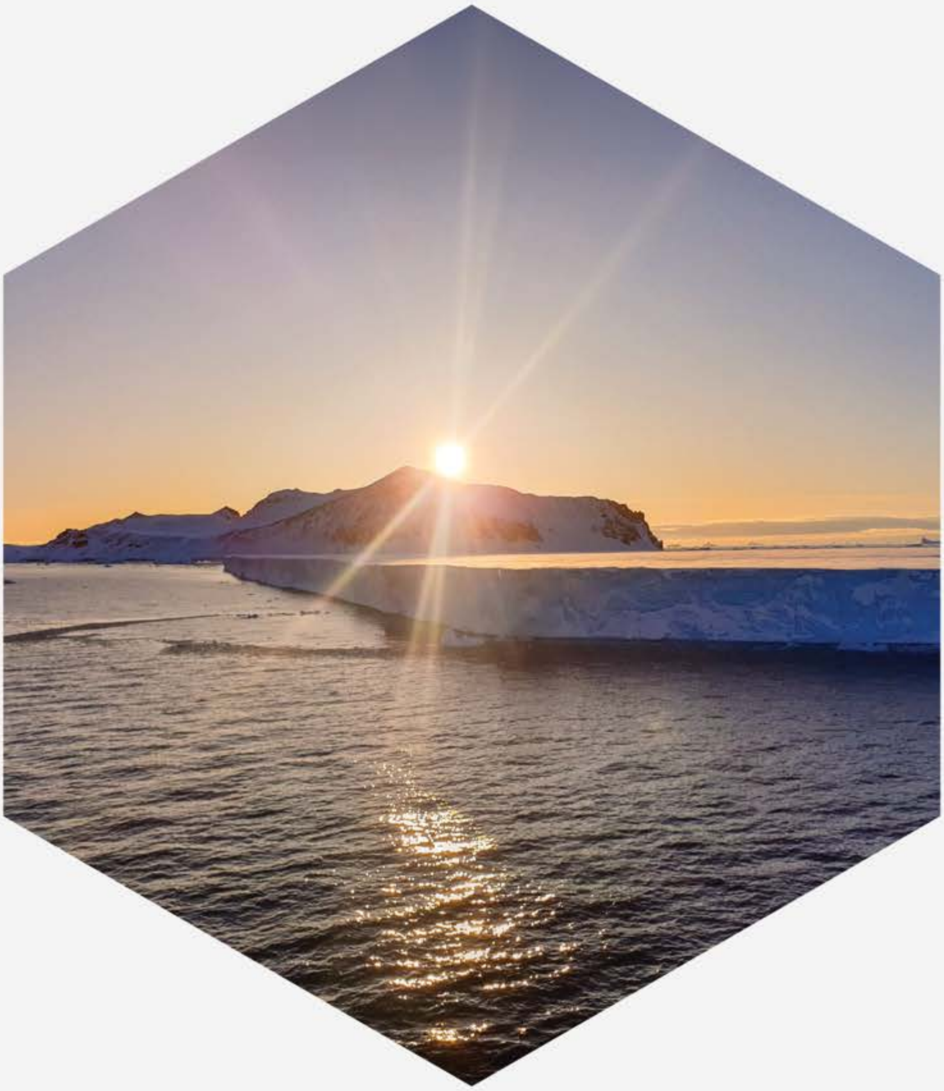
Carbon Measurement Fundamentals for Engineers

ENGINEERS AUSTRALIA



Version 1

Carbon Measurement Fundamentals for Engineers

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CSE Carbon Measurement Fundamentals for Engineers

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Executive Summary

The Australian Government is implementing mandatory climate-related disclosures for both Commonwealth entities, and entities required to lodge financial reports under the Corporations Act 2001 (Cth). These provisions are due to come into effect from 1 January 2025 for large institutions, rolling out to smaller institutions and all National Greenhouse and Energy Reporting (NGER) entities to 2027. Climate-related disclosures are a potent tool for increasing the visibility of an organisation's climate impact and holding it accountable for systemic management of transitionary climate risks.

The introduction of mandatory climate related financial disclosures is seen as a key regulatory instrument to introduce large-scale carbon accounting and by extension, carbon minimisation strategies in an internationally aligned disclosure reporting regime.

By means of example, up to 70% of Australia's annual greenhouse gas (GHG) emissions relate to the lifecycle of infrastructure through operational, enabled, and embodied emissions (Reference 1). Project emission reduction targets require whole of life carbon estimates as a basis for setting targets and demonstrating reductions. Reliable GHG emissions estimating and reporting, however, is a challenge for all involved in the creation and management of products, buildings, infrastructure and services. Engineers, scientists, and design professionals need training and support to engage with projects, communities and clients to deliver carbon reductions.

This Guide provides engineers with foundational knowledge on carbon measurement methods and considerations. Key concepts include:

- Economic and financial literacy to quantify, evaluate and present whole of life carbon costs, including Real Rate of Return (RRoR), carbon pricing and Net Present Value (NPV).
- Whole-of-life Carbon Assessment (WLCA) and Lifecycle Costing (LCC)
- Environmental Product Declarations (EPD)

The Carbon Fundamentals Working Group offers the following key insights:

Topic	Reference	Key Insight
The role of engineers	A8	The engineering workforce has an important role to play in the development, testing and application of carbon management and measurement practice.
Engineering demand & skilling	A9	Considerable climate policy progress in 2023/2024 by state and federal Government is driving accelerated carbon measurement, reduction and reporting in infrastructure. This highlights the urgent need to update the skills and knowledge of our engineering workforce to rise to this demand.
Environmental Product Declarations (EPDs)	B1.1	Major product suppliers must be required to supply independently certified Type III EPDs, allowing for greater analysis of critical issues such as materials and product substitution; and mandated reporting of GHG emissions.
Environmental Product Declarations for Construction Works	B1.2	While adherence to EN 15804 is possible without third-party verification, it is recommended that construction materials that align with both EN 15804 and ISO 14025 be selected for added assurance. There is potential confusion where project specific EPDs can appear to be type III at first glance but lack independent verification.
Australian Standards/practices	B1.3	Variation in data sources is a significant source of inconsistency between calculation and evaluation. Governments adopting globally recognised standards, beginning with EPD's and nationally consistent emission intensity factors will provide clearer direction to organisations and comparison of options.
Professional development	C2	Analysis of carbon reduction is most impactful during project planning and design processes. Whole of life carbon estimates as a basis for finding whole of life reductions will also require special training to engage with clients due to a likely consequential unfunded change to capital cost. Project optimisation does not usually extend beyond project handover to operations.

Figure 1 Summary of Key Insights

Part A: Introduction and Fundamentals

A1 Introduction

Undertaking credible carbon emissions estimation underpins both evaluation and reduction strategies. Without a measured carbon baseline, it is impossible to set targets and measure the effectiveness of decarbonising techniques. Part of enabling credible estimations is consistency & standardisation of calculation methods (including regularly updated emissions intensity factors for materials).

Nationally, there are a range of important developments that will enable greater consistency, standardisation and verification of carbon evaluation. For example, the Infrastructure NSW Embodied Carbon Measurement for Infrastructure Technical Guidance has been endorsed at a national level by the Infrastructure and Transport Ministers Meeting, and the Embodied Carbon tool by NABERS provides emissions intensity factors for a range of common materials found in the built environment and infrastructure projects. Further, the introduction of Climate-related Financial Disclosures from 1 January 2025, mandates that all entities captured under the scheme will be required to calculate and disclose all Scope 1, 2 & 3 emissions annually, driving consistency, standardisation and verification.

Engineers, scientists, architects and project developers will play an ever-increasing role in carbon evaluations, reporting processes and reduction techniques. Presently, the skills, experience and understanding required to facilitate this uptake is disparate between sectors and professions. It is the aim of this guidel to provide practical guidance through outlining a range of methods and concepts aimed at carbon measurement.

Engineering professions, however, hold key positions in capital projects and are bound by the Engineers Australia (EA) Code of Ethics. In particular, Engineers Australia members have a responsibility to demonstrate integrity, practice competently, exercise leadership and promote sustainability. Accordingly, engineers need to be aware of the available carbon evaluation methods outlined in this guide.

For noting, this document refers to carbon as meaning Greenhouse Gas (GHG) emissions, which includes carbon dioxide (CO_2) and other gases with a Global Warming Potential. Further, carbon emissions refer to those that result from the extraction, transport, manufacture, construction, use and disposal of materials, products and assets.

About Engineers Australia

As Australia's national body for engineering, we are the voice of 125,000-plus members. We provide our members with the resources, connections, and growth they need to undertake ethical, competent and high-value work in our communities.

A mission-based, not-for-profit professional association, Engineers Australia is constituted by Royal Charter to advance the science and practice of engineering for the benefit of the community. We back today's problem-solvers, so they can shape a better tomorrow.

Engineers Australia supports active strategies to manage the transition to a net zero emissions future and values the critical role of engineering in achieving that goal. In doing so, Engineers Australia established the Climate Smart Engineering (CSE) initiative which offers an annual conference, and the opportunity to establish member-led working groups on a range of climate-related issues. The *Carbon Measurement Fundamentals* working group is the first member-led working group to deliver a comprehensive guide under the CSE banner.

A2 Guide Structure

This Guide is intended to be used by all engineers and associated professions who wish to increase their understanding of carbon measurement to enhance their professional capability and deliver on ethical obligations to sustainable development.

The Guide introduces:

- The fundamental concepts associated with carbon measurement **(Part A)**

- Carbon in Materials and Products **(Part B)**
- Carbon in the Built Environment **(Part C).**

There is also a range of useful material in the Appendices to assist with managing, measuring and reducing carbon, for example, Appendix C-4 Standards recommended by MECLA.

A3 Carbon Fundamentals Working Group

The *Carbon Measurement Fundamentals* working group was developed under the Climate Smart Engineering banner, by Engineers Australia. The working group was convened by Simon Koger, Climate Change Manager, and was Co-chaired by Nolan Bear and Grant Scott, past chairs of the Cost Engineering Society and Chemical College respectively.

Objective

The objective of the working group was to undertake a preliminary review of best practices for measuring or calculating carbon emissions in the built environment. 'Built environment' is taken to include everything engineers build such as buildings, infrastructure, roads, defense assets and public transport.

The review scope spans the built environment lifecycle and whole-of supply chain to provide guidance and help inform deeper engineering considerations, practices, and delivery of carbon measurement approaches to carbon calculation.

A4 Role of engineers

Engineers are prominent influencers of the selection, design and implementation of projects. Engineers are well placed to identify interdependencies, synergies, and relationships between elements of products and projects. Engineers are able to engage with relevant stakeholders across an asset's lifecycle to identify and mitigate carbon risks with a range of technical problem-solving skills.

While it is not imperative for every engineer to be fully versed in the deep complexities of carbon accounting, it is essential to understand the fundamentals so as to support carbon assessments and evaluations as a means of informing project and operational decision making.

Further, understanding the basic techniques of project evaluation and an adequate appreciation of economic literacy will enable engineers to competently verse with finance professionals, project developers, and project managers in the optimisation of cost-benefits, including carbon, in projects.

Value proposition: For clients and the community

Engineers understand the scope behind cashflows. They use this understanding to mediate between the value behind project costs and risks, and the services and products derived by clients and consumers. Engineers also understand the technical requirements of existing systems and the feasibility of alternative technologies proposed to decarbonise them.

Value proposition: For engineers, architects, and science-based professionals

Understanding the basics of financial analysis will afford engineers a greater voice in project selection and optimisation. Gaining an appreciation for where carbon emissions occur within their designs, specifications, projects and assets also empowers engineers to innovate and identify where they can propose alternative, lower carbon solutions including net negative options.

A5 Emissions Boundaries

It is a well-established practice for organisations to classify emissions into 'scopes' defined by the GHG Protocol, as follows:

- Scope 1: Direct emissions from operations controlled by the entity
- Scope 2: Indirect energy emissions from imported energy such as electricity
- Scope 3: Other indirect emissions not included in 1 or 2.

This is consistent with emissions boundaries related to mandatory climate related disclosures for organisations and is how the Australian government categorises emissions for national reporting requirements, for example NGER.

For projects however, emission calculations are independent of the organisation and use lifecycle 'modules' defined by the EN15978:2011 and EN17472:2022 standards. These modules are:

- A0-A5 Upfront carbon (pre-construction, products and construction)
- B1-B8 In-use, operations and user carbon stages
- C1-C4 End of Life stages
- D: Benefits and emissions beyond the project lifecycle.

Overall, the use of a comprehensive boundary of assessment, covering all relevant and materially significant sources of carbon emissions across the lifecycle is a critical issue for robust carbon measurement, and a common area of inconsistency between projects.

Carbon is emitted by the creation and use of products and assets. Guidance documents and practices may focus on some carbon emitting activities more than others primarily due to their higher materiality. An example of whole of life carbon components are shown in Figure 2.

Common terms used to refer to components of carbon emissions include:

- **Cradle to Gate emissions:** A1-3 Product stages
- **Cradle to Grave emissions:** A1 Product to C4 End of life
- **Cradle to Cradle emissions:** A1 Product to D Benefits and loads beyond the asset lifecycle
- **Embodied carbon:** A1-5 Up-front + B1-5 In-use + C1-4 End-of life carbon

Refer to

Part C: Carbon in the Built Environment for further details.

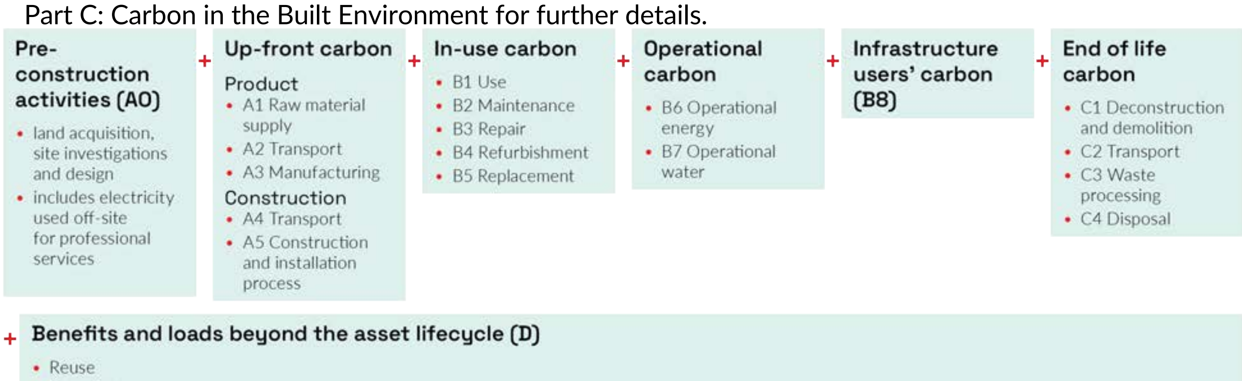

Figure 2 Whole of Life Carbon, Engineers Australia 2024

A6 Emissions Measurement and Analysis Process

While carbon accounting can be a complex and constantly evolving area of analysis, assessing carbon emissions for products, services, organisations, projects and assets commonly involves a few key steps.

- **Setting an assessment boundary:** Defining which relevant processes result in a carbon impact and need to be included in the assessment model. This may include imposing constraints on the assessment including physical, process, temporal and geographical limits of activities. See Appendix B-3 Key Points and issues of EN 15804 for details.
- **Establishing an inventory of activity data and emission factors:** Developing quantitative data to represent the activities with a carbon impact and compiling a set of best available factors which represent the quantity of greenhouse gases emitted per unit of activity. Refer NABERS emissions intensity database.
- **Evaluating results and integrating into decision making:** Combining activity data and emissions factors to develop an estimate of carbon emissions and analysing results to find key contributions and opportunities for reduction.

At a base level, cost accounting and carbon accounting have similarities. Project cost accounting uses Bills of Quantities showing the overall cost impact of each item as being the quantity multiplied by the unit rate (or “unit cost”); leading to a project cost which is the sum of each item. Carbon accounting is similar in that it determines the carbon impact of each item by multiplying the quantity by the carbon intensity (or “emissions factor”) associated with that type of item, and then the project carbon impact is the sum of the carbon impacts of each item. Therefore, the equation for the measurement of carbon is provided below.

$$Emissions\ (tCO_2e) = \sum_{x=1}^{n} Activity\ data\ (unit)_x\ \times Emissions\ factor\ (tCO_2e\ per\ unit)_x$$

Where:

- ‘x’ is an individual activity / process with a carbon impact
- ‘n’ is the total number of activities included within the assessment boundary.

For engineers involved in the carbon measurement process, it is critical they can:

- Evaluate whether an appropriate and consistent boundary has been identified, when using carbon estimates in decision-making.
- Provide relevant and accurate activity data to feed into carbon measurement inventories.
- Identify appropriate sources of emissions factors and understand their impact on the accuracy and comparability of emissions estimates.
- Effectively use estimates of carbon for their products, services, projects and assets to influence decision making, through multi-criteria analysis (MCA) or the use of carbon pricing for financial or economic assessment.

Integration of carbon measurement into existing decision-making models

Evaluation methods for carbon emissions are at present inconsistent. Methods which can effectively use carbon as a decision-making metric are:

- Insertion of carbon in multi-criteria analysis (MCA).
  By treating carbon as a percent weighted criterion, scored amongst other metrics such as cost, constructability, timing and other social or environmental issues, an MCA can produce an overall weighted score to compare project options. While commonly used and beneficial, this can have limitations related to subjectivity in scoring definitions and weighting allocation.

Whole of life cost model including a price on carbon emissions.
This is a more robust method of driving carbon emission decisions by using carbon pricing in a standard economic lifecycle model. By allocating a cost to carbon emissions, a lifecycle project cost and benefit can be assessed and optimised. This is discussed further in

- Part C: Carbon in the Built Environment.

Stages of assessment

Carbon measurement is typically undertaken in two key forms:

1) A forward-looking estimate of the expected carbon emissions, used to inform decision making and plan interventions for emissions reduction before they occur.
2) Monitoring and reporting of actual emissions from activities which have already occurred, used for disclosures and transparency as well as reflection on the impact of emissions reduction initiatives relative to targets set.

In common with cost estimating, the earlier a carbon assessment is undertaken, the lower the accuracy (and greater the uncertainty) but the greater the influence on the decision making for an engineer. Over time these estimates are firmed and assessed with greater confidence.

Project selection

Project selection begins with the minimum definition sufficient to identify project characteristics that allow ranking of projects compared to alternate options. For the purposes of this Guide, minimum characteristics include cost and carbon emissions on a whole of life basis. Where information is limited, these estimates can be derived through benchmarks from similar completed and reported projects across the sector and existing operations, combined with economic or financial carbon valuation.

Project execution

Following project selection and funding, and as the scope is refined, estimates and budgets are progressively defined, and accuracy improved using more developed quantities and more specific emissions data such as Environmental Product Declarations (EPDs)[1] applied to quantities.

As this project definition evolves, whole of life cost and carbon estimates are the basis for evaluations to reduce emissions (e.g. considering alternatives that address the largest contributions to the project's carbon impact) and consolidate the project benefits.

Reporting of cost and carbon expectations

Periodic reporting continues throughout project execution, enabling input into company reporting processes (which is becoming increasingly mandatory).

Project Completion

Actual assessed carbon emissions are reported based on as built quantities, certified EPDs where available, and final project data, leading into operations reporting.

See

Part C: Carbon in the Built Environment for the fundamental issues involved in measuring project carbon emissions.

A7 Targets for reductions in GHG emissions

At a national level, Australia's emissions reduction targets are calculated by sector and are evaluated against the Nationally Determined Contribution (NDC) as prescribed by the Paris Agreement. Presently, Australia has committed to a 43% reduction of 2005 emissions levels by 2030 and net zero by 2050. Various States and jurisdictions have differing (often more ambitious) emissions reduction targets, and these efforts will work to hasten Australia's NDC's.

Within sectors there are various regulatory schemes aimed at balancing emissions reduction with economic achievability. This invariably results in a mix of voluntary and mandatory regulatory requirements. Voluntary schemes coupled with the National Greenhouse Gas Reporting Scheme (NGERS) have been Australia's staple since the Emission Trading Scheme was revoked in 2012. Even the introduction of the Safeguard Mechanism in 2016 was largely ineffectual.

Despite a weak regulatory framework, large organisations have generally responded to Environmental, Social and Governance (ESG) reporting processes and have worked to improve rankings in this regard - largely as a means of demonstrating good corporate citizenship. Work continues to develop in a voluntary capacity with the introduction of:

- Infrastructure Victoria's 'Opportunities to reduce greenhouse gas emissions of infrastructure' (Reference 1), which outlines a recommendation to include a shadow price of carbon, set at $123 per tonne.
- NABERS 'Embodied Carbon Tool', including the National emission factors database which includes a list of Environmental Product Declarations (EPDs) (Reference 2).

However, as Australia's emissions reduction processes matures, there will be a greater mix of mandatory regulations coming into effect. There are a number of recent examples:

- Safeguard Mechanism Legislation Amendment (2023 Measures No. 1) Regulations 2023 and the Safeguard Mechanism (Crediting) Amendment Bill 2023.
    - o This amending legislation provided much needed robustness to the existing Safeguard Mechanism and requires 200 of Australia's largest emitters to reduce emissions by

[1] The most accurate environmental emissions data for products incorporated into projects is the Environmental Product Declaration (EPD). EPD's identify the carbon emissions incurred, due to the manufacture of a product. How EPD's can be used depends on the project data available for estimation.
Part B of this report provides more detail on the requirements for creation and use of an EPD.

4.9% annually to 2030, reducing their combined emissions total from 143Mt to 100Mt per year.

- Environmentally Sustainable Procurement (ESP) Policy and Reporting Framework
    - o This policy targets government procurement and focusses on emissions reduction and circular economy principles.
- Infrastructure Australia's Guide to assessing greenhouse gas emissions
    - o These requirements dictate the assessment and economic valuation of carbon within project business case submissions seeking federal funding
- Infrastructure NSW Decarbonising Infrastructure Delivery Policy and NSW Treasury Carbon value in cost-benefit analysis technical note
    - o This policy and guidance require carbon management throughout the infrastructure lifecycle for state funded projects and carbon valuation in business cases
- Climate Related Financial Disclosures, which will be further outlined in the next section.

> ***Key insight (A8):*** The engineering workforce has an important role to play in the development, testing and application of carbon management and measurement practice.

A8 Mandatory disclosures

The Australian Federal Treasury is implementing mandatory climate-related financial disclosures as outlined in the Treasury Laws Amendment (Financial Market Infrastructure and Other Measures) Bill 2024. This will require carbon disclosure for entities that are required to lodge financial reports under the Corporations Act 2001 (Cth).

Climate-related financial and carbon disclosure is a potent tool to manage systemic and organisational emissions.

	Required to lodge financial reports under Chapter 2M of the Corporations Act 2001 and falls within one (or more) of the following three categories (sustainability reporting thresholds)				
	Meet two of three reporting thresholds:			National Greenhouse and Energy Reporting (NGER) Reporters	Asset Owners (Registered schemes, Registrable superannuation entities and retail CCIVS)
	Consolidated gross revenue (For the financial	Consolidated assets (At the end of the financial year)	Employees		
Group 1 First annual reporting periods beginning on or after **1 January 2025**	$500 million or more	$1 billion or more	> 500	Above NGER publication threshold	**Scoped out of Group 1**
Group 2 First annual reporting periods beginning on or after **1 July 2026**	$200 million or more	$500 million or more	> 250	All other NGER reporters	$5 billion or more assets under management
Group 3* First annual reporting periods beginning on or after **1 July 2027**	$50 million or more	$25 million or more	> 100	N/A	Refer to other reporting thresholds (see left)

FIGURE 3 AUSTRALIAN GOVERNMENT, TREASURY. (REFERENCE 3)

A significant issue with the pace, scale and detail of the reporting required by Treasury is the availability of experienced and competent practitioners to implement and report. While the rollout of this legislation was deferred by six months from 1 July 2024 to 1 January 2025, this marginal delay won't necessarily impact both the capacity and skills shortages required to facilitate this new scheme.

> ***Key Insight (A9):*** *Considerable climate policy progress in 2023/2024 by state and federal Government is driving accelerated carbon measurement, reduction and reporting in infrastructure. This highlights the urgent need to update the skills and knowledge of our engineering workforce to rise to this demand.*

Part B: Carbon in Products

B1 Carbon content of products and use

Reporting and analysis of the carbon emissions generated by the lifecycle of products is referred to as the carbon content or embodied carbon of products. Assessing product level emissions is important not just to inform the optimisation of their design and manufacture, but also for their use in supporting organisational or project level carbon assessments and mandated reporting.

Whilst there are generic factors for the emissions intensity of different product types, the actual carbon content within products varies and accuracy to support a choice between low carbon products is dependent on declaration by suppliers. Sources like the Australian Life Cycle Inventory Database Initiative and the NABERS emissions factors database (July 2024) provide emissions intensity guidance.

These declarations are governed by International Organisation for Standardisation (ISO) and European standards that have Australian and International acceptance.

The first of these standards applies to all products and the second focusses on construction and operating.

ISO14025 Environmental Product Declarations (EPDs)

ISO 14025 focuses on Type III EPDs. EPDs are documents that provide information about the environmental performance of a product throughout its lifecycle.

Common environmental performance indicators include (but are not limited to):

- **Global Warming Potential (GWP):** The total greenhouse gas emissions associated with the product. This is measured in kg CO_2equivalent and is often differentiated by source (e.g. total, fossil or biogenic).
- **Resource Depletion:** The consumption of non-renewable resources such as minerals and fossil fuels.
- **Acidification Potential:** The release of acidic substances into the environment.
- **Eutrophication Potential:** The contribution to nutrient enrichment in water bodies.

These indicators provide a standardised set of metrics that allow engineers and associated professions to assess and compare the environmental performance of different products.

Type I, Type II and Type III environmental labels are three different approaches to providing environmental information about products, and they serve distinct purposes. The distinctions between these label types are reflected in their development processes, the level of transparency, and the scope of information provided.

- Type I environmental labels focus on overall environmental performance with third-party verification,
- Type II environmental claims involve self-declared claims made by the manufacturer.
- Type III environmental declarations are commonly referred to as Environmental Product Declarations (EPDs) and provide comprehensive and standardised information based on a lifecycle assessment, also with third-party verification which leads them to be often preferred for those seeking detailed and credible information about the environmental performance of products.

Type I environmental labels and Type II environmental claims can be used (with rigorous review) for estimates during project selection and execution. For further detail on EPD's see Appendix B-1 Environmental Labels and Appendix B-2 Certification schemes and supporting organisations.

Type III environmental declarations (EPDs) with independent certification are generally considered the most robust and transparent option for communicating environmental performance.

Key Insight (B1.1): *Major product suppliers must be required to supply independently certified Type III EPDs, allowing for greater analysis of critical issues such as materials and product substitution; and mandated reporting of GHG emissions.*

EN 15804 – Sustainability of Construction Works

EN 15804 specifically focuses on the core Product Category Rules (PCR) for construction products. PCRs define the rules and requirements for creating EPDs for a particular product category, ensuring consistency and comparability of environmental information.

It's crucial to recognise that the presence and acknowledgment of Type III EPDs can differ among regions and industries. Ensuring uniformity in data collection methods and the format of declarations is essential for effectively comparing all the available options. The development of 'EN 15804 – Sustainability of Construction Works' aims to address this challenge by providing a clear method for collecting and presenting data, alleviating the difficulty of comparing disparate information and ensuring a more standardised assessment.

For further detail on EN 15804 see: Appendix B-3 Key Points and issues of EN 15804.

Key Insight (B1.2): *While adherence to EN 15804 is possible without third-party verification, it is recommended that construction materials that align with both EN 15804 and ISO 14025 be selected for added assurance. There is potential confusion where project specific EPDs can appear to be type III at first glance but lack independent verification.*
Key Insight (B1.3): *Variation in data sources is a significant source of inconsistency between calculation and evaluation. Governments adopting globally recognised standards, beginning with EPD's and nationally consistent emission intensity factors will provide clearer direction to organisations and comparison of options.*

Part C: Carbon in the Built Environment

C1 Background

Analysis of a proposed project's cost and impact on whole of life carbon emissions are essential inputs to optimise the selection of projects that are both affordable and contribute to targets for carbon reduction. A basic understanding of these concepts will allow engineers to effectively engage with clients and teams tasked with selection and optimisation of projects and operations. These fundamental concepts are outlined below.

Embodied Carbon

Embodied carbon is the declaration by a producer of the carbon emissions generated (in kilograms of CO_2-equivalent emissions) to produce a unit of supply (such as per kilogram of steel beam). This measure is the basis for any report or analysis of carbon by industry and government.

Lifecycle Assessment (LCA), Whole Life Carbon Assessment (WLCA) and Lifecycle Costing (LCC)

There are various evaluation methods available to ascertain the environmental and carbon impact of products and processes. Lifecycle Assessment (LCA) is an established and comprehensive method that takes a systemic approach to environmental evaluation. LCA guidance for buildings and infrastructure is covered by the EN15978:2011 and EN17472:2022 standards respectively. Note that the LCA standards cover all environmental impacts and not only carbon emissions.

Building upon LCA in carbon evaluations is the Whole Life Carbon Assessment (WLCA), developed by the Royal Institution of Chartered Surveyors (RICS). This is an international benchmark of carbon evaluation that aligns carbon & cost reporting structures, has extended application across infrastructure types and has a longer lifecycle assessment period of up to 60 years.

Lifecycle costing (LCC) is an LCA with a carbon price included – like RICS WLCA.

Cost Modelling with Carbon

The unique concepts behind all comparative financial analysis of projects are the net present value (NPV) of money, the Real Rate of Return (RRoR), and the present value of the Ratio of Benefits compared to Costs (BCR) for any investment. Model costs and benefits can be escalated to future values, or, for early-stage proposals, they can be in current dollars with an applied RRoR.

Factoring carbon, the financial net present value (NPV) and the carbon NPV are tallied to provide an overall NPV value for use in financial comparison between projects and alternatives.

See Appendix C-1 Net Present Value, escalation, and the Real Rate of Return for further conceptual detail.

Sensitivity Analysis

The Office of Impact Analysis (refer Reference 4) describes sensitivity analysis as a method that shows how sensitive predicted net benefits are to different values of uncertain variables and to changes in assumptions. Conducting sensitivity analysis can determine how the cost of carbon and carbon reduction affects RRoR and Benefit Cost Ratio (BCR) depending on the assumed cost of carbon and carbon reduction. The Infrastructure Australia Guide to assessing greenhouse gas emissions (Reference 18) and NSW Treasury Cost Benefit Guide (Reference 5) mandate sensitivity analysis. The accompanying technical notes on the carbon value in cost-benefit analysis (Reference 6 and Reference 19) provide carbon emissions values and other guidance for the purpose of evaluating the sensitivity of cost-benefit analysis results to carbon costs.

C2 Assessment techniques

Different assessment techniques for carbon measurement apply at different stages of project development depending on the maturity of the project. This is analogous to the level of cost information used to make decisions at different stages of the project. Whether it is cost or carbon, sufficient detail is required for decision making. In early stages of a project, it is often possible to make decisions by high-level assessment of key differences between alternatives (i.e. ignoring all aspects that are common to the alternatives).

By means of example, the Embodied Carbon Measurement for Infrastructure: Technical Guidance (Guide), Infrastructure NSW, 2024, refers to three stages of project maturity:

- Stage 1 - Strategic Options and Business Case, which uses summary “asset level benchmark” measures of embodied carbon in initial project carbon estimates as part of project selection processes.
- Stage 2 – Planning Approval, Design and Procurement, which is used for design through to Procurement. Where appropriate, EPD’s are applied with preliminary designs and studies to find options to minimise whole of life carbon emissions at an acceptable cost.
- Stage 3 – Construction and Practical Completion, which is used for project construction through to hand over. Project carbon embodiment and whole of life emissions are estimated using detailed as built quantities applied to project data including EPDs.

> ***Key Insight (C2):*** *Analysis of carbon reduction is most impactful during project planning and design processes. Whole of life carbon estimates as a basis for finding whole of life reductions will also require special training to engage with clients due to a likely consequential unfunded change to capital cost. Project optimisation does not usually extend beyond project handover to operations.*

C3 Cost of Carbon

On an economy wide basis, the cost of carbon is typically measured in dollars per tonne of carbon dioxide equivalent (\$/tCO_2e). The value placed on carbon has many influences, especially geopolitically, and represents a range of both regulatory and physical costs.

Regulatory costs can be incurred nationally and internationally in the form of a carbon tax or levy on specific goods and services, emissions trading schemes (ETS), mandatory carbon reporting and disclosure frameworks or in the form of a carbon border adjustment method (CBAM), which addresses carbon leakage between countries in the form of an adjustment levy.

Physical costs are generally incurred at the sector level and are represented as the physical cost of carbon abatement itself. For carbon emitting organisations, this could mean costs incurred in research, development & commercial innovation of decarbonising methods, products and materials; or if an organisation needs to purchase carbon offset units (Australian Carbon Credit Units - ACCU's in Australia's case) as a means of balancing high emissions from their activities.

Australia has no mandatory carbon tax, and so pricing is subject to varying influences and estimations, suggesting a shadow carbon price. A shadow price may also gauge future social impacts and net present values over time. At a minimum, however, there is an international and economy wide effort to decarbonise which will invariably put pressure on firming the value of carbon.

Specifically, as regulatory and physical costs of carbon mature over time, further carbon pricing definition will naturally occur, establishing a more reliable pricing framework with which to factor into projects and processes. This will likely be in the form of a carbon price per square metre for the built environment, and economy wide consensus on a dollar value per tonne of carbon.

Presently, there is substantial variation in carbon pricing and listed below are some key estimations from relevant agencies:

- Infrastructure Australia's 'Valuing emissions for economic analysis' suggests that in 2024 the average price should be AUD56/t CO_2e, growing to AUD377/t CO_2e in 2050.
- Australian Transport Assessment and Planning (ATAP) guides adopt a static carbon price of AUD60/t CO_2e without escalation over time.
- The ACT Government which uses an interim static value of AUD20/t CO_2e applied to government operations only.
- The NSW Government and Infrastructure Victoria uses values based on the European Emissions Trading Scheme (ETS) where the carbon value is equal to AUD123/t CO_2e in 2023, rising 2.25% pa to AUD150/t CO_2e in current dollars by 2032. The escalation rate of 2.25% is real, so modelling needs to add nominal escalation or use a RRoR.

C4 Boundary Setting and Categorisation

The concept of emissions boundaries is introduced in Part A5.

The GHG Protocol was established as a framework for corporate GHG inventories and hence its application to projects depends on the organisation's perspective.

Typically, the head contractor allocates project emissions to Scopes. However, this creates confusion for the principal as almost all projects deliver emissions that are their Scope 3.

Therefore, there is a trend to define project emissions independent of the organisational perspective, by using lifecycle 'modules' defined by the EN15978:2011 and EN17472:2022 standards. These include:

- A0-A5 Upfront carbon (pre-construction, products and construction)
- B1-B8 In-use, operations and user carbon stages
- C1-C4 End of Life stages
- D: Benefits and loads beyond the project lifecycle.

The use of a comprehensive boundary of assessment, covering all relevant and materially significant sources of carbon emissions across the lifecycle is a critical issue for robust carbon measurement, and a common area of inconsistency between projects. See Appendix B-3 Key Points and issues of EN 15804 for further details.

C5 LCC span of evaluation

Example service life durations considered in a WLCA/LCC include:

- Buildings: 60 years (Green Star Buildings), 60 years (RICS WLCA, Reference 8)
- Fit outs: 10 years (Green Star Buildings), 20 years and 60 years (RICS WLCA)
- Infrastructure: 120 years (RICS WLCA), 50 years or the shortest live design life (ISC).

C6 Using emissions factors in project modelling

Project selection must use consistent, widely agreed emission factor datasets as a critical aspect of comparability. For some emissions sources, such as those covered by the Australian National Greenhouse Account Factors, there is a greater degree of consistency and ease of access. For materials, however, there is wider variation and often a lack of accessibility, leading to inconsistencies across projects.

In early stages, prior to products being specified, generic emission factors representing default conservative and credible average emissions intensities can be used. At present, there are several workstreams establishing these for datasets for buildings and infrastructure:

- ‘Embodied carbon measurement for Infrastructure technical guidance April 2024.’ Infrastructure NSW. Default assumptions for emission intensity rates.
- NABERS have released an Australian wide emissions intensity database for infrastructure projects.
- Australian National Lifecycle Inventory Database (AusLCI) databases are generally appropriate sources until these datasets are established.

In later stages of project execution, and where available, use supplier EPDs in place of generic data. In the absence of EPDs, emissions intensities from Climate Active Product Disclosure Statements are the next preferred source for individual products.

During project development, including evaluation of alternative project concepts, it is important to ensure that competing options must have consistent boundaries, assumptions, and techniques. Any variances in the emissions intensity between products, for example, must be substantiated using independently verified EPD’s with consistent functional units and boundaries.

It is generally not appropriate to compare rates for projects with well-developed options at later project stages, with estimates of a higher uncertainty for projects at earlier stages, without appropriate adjustment.

C7 Contingency and the uncertainty of estimates

Many standards emphasise the use of one or more design iterations of carbon assessment. Practitioners should be mindful of the potential for misleading outcomes in the early stages as the data sources will update as the design progresses.

Just like estimates of money, estimates of carbon will evolve with project definition. A major policy issue is the need for independent assessment and review of carbon declarations and estimates just like for building inspections. Engineers can't wait for perfect estimates, so they proceed to optimise design and procurement with what they have while recognising in the final project report that they need to generate a validated final assessment.

For example, a concrete strength must be assumed for an assessment to be completed prior to any significant structural design. Higher strength concrete mixes generally require larger cement quantities which is the main contributor to the embodied carbon content of the material. As concrete can be a significant source of embodied carbon in a project, under or over-estimating the required concrete strength can produce arbitrary reductions or increases in total carbon, with no connection to improvements from conscious design decisions.

Default contingency factors to account for uncertainty, adapted from the Royal Institute of Chartered Surveyors (RICS) Whole Life Carbon Assessment for the Built Environment (refer Refence 8), are summarised. These contingencies for the carbon estimate should be applied to the project cost estimate including the cost contingency.

TABLE 1 DEFAULT CONTINGENCY FACTORS

Project phase	Default contingency factor to apply to all lifecycle stages and modules
Early design	15%
Technical design and construction	6%
Post-completion	0%

C8 Further resources

A selection of further resources relating to the calculation of embodied carbon in the built environment is provided below:

- **Refer to Parts C2 and C3 for a detailed summary** of techniques and resources used by experienced carbon assessment professionals.
- **NABERS default set of emissions intensity factors** for sources of upfront carbon emissions for buildings and associated infrastructure.
- **Climate Active** (Reference 7), an Australian Government program that supports national policy by driving voluntary climate action and certification by Australian businesses, provides a raft of practical resources including guides for how to be climate neutral and how to measure and certify performance of upfront carbon for buildings.
- **Federal and State Governments** have, and continue to develop, a variety of resources to provide guidance on carbon targets and policy and methods for evaluating options. Examples include:
    - Guide to assessing greenhouse gas emissions', March 2024, Infrastructure Australia,
    - Valuing emissions for economic analysis', February 2024, Infrastructure Australia,
    - Technical note to NSW Government Guide to Cost-Benefit Analysis TPG23-08 and
    - Embodied carbon measurement for Infrastructure technical guidance April 2024.' Infrastructure NSW and adopted by the other states & territories.
- **The Green Building Council of Australia** provides a practical guide to reduce upfront carbon emissions in new buildings and major refurbishments, refer Reference 12.

Climateworks recommends techniques such as using carbon as a separate weighted criteria under a multi-criteria analysis (MCA); opting for the lowest cost whole of life selection of opportunities that achieve a desired target reduction (as shown in Figure 4).

Marginal Abatement Cost Curve:

For Companies to manage their mandated emission targets they will need to allocate budgets and optimise their portfolio of capital projects relative to both cost and emissions. The strategy and funds allocated is a material issue to shareholders and financiers.

One useful technique is to plot a portfolio of possible projects on a bar chart of \$/t CO_2e against the cumulative emission reductions. This chart is called a Marginal Abatement Cost Curve (MACC) and is a way of prioritising potential energy efficiency and carbon reduction projects and ranks them based on their potential economic and carbon impact.

Refer an explainer below and further advice on using MACC's in Reference 18:

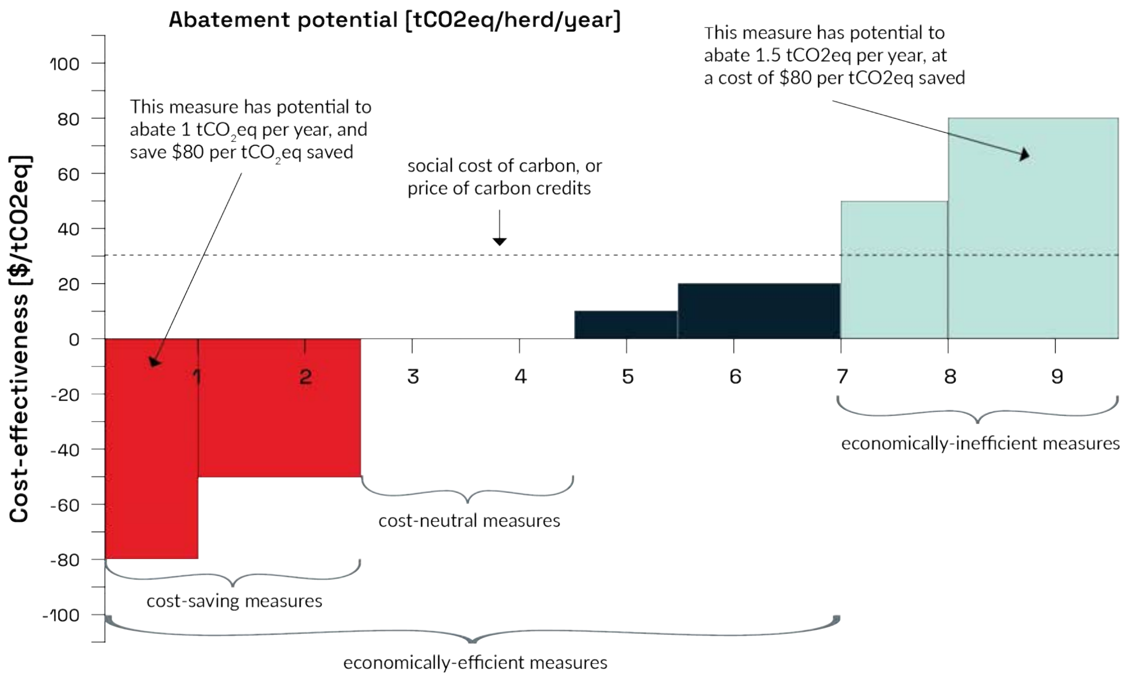

FIGURE 4 MARGINAL ABATEMENT COST CURVE EXPLAINER
(Reference 10)

Appendix A-1 Glossary

Term	Definition	Source
Activity data	Data based on a unit quantity of input or output of the studied system or a process within it. Can be a physical quantity such as mass (kg). a unit of cost ($), or a unit of energy (kWh)	PAS2080 (2023)
Assessment boundary	Defines the unit processes to be included in the assessment model. Boundary constraints may include physical, process, temporal and geographical limits of activities to assess GHG emissions and removals. Also known as a system boundary.	RICS (2023) PAS2080 (2023)
Benefit cost ratio (BCR), aka Cost Benefit Ratio (CBR)	BCR: equal to the sum of the NPV of the cashflow of benefits divided by the sum of the NPV of the cashflow of costs. A common financial measure for ranking potential projects. Also called CBR but calculated the same as BCR	
Biogenic Carb**on**	Carbon Dioxide captured by growing organisms such as plants, fungi and bacteria, or emitting following their combustion or decomposition.	
Carbon Accounting	Carbon accounting is a way of categorising and reporting how much greenhouse gas an organization emits.	
Carbon Dioxide Equivalents (CO_2e)	A standard measure that takes account of the global warming potential of different greenhouse gases and expresses the effect in a common unit.	DCEEW (2023)
Carbon emissions	Commonly used interchangeably with 'greenhouse gas emissions'; refer to greenhouse gas emissions.	-
Carbon footprint	A measure of the GHG Emissions that are attributable to an activity. A carbon footprint can relate to the emissions of an individual, household, organisation, product, service, event, building or precinct. This can also be known as a carbon inventory or carbon account and typically has an implied span of time. Also known as a GHG footprint, carbon inventory, GHG inventory.	MECLA (2022)
Carbon price	In the absence of a regulated price, carbon pricing is defined as a shadow price which is used by an entity to assess the financial implications of changes to investment, production and consumption patterns, and of potential technological progress and future emissions-abatement costs. An entity can use an internal carbon price for a range of business applications. Two types of internal carbon prices that an entity commonly uses are: • a shadow price, which is a theoretical cost or notional amount that the entity does not charge but that can be used to understand the economic implications or trade-offs for such things as risk impacts,	IFRS (2023) SR2

Term	Definition	Source
	new investments, the net present value of projects, and the cost and benefit of various initiatives; and • an internal tax or fee, which is a carbon price charged to a business activity, product line, or other business unit based on its greenhouse gas emissions (these internal taxes or fees are similar to intracompany transfer pricing).	
Embodied carbon	GHG Emissions associated with materials and construction processes throughout the whole lifecycle of a building or infrastructure being the sum of upfront embodied carbon, in-use embodied carbon, and end-of life embodied carbon, measured as CO_2e.	MECLA (2022)
Emission factors	The quantity of greenhouse gases emitted per unit of some specified activity. Emission factors are used to convert a unit of activity into its emissions equivalent. E.g. a factor that specifies the kilograms of CO_2-e emissions per unit of activity.	DCEEW (2023)
Environmental Product Declaration (EPD)	An independently verified and registered document that communicates transparent and comparable information about the life-cycle environmental impact of products and services in a credible way. An EPD is compliant with the standard ISO 14025 and is known as a Type III environmental declaration. Many compliant EPD schemes exist globally.	MECLA (2022)
Functional Unit	Quantified performance of a product system for use as a reference unit	ISO 14044
FX or FOREX	Foreign exchange variance, generally the variance to Australian dollar	
Global warming potential (GWP)	Represents the relative warming effect of a unit mass of a greenhouse gas compared with the same mass of CO_2 over a specific period. Multiplying the actual amount of gas emitted by the GWP gives the CO_2-equivalent (CO_2-e) emissions. The GWPs generally used are those from the IPCC Fifth Assessment Report (AR5), consistent with rules agreed under the Paris Agreement.	DCEEW (2023)
Greenhouse gas (GHG) emissions	Release of a greenhouse gas into the atmosphere. Also commonly referred to in shorthand as solely ‘carbon emissions’ in many areas, but where done so, is generally intended to refer to all greenhouse gases.	ISO IWA 42:2022
Greenhouse gases	Gaseous constituents of the atmosphere, both natural and anthropogenic, that contribute to the greenhouse effect. Water vapour (H2O), carbon dioxide (CO_2), nitrous oxide (N2O), methane (CH4) and ozone (O3) are the primary GHGs in the Earth’s atmosphere. Humanmade GHGs include sulphur hexafluoride (SF6),	IPCC (2021) GHG Protocol (2011)

Term	Definition	Source
	hydrofluorocarbons (HFCs), chlorofluorocarbons (CFCs) and perfluorocarbons (PFCs). Typically, water vapour and ozone are not included within GHG accounting at a corporate or project level which is limited to the six gases covered by the United Nations Framework Convention on Climate Change (UNFCCC): carbon dioxide (CO_2); methane (CH4); nitrous oxide (N2O); hydrofluorocarbons (HFCs); perfluorocarbons (PFCs); and sulphur hexafluoride (SF6).	
Lifecycle Costing (LCC)	Lifecycle Costing is a standard cash-flowed estimate of costs and benefits over the lifetime of an asset. LCC accounts for the present value of a cashflow and accounts for escalation and FX. Comparison of total costs to benefits at a defined rate of return allows a financial comparison of projects.	MECLA (2022)
Lifecycle Assessment (LCA)	An analysis of the environmental and/or social impacts of a product, process or a service for its entire lifecycle. It looks at the raw material extraction, production, manufacture, distribution, use and disposal of a product. Note that a full Lifecycle Assessment typically considers multiple impact categories beyond just GHG emissions.	MECLA (2022)
Lifecycle stages	Defined stages throughout the lifecycle of a building or infrastructure, such as Raw material supply, Transport, Manufacturing, Construction and Installation, Use, Maintenance, etc. Typically defined through modules (e.g. A1, A2… B1, B2, etc) as set out in EN 17472 (Civil engineering works) and EN 15978 (Buildings).	MECLA (2022) EN 17472 EN 15978
Multi-criteria analysis (MCA)	An analysis tool that differentiates and evaluates options using a set of project-specific criteria with weights assigned to each criterion. The analysis involves scoring and weighting each option against each criterion. MCA can be used for analysing a list of options against how they address problems and opportunities, but should not be used by itself to shortlist options.	Infrastructure Australia Guide to multi-criteria analysis (2021)
Net Present Value (NPV) or just present value (PV)	Any cashflow of costs and benefits can be represented by how much money in a bank account today at a given interest rate or return is required to pay for a future cashflow	
Operational carbon	Greenhouse gas emissions and removals associated with the operation of an asset, network and/or system required to enable it to operate and deliver its service	PAS2080 (2023)
Residual emissions	Greenhouse gas emission that remains after actions to implement emissions reductions.	ISO IWA 42:2022
Real Rate of Return (RRoR)	The nominal interest rate or return reduced by the average expected escalation rate	

Term	Definition	Source
Scope 1 Emissions	Direct emissions of greenhouse gases from sources that are owned or operated by a reporting organisation	GHG Protocol (2011)
Scope 2 Emissions	Indirect emissions from the generation of purchased energy consumed by a reporting organisation	GHG Protocol (2011)
Scope 3 Emissions	All indirect emissions (not included in scope 2) that occur in the value chain of the reporting organisation, including both upstream and downstream emissions.	GHG Protocol (2011)
Social cost of carbon	The net present value of aggregate climate damages (with overall harmful damages expressed as a number with positive sign) from one more tonne of carbon in the form of carbon dioxide (CO_2), conditional on a global emissions trajectory over time.	IPCC (2018)
Upfront carbon	The emissions caused in the materials production and construction phases of the lifecycle before the building or infrastructure begins to be used.	MECLA (2022)
User carbon	Greenhouse gas emissions associated with users' use of an asset, network and/or system, and the service it provides during operation. A common example may be the emissions associated with vehicles driving on a road asset during its operational life. Also sometimes referred to as enabled carbon.	PAS2080 (2023)
Whole life carbon Assessment (WLCA)	Sum of greenhouse gas emissions and removals from all work stages of a project and/or program of works within the specified boundaries. Covers upfront, in-use, operational and end of life carbon impacts.	RICS (2023) PAS2080 (2023)

Appendix A-2 Working Group members, consulted organisations and key technical manuals

Working Group Members

Simon Koger: Working group Convenor. Climate Change Manager, Engineers Australia.

Nolan Bear: Chair; past chair Australian Cost Engineering Society

Grant Scott: Co-Chair; past Chair Chemical College

Keith Sharp: Alt co-chair; Chair Chemical College

Gregory Laver: Associate, Structural Engineer Northrop Consulting Engineers

Skye Blair: Associate Director, KPMG

Rebecca Dracup: Principal, Sustainability Team Leader, Stantec

James Wilkinson: Senior Associate Climate Response & ESG, Jacobs

Julie Atkinson: A/g Director Engineering, Infrastructure Division, Department of Finance and Treasury, Victoria

Consulted Organisations

- National Greenhouse and Energy Reporting (NGER): Australia Government Treasury mandated reporting of GHGe emissions, including enforcement penalties.
- Infrastructure Australia (IA): carbon measurement and parameters for selection of projects.
- NSW Infrastructure (INSW): procedures for consistent measurement of carbon.
- Materials and Embodied Carbon Leaders Alliance (MECLA): Industry based programs driving reductions in embodied carbon for products used in the building and construction industry.
- National Australian Built Environment Rating System (NABERS): buildings rating system assessed after completion.
- Greenhouse Building Initiative and others with NABERS.
- The Upfront Carbon for Buildings Guide: This guide focuses on the delivery phase of the building lifecycle, A1 to A5.
- Australian Institute of Architects (AIA): professional (CPD) training for architects.

Standards and Manuals:

- ISO Aus 14025 Sustainability in Buildings and Civil Engineering Works – Core Rules for Environmental Product Declarations of Construction Products and Services.
- ISO21930 Environmental labels and declarations - Type III environmental declarations - Principles and procedures.
- EN 15804 (Euro standard) Sustainability of construction works - Environmental product declarations - Core rules for the product category of construction products.
- BSI PAS 2080:2023 (UK standard) Carbon management in buildings and infrastructure.
- RICS (2023) (UK based) Whole life carbon assessment (WLCA) 2nd edition.
- Sustainable Procurement Guide: Australian Government.

Appendix A-3 Role of engineers in achieving low carbon emissions and reporting results

Carbon Management Process

ENGINEERS ARE WELL SUITED TO DEVELOP CARBON MANAGEMENT PROCESSES FOR PROJECTS, OR WORKFLOWS FOR ASSET OWNERS, AT EVERY WORK STAGE (AS SHOWN IN FIGURE 5 EXAMPLE CARBON MANAGEMENT PROCESS FROM PAS 2080:2023
(Reference 13)

Engineer's role in decarbonisation includes:

- Quantification of Operational Impacts
- Design Influence
- Actions and activities for project selection, implementation and operations.

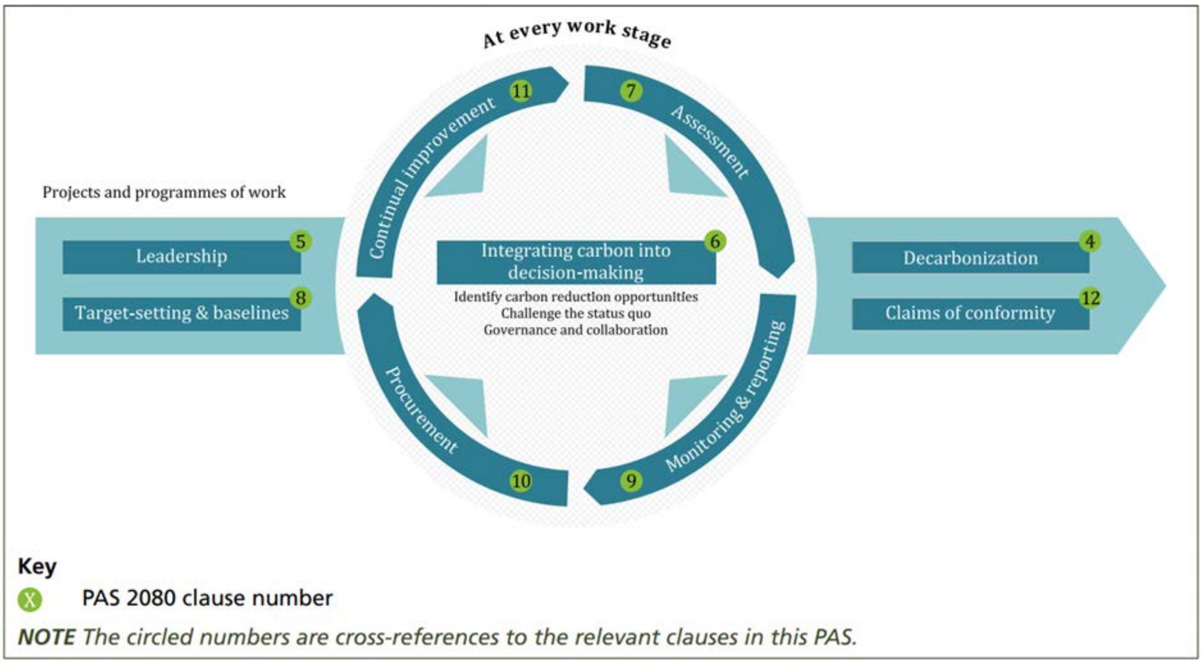

FIGURE 5 EXAMPLE CARBON MANAGEMENT PROCESS FROM PAS 2080:2023
(Reference 13)

Quantification of Operational Impacts

Quantity surveyors and Building Information Management (BIM) systems often provide material quantities; however engineers and architects are typically needed to decipher the materials listed and map these to the most appropriate elements from a Lifecycle Inventory database.

Assumptions need to be made around materials, products and services, which requires a broader understanding of the building project contents such as the structural design, utilities, pre-assembly and on-site construction methods.

Design Influence

Engineers are prominent design influencers. They are well placed to identify interdependencies, synergies and relationships between elements of their project and engage with relevant stakeholders to identify carbon reduction opportunities and risks.

Engineers should implement carbon reduction opportunities in the following order of priority (hierarchy of control) to have the greatest influence on a project's carbon impacts:

1. Avoid emissions.
2. Switch to options that offer lower carbon emissions.
3. Improve remaining items by reducing intensity of emissions.

Project selection, implementation and operations

Engineers can play a key role in decarbonisation through the following actions and activities for project selection, execution and operations:

Project selection

- Support asset owners in identifying and implementing carbon reduction opportunities, including brokering collaborations with relevant stakeholders.
- Challenge existing standards, guidance, and requirements, that have an impact on whole life carbon.
- Participate in selection of projects to achieve maximum carbon emission reductions at affordable cost.
- Assess and report on expected whole life carbon emissions.
- Include decarbonisation requirements and targets in project definition.

Project execution

- Set clear requirements and guidance for their own suppliers working on projects and programs to help prioritise whole life carbon reduction outcomes.
- Enable/encourage cross-discipline coordination to drive low-carbon solutions throughout design development.
- Develop a culture to encourage design and technological innovation that drives decarbonisation.
- Engage with value chain members in the contract to agree on decarbonisation solutions.
- Provide decarbonisation options in tenders for project purchasing.
- Comply with targets defined by the asset owner/manager for the project or program of work and challenge targets where there is potential for improvement.
- Monitor and report on carbon emissions and identify hotspots.

Project Completion and operation

- Assess total carbon emissions using certified EPD where possible and project data.
- Demonstrate how the carbon reduction targets have been followed.
- Document recommendations for low carbon operations.
- Provide a strategy for future adaptability and material recovery.
- Develop further decarbonisation proposals to asset owners.

Appendix B-1 Environmental Labels

A good resource for information on environmental labelling:
https://www.iso.org/files/live/sites/isoorg/files/store/en/PUB100323.pdf

Type I Environmental Labels

Characteristics:

- Third-party verified.
- Comprehensive and standardised information.
- Covers multiple environmental aspects.

Purpose:

- To communicate a product's overall environmental performance.
- To facilitate comparisons between products within the same product category.

Examples:

Eco-labels like the Australia's Energy Rating Programme, Fairtrade, and Australia Certified Organic. Ecolabels used throughout Australia can be found at the following website:
https://www.ecolabelindex.com/ecolabels/?st=country,au

Type II Environmental Claims

Characteristics:

- Type II Environmental labels are created by the product manufacturers or suppliers based on their own assessments and data.
- Self-declared, not independently verified.
- The information provided is typically generic and may not be as comprehensive or standardised as in Type III Environmental label or EPD.
- The credibility of Type II Environmental Labels relies on the trustworthiness of the manufacturer or supplier making the claims.
- May focus on specific environmental attributes rather than the overall product lifecycle.

Purpose:

- To allow manufacturers to make specific environmental claims about their products.
- To provide basic environmental information without third-party verification.

Type III Environmental Declarations or Environmental Product Declarations (EPDs)

Characteristics:

- Type III Declarations follow the guides set by standards like ISO 14025.
- Based on Lifecycle Assessments (LCA) and consider the environmental impact of a product from raw material extraction to disposal.
- Provide detailed and verified information, allowing for more accurate comparisons between products.

Purpose:

- To be transparent, comparable and trustworthy, providing consumers and businesses with credible environmental information to make informed choices.

Appendix B-2 Certification schemes and supporting organisations

Examples of Australian and International Certification schemes based on EPD's

The International EPD® System is a global program for Type III EPDs. It follows the ISO 14025 standard and provides a framework for the development and registration of EPDs worldwide. Products with International EPD® System labels have undergone a rigorous process of lifecycle assessment and third-party verification.

Green Building Certification Programs

National Australia Built Environment Rating System (NABERS) is a performance-based rating system with an up to 6 stars rating. The scheme is managed by a National Administrator and funded by the NSW government.

Green Building Council of Australia (GBCA)

The GBCA manage the 'Green Star' rating scheme for buildings, fitouts and communities and is Australia's largest voluntary rating scheme. They also provide education and advocacy and represent over 650 member organisations.

Infrastructure Sustainability Council (ISC)

ISC manage the Infrastructure Sustainability (IS) rating scheme for planning, design, construction and operations of infrastructure assets and portfolios. They also provide education, supplier connections, advocacy and collaboration platforms amongst members.

LEED (Leadership in Energy and Environmental Design) required and recognises Type III EPDs for certain building materials and products. LEED encourages the use of products with environmental declarations that meet ISO 14025.

Global GreenTag

Global GreenTag is an Australian-based organisation that provides environmental product certifications and EPDs based on lifecycle assessment principles. Global GreenTag covers a wide range of construction and building products.

The reporting of its LCA studies is issued as an ISO 14025 compliant EPD. These summary LCA reports where requested or relevant to local scheme requirements, can also be reported in accordance with ISO 21930 or EN 15804"[2].

Australian Lifecycle Assessment Society (ALCAS)

Australian Lifecycle Assessment Society (ALCAS) is an Australian organisation that promotes lifecycle assessment (LCA) and sustainable practices. While not directly providing EPDs, they may be a resource or a point of contact for information on LCA and sustainability in the construction and infrastructure sectors. In 2014, ALCAS partnered with International EPD Programme to develop Australasia EPD.

[2] Global GreenTag. The world's best eco products. Certified.

Appendix B-3 Key Points and issues of EN 15804

EN 15804 specifically focuses on the core Product Category Rules (PCR) for construction products. PCRs define the rules and requirements for creating EPDs for a particular product category, ensuring consistency and comparability of environmental information.

Key Points of EN 15804 include:

- **Product Information:** Identification of the product and its intended use.
- **Lifecycle Assessment (LCA):** The standard requires a lifecycle assessment that considers various environmental impacts such as resource use, emissions, and energy consumption. Additional information such as databases and tools used to carry out the LCA should also be clarified.
- **Functional Unit:** The functional unit, which represents the function of the product and serves as a basis for comparison, is defined in accordance with the standard.
  For example, concrete is measured in cubic meters of concrete (m3). Different concrete products can be easily compared if all EPDs for concrete are presented in cubic meters of concrete.
- **System Boundaries:** The standard outlines the system boundaries for the lifecycle assessment. This ensures that all relevant stages of the product's life, from raw material extraction to disposal, are considered. System boundaries typically include stages such as raw material extraction, manufacturing, transportation, use, and end-of-life disposal.

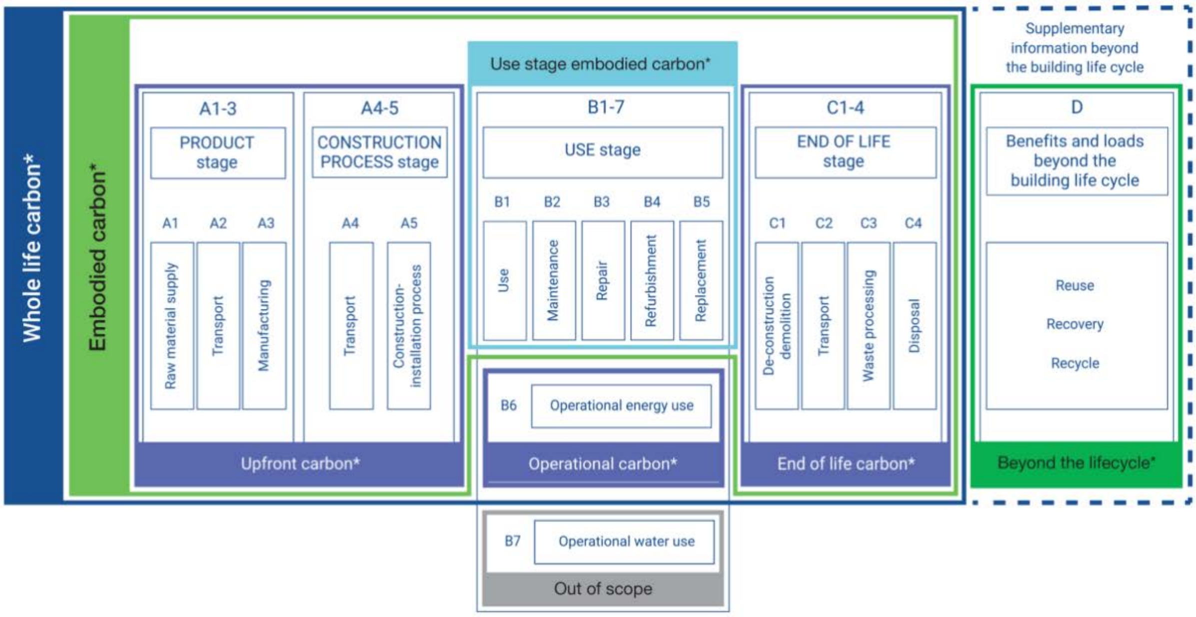

FIGURE 6 TERMINOLOGY AND RELATED LIFECYCLE STAGES

(Reference 14)

Many construction materials with EPDs, only cover A1, A2, and A3 of the product’s full lifecycle. Often referred to as “Cradle to Gate”, A1-A3 covers raw material supply, material transport to the manufacturing facility, and the manufacturing process. EN 15804 specifies the environmental performance indicators that should be included in the EPD, providing a standardised set of metrics for reporting.

Transport to construction sites and environmental impacts from the installation or construction process are generally assessed on a project-by-project basis. This is driven by the variance in travel distances, mode of transport and construction methodologies.

Project Specific EPDs

Project-specific EPD's can cause some market confusion, because some European peer EPD programme operators offer the option to publish non-third party verified LCA-reports via their EPD systems.

These reports are essentially ISO14021 (type II) self-declared environmental claims that do refer to EPDs, but do not fulfil the third-party verification requirements under ISO14025. Often these reports claim ISO14025 compliance but are accompanied with notations regarding the EPDs' internal verification or self-declaration characteristics[3].

Before comparing product-specific EPDs check that these items are similar from a system boundaries perspective:

- **Declaration Format**: The standard defines the format and structure of the EPD, ensuring that the information is presented in a clear and standardised manner to facilitate comparison between different products.
- **Assumptions and Exclusions**: Assumptions made during the assessment and identifying any stages or aspects excluded from the study. This may include stating whether waste products used in the manufacturing of the product have been considered to be burden-free, as they are classified as a recycled material.
- **Review and Verification:** EN 15804 establishes requirements for the review and verification of EPDs to ensure their accuracy and reliability. EN 15804 does not specifically mandate third party verification although it does recommend that it be carried out.

[3] Refer to The International EPD System, https://www.environdec.com/home

Appendix C-1 Net Present Value, escalation, and the Real Rate of Return

The two simple concepts behind all comparative financial analysis of projects are net present value (NPV) of money and Real Rate of Return (RRoR).

Net Present Value

NPV can be conceptualised as the amount of money needed in the bank today, at a given interest rate, to pay for a future cashflow.

So, if a project requires $100 in one year's time and it has a bank account that pays 10% pa interest, then it needs approximately $91 in the account today. i.e.

$91 deposited today

+ $91 x 10% pa = $9 interest over a year

= $100 total available in one year

So, $91 is NPV of $100 in one year's time at a return of 10%.

This can be extrapolated to a compound NPV of $83 to achieve $100 balance in 2 years and so on.

Any future cash flow of costs and benefits can be represented by the sum of its NPVs.

NPV Compound Formula:

$$NPV = 1 / (1+i)^n$$

Where: i =interest % per period and power of n = number of periods

Impact of escalation and the concept of real return

Price escalation reduces the future buying power of money and this reduces the effective return.

With an escalation rate of 3%, $100 will buy $97 worth of goods in one year.

So, to achieve $100 buying power in one year's time we must increase the NPV, in the example above, by $3 to $94.

The 'real' rate of return is a convenient approximation that reflects the impact of escalation.

For this example the return in a year is reduced to (10% interest rate - 3% escalation rate =) 7%. This 7% is commonly referred to as the 'real' rate of return and is applied to a cashflow in current dollars.

NPV Compound Formula including escalation impact:

$$NPV = (1 + e)^n / (1+i)^n$$

Where: e = escalation % per period, i =interest % per period and power of n = number of periods

For significant projects where credible forecasts of the required nominal return, escalation, and foreign exchange (FOREX) rates are available, a comprehensive model will use forecast escalation in the country of origin, FOREX rates and nominal forecast returns, rather than the simple approximation that is imbedded in a RRoR. See the following LCA model for how these formulas calculate out.

Australian Governments have generally used a RRoR of 7%. Corporations generally have a much higher Weighted Average Cost of Capital that incorporates return to owners and cost of loans.

Appendix C-2 Sample project Lifecycle Cost model

Including a price on carbon emissions.

Included below is a sample WLCA Excel model that demonstrates the essential elements of incorporating a price on carbon into a LCC model.

BCR is the most frequently published measure of a cost model. This model generates a BCR = sum of the NPV of the cashflow of benefits Divided by the sum of the NPV of the cashflow of costs.

Year number	0	1	2	3	4	5	6	7	8	9	10	Total
Investment:												
Project ($'000)	$ 5,000	$ 100									$ 300	**$ 5,400**
Operations ($'000)		$ 100	$ 100	$ 100	$ 100	$ 100	$ 100	$ 100	$ 100	$ 100	$ 100	**$ 1,000**
Total cost ($'000)	**$ 5,000**	**$ 200**	**$ 100**	**$ 100**	**$ 100**	**$ 100**	**$ 100**	**$ 100**	**$ 100**	**$ 100**	**$ 400**	**$ 6,400**
Carbon:												
Carbon (tCO2e)	10.0	2.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	3.0	**23**
Carbon Price ($/tCO2e)	$ 123	$ 126	$ 129	$ 131	$ 134	$ 137	$ 141	$ 144	$ 147	$ 150	$ 154	
Carbon Cost ($'000)	$ 1,230	$ 252	$ 129	$ 131	$ 134	$ 137	$ 141	$ 144	$ 147	$ 150	$ 461	**$ 3,056**
Total Cost ($'000)	**- 6,230.0**	**- 451.5**	**- 228.6**	**- 231.5**	**- 234.4**	**- 237.5**	**- 240.6**	**- 243.7**	**- 247.0**	**- 250.3**	**- 861.0**	**- 9,456**
NPV Cost ($'000)	**- 6,230.0**	**- 422.0**	**- 199.7**	**- 189.0**	**- 178.9**	**- 169.3**	**- 160.3**	**- 151.8**	**- 143.7**	**- 136.1**	**- 437.7**	**- 8,418**
Income:												
Production (kt)		8.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	**134**
Average sale ($/t)		$ 180	$ 180	$ 162	$ 146	$ 131	$ 131	$ 131	$ 131	$ 131	$ 131	**$ 144**
Total income ($'000)	$ -	$ 1,440	$ 2,520	$ 2,268	$ 2,041	$ 1,837	$ 1,837	$ 1,837	$ 1,837	$ 1,837	$ 1,837	**$ 19,292**

NPV Income ($'000)	$ -	$ 1,346	$ 2,201	$ 1,851	$ 1,557	$ 1,310	$ 1,224	$ 1,144	$ 1,069	$ 999	$ 934	**$ 13,636**
Carbon (A1-A3)												
Carbon (tCO2e)	10.0	2.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	3.0	**23**
Production (kt)	-	8.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	**134.00**
Carbon intensity (A1-A3)												
tCO2e / t production	**NA**	**0.25**	**0.07**	**0.07**	**0.07**	**0.07**	**0.07**	**0.07**	**0.07**	**0.07**	**0.21**	**0.17**
Financial Return:												
Cashflow Net $'000	-$ 6,230	$ 988	$ 2,291	$ 2,037	$ 1,807	$ 1,600	$ 1,597	$ 1,593	$ 1,590	$ 1,587	$ 976	$ 9,836
NPV Cost	-$ 6,230	-$ 422	-$ 200	-$ 189	-$ 179	-$ 169	-$ 160	-$ 152	-$ 144	-$ 136	-$ 438	-$ 8,418
NPV Income	$ -	$ 1,346	$ 2,201	$ 1,851	$ 1,557	$ 1,310	$ 1,224	$ 1,144	$ 1,069	$ 999	$ 934	$ 13,636
Cumulative NPV	**-$ 6,230**	**-$ 5,306**	**-$ 3,305**	**-$ 1,642**	**-$ 264**	**$ 876**	**$ 1,940**	**$ 2,933**	**$ 3,858**	**$ 4,721**	**$ 5,217**	
									Benefit cost Ratio (BCR):			**1.62**
									RRR			**23.2%**

The above model is provided as an indicative example only. Different subjects of assessment will justify different boundaries and sources of cost, revenue and carbon. Carbon price 'escalation' rate is assumed at 2.25% real (additional to price escalation). RRoI is assumed at 7%. This will vary depending on the project client and context.

Appendix C-3 Advanced carbon assessment syllabus

Topic	Organisations	Products and services	Buildings/Infrastructure
Key drivers	**Gov** Federal and State government targets, treasury mandatory reporting obligations being introduced, NGER reporting in some instances. **Private** Investor/financier and other stakeholder pressures, mandatory climate reporting being introduced (AASB SR1, ISSB IFRS SR2, CSRD), NGER reporting, safeguard mechanism, Carbon Border Adjustment Mechanism (CBAM), stranded asset risks	The contribution of products to organisational targets and commitments (top-down) Increasing consumer expectations and maintaining competitiveness Implications of Carbon Border Adjustment Mechanism (CBAM) on pricing in overseas markets Increasing adoption of third-party certifications (e.g., Climate Active) Potential for cost savings and greater supply chain efficiency	Targets from private and government proponents flowing down contractually in project delivery requirements. Changes to government policy (e.g., NSW Sustainable Buildings SEPP, NABERS, Infrastructure Australia business case requirements, INSW decarbonising infrastructure policy, Vic Recycled First, etc) Increasing adoption of sustainability rating schemes as minimum delivery expectations for government agencies (Green Star, Infrastructure Sustainability scheme) Increased valuations for buildings with Green Star ratings
Relevant Standards	Australian Accounting Standards Board (AASB) SR1 International Financial Reporting Standards (IFRS) SR2 GHG Protocol National Greenhouse and Energy Reporting (NGER) Carbon Emissions Reduction Transparency (CERT) scheme ISO 14064.1 ISO 14068-1 ISO IWA42:2022 Net Zero Guides Science Based Targets initiative (SBTi)	ISO 14040 / 14044 ISO 14067 EN 15804+A2 GHG Protocol for Products Climate Active	PAS2080 Green Star Infrastructure Sustainability scheme RICS Whole life carbon assessment (WLCA) EN15978 EN 17472 NABERS Embodied Emissions guidance (to be released) INSW Embodied Carbon Measurement for Infrastructure Technical Guidance
Emissions definitions	Scopes (1, 2, 3) as per GHG Protocol	Lifecycle stages / Modules (A, B, C, D) as per ISO/EN standards (particularly for building products) or Upstream/core/downstream (for other products)	Lifecycle stages / Modules (A, B, C, D) as per ISO/EN standards

Topic	Organisations	Products and services	Buildings/Infrastructure
Frequency / stages of assessment	Commonly annual reporting is retrospective (financial or calendar year aligned) Forecasting scenarios into the future is common for planning decarbonisation pathways	Product design stage (estimates) Annual updates (actual production reflections)	Planning and Business case (prediction) Environmental Approvals (prediction) Design (prediction) Construction (as-built, actuals, retrospective) Operational typically wrapped up in organizational unless reporting under frameworks such as NABERS or GS and IS Operations ratings (actuals, retrospective)
Functional or declared units and benchmarks	Depends heavily on the organisation, can be aligned with activities (e.g. tCO_2e/product or tCO_2e/tonne) or revenue metrics (e.g. tCO_2e/$M)	Depends on the product function and product category rules (PCR)	Declared units for different typologies within the INSW Embodied Carbon Measurement for Infrastructure Technical Guidance
Calculation tools (not exhaustive)	Avarni Persefoni IBM Envizi sustain.life Microsoft Sustainability Cloud Climate Active calculators Etc, etc	OpenLCA SimaPro GABi Etc, etc	Cerclos eTool OneClick LCA Speckel The Footprint Calculator IS Materials Calculator Green Star Upfront Carbon NABERS (in development) TfNSW Carbon Tool (in trials) Austroads ANZ Carbon Tool (in development)
Emission factor sources	National Greenhouse Accounts Factors Environmental Product Declarations via EPD Australasia or EPD international AusLCI Footprint Labs Supply Chain GHG Factors (ex IELab) Climate Active carbon inventory	Default carbon intensity emission rates for infrastructure. National Greenhouse Accounts Factors Environmental Product Declarations via EPD Australasia or EPD international AusLCI Climate Active carbon inventory	Embodied carbon measurement for Infrastructure technical guidance April 2024. National Greenhouse Accounts Factors Environmental Product Declarations via EPD Australasia or EPD international NABERS (in development) AusLCI
Data sources	Metering / sub-metering Invoicing and procurement/sales records (e.g. fuel card data) Supplier engagement and reporting Asset registers Proxies and estimates	Product team take-offs and predictions Invoicing and supplier reports Supplier engagement and reporting Metering / sub-metering	Shifts over the delivery cycle of the asset. Begins with benchmarks, then QS / Cost teams and digital modelling extracts in early stages and moves through to monitoring through metering, invoices, supplier engagement and reporting during delivery

Topic	Organisations	Products and services	Buildings/Infrastructure
Pricing mechanisms	Government organisations -> Treasury CBA guidance or other pricing methods (e.g. IA valuing emissions guide, NSW CBA guide, ACT pricing, Vic Government interim recommendations) Potential future adoption of frameworks like social cost of carbon or target-consistent pricing. Private organisations -> Offset costs or safeguard mechanism credits costs (where applicable), costs of renewable energy certificates (RECs) e.g. Large Scale Generation Certificates (LGCs) or similar. Target-consistent pricing based on marginal abatement cost curves or similar. Use of similar shadow pricing to test sensitivity for scenarios of future mandatory carbon pricing exposure	As per organisations (depends on the use by the parent organisation)	Infrastructure -> Depends if it is funded through state or federal sources, if so, will be increasingly a requirement to include in business cases. Value is pending resolution by Infrastructure Australia but there are temporary values such as NSW CBA guidance pricing, ACT price, VIC government interim price or ATAP Environmental Parameter Guides Buildings -> as per organisations (depends on the use by the developing organisation) but may also be appropriate to adopt some shadow pricing of offsets and RECs under future Green Star requirements for 'Climate Positive Buildings' where there are Green Star targets in place
Common pitfalls or difficulties (where do people go wrong or get stuck)	Focusing on a limited boundary e.g. • Energy related Scope 1 and 2, without considering fugitive/process emissions or implications on value chain and Scope 3 • Focusing on upstream emissions impacts of the supply chain without considering the impacts of downstream emissions and customers Inappropriate use of the operational control or relevancy principles Changing boundaries or calculation methods over time and not re-baselining or capturing variations	Focusing on a limited boundary e.g. • Energy consumption of the parent organisation, without considering implications on the broader value chain • Upstream emissions impact of the supply chain without considering the lifecycle impacts (repairability, efficiency of use, lifespan and end of life) Use of inappropriate emission factor datasets	Focusing on a limited boundary e.g. • Looking at the emissions associated with only materials or only upfront carbon without considering broader lifecycle implications. • Neglecting the impact of land-use • Lack of consideration to, or sole reliance on, induced/enabled emissions from users of the infrastructure or benefits and loads beyond the boundary. Use of inappropriate emission factor datasets Lack of access to activity data at early stages Lack of consideration to external factors and changes over time in whole of life modelling (e.g. decarbonising electricity grid, uptake of electric vehicles)

Topic	Organisations	Products and services	Buildings/Infrastructure
Key risks from a lack of consideration	Investment in growth strategies and assets that are not aligned with a transition to a low-carbon society (stranded assets and/or failing business model) Lack of access to finance Declining shareholder/stakeholder confidence Reputational kickback and consumer neglect Exposure to future carbon pricing Litigation risk (e.g. watchdog crackdowns on greenwashing, consumer class action lawsuits)	As per organisational	Creation of stranded assets and the need for significant retrofits to meet future requirements for a low carbon society. Unable to secure business case support and funding due to inadequate consideration of carbon Missed revenue opportunities (due to increased value of sustainable building stock)

Syllabus provided by James Wilkinson, Jacobs.

Appendix C-4 Standards recommended by MECLA

There are many standards readily available which provide comprehensive and science-based methods and measurement procedures. While engineers in Australia may more commonly work day-to-day with the methods outlined in certification and rating schemes such as NABERS, Green Star, and Infrastructure Sustainability, these schemes reference recognised standards for the underlying protocols. Below is an adapted selection of standards developed by MECLA per its Upfront Carbon in the Built Environment Discussion Paper (Reference 15) which may be applied to any project seeking to quantify its carbon impact.

Note: Please refer to the most recent advice from MECLA as the authoritative source as standards are rapidly evolving.

TABLE 2 HIERARCHY OF STANDARDS ADAPTED FROM MECLA'S UPFRONT CARBON IN THE BUILT ENVIRONMENT DISCUSSION PAPER, 2022

Application	Application Description	Broader environmental impact categories (multi- indicator including carbon)	Carbon Footprint (single indicator)
Products	Standards which provide requirements and guidance for quantifying/ communicating the footprint of a product/material.	EN 15804:2019 ISO 14025:2006 ISO 21930:2017	GHG Protocol - Product Standard ISO 14067:2018 PAS 2050: 2011
Buildings	Standards that provide requirements and guidance for assessing the footprint of a building (base building and or fitout / whole building)	EN 15978:2011 ISO 21929-1:2011 ISO 21931-1:2010	International Cost Management Standard 3 RICS - Whole of life carbon assessment for the built environment PAS 2060 ISO 14067:2018
Infrastructure	Standards that provide requirements and guidance for assessing the footprint of infrastructure (e.g. road / rail / dam / port etc.)	ISO 15392:2019 ISO/TS 21929-2:2015 ISO 21931-2:2019	International Cost Management Standard 3 ISO 14064-1:2018 PAS 2080
	Lifecycle Assessment	ISO 14040:2006 / ISO 14044:2006	
Organisational/ Business emissions reporting	Standards that provide requirements and guidance for companies/organisations to report emissions and understand environmental footprint	ISO 14007:2019	GHG Protocol - Corporate Standard

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