



INFRASTRUCTURE AND
TRANSPORT MINISTERS

Embodied Carbon Measurement for Infrastructure

Technical Guidance

2024

FOR USE BY THE AUSTRALIAN GOVERNMENT, STATES AND TERRITORIES

Contents

Contents	a
1 About this Guide	3
2 Terms and definitions	5
3 What to measure?	9
Life cycle stages and system boundary	9
Embodied carbon	12
Operational and asset user carbon	12
General exclusions.....	12
Optimising whole life carbon	13
4 When to measure?	16
Three key measurement stages	16
Purpose of measurement at each stage	17
5 How to measure?	18
Overview of measurement process	18
Calculation approaches by project stage	18
Data hierarchy	20
Suitability of data sources at each stage of measurement.....	21
Emission factors and carbon intensity benchmarks.....	22
Emission factor and carbon intensity benchmark hierarchy	22
Stage 1 – Business case (measurement guidance).....	24
Use of early project details and carbon intensity benchmarks	24
Stage 2 – Planning approval, design and procurement (measurement guidance).....	27
Minimum inclusions	27
Scope and completeness of assessment.....	28
Stage 3 – Construction and practical completion (measurement guidance).....	30
Updating assessment with available actual quantity data	30
Additional measurement guidance	31
Consistency in options analysis and comparisons	31
Using contribution analysis to inform decision-making.....	32
Measuring carbon reductions through stages of measurement	33

6	How to report?	36
	Monitoring and reporting.....	36
	External reporting requirements.....	36
	Use of functional or declared units.....	37
	Stage 1 – Business case (reporting guidance)	38
	Stage 2 – Planning approval, design and procurement (reporting guidance)	40
	Stage 3 – Construction and practical completion (reporting guidance)	41
7	References	42
	Appendix 1: Addendum to the Technical Guidance	44
	Appendix 2: Supporting tools and resources	52
	Appendix 3: Default emission factors	54
	Appendix 4: Detailed worked example – social infrastructure	62
	Appendix 5: Data required and potential sources	73
	Appendix 6: How to source emission factor data from literature	75
	Appendix 7: Asset level carbon intensity benchmarks	78
	Appendix 8: Asset specific minimum inclusions	89
	Appendix 9: Default calculation assumptions	96
	Appendix 10: Reporting templates	106
	Appendix 11: Recommended declared units	112

1 About this Guide

The *Embodied Carbon Measurement for Infrastructure: Technical Guidance* (Guide) is designed to support consistent measurement of embodied carbon by infrastructure delivery agencies, their advisors, delivery partners, and emissions tool vendors. This Guide supports consistency across all Australian jurisdictions by providing common methodology, assumptions, approach to data use, and reporting approaches.

Measurement of embodied carbon is crucial for its effective management. Embodied carbon emissions are set to form a major and increasing part of infrastructure related emissions, as the electricity grid transitions to decarbonised sources and operational emissions decline.¹

The Guide sets out the scope and methodology to support consistent measurement and reporting of embodied carbon emissions across public infrastructure projects. It is anticipated that this Guide will evolve over time to enhance measurement and reporting as maturity increases across Australian jurisdictions and infrastructure delivery agencies (see Box 1). The entity responsible for coordinating future updates to this Guide and data collation will be confirmed as part of implementation process.

Box 1: Policy context for embodied carbon measurement

Embodied emissions are those that result from the construction, maintenance, and end-of-life disposal of an asset. Government policy and regulatory responses targeted at emissions reduction are currently focused on operational emissions. However, embodied carbon emissions are set to form an increasingly significant share of emissions from infrastructure over the coming decades, as the electricity grid transitions to decarbonised sources and operational emissions decline.

The absence of a consistent approach to measurement is a key barrier to reducing embodied emissions. At the NSW *Decarbonising Infrastructure Delivery* roundtables in 2022, consistent measurement was identified as a top priority for Government action due to the significant disparities that can be found in estimates of embodied carbon. This Guide addresses that key barrier by setting out a consistent scope of carbon to measure and approach to measuring across infrastructure asset types.

This document should be read in conjunction with the relevant jurisdiction-specific Addendum to the Guide. Each Addendum is intended to support measurement in addition to the scope and methodology set out in this Guide. A template is provided in Appendix 1 outlining the way in which jurisdictions may provide additional measurement methodology, and minimum standards for data and reporting. They may cover jurisdiction-specific requirements, including in relation to tender processes, and additional assumptions to support measurement.

National supporting tools and resources for users are also provided in Appendix 2.

A brief overview of each section of this Guide is shown in the figure below.

¹ Green Building Council of Australia (GBCA) and thinkstep-anz, [Embodied Carbon and Embodied Energy in Australia's Buildings](#), GBCA and thinkstep-anz, 2021; Architecture 2030, [Why the Built Environment?](#), Architecture 2030 website, n.d., accessed 18 January 2024; Clean Energy Finance Corporation (CEFC), [Australian bodies and infrastructure: Opportunities for cutting embodied carbon](#), CEFC, 2021.

Section 1 – About this guide	Provides context and purpose
Section 2 – Terms and Definitions	A glossary of key terms and definitions used in this guide
Section 3 – What to measure?	Explanation of the scope of measurement and how to consider whole of life carbon trade-offs
Section 4 – When to measure?	Introduction to the three main project stages requiring measurement and data expectations
Section 5 – How to measure?	More technical and detailed measurement guidance for robust and consistent estimation of embodied carbon. This includes targeted sections for each of the three measurement stages
Section 6 – How to report?	Detail on how and when to report embodied carbon across the three stages of measurement
Appendices	Detailed supporting reference information to support measurement, including carbon intensity benchmarks, default assumptions, emissions factors and reporting templates

Figure 1.1 Guide overview

2 Terms and definitions

Term	Definition
Activity data	Data based on a unit quantity of input or output of the studied system or a process within, including materials, energy, waste, transport and land clearing. ²
Agency	All infrastructure delivery agencies.
Baseline (or reference case)	A business as usual scenario for the level of carbon emissions in the absence of additional measures to reduce emissions levels. ³
Benefit Cost Ratio (BCR)	The ratio of the present value of the economic benefits to the present value of economic costs. It is an indicator of the economic merit of a proposal presented at the completion of a cost-benefit analysis. ⁴
Capital expenditure (or capex)	A form of expenditure that is incurred when money is spent to buy, construct, renovate or acquire an asset. Capital expenditure is clearly assigned to the acquisition and maintenance of capital assets including property, raw materials or technology. ⁵
Carbon emissions	Emissions of greenhouse gases, measured in kilograms or tonnes of carbon dioxide equivalent emissions (CO ₂ -e).
Carbon intensity benchmarks	<p>Estimates of carbon emissions for an asset, element or process which is based off actual data from comparable projects. The following types of carbon intensity benchmarks are referred to in this Guide:</p> <ul style="list-style-type: none"> • Sub-asset or element carbon intensity benchmark - an element level rate of carbon emissions per item, length or area (e.g., tCO₂-e/m² of roadway or tCO₂-e/km). These carbon intensity benchmarks can be used to estimate an asset's upfront emissions where details of the asset's key elements and size are known but material quantity data is unavailable. • Asset level carbon intensity benchmark - An asset level rate of carbon emissions per dollar of capital investment (i.e., tCO₂-e/\$). These carbon intensity benchmarks are used to estimate an asset's upfront emissions when material quantity data and sub-asset carbon intensity benchmarks are not available for the asset type.
Carbon Management Plan	<p>A carbon management plan is a framework designed to identify and manage greenhouse gases (in the form of CO₂-e) for the identified project, asset or organisation. It is intended to be a <i>living</i> document that is revised and updated over the project lifecycle. It allows agencies and their delivery partners to:</p> <ul style="list-style-type: none"> • define their approach to and opportunities for carbon management and reduction at procurement, design and construction stages • demonstrate who will be responsible for driving, tracking and reporting carbon reductions achieved at various stages of project delivery

² British Standards Institution, PAS 2080 - [Carbon Management in Buildings and Infrastructure \(2023\)](#), Section 3.2 Terms and Definitions, BSI, 2023

³ British Standards Institution, PAS 2080 - [Carbon Management in Buildings and Infrastructure \(2023\)](#), Section 3.5 Terms and Definitions, BSI, 2023

⁴ Infrastructure Australia, [Infrastructure Australia Assessment Framework](#), Glossary, IA, 2023

⁵ Methodology from: Australian Bureau of Statistics, [Private New Capital Expenditure and Expected Expenditure, Australia](#), ABS, 2023

Term	Definition
	<ul style="list-style-type: none"> document the methodologies used to assess carbon reductions.
Carbon sequestration	The capture and storage of carbon emissions from the atmosphere. ⁶
Circular economy	An economy that is restorative and regenerative by design, and which aims to keep products, components and materials in circulation through processes like reuse, refurbishment, and recycling (as opposed to a linear “take-make-dispose” model). ⁷
Contribution analysis	Analysis undertaken to determine the importance of different elements of an asset in contributing to overall carbon emissions to identify hotspots and target mitigation efforts to inform decision-making.
Cost Benefit Analysis (CBA)	An economic analysis technique for assessing the economic merit of an infrastructure proposal. It involves assessing the benefits, costs and net benefits to society that the proposal would deliver. It aims to attach a monetary value to the benefits and costs wherever possible and provide a summary indication of the net benefit. ⁸
Declared unit	A reference quantity used to report carbon results of a product, project or process when the full life cycle is not being assessed e.g. m ² Gross Floor Area (GFA) for a building. Unlike a functional unit (see definition below), a declared unit typically does not have a time dimension and so is not suitable when comparing the full life cycle of an asset.
Design life	The period of time during which an asset is expected by its designers to function within its specified parameters.
Embodied carbon	The greenhouse gas emissions and removals associated with the creation, maintenance and end-of-life disposal of an asset. This includes the emissions associated with the production and transportation of materials, construction related emissions and end-of-life emissions. In-use stage material-related emissions associated with maintenance, repair, replacement and refurbishment over the asset life are also considered part of embodied carbon. Note: this aligns with definitions in PAS 2080:2023 and RICS <i>Whole life carbon assessment for the built environment</i> ⁹ , excluding in-use stage emissions relating to operational expenditure, which is part of operational carbon (see definition below).
Emission factor	A conversion factor used to estimate the quantity of carbon dioxide equivalent emissions generated by an activity or process (e.g. the manufacture of a product).
Emissions life cycle module	The different periods of an asset’s life are known as its life-cycle stages. Life cycle modules provide standardised designations for each life cycle stage, from A1 to D. They are referred to as product (A1-A3), construction (A4-A5), in-use (B1-B5), end-of-life (C1-C4), operational carbon (B6-B7), user carbon (B8), and benefits beyond the asset life cycle (D).
Enabled emissions (user carbon)	Emissions associated with activities enabled by an asset (e.g. emissions from third-party vehicles driving on a road).

⁶ Green Building Council Australia, *A practical guide to upfront carbon reductions*, GBCA, 2023

⁷ Adapted from: International Organisation for Standardisation, *ISO 20400:2017 Sustainable Procurement - Guidance*, Section 3.1, ISO, 2017

⁸ Infrastructure Australia, *Infrastructure Australia Assessment Framework*, Glossary, IA, 2021

⁹ Royal Institute of Chartered Surveyors (RICS), *Whole life carbon assessment for the built environment (2nd Ed.)*, Glossary, RICS, 2023

Term	Definition
End-of-life carbon	Carbon associated with the deconstruction, transport, waste processing, and disposal of capital assets at the end of their useful life. This forms part of embodied carbon. ¹⁰
Environment Product Declaration (EPD)	An independently verified and registered document that communicates transparent and comparable information about the life-cycle environmental impact (including carbon emissions) 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.
Functional unit	The reference quantity or performance measure of the product, process, or service being assessed. It defines the primary function or purpose of the system under analysis, allowing for comparison of different alternatives that fulfill the same function, e.g., generation of one MWh of electricity. Where relevant to make a comparison, a functional unit must also specify a time dimension, e.g., one m ² of conditioned floor area for one year, with a minimum floor-to-ceiling height of 2.4m.
Maintenance	All actions necessary for retaining an asset as near as practicable to its original condition, or to reduce its rate of deterioration. Road maintenance, as an example, is the work required to keep a road at its specified level of service, including the road surfacing, structure, furniture and drainage system. ¹¹
Operational carbon	The emissions associated with the operation (i.e., the in-use stage) of assets, particularly operational energy (module B6) and operational water (module B7). It can also include any module from B1 to B5 linked to operational expenditure. Examples include fugitive emissions of refrigerants (B1) and treatment chemicals for (waste) water infrastructure (B2).
PAS 2080:2023 Carbon management in buildings and infrastructure	Specifies requirements for the management of whole life carbon emissions in buildings and infrastructure in the provision, operation, use and end-of-life of new projects or programmes of work as well as the management or refurbishment of existing assets and networks.

¹⁰ British Standards Institution, PAS 2080 - [Carbon Management in Buildings and Infrastructure \(2023\)](#), Section 3.22 Terms and Definitions, BSI, 2023

¹¹ Austroads, [Glossary of Terms](#), 2015

Term	Definition
Refurbishment	<p>Refurbishment (also called retrofit or rehabilitation), as distinct from replacement, is defined as a planned alteration or improvement to the physical characteristics of the built asset, in order for it to perform a future function that was identified and quantified at the outset.¹²</p> <p>Some examples include:</p> <ul style="list-style-type: none"> • pavement: major surfacing action for the purpose of returning the structural condition of the pavement to its as-constructed or design condition (i.e. recurring or maintenance), or to exceed the as-constructed condition (i.e. capital or construction)¹³ • bridge: the actions necessary to restore a bridge to its originally intended level of service in order to retain it in service for as long as possible. It is characterised by major repairs which are remedial in nature, are costly and less frequent than those undertaken for maintenance.¹⁴
Rehabilitation	Refer refurbishment definition above.
Supply chain	A network of organisations that convert raw materials into finished products and deliver them to the consumer.
System boundary	The spatial, temporal, and functional scope of a life cycle assessment or carbon assessment. It outlines what must be taken into account for the assessment and, therefore, what must be excluded. ¹⁵
Upfront carbon	The carbon emissions and removals associated with the creation of an asset, network or system up to practical completion. This includes the emissions associated with the production and transportation of materials and construction-related emissions. It excludes emissions generated during the use and end-of-life stage of an asset.
Upscaling	A technique which can be applied to carbon calculations to account for emissions that are not quantified. It involves determining the coverage of the calculated emissions (for instance, covering 80% of all materials used), and scaling the measured emissions up to 100% for a more accurate representation of the complete carbon account.
Whole life carbon (or whole of life carbon)	The total greenhouse gas emissions and removals associated with the creation, operation, maintenance and end-of-life disposal of an asset. This includes upfront carbon as well as in-use emissions (from maintenance, repair, refurbishment and operation of the asset), end-of-life disposal, and benefits and loads beyond the system boundary (e.g. avoided material production from utilisation of recycled or reused products).
Value chain	The organisations, agencies, and industry stakeholders involved in creating, operating, and managing assets. ¹⁶

¹² Royal Institute of Chartered Surveyors (RICS), [Whole Life Carbon Assessment for the Built Environment 2nd Edition](#). "Assessing life cycle stages and information modules". RICS website. 7 March 2023.

¹³ Austroads, [Glossary of Terms](#), 2015

¹⁴ Austroads, [Glossary of Terms](#), 2015

¹⁵ British Standards Institution (BSI), BS EN 17472:2022 [Sustainability of construction works. Sustainability assessment of civil engineering works. Calculation methods](#), BSI, 2022

¹⁶ British Standards Institution, PAS 2080 - [Carbon Management in Buildings and Infrastructure \(2023\)](#), Section 3.52 Terms and Definitions, BSI, 2023

3 What to measure?

Life cycle stages and system boundary

The system boundary determines the asset life cycle stages that will be included in the carbon assessment. This Guide aligns with PAS2080:2023 *Carbon management in buildings and infrastructure*, a global standard, which specifies requirements for the management of whole life carbon in buildings and infrastructure (refer to Box 2). PAS2080 refers to the following more detailed life cycle assessment standards for definition of life cycle stages and the system boundary, which should also be referred to for detailed calculation guidance, depending on the type of project:

- **Buildings or Social Infrastructure** – EN 15978:2011 *Sustainability of construction works. Assessment of environmental performance of buildings. Calculation method*.¹⁷
- **Civil (or economic) Infrastructure** – EN 17472:2022 *Sustainability of construction works. Sustainability assessment of civil engineering works. Calculation methods*.¹⁸

Box 2: PAS 2080:2023 decarbonisation principles

PAS 2080:2023 is an internationally recognised standard, which provides guidance for management of whole life carbon. This includes the management of carbon in the provision, operation, use and end of life of new projects and/or programmes of work, as well as the management or refurbishment of existing assets and networks.

Key principles for PAS 2080:2023 include:

- **Managing whole life carbon under the control and influence of the value chain.** This includes demonstrating the approach to integrating carbon in decision-making when delivering projects.
- **Aligning to a net zero carbon transition**, e.g., taking a system approach by optimising carbon to reduce whole life emissions in the built environment. The "systems" or "network" approach integrates and balances carbon reductions with co-benefit opportunities such as climate adaptation, resilience improvement, nature-based solutions, circular economy, and biodiversity in a whole of life carbon management framework.
- **Implementing appropriate governance to manage whole life carbon.** This includes ensuring consistency in the process of carbon management, including assessment, use of data, procurement, target setting, continuous improvement, monitoring, reporting, leadership, governance and collaboration for decarbonisation.
- **Managing whole life carbon by applying the carbon reduction hierarchy:** the "Avoid, Switch, Improve" hierarchy encourages carbon consideration at the earliest stages of a project.

Refer Case Study 1 below for an example of how PAS 2080 principles have been implemented in practice.

¹⁷ British Standards Institution, BS EN15978:2011 *Sustainability of construction works. Assessment of environmental performance of buildings. Calculation method*, BSI, 2011

¹⁸ British Standards Institution, BS EN 17472:2022 *Sustainability of construction works. Sustainability assessment of civil engineering works. Calculation methods*, BSI, 2022

Case Study 1: National Highways Net Zero Highways Plan

National Highways has demonstrated a commitment to sustainable solutions by becoming the first major roads organisation to achieve a PAS 2080 accreditation. National Highways is responsible for operating, maintaining, and improving England's motorways and major roads.

The Net Zero Highways Plan outlines the agency's approach to achieve net zero carbon emissions across its operations, road maintenance, and construction projects by 2050 ([Net zero highways: our 2030 / 2040 / 2050 plan, 2021](#)).

Some approaches to minimising emissions from embodied carbon include:

- zero carbon construction products
- zero carbon material transport
- low carbon construction methods
- digital technologies to increase the capacity of the existing network and minimise new construction (Digital Roads program) ([Digital Roads, 2021](#)).

National Highways will use a carbon management system to embed approaches that minimise emissions. The agency's updated Design Manual for Roads and Bridges provides clear requirements to assess and report on the climate impacts of operation, maintenance and construction projects. This aids in assessing the relevant carbon cost of its infrastructure projects and making strategic decisions aimed at reducing its carbon emissions across operations.

Annual audits will also provide clear evidence of progress made against the agency's target reduction in whole-

This Guide is also largely aligned with the Royal Institute of Chartered Surveyors (RICS) *Whole life carbon assessment for the built environment* standard¹⁹, which uses these same underlying life cycle assessment standards. RICS' document provides detailed guidance for buildings, and for assessing embodied carbon emissions. Agencies and project teams may also wish to refer to additional guidance in the RICS document but should note that there are differences in the approaches to upscaling and uncertainty assumptions.

Figure 3.1 provides an overview of life cycle emissions by modules from EN17472:2022, which incorporates EN 15978 modules and adds pre-construction (A0) and user's utilisation (B8) emissions (note that module A0 is not shown in Figure 3.1 below and not required to be assessed in this guidance). This Guide focuses on modules A1-A5, or upfront carbon associated with the product and construction stages. Additional high-level guidance is provided for in-use (B1-B5) and end of life stage (C1-C4) embodied carbon emissions. Agencies should refer to their relevant jurisdiction-specific Addendum to confirm what other life cycle stages should be included in a carbon estimate.

¹⁹ Royal Institute of Chartered Surveyors (RICS), [Whole Life Carbon Assessment for the Built Environment 2nd Edition](#), RICS, 2023.

Whole of life carbon



Figure 3.1 Sources of whole life carbon emission and illustration of definitions use in this document (adapted from PAS2080:2023 and modules in EN 17472:2022)

Note: circular economy principles can be applied across all work stages of projects and/or programmes of work to assess materials/products in terms of reuse and recycling potential after end of life, as well as their flexibility in being repurposed or refurbished whilst satisfying the whole life performance required from their respective assets and networks.²⁰

²⁰ PAS 2080:2023, S3.14

Embodied carbon

The following reporting modules should be considered part of embodied carbon:

- **Modules A1-A3:** Carbon emissions from the manufacture of products and materials used in the building or infrastructure asset.
- **Module A4:** Carbon emissions from the transport of products to site
- **Module A5:** Carbon emissions from construction, installation and commissioning processes, including:
 - Energy (primarily diesel and electricity) used in construction machinery or site offices. E.g., operation of cranes, excavators, tunnel boring machines, building site services.
 - Manufacture, transport, and end-of-life treatment of material that becomes construction waste.
 - Land use change from any land clearing activities (especially important for greenfield developments)
 - Enabling works to prepare land for the delivery of the project (note that this could be considered part of A0 but is included here for simplicity)
 - The commissioning of an asset prior to handover to the client.
- **Module B1:** Use (material emissions and removals)
- **Module B2:** Maintenance
- **Module B3:** Repair
- **Module B4:** Replacement
- **Module B5:** Refurbishment (rehabilitation)
- **Module C1:** Deconstruction
- **Module C2:** Transport of waste
- **Module C3:** Waste processing for any reuse, recycling and recovery
- **Module C4:** Waste disposal (e.g., to landfill)

Module D (benefits and loads beyond the asset life cycle, including reuse, recycling and energy recovery) is not considered part of embodied carbon. However, this module does relate to embodied carbon impacts as part of whole of life carbon. It may also be relevant to consider and is included in reporting templates in Appendix 10 for completeness.

Further information on the considerations of trade-offs for these emission sources can be found in Section 0.

Operational and asset user carbon

The following modules, part of whole life carbon assessment, do not form part of embodied carbon and, as such, are **not covered by this Guide**:

- Module B1: Use (operational expenditure and other operational related activities)
- Module B6: Operational energy use
- Module B7: Operational water use
- Module B8: User carbon (also known as enabled emissions)
- Module D: Benefits and loads beyond the asset life cycle (including from reuse, recycling, and energy recovery).

Refer to Appendix 2 for additional resources that can be used to support measurement of operational and user carbon.

General exclusions

The following activities **may be excluded** from assessments, as they typically contribute relatively little to embodied carbon and are time consuming to measure:

- Module A0 (from EN17472:2002²¹ and not shown in Figure 3.1 above): pre-construction activities, such as land acquisition, site investigations and design, including electricity used off-site for professional services. However, any significant enabling civil works or land clearing should be captured in A5.
- Manufacture of machinery and other capital goods used during construction activities (component of A1-3)
- Transport of temporary construction plant and equipment to site (component of A4)
- Demolition of existing structures (for which the majority of embodied carbon is considered part of the previous asset’s life cycle) (component of A5)
- Transport of staff to and from the construction site (component of A5).

This Guide notes that some jurisdictions may require measurement of the carbon associated with these activities, where they are a material part of the overall project footprint (see the relevant jurisdiction-specific Addendum).

For example, the transport of plant, equipment and personnel may be a material contributor to emissions for a project in a remote location with ‘fly-in-fly-out’ workers. Transport of temporary plant and equipment and staff to and from the construction site may also be significant for some projects, which may warrant inclusion and investigation.

Optimising whole life carbon

While this Guide focuses on the quantification of embodied carbon, agencies and project teams should recognise the importance of considering whole life carbon in decision-making, and the potential carbon trade-offs that could occur when only assessing upfront carbon or embodied carbon.

To support agencies with considering trade-offs, Table 3.1 identifies in-use (B1-B5), operational carbon (B6-B7) and user carbon (B8) that may have carbon trade-offs.

Table 3.2 provides examples of whole life carbon trade-offs. Where a life cycle stage has a greater contribution or influence on carbon emissions, it is more important to consider it and potential trade-offs when making decisions. This is particularly important during early options analysis. Plans to shift towards renewable energy in the electricity grid are an important consideration for in-use and operational carbon emissions. The emission intensity of the Australian grid is steadily declining (see Appendix 3). This should be considered when conducting operational carbon emissions calculations (B6-B7), particularly for operational energy use calculations (B6).

Projects should undertake analysis to determine the whole life carbon implications to take into account potential trade-offs. Qualitative assessment can be undertaken where the required data for a quantitative assessment are not available.

Any potential trade-offs should be identified and considered where relevant. Table 3.2 provides some examples of potential whole life carbon trade-offs that could occur.

Table 3.1 Sources of in-use, operational carbon and user carbon emissions of different asset types that may have carbon trade-offs when reducing upfront or embodied emissions

Asset type	In-use (B1-B5) and operational carbon (B6-B7)	User carbon emissions – enabled and avoided (B8)
Building (e.g., precincts, schools, hospitals, correctional facilities)	<ul style="list-style-type: none"> • Refrigerant leakage (B1) • Operational energy, when not from a renewable source (B6)²² 	<ul style="list-style-type: none"> • Energy and transport associated with tenants (if not captured in B6 ‘operational energy’) (enabled)

²¹ British Standards Institution, BS EN 17472:2022 *Sustainability of construction works. Sustainability assessment of civil engineering works. Calculation methods*, BSI, 2022

²² This is expected to become a progressively smaller share of emissions as the grid transitions to renewable sources and a greater share of building services are electrified.

Asset type	In-use (B1-B5) and operational carbon	User carbon emissions – enabled and
Road	<ul style="list-style-type: none"> Pavement rehabilitation (B4-B5) 	<ul style="list-style-type: none"> Emissions associated with road users
Rail	<ul style="list-style-type: none"> Replacement of cable support and 	<ul style="list-style-type: none"> Rolling stock energy use (enabled)²³
Water and Sewerage treatment, supply (network/pipelines), dams	<ul style="list-style-type: none"> Fugitive emissions from wastewater 	<ul style="list-style-type: none"> If dams/reservoirs are associated with
Energy generation (renewables) and transmission	<ul style="list-style-type: none"> Sulphur hexafluoride (SF₆) leakage 	<ul style="list-style-type: none"> Displacement of emissions from

Table 3.2 Example whole life carbon trade offs

Trade-off example	Description
Surface road vs tunnel	Tunnels have significantly higher operational energy requirements than surface
Building insulation and operational energy performance	The addition of insulation or the selection of façade materials with better
Road pavement type	<ul style="list-style-type: none"> Different pavement types may have trade-offs between upfront and in-use phase carbon emissions; for example, a pavement type with greater upfront carbon may also have improved durability requiring less refurbishment/rehabilitation (and less emissions) over the asset life. Increased pavement roughness of an option may result in greater fuel consumption and carbon emissions in use (B8 – user carbon).
Electrified vs non electrified railway	Electrified rail networks require more infrastructure such as cabling, overhead wiring and gantries (higher upfront carbon). However, they will generally have a

²³ Rolling stock energy could be classified as operational or enabled emissions, depending on ownership of the fleet

Trade-off example	Description
	lower operational emission intensity (operational carbon) compared to diesel rail networks.
Water treatment process complex in-use emissions	A certain secondary treatment process may have smaller tank structures (lower upfront carbon) but require greater operational energy and treatment chemicals (operational carbon).
Renewable vs fossil power generation	Renewable energy generation options such as wind and solar require more materials (embodied carbon) per unit of electricity produced, compared to fossil fuel power plant alternatives. However, renewable energy generation has far less in-use and operational carbon emissions, and only a small fraction of the whole life carbon per unit of electricity output.
Cable sizing and transmission losses	Cables with smaller cross sections would result in lower upfront carbon, but could increase resistance and result in higher transmission losses (operational carbon).

4 When to measure?

Measurement of embodied carbon is an important aspect of project decision making at key project stages. During the early stages of a project the ability to influence carbon outcomes is greatest, and intervention likely to be more cost effective, even though estimates are less accurate. As the project progresses through the various stages, the accuracy of assessments increases with more data availability, while influence over emissions declines. This section discusses the three key stages for measuring emissions.

Three key measurement stages

Guidance on how to measure embodied carbon is provided over the key stages shown in Figure 4.1, which also shows the relationship between the ability to influence carbon at each project stage, and the accuracy of embodied carbon assessments.



Figure 4.1 Accuracy of measurement and ability to influence carbon emissions at each measurement stage (adapted from PAS2080:2023 s7.1 Figure 7)

Purpose of measurement at each stage

Table 4.1 outlines the purpose of measurement at the three stages.

Table 4.1 Recommended stages for the measurement and reporting of embodied carbon

Stage	Purpose
Stage 1 Business case	<ul style="list-style-type: none">• Enable effective consideration of carbon emissions in decision-making during
Stage 2 Planning approval, design and procurement	<ul style="list-style-type: none">• Inform planning and other statutory approval applications where relevant.• Focus efforts from design and procurement teams on carbon reduction opportunities.• Inform design development, procurement, and the implementation of lower-carbon solutions in tendering and detailed design.• Where applicable, enable the setting of informed carbon reduction targets, and the monitoring, tracking, and reporting of carbon reductions achieved through design and delivery activities.
Stage 3 Construction and practical completion	<ul style="list-style-type: none">• Enable construction contractors during delivery to readily compare the carbon intensity of different materials and construction methods to facilitate triple-bottom line decision-making.• Enable regular review and monitoring of carbon data during delivery to ensure performance is aligned to emissions reduction target.• Confirm the carbon emissions resulting from the project using actual data.• Inform carbon intensity benchmarks.• Where applicable, assess whether carbon reduction objectives and targets were met.

5 How to measure?

The approach to measuring embodied carbon varies throughout the stages of the infrastructure life cycle and depends heavily on the level of information available at each stage. The level of detail in estimating carbon emissions should be proportionate to data availability, project size and time available to inform decisions.

This section steps out the process of measuring carbon emissions at each stage to support consistency and completeness. A worked example across the three reporting stages is provided in Appendix 4.

Overview of measurement process

Good practice carbon measurement, in line with PAS2080:2023, follows a common process:²⁴

1. **Establish the system boundary for assessment (see section 3)** by identifying the infrastructure's design life, sources of emissions and removals, and considering potential trade-offs (in-use, operational carbon, end of life, and impacts on the network or system).
2. **Assess the impact of carbon emissions and removals (this section)** to the appropriate level of accuracy and detail for the stage in the infrastructure life cycle. Where data to enable quantification is limited in the early project stages, available carbon intensity benchmarks, initial quantities and qualitative assessment may be used to allow options comparison.
3. **Monitor and report carbon emissions and removals (see sections 4 and 6)** to the level of detail appropriate for the stage in the infrastructure life cycle.

Calculation approaches by project stage

The calculation approach varies depending on the project stage and level of information available. At the early project stages, if detailed project data are not available, agencies can estimate carbon emissions based on high-level carbon intensity benchmarks rather than material quantities. However, as more detailed information becomes available throughout the project stages, the approach to calculating carbon emissions becomes more accurate.

Figure 5.1 provides an overview of the suitability of data and calculation approaches over the project life cycle. Each stage is not limited to one calculation approach, and a combination could be used depending on data availability and purpose of assessment. Note that the more accurate methods further on in the project lifecycle must be used in earlier stages if available.

²⁴ British Standards Institution, PAS 2080 Carbon Management in Buildings and Infrastructure (2023), Section 3.22 Terms and Definitions, BSI, 2023

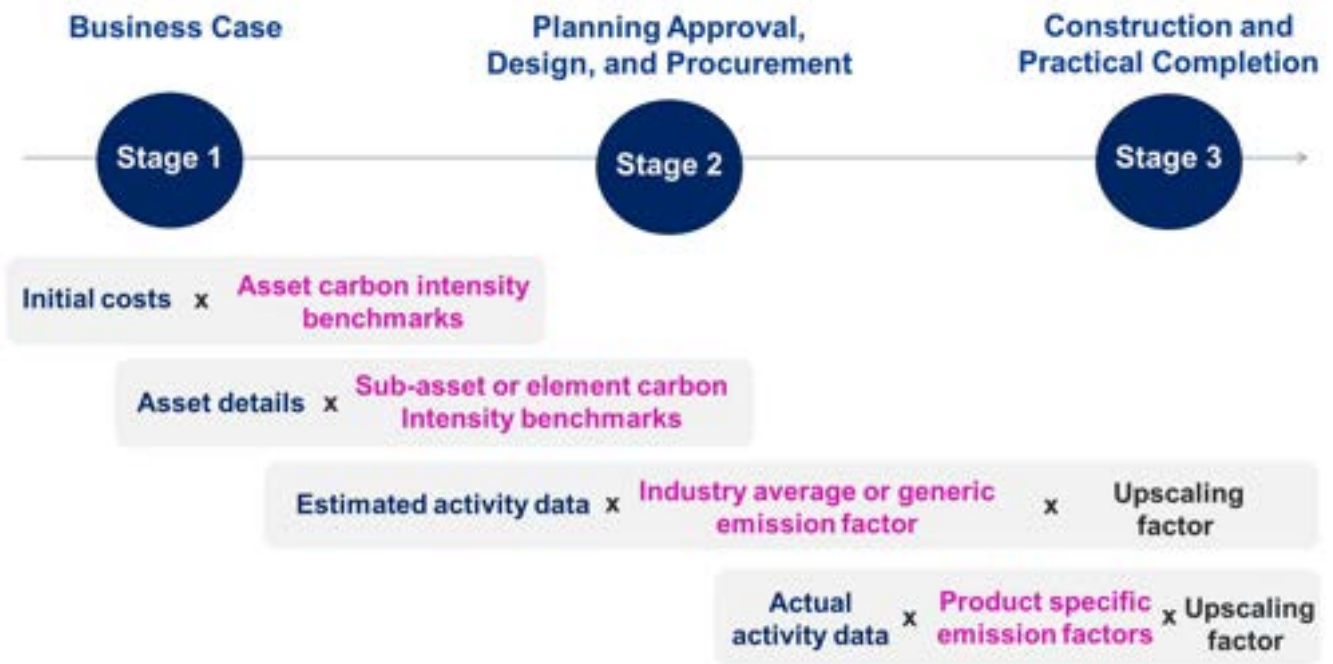


Figure 5.1 Suitable emission calculation approaches at each project stage

Data hierarchy

The below input data hierarchy shows which data sources must be prioritised when conducting embodied carbon assessments. There may be benefit in project teams engaging with their technical advisors or tool vendors to ensure that the most accurate source is being used depending on the level of data available.

1. **Actual construction data** – resource use quantities reported or collected during the construction stage.
2. **Estimated quantities** – resource use quantities estimated from design e.g., Quantity surveyor estimates or material take-offs from a digital model.
3. **Early asset details (linked to sub-asset or element specific carbon intensity benchmarks)** – project scope information broken down to the sub-asset element, for example, m² of road pavement.
4. **Material/capital spend (asset level carbon intensity benchmarks)** – project scope information at the asset level e.g., \$ capex or material spend for the asset.

Appendix 5 provides further guidance on suitable data requirements and potential sources of data.












As actual construction data is the most accurate source of information, carbon assessments should prioritise using this when available. However, where actual data are not available, projects can use estimated quantities from a quantity surveyor, digital model take-offs, or other project measurements such as quantities placed for respective materials' contract cost items. Where data from a quantity surveyor is available, this will be more accurate and should be prioritised over digital models. Projects in the earlier stages may not have access to either of these and can refer to their asset details or material spend data to estimate the carbon emissions.

Carbon intensity benchmarks must only be used when material quantity data are unavailable. These should only be required in Stage 1 – Business case.

Suitability of data sources at each stage of measurement

Acknowledging that there are limitations in data availability across infrastructure project stages, Table 5.1 below provides an overview of the data available and relevant calculation method at each project stage. Refer to Section 6.1 for tracking measurement through a Carbon Management Plan.

Table 5.1 Suitability of the data sources across the three stages

Data Input	Benchmark or emission conversion factor (priority)	Stage 1 Business case	Stage 2 Planning approval, design, and procurement	Stage 3 Construction and practical completion
 Material spend	× <ul style="list-style-type: none"> Asset-level carbon intensity benchmarks 	 Where estimated quantities and sub-asset benchmarks unavailable		
 Early asset details	× <ul style="list-style-type: none"> Sub-asset or element specific carbon intensity benchmarks 	 Where early asset details are available	 Where estimated data are unavailable	
 Estimated quantities	× <ul style="list-style-type: none"> Industry average emission factor Generic emission factor from database Generic emission factor from global literature scan 	 Where estimated quantities are available	 Where estimated quantities are available	 Where actual data are unavailable
 Actual construction data	× <ul style="list-style-type: none"> Product specific emission factor Industry average emission factor Generic emission factor from database or global literature scan 			 Where data available (focusing on key emission sources)

Note: the ticks represent the suitability of each data input across the three measurement stages. The **green** ticks indicate the likely suitable input for each stage.

Emission factors and carbon intensity benchmarks

Emissions calculations are most accurate when based on measured/estimated material quantities, while carbon intensity benchmarks enable earlier carbon measurement when project data is limited. The following sections provide guidance on how to prioritise different types of emission factors, and how to obtain these from various sources. Section 5.5.1 provides guidance on carbon intensity benchmarks that should be used when estimated quantities are unavailable.

Emission factor and carbon intensity benchmark hierarchy

The below hierarchy must be followed when selecting emission factors depending on availability.

There are efforts underway to develop a centralised database of emission factors, and tools that incorporate carbon intensity benchmarks. The following hierarchy has been provided to show the recommended sources of emission factors that are available now, and others that should be prioritised once available (with interim options also provided).

Table 5.2 Emission factor and carbon intensity benchmark hierarchy to be applied when calculating embodied carbon

Conversion factor type and hierarchy	Supported data sources
	
	
	
	
	
	<ul style="list-style-type: none"> Asset level carbon intensity benchmarks are provided in

²⁵ Forthcoming as of February 2024

Note: *This hierarchy provides a minimum standard, jurisdictions can provide additional detail to their jurisdictional addendum*

A non-exhaustive list of emission factors has been provided in Appendix 3. In addition to these, agencies or their tool providers may need to source their own emission factors and must follow the emission factor hierarchy in Table 5.2 above. Appendix 6 also provides guidance on how to source emission data from literature.

Stage 1 – Business case (measurement guidance)

The problem definition and Business Case stages are when agencies and project teams will have the greatest ability to influence carbon emissions through option selection, scope definition and investment decision. Although the accuracy of assessment may be low, measurement at this stage encourages low-carbon behaviours and decisions, even in the absence of detailed data. Measurement at the Business Case stage may be required by jurisdictional or national guidelines and is recommended to be incorporated within cost-benefit analysis as best practice, using an appropriate carbon value.²⁶ The use of initial estimates (where available), high-level project details and carbon intensity benchmarks (for upfront carbon) can overcome data availability barriers to measurement.

While assessments using carbon intensity benchmark data are less accurate, they are appropriate in earlier stages of the infrastructure asset life cycle, since estimated quantities are often unavailable (or limited to major civil and structural elements). The accuracy of the assessment should be proportionate to the size, risk, available information and complexity of the investment proposal. Where further detail and accuracy is required and data are available, please refer to section 5.6 for the Stage 2 measurement approach.

Use of early project details and carbon intensity benchmarks

Figure 5.2 below provides an illustration of the information and example units for the two key types of carbon intensity benchmarks referred to in this guidance:

- **Asset-level carbon intensity benchmarks** represent carbon intensity for the whole asset and allow carbon to be estimated based on physical characteristics or materials expenditure. These have low accuracy and are most suitable at early stages in the project life cycle (Stage 1) when little project information is available. Default asset-level carbon intensity benchmarks for upfront carbon have been provided in Appendix 7. These are based on the predicted expenditure on materials and are detailed further in the section below.
- **Sub-asset or element specific carbon intensity benchmarks** are generally bottom-up benchmarks that have been developed for a certain type of asset and should ideally be based off design standards or a representative sample of projects. These should be prioritised relative to asset-level benchmarks if available. These have not been provided in this Guide, but agencies may wish to develop and use their own sub-asset or element carbon intensity benchmarks if they have been developed.

²⁶ Infrastructure Australia, [Guide to assessing greenhouse gas emissions \(interim\)](#), Australian Government, 2023. Updated guide forthcoming.

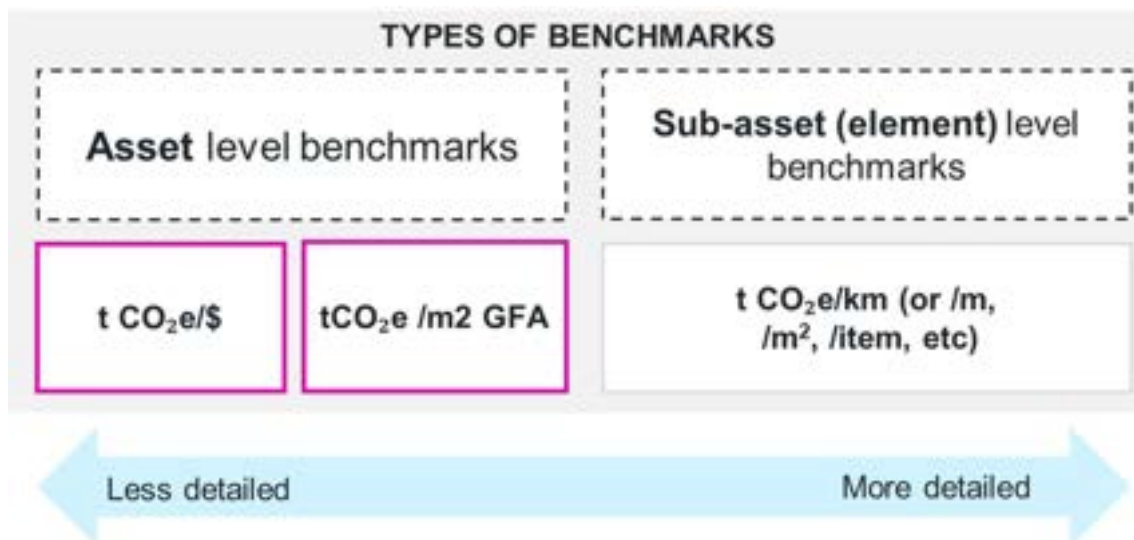


Figure 5.2 Types of carbon intensity benchmarks

Note: asset-level benchmarks outlined in pink are provided in Appendix 7 (for upfront carbon only).

5.1.1.1 Asset-level carbon intensity benchmarks provided in Appendix 7

Asset-level carbon intensity benchmarks have been developed as part of the Infrastructure Australia's *Embodied Carbon Projections for Australian Infrastructure and Buildings* study²⁷ and are provided in Appendix 7. These asset-level carbon intensity benchmarks are based on predicted expenditure on materials and aggregated carbon emission activity data at the economy level. These are provided for the product stage (A1-A3), transport (A4) and construction and installation process (A5) separately, and account for all emissions within the module.

When using asset-level carbon intensity benchmarks, the following must be noted:

- Asset-level carbon intensity benchmarks for A1-A3 should not be used alongside other measurement techniques (e.g. material quantity estimates and emission factors).
- Where A1-A3 specific material quantities are known and used to calculate these impacts:
 - A4 transport to site impacts should be calculated from quantities using the default assumptions in Appendix 9.
 - A5 construction carbon intensity benchmarks may still be used (in the absence of available data on construction activities).
- Where the predicted expenditure on materials is unknown, projects can use default assumptions for the proportion of capital expenditure on materials, provided in Appendix 7. Projects may also choose to adopt qualitative and semi-qualitative assessment when data is limited.
- Where estimating embodied carbon (beyond upfront carbon), the current carbon intensity benchmarks are limited and do not cover in-use modules (B1-B5). Estimation of these impacts will either require material quantity data to be used, or further development of carbon intensity benchmarks.

Case Study 1 below demonstrates how asset-level carbon intensity benchmarks and default assumptions can be used during the early planning stages of a project.

²⁷ Forthcoming as of February 2024

Case Study 1: Using asset level carbon intensity benchmarks

A project is conducting an upfront carbon calculation during the Business Case phase. In the absence of better information, such as high-level material quantities or sub-asset carbon intensity benchmarks, the following asset-level benchmark methodology was used:

$$\textit{Total Upfront Carbon (tCO}_2\textit{e)} = (a + b + c) \times (d) \times (\$)$$

Where:

a is the asset level benchmark for the product stage (A1-A3) module

b is the asset level benchmark for the transport (A4) module

c is the asset benchmark for the construction and installation process (A5) module

d is the percentage of project CAPEX which is typically allocated to materials

\$ is the project CAPEX

*Note: inputs **a-d** can be found in Appendix 7.*

Stage 2 – Planning approval, design and procurement (measurement guidance)

At this stage of measurement, estimated quantities will become available through design development, quantity surveyors or more detailed cost estimation. Carbon measurement should be undertaken during design development and inform procurement. A robust carbon assessment can help to identify high impact areas for potential reductions and should be completed prior to procurement and / or detailed design. This assessment can be used to inform carbon reduction targets and requirements in procurement.

Minimum inclusions

Carbon calculations should cover a minimum of 80% of materials and 80% of construction activities (based on predicted spend on materials). To achieve the 80% completeness target in embodied carbon calculations, minimum inclusions (for modules A1-A5 and B1-B5) have been outlined for some of the main asset types (as defined in Infrastructure Australia’s *Infrastructure Market Capacity Report 2022*, shown in Figure 5.3 below).²⁸ These have been provided in Appendix 7.

Super sector	Master type	Typecast
Transport	Road	State road (highways/freeways)
		Bridge (road)
		Tunnel (road)
	Rail	Main line works (rail) (greenfield)
		Bridge (rail)
		Tunnel (rail)
Utilities	Water and Sewerage	Water pipeline
		Water treatment plant
		Dam
	Energy	Wind
		Solar (utility)
Buildings	Education, Health and Justice	School and higher education, hospital, correction centre

Figure 5.3 Infrastructure asset types covered in this Guide (aligned with Infrastructure Australia’s Market Capacity Report)

For the construction stage (modules A4-A5), the following activities should be included in the embodied carbon calculation as a minimum:

- Construction energy
- Land use change
- Transport of materials to site
- Waste generated during construction (on-site)

²⁸ Infrastructure Australia, *Infrastructure Market Capacity Report*, Australian Government, 2022

- Commissioning energy

Further details on construction stage minimum inclusions are provided in Appendix 7.

Where project teams do not have the data to cover the minimum inclusions, default calculation assumptions provided in Appendix 9 can be used. This Guide provides default calculation assumptions across the following areas:

- Transport distances and vehicle load assumptions for materials and waste
- Construction waste generation rates
- End-of life treatment rates (recycling vs disposal).

If a jurisdiction has more detailed assumptions for construction electricity and fuel use (for example fuel burn rates for site vehicles and stationary plant), these will be reflected in the jurisdiction-specific Addendum.

The following case study (Case Study 2) demonstrates how to use transport distance assumptions to calculate the emissions from transport when no supplier distances are available.

Case Study 2 – Calculating carbon emissions from transport of materials to site

During the detailed design phase, a project is seeking to calculate the transport emissions associated with the **50 tonnes of gravel** required.

Without knowing who the supplier will be, the project used the default transport distances and transport mode provided in Appendix 9 and transport emission factors in Appendix 3.

- **Gravel transport assumptions** – 66km via **articulated truck**.
- **Articulated truck emissions** – 0.00007 tonnes CO₂-e/tonnes.km transported

These were then multiplied by the quantity of gravel needed using the following equation.

$$\begin{aligned} \text{Transport emissions (tCO}_2\text{-e)} &= 50 \text{ tonnes (gravel)} \\ &\times 66 \text{ km} \times 0.00007 \text{ tCO}_2\text{-e /tonnes.km} \end{aligned}$$

The total transport emissions for the gravel required was calculated to be **0.231 tonnes CO₂-e**.

Scope and completeness of assessment

Carbon calculation at the planning approval, design and procurement stages should aim to include all emission generating activities as far as feasible. However, it is recognised that there will be emissions that are not quantified due to time or information constraints. Where this has occurred, upscaling must be used to ensure carbon assessments are complete and comparable.

To upscale an assessment, projects teams must determine completeness of the carbon assessment, and then upscale for the remainder to account for the activities not quantified. Completeness and upscaling can be conducted using the following approach for each module:

- **Product stage (A1-A3), repair, replacement and refurbishment (B3-B5)** – completeness is to be assessed against the total material cost and then upscaled to 100%
- **Transport (A4)** – completeness is to be assessed against the total material cost and calculations in line with coverage for A1-A3, with calculations upscaled to 100%
- **Construction and installation process (A5)** – the approach for assessment of completeness will vary with data availability, and calculations are to be upscaled to 100%. If available, using estimated data will improve the accuracy of assessments and support consistent comparison between options and assets. While less accurate, carbon intensity benchmarks and upscaling for A5 emissions, are suitable where data is limited, and will

reduce the burden of data collection and analysis. The approach to calculating completeness based of each data source is as follows:

- where construction data is not available to estimate carbon emissions, the module A5 carbon intensity benchmarks in Appendix 7 can be used
- where construction waste data is available, waste generation estimates should be based on materials included in the product stage calculations, and the same completeness as modules A1-A3 can be assumed
- where data for plant and equipment use is available, then completeness for electricity and fuel use calculations should be assessed against the total plant and equipment costs
- estimates of land clearing impacts should be aiming for 100% completeness based on the best information available.

For modules B1 (use – material emissions and removals), B2, C1-C4, and D, the contribution to emissions is typically relatively low, and therefore outside the 80% threshold for minimum inclusions.

Where projects have included all minimum inclusions outlined in Appendix 8, and available spend data does not allow for completeness of calculations to be assessed, a default completeness of 80% can be assumed (where coverage of estimated quantities that emissions have been calculated are unknown). Case Study 3 below outlines the methodology which is to be used when upscaling calculated emissions to 100%.

Case Study 3: Using the upscaling methodology

During detailed design stage, a school project is conducting an upfront carbon assessment and has included all the product stage (A1-A3), transport (A4) and construction and installation process (A5) minimum inclusions outlined in Appendix 8.

With all minimum inclusions covered, the project has assumed a **default completeness rate of 80%**, requiring each module to be upscaled by 20%. However, if the upfront carbon calculations went above and beyond the minimum inclusions, a project specific completeness rate can be calculated instead, increasing the accuracy of the assessment.

To upscale the upfront carbon calculation from 80% to 100%, the following methodology was used.

$$\text{Total Upfront Carbon (tCO}_2\text{-e)} = \frac{a}{80\%} + \frac{b}{80\%} + \frac{c}{80\%} + d$$

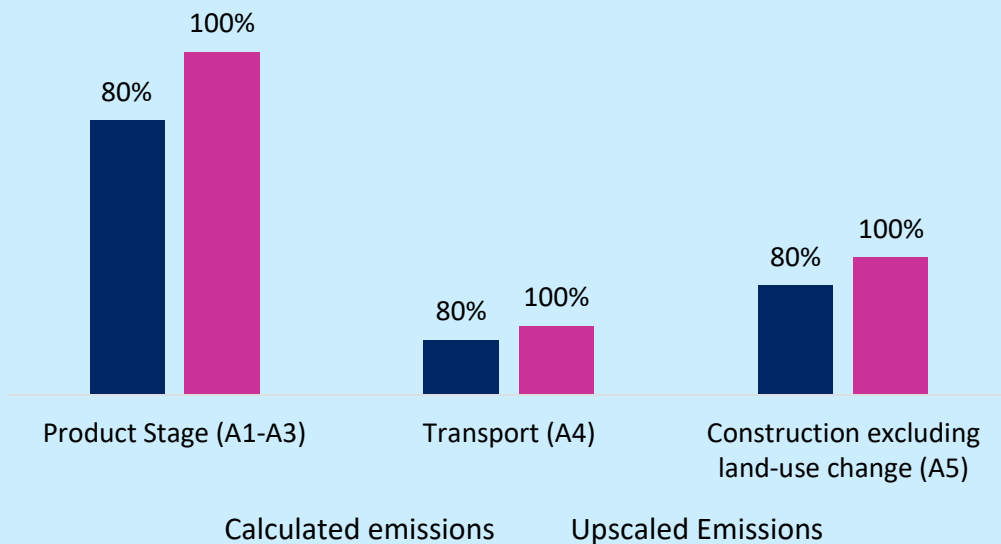
Where:

a is the calculated product stage (A1-A3) emissions (80% completeness)

b is the calculated transport (A4) emissions (80% completeness)

c is the calculated construction energy and waste (A5) emissions (80% completeness)

d is the calculated land-use change emissions (100% completeness)



Stage 3 – Construction and practical completion (measurement guidance)

At construction and practical completion, the accuracy of carbon measurement should be improved with actual data on key activities (major contributors to upfront carbon). This Guide recognises that data accuracy will improve over time as capability to track emissions increases across industry and agencies will be able to report actual data on a larger share of their activities.

Updating assessment with available actual quantity data

To facilitate this process, key activities should be tracked throughout the construction stage, including:

- **Material use for major elements** – e.g., concrete, steel, asphalt, granular pavement material, etc

- **Construction energy use** – including grid electricity, renewable electricity, diesel, biofuels and gases
- **Construction waste** – including quantities and disposal/treatment methods.

For any inputs or activities for which actual data are not available, the latest available design estimates can be used, for example, design estimates that are Issued for Construction (IFC). Where there are significant changes to design in construction, these estimates should be updated with as built documentation.

Additional measurement guidance

This section is for agencies and project teams with maturing carbon measurement capabilities, or those setting baselines and target or comparing options. The following sections cover how to ensure consistency in:

- options analysis and comparisons
- contribution analysis
- setting baselines
- measuring reductions through the project life cycle.

Consistency in options analysis and comparisons

The embodied carbon assessments conducted at different project stages cannot be used for absolute comparison, due to changing data quality.

If project teams are undertaking comparative carbon assessment, such as for options analysis or target setting, the options must have consistent:

- Scope, function and level of services, except where options with differing scope and function are being compared in the options assessment or and business case stages of project planning. Where this is the case, this should be acknowledged when making comparisons
- Practical asset lifetime, used to account for In-use phase emissions
- Life cycle stage system boundary
- Calculation methodology
- Data sources, quality and completeness (noting that level of detail can vary significantly with level of design)
- Carbon intensity benchmarks and/or emission factors data hierarchy
- Site work boundary
- Building and infrastructure asset elements boundary
- Cut-off rules
- Assumptions on carbon sequestration, carbon neutral products, and carbon offsets
- Considerations for demolition and reuse of existing building and infrastructure assets
- Functional or declared units to enable fair comparison in decision-making (sometimes options may provide differing levels of function or service). For comparisons against a reference project in tendering, the tendered offer should have the same function or service provision.

The baseline must represent business-as-usual performance, i.e., it must not be an artificially high-carbon option to make the improvements look larger.

- Account for improvements that would typically be made during the project for reasons other than carbon, e.g., through value engineering.

Differences between the base case and proposed projects or options can include:

- Reuse of existing elements
- Novel and innovative improvements through value engineering that are beyond business-as-usual design development (where explanation of the interventions taken should be provided for context)
- Material selection and procurement (products which provide the same function with lower impact)

- Transport mode, distance, and emissions such as savings through locally sourced materials.
- Construction process and emissions.

If considering in-use embodied carbon differences, additional differences between the base case and proposed project or options can include:

- Design life of materials/ elements reducing or increasing replacement rates
- Material or product selection that influences maintenance scheduling and ease of refurbishment or replacement.

Agencies are encouraged to use a Carbon Management Plan to track these considerations and ensure appropriate comparative carbon assessments.

Using contribution analysis to inform decision-making

Contribution analysis is an important step in carbon assessments for building and infrastructure. It provides valuable insights into the relative importance of different elements, processes, specific materials or life cycle stages in contributing to the overall carbon emissions. It helps decision-makers to:

- **Identify hotspots** or better understand drivers of carbon emissions e.g. specific construction materials which may be responsible for a large share of embodied carbon
- **Target mitigation efforts** by focusing on the most significant opportunities to reduce carbon emissions
- **Compare alternative options** within the assessment boundary
- **Provide more transparent communication** of results
- **Support benchmarking** of sub-asset elements if there is consistent classification and reporting by asset elements.

Contribution analysis is important to understand which project elements and processes contribute most to the overall carbon footprint. It also pinpoints areas for implementing carbon reduction opportunities.

When performing contribution analysis by asset element, it is recommended to align with an appropriate classification system for your agency and project. The following examples are often used for quantity surveying:

- *Australian Cost Management Manual*²⁹
- *CESMM4: Civil Engineering Standard Method of Measurement, Fourth edition*³⁰ (most appropriate for linear infrastructure)
- *ICMS3: Global Consistency in Presenting Construction Life Cycle Costs and Carbon Emissions*³¹ (most appropriate for buildings)

The following case study (Case Study 4) demonstrates the value of conducting a contribution analysis and how this can inform decision making.

²⁹ IQS, *Australian Cost Management Manual* (2023)

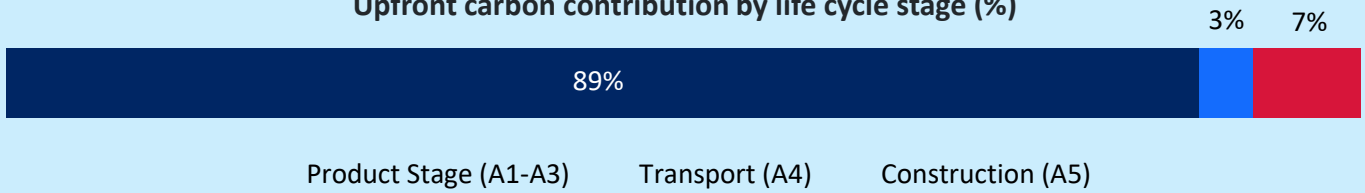
³⁰ ICE, *CESMM4: Civil Engineering Standard Method of Measurement, Fourth edition* (2012)

³¹ RICS, *ICMS3: Global Consistency in Presenting Construction Life Cycle Costs and Carbon Emissions* (2021)

Case Study 4: Contribution analysis for an example road project

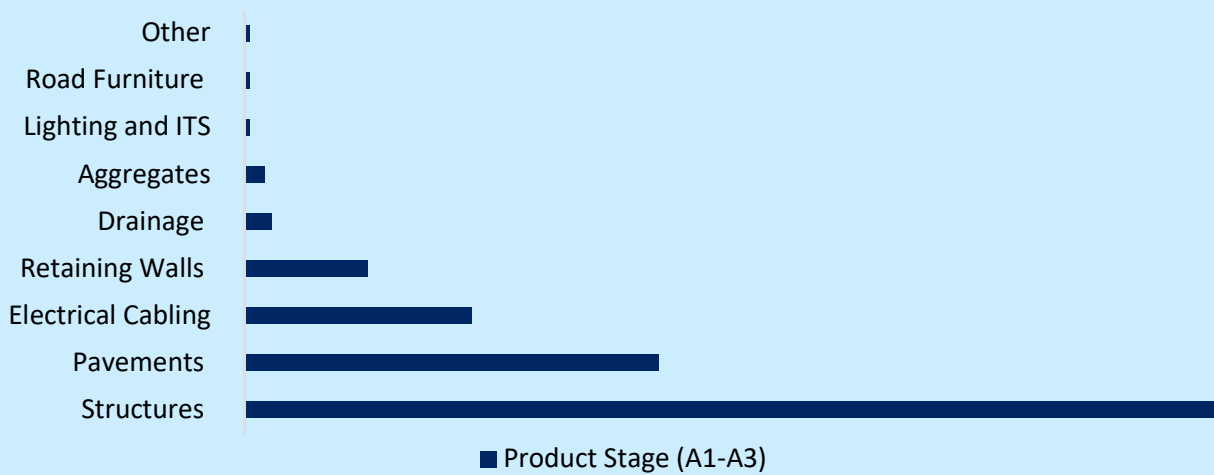
A major road project with significant bridge structures could generally result in upfront carbon emissions per lifecycle stage shown in the chart below. That is, most emissions result from the product stage. However, to understand the source of emissions, further contribution assessments are required.

Upfront carbon contribution by life cycle stage (%)



The chart below shows a material (A1-A3) contribution assessment, displaying the major sources of emissions for the product stage. This further analysis reveals that the structural components contribute the most to product stage emissions, therefore warranting more focus for mitigation efforts.

Material upfront carbon contribution (A1-A3)



Measuring carbon reductions through stages of measurement

5.1.1.2 Setting baselines

If setting a carbon reduction target, an accurate and comparable baseline (or reference case) should be used to measure the carbon reductions expected or achieved for a project against that target.³² A baseline provides a scenario for carbon emissions that will be produced under a business-as-usual approach.

When a baseline has been set, projects can measure carbon reductions available. This can be used to compare against various design options, or to assess reductions achieved through design refinement and construction through to practical completion. When doing so, the baseline and any compared options must follow the guidance in section 5.8.1 above (consistency in options assessment and comparisons).

For some design and procurement options, a complete project baseline may not be required. However, reference or baseline assumptions should still be clearly shown for completeness.

³² PAS 2080:2023, S8.

5.1.1.3 Baseline refinements

Baselines should be refined over time as scope and data certainty increase over time (see Figure 5.4). The baseline must be revised to reflect any changes to the assumptions and quantities used for the carbon calculations, such as changes in level of detail (affecting data quality and completeness), or changes to the scope of the project (e.g. reducing the number of lanes on a road).

For example, updates to the baseline may be made prior to procurement to better inform contributions to carbon reduction opportunities. Both the baseline and the target should also be revisited following procurement to reflect any further carbon reductions proposed by the successful bidder.

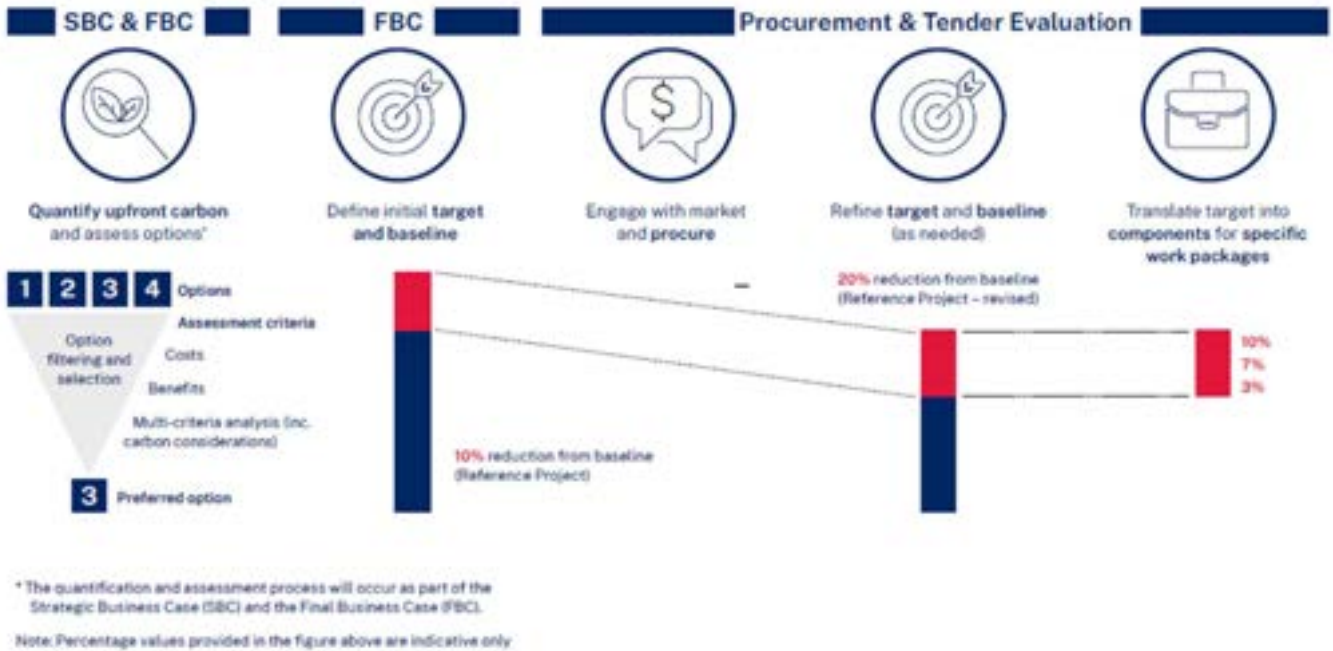


Figure 5.4 Baseline and target setting for maturing agencies, refining with data and scope certainty

5.1.1.4 Measuring carbon reductions

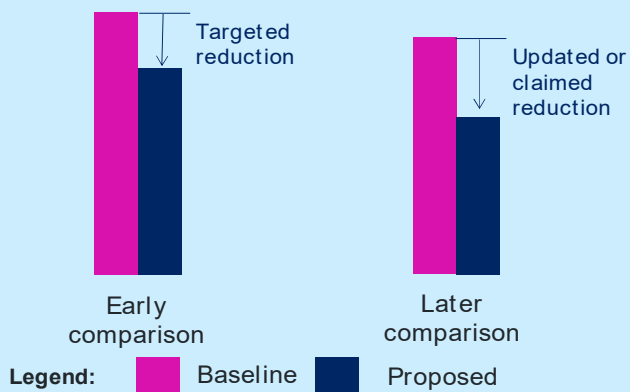
When carbon reductions are measured during the construction phase or at practical completion, the assessment must use actual data available to assess the reduction achieved. Refer to Section 0 and Section 5.8.2 above for further details on setting baselines and making fair comparisons.

Projects undertaking Green Star or Infrastructure Sustainability Ratings should refer to associated guidance for the development of a baseline and measuring carbon reductions.

The following case study (Case Study 5) demonstrates a scenario where the baseline would need to be recalculated due to significant project and scope changes in detailed design.

Case Study 5: Updating the baseline as you move through stages of measurement

During the concept design stage, a carbon assessment was conducted for a school project that led to the development of a carbon emissions baseline and carbon reduction target.



However, during detailed design, the scope of the project was refined, resulting in a reduction in the size of the buildings and number of classrooms provided. This significantly decreased the total gross floor area of the project.

As this was a scope change from the original design, a revised baseline was required.

The carbon baseline was updated at practical completion to reflect the scope changes. The project's carbon emissions at practical completion were then compared against the updated baseline to understand the level of carbon reductions achieved.

6 How to report?

Consistent reporting of embodied carbon at key project delivery stages should be undertaken to support decision-making.

- Iterative reporting within project teams and agencies is recommended to monitor progress against targets and KPIs.
- External reporting of carbon emissions may also be required, depending on jurisdictional policy requirements, as part of business cases, planning approval submissions or delivery monitoring and evaluation.

Collecting consistent reporting data across agencies will assist comparison of asset types across Australian jurisdictions and will be essential to develop improved carbon intensity benchmarks and assumptions across the infrastructure sector.

Where possible, reporting should use consistent units to convey the project's embodied carbon, as well as provide breakdowns of carbon emissions based on the asset's life cycle stage, asset type and, where possible, key asset elements contributing to carbon emissions. Further details to guide consistent embodied carbon reporting are provided in the section below.

Monitoring and reporting

Aligning with PAS2080:2023, project teams should establish robust, frequent and transparent monitoring and reporting. It is good practice for agencies to also report internally to demonstrate projects and/or programs of work that are progressing against carbon reduction targets. Reports should:

- address relevant legislative, policy and funding obligations
- support decision-makers to manage whole life carbon
- provide information for future continuous improvement.

A Carbon Management Plan for projects and programs is a useful tool to monitor and report on carbon estimates and reductions. The objective of a Carbon Management Plan is to document the project's carbon management processes including measurement. It is intended to be a living document that could be included in the business case stage of project planning, and updated with measurement data at:

- Design and procurement (ideally prior to tender)
- Practical completion (for use in evaluation and development of lessons learned).

Agencies should develop a monitoring and reporting method for carbon assessment results, whether through a Carbon Management Plan or as part of other plans and progress reports.

External reporting requirements

An overview of the recommended external reporting stages is outlined in Figure 6.1 and discussed in this section below. External reporting requirements may differ across jurisdictions and may reflect policy objectives to have carbon measurement and valuation included in cost-benefit analysis or as part of planning consents. Where a project is seeking planning approval, external reporting of carbon measurement may be required as part of planning approval documentation. As the carbon calculations become more detailed throughout each measurement stage, it is recommended that reporting also becomes more detailed to provide clear, transparent, and useful data.



Figure 6.1 External reporting of carbon emissions at each project stage

Outside of external reporting requirements, agencies should consider additional iterations of measurement and reporting in Stage 2 to inform design development and/or procurement. During both Stage 2 and Stage 3, projects should aim to report on total emissions per life cycle module and emissions per declared unit (see Appendix 10).

Where assets have multiple asset types, a separate reporting template with results for each asset type should be reported. This will facilitate the accurate comparison and benchmarking of emissions for project types and allow a better understanding of carbon emissions associated with assets and sub-asset components. For example, when comparing road projects, the carbon emissions for at grade portions (with no bridge or tunnel components) will be significantly different to those with bridges or tunnels included.

Reporting templates which capture the components discussed above have been provided in Appendix 10.

Use of functional or declared units

In addition to reporting the total embodied carbon quantified, carbon totals should be provided in relation to suitable declared units. This is important to support the comparison and evaluation of options and enable the development of carbon intensity benchmarks.

Functional or declared units are an important concept in life cycle and carbon assessments for building and infrastructure projects, as they provide a standardised basis for comparison and evaluation of options. The declared unit acts as a reference quantity that represents the primary purpose or function of the project or options being assessed.

For instance, the embodied carbon from a road project relating to a functional or declared unit is often expressed in tonnes of carbon dioxide equivalent per lane kilometre (tonnes CO₂-e/lane.km), whilst the embodied carbon metric for building projects is typically tonnes of carbon dioxide per gross floor area (tonnes CO₂-e/GFA).

Recommended declared units for different asset types are given in Appendix 11.

The specific benefits of functional and declared units include:

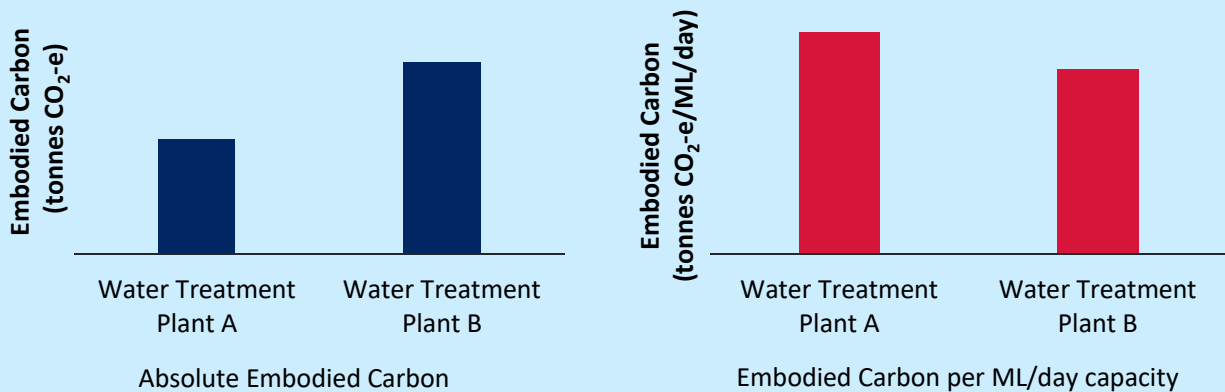
- **Fair comparison:** they enable meaningful comparisons between different products or services that might have different characteristics, functions, or production processes.
- **Normalisation of results:** carbon impacts often depend on the scale of asset or service provided. The functional or declared unit allows normalising the impacts to a standardised reference quantity, ensuring that the results can be interpreted correctly regardless of the scale of production.
- **Decision-making:** they help in making more informed decisions during evaluation of options, as they provide a clear representation of impact relative to the desired function or service (project needs).
- **Enabling development of future carbon intensity benchmarks:** reporting of embodied carbon by a functional or declared unit can help to develop future carbon intensity benchmarks across projects of differing scale and service capacity, which can then be used to inform early planning and business cases.

Case Study 6 below demonstrates the use of declared units when comparing two design options.

Case Study 6: Use of declared units for comparison

Two designs for water treatment plants are being compared in an early-phase options analysis. Water Treatment Plant A is designed to treat a total of 150 ML/day of wastewater, whilst Water Treatment Plant B has the capacity to treat 250 ML/day.

In comparing the options, Water Treatment Plant A results in a lower total embodied carbon, however, it is not until you compare based on the declared unit (ML water treated per day) that you see Water Treatment B is a more efficient design.



Stage 1 – Business case (reporting guidance)

The results of carbon assessments are increasingly being requested as part of business case submissions by incorporating carbon considerations into a project’s cost-benefit analysis. At these early stages of the infrastructure life cycle, limited project information means that achieving detailed and accurate estimates of embodied carbon is challenging. Reporting is therefore likely to be less detailed. Use of high-level carbon intensity benchmarks is also a limitation to detailed reporting.

Results for embodied carbon estimates should be reported (refer EN15978³³ or EN17472³⁴ stages and modules) for absolute emissions (t CO₂-e) as follows:

- **Product stage (A1-A3)**
- **Construction transport (A4)**
- **Construction process (A5)**, excluding land use change emissions and removals.

³³ BS EN15978:2011 *Sustainability of construction works. Assessment of environmental performance of buildings. Calculation method* (2011)

³³ BS EN 17472:2022 *Sustainability of construction works. Sustainability assessment of civil engineering works. Calculation methods* (2022)

³⁴ PAS 2080 - *Carbon Management in Buildings and Infrastructure (2023)*, Section 3.2 Terms and Definitions

- **Construction land use change emissions (A5)**, with emissions and removals also reported separately.
- **Repair, refurbishment and replacement (including rehabilitation for pavements) (B3-B5)**
- **Total upfront carbon (A1-A5)**
- **Total embodied carbon³⁵**

The following modules may also be included, however the contribution to emissions is typically relatively low (outside the 80% threshold for minimum inclusions):

- **Use phase material emissions and removals (B1)**
- **Maintenance (B2)**
- **Deconstruction/demolition (C1)**
- **Waste transport (C2)**
- **Waste processing for reuse/recycling (C3)**
- **Waste disposal (C4)**
- **Benefits and loads beyond the system boundary (D)**

Data for these emission sources is also limited and the effort to calculate significant. The end-of-life and module D impacts are also a long time in the future with more uncertain impacts.

Please refer to your jurisdiction-specific Addendum and/or jurisdiction-specific policy for mandatory and optional reporting requirements.

Where options have a differing scale, function or service provision, reporting of carbon emissions per declared unit (t CO₂-e/unit) can be considered to support comparison. Where projects include structural timber elements, emissions and removals for these products should also be reported separately (in line with PAS2080:2023³⁶). Refer to Appendix 6 and Appendix 10 for more details.

Projects are encouraged to undertake analysis to determine the whole life carbon implications to take into account potential trade-offs. Refer to section 3.3 for further information on consideration of trade-offs.

³⁵ This may be inclusive of modules B1 (use - material emissions and removals), C1-C4, and D where these have been estimated, noting that these modules are not covered by this Guide.

Stage 2 – Planning approval, design and procurement (reporting guidance)

As infrastructure projects proceed through design and planning approval, more detailed project information will be available for the embodied carbon assessment.

Results for embodied carbon estimates should be reported (refer EN15978³⁷ or EN17472³⁸ stages and modules), for both absolute emissions (t CO₂-e) and per functional or declared unit (tCO₂-e/unit), as follows:

- **Product stage (A1-A3)**
- **Construction transport (A4)**
- **Construction process (A5)**, excluding land use change emissions and removals.
- **Construction land use change emissions (A5)**, with emissions and removals also reported separately.
- **Repair, refurbishment and replacement (including rehabilitation for pavements) (B3-B5)**
- **Total upfront carbon (A1-A5)**
- **Total embodied carbon³⁹**

The following modules may also be included, however the contribution to emissions is typically relatively low (outside the 80% threshold for minimum inclusions):

- **Use phase material emissions and removals (B1)**
- **Maintenance (B2)**
- **Deconstruction/demolition (C1)**
- **Waste transport (C2)**
- **Waste processing for reuse/recycling (C3)**
- **Waste disposal (C4)**
- **Benefits and loads beyond the system boundary (D)**

Please refer to your jurisdiction-specific addendum and/or jurisdiction-specific policy for mandatory and optional reporting requirements.

Where projects include structural timber elements, emissions and removals for these products should also be reported separately (in line with PAS2080:2023⁴⁰). Refer to Appendix 6 and Appendix 10 for more details.

For large and complex projects with multiple asset types, results should be broken down by asset types. To support decision-making and the development of future carbon intensity benchmarks, emissions may also be broken down by locations or sub-asset elements within a project boundary.

³⁷ BS EN15978:2011 [Sustainability of construction works. Assessment of environmental performance of buildings. Calculation method](#) (2011)

³⁷ BS EN 17472:2022 [Sustainability of construction works. Sustainability assessment of civil engineering works. Calculation methods](#) (2022)

³⁸ PAS 2080 - [Carbon Management in Buildings and Infrastructure \(2023\)](#), Section 3.2 Terms and Definitions

³⁹ This may be inclusive of modules B1 (use - material emissions and removals), C1-C4, and D where these have been estimated, noting that these modules are not covered by this guide.

Stage 3 – Construction and practical completion (reporting guidance)

At construction and practical completion, further as-built data will be available to conduct a more detailed carbon assessment based on actual quantities of resources used. Please refer to your jurisdiction-specific addendum and/or jurisdiction-specific policy for mandatory and optional reporting requirements.

An important objective of this Guide is that there is cross-jurisdictional consistency on Stage 3 reporting so that data can be consolidated and used to monitor progress and inform future embodied carbon benchmarks. To achieve this, reporting for embodied carbon estimates should include a breakdown by the following life cycle modules (refer EN15978⁴¹ or EN17472⁴² stages and modules in Section 3.1), for both absolute emissions (t CO₂-e) and per functional or declared unit (t CO₂-e/unit), as follows:

- **Product stage (A1-A3)**
- **Construction transport (A4)**
- **Construction process (A5)**, excluding land use change emissions and removals.
- **Construction land use change emissions (A5)**, with emissions and removals also reported separately.
- **Repair, refurbishment and replacement (including rehabilitation for pavements) (B3-B5)**
- **Total upfront carbon (A1-A5)**
- **Total embodied carbon⁴³**

The following modules may also be included, however the contribution to emissions is typically relatively low (outside the 80% threshold for minimum inclusions):

- **Use phase material emissions and removals (B1)**
- **Maintenance (B2)**
- **Deconstruction/demolition (C1)**
- **Waste transport (C2)**
- **Waste processing for reuse/recycling (C3)**
- **Waste disposal (C4)**
- **Benefits and loads beyond the system boundary (D)**

Where projects include structural timber elements, emissions and removals for these products should also be reported separately (in line with PAS2080:2023⁴⁴). Refer to Appendix 6 and Appendix 10 for more details.

For large and complex projects with multiple asset types, results must be broken down by asset types. To support decision-making and the development of future carbon intensity benchmarks, emissions may also be broken down by locations or sub-asset elements within a project boundary.

⁴¹ BS EN15978:2011 [Sustainability of construction works. Assessment of environmental performance of buildings. Calculation method](#) (2011)

⁴¹ BS EN 17472:2022 [Sustainability of construction works. Sustainability assessment of civil engineering works. Calculation methods](#) (2022)

⁴¹ PAS 2080 - [Carbon Management in Buildings and Infrastructure \(2023\)](#), Section 3.2 Terms and Definitions

⁴³ This may be inclusive of modules B1 (use - material emissions and removals), C1-C4, and D where these have been estimated, noting that these modules are not covered by this guide.

7 References

- ALCAS. (n.d.). *AusLCI Carbon Emissions Factors*. Retrieved from <https://www.alcas.asn.au/auslci-emissions-factors>
- Australian Bureau of Statistics. (2023). *Private New Capital Expenditure and Expected Expenditure, Australia*. Retrieved from <https://www.abs.gov.au/statistics/economy/business-indicators/private-new-capital-expenditure-and-expected-expenditure-australia/latest-release>
- BSI. (2023). *PAS 2080 - Carbon management in buildings and infrastructure*. Retrieved from <https://www.bsigroup.com/en-GB/our-services/product-certification/product-certification-schemes/pas-2080-carbon-management-in-infrastructure-verification/>
- European Standards. (2011). *EN 15978:2011 Sustainability of construction works. Assessment of environmental performance of buildings. Calculation method*. Retrieved from <https://www.en-standard.eu/bs-en-15978-2011-sustainability-of-construction-works-assessment-of-environmental-performance-of-buildings-calculation-method/>
- European Standards. (2019). *EN 15804:2012+A2:2019 Sustainability of construction works - Environmental product declarations - Core rules for the product category of construction products*. Retrieved from <https://www.en-standard.eu/bs-en-15804-2012-a2-2019-sustainability-of-construction-works-environmental-product-declarations-core-rules-for-the-product-category-of-construction-products/>
- European Standards. (2022). *EN 17472:2022 Sustainability of construction works. Sustainability assessment of civil engineering works. Calculation methods*. Retrieved from <https://www.en-standard.eu/bs-en-17472-2022-sustainability-of-construction-works-sustainability-assessment-of-civil-engineering-works-calculation-methods/>
- Government Information (Public Access) Act 2009 No 52, s 4(1), Sch 4. Retrieved from <https://legislation.nsw.gov.au/view/whole/html/inforce/current/act-2009-052#statusinformation>
- Green Building Council of Australia. (2023). *A practical guide to upfront carbon reductions - For new buildings and major refurbishments*. Retrieved from <https://gbca-web.s3.amazonaws.com/media/documents/a-practical-guide-to-upfront-carbon-reductions.pdf>
- ICE. (2012). *CESMM4: Civil Engineering Standard Method of Measurement, Fourth edition*. Retrieved from <https://www.icevirtuallibrary.com/doi/book/10.1680/cesmm.57517>
- Infrastructure Australia. (2021). *Infrastructure Australia Assessment Framework*. Australian Government. Retrieved from <https://www.infrastructureaustralia.gov.au/sites/default/files/2021-07/Assessment%20Framework%202021%20Overview.pdf>
- Infrastructure Australia. (2022). *Infrastructure Market Capacity Report*. Retrieved from <https://www.infrastructureaustralia.gov.au/publications/2022-market-capacity-report>
- Infrastructure Australia. (2023). *Guide to assessing greenhouse gas emissions (interim)*. Australian Government. Retrieved from <https://www.infrastructureaustralia.gov.au/guide-assessing-greenhouse-gas-emissions-interim>
- International Organization for Standardization. (2017). *ISO 20400:2017 Sustainable Procurement - Guidance*. Retrieved from <https://www.iso.org/standard/63026.html>
- IQS. (2023). *Australian Cost Management Manual*. Retrieved from <https://www.aiqs.com.au/shop/australian-cost-management-manual-volume-1>
- NSW Treasury . (2018). *TPP 18-06 NSW Government Business Case Guidelines*. Retrieved from <https://www.treasury.nsw.gov.au/sites/default/files/2021-05/TPP18-06%20%20NSW%20Government%20Business%20Case%20Guidelines.pdf>
- NSW Treasury. (2018). *TPP18-07 Organisational Resilience: Practitioner Guide for NSW Public Sector Organisations*. Retrieved from <https://www.treasury.nsw.gov.au/sites/default/files/2018-09/TPP18-07%20Organisational%20Resilience%20-%20Practitioner%20guide%20for%20NSW%20Public%20Sector%20Organisations%20-pdf.pdf>
- NSW Treasury. (2023). *TPG23-08 NSW Government Guide to Cost-Benefit Analysis*. Retrieved from https://www.treasury.nsw.gov.au/sites/default/files/2023-04/tpg23-08_nsw-government-guide-to-cost-benefit-analysis_202304.pdf
- Paul, K.I et al. (2016). Testing the generality of above-ground biomass allometry across plant functional types at the content scale. *Global change biology* , 22(6), 2106-2124.

- Paul, K.I et al. (2019). Testing the generality of above-ground biomass allometry across plant functional type. *Forest Ecology and Management*, 432, 102-114.
- RICS. (2021). *ICMS: Global Consistency in Presenting*. Retrieved from <https://www.rics.org/profession-standards/rics-standards-and-guidance/sector-standards/construction-standards/icms3>
- Transport for NSW. (2023). *Carbon Estimate and Reporting Tool (CERT)*. Retrieved from <https://www.transport.nsw.gov.au/industry/doing-business-transport/sustainability-at-transport>

Appendix 1: Addendum to the Technical Guidance

This Addendum provides additional support in applying the Guide in each jurisdiction, including:

- Jurisdiction-specific policy requirements for embodied carbon measurement and reporting
- Additional jurisdiction-specific tools, resources, and data sources.

Infrastructure delivery agencies should primarily follow the approaches outlined in the Guide, complemented by additional materials provided in this Addendum. Information included in this Addendum is provided for illustrative purposes, and each jurisdiction can provide additional information and amend the Addendum as required.

An overview of this Addendum is provided in Table A1.1 below.

Table A1.1 Jurisdiction-specific policy requirements and system boundaries for measurement

Section of this Addendum	Sub section	Relevant sections of the Guide
Policy requirements	Relevant policies and their scope of measurement	Section 3
	External reporting requirements	Section 4, Section 6
Additional resources	Supporting tools	Appendix 2
	Jurisdiction-specific parameters	Appendix 3, Appendix 9

Policy requirements

This section provides an overview of the relevant carbon measurement policies in this jurisdiction.

Note: Both the Guide and this jurisdiction-specific Addendum aim to identify the general expectations on agencies while noting that this does not preclude project teams from doing more than expected.

Table A1.1 sets out relevant policies that require measurement of a certain scope (or system boundary) for infrastructure projects.

The Guide provides a methodology to quantify embodied carbon but identifies whole life carbon quantification as best practice. Each jurisdiction or agency may have additional guidance to support quantification of carbon emissions for modules A0 and B6-D.

Note: A policy must require measurement or reporting with reference to one of the table’s life cycle stages to be included in Table A1.2.

Table A1.2 Jurisdiction-specific policy requirements and system boundaries for measurement

Policy	Asset type	Life cycle stage		
		Upfront carbon	In use carbon	Other (Please specify)
		A1-A5	B1 B5	
<i>Example policy 1</i>	All ^a	Required	Required	Emissions from the combustion
<i>Example policy 2</i>	All	Required	Recommended	Whole life carbon recommended
<i>Example policy 3</i>	Buildings	Required		
<i>Example policy 4</i>	Transport	Recommended	Recommended	Whole life carbon recommended

Note: Jurisdictions may wish to add footnotes to this table with superscript references. e.g. Note: (a) General Government Agencies and non-commercial Public Non-Financial Corporations

A. External reporting requirements for embodied carbon (Sections 4 and 6 of the Guide)

Table A1.3 sets out reporting to external parties that is required as part of documentation or approval of a given project (e.g., when applying to a planning consent authority). External reporting also supports future benchmark development and policy monitoring for embodied carbon.

Each jurisdiction or agency may have additional guidance to support reporting of emissions beyond modules A1-B5.

Table A1.3 Jurisdiction-specific external reporting requirements for embodied carbon

Infrastructure type	Business case	Planning approval, design, and procurement	Construction and practical completion
Buildings	<input type="checkbox"/> A1-A5	<input type="checkbox"/> A1-A5	<input type="checkbox"/> A1-A5
	<input type="checkbox"/> B1-B5	<input type="checkbox"/> B1-B5	<input type="checkbox"/> B1-B5
Transport	<input type="checkbox"/> A1-A5	<input type="checkbox"/> A1-A5	<input type="checkbox"/> A1-A5
	<input type="checkbox"/> B1-B5	<input type="checkbox"/> B1-B5	<input type="checkbox"/> B1-B5
Other^a	<input type="checkbox"/> A1-A5	<input type="checkbox"/> A1-A5	<input type="checkbox"/> A1-A5
	<input type="checkbox"/> B1-B5	<input type="checkbox"/> B1-B5	<input type="checkbox"/> B1-B5

Note: Jurisdictions may wish to add footnotes to this table with superscript references. e.g. Note: (a) Other infrastructure developed by General Government Agencies (or Budget Material Agencies)

Additional resources

A key principle of the Guide and this Addendum is to encourage use of better information when available, whether jurisdiction or project specific. This section outlines additional resources and parameters in this jurisdiction to support measurement.

Supporting tools and resources

In addition to the tools in Appendix 2 of the Guide, infrastructure delivery agencies also have access to the jurisdiction-specific measurement tools in Table A1.4.

Note: The tools identified in Table A1.3 must not conflict with the methodology, scope or data and emissions factor hierarchies identified in the Guide. Infrastructure delivery agencies are encouraged to request tool vendors align with the Guide on prioritised emission factor sources, prioritised calculation approaches, and reporting summaries.

Table A1.4 Jurisdiction-specific tools and resources to support measurement

Document	Author	Aligned with Guide	Relevant content
		<input type="checkbox"/> Yes <input type="checkbox"/> In progress	
		<input type="checkbox"/> Yes <input type="checkbox"/> In progress	
		<input type="checkbox"/> Yes <input type="checkbox"/> In progress	
		<input type="checkbox"/> Yes <input type="checkbox"/> In progress	
		<input type="checkbox"/> Yes <input type="checkbox"/> In progress	

Jurisdiction-specific parameters

The Guide provides all emission factors and calculation assumptions necessary to conduct measurement, including some jurisdiction-specific parameters. However, the Guide also encourages agencies to preference more precise emission factors and calculation assumptions than the defaults provided if available.

Note: Jurisdictions may wish to specify more regionally representative emission factors in Table A1.5, Table A1.6, and Table A1.7 in cases where this is relevant.

Table A1.5 Jurisdiction-specific emission factors for the transport stage (A4)

Transport mode	Quantity	Unit	Source
Articulated Truck		tonnes CO ₂ -e/tonnes.km transport (tkm)	
Concrete Agitator Truck		tonnes CO ₂ -e/tkm	
Light Commercial Vehicles		tonnes CO ₂ -e/tkm	
Rail, Bulk Transport		tonnes CO ₂ -e/tkm	
Rigid Truck		tonnes CO ₂ -e/tkm	
Shipping		tonnes CO ₂ -e/tkm	

Table A1.6 Jurisdiction-specific emission factors for construction (A5)

Resource	Quantity	Unit
Electricity		
Standard grid electricity		kg CO ₂ -e/kWh
Renewable electricity (onsite, behind the meter)		kg CO ₂ -e/kWh
Renewable (offsite, GreenPower, LGCs etc)		kg CO ₂ -e/kWh
Fuel Use		
Diesel oil		kg CO ₂ -e/kL
Liquified petroleum gas		kg CO ₂ -e/kL
Biodiesel (B5)		kg CO ₂ -e/kL
Biodiesel (B10)		kg CO ₂ -e/kL
Biodiesel (B20)		kg CO ₂ -e/kL
Biodiesel (B100)		kg CO ₂ -e/kL
Petroleum based greases		kg CO ₂ -e/kL
...		
Waste generation		

Resource	Quantity	Unit
Total waste to landfill		tonnes CO ₂ -e/tonne
Total waste to recycling		tonnes CO ₂ -e/tonne
Waste to landfill - inert waste (concrete/metals/plastics/glass)		tonnes CO ₂ -e/tonne
Waste to landfill - food		tonnes CO ₂ -e/tonne
Waste to landfill - paper and cardboard		tonnes CO ₂ -e/tonne
Waste to landfill - garden and green		tonnes CO ₂ -e/tonne
Waste to landfill - wood		tonnes CO ₂ -e/tonne
Waste to landfill - textiles		tonnes CO ₂ -e/tonne
Waste to landfill- sludge		tonnes CO ₂ -e/tonne
Waste to landfill - rubber and leather		tonnes CO ₂ -e/tonne
Land use and land use change		
Total land cleared		tonnes CO ₂ -e/ha
Total trees cleared		kg CO ₂ -e/tree
Land clearing - Vegetation Class A3		tonnes CO ₂ -e/ha
Land clearing - Vegetation Class A4		tonnes CO ₂ -e/ha
Land clearing - Vegetation Class A5		tonnes CO ₂ -e/ha
Land clearing - Vegetation Class A6		tonnes CO ₂ -e/ha
Land clearing - Vegetation Class A7		tonnes CO ₂ -e/ha
Land clearing - Vegetation Class B3		tonnes CO ₂ -e/ha
Land clearing - Vegetation Class B4		tonnes CO ₂ -e/ha
Land clearing - Vegetation Class B5		tonnes CO ₂ -e/ha
Land clearing - Vegetation Class B6		tonnes CO ₂ -e/ha
Land clearing - Vegetation Class C1		tonnes CO ₂ -e/ha
Land clearing - Vegetation Class C2		tonnes CO ₂ -e/ha
Land clearing - Vegetation Class C3		tonnes CO ₂ -e/ha
Land clearing - Vegetation Class C4		tonnes CO ₂ -e/ha
Land clearing - Vegetation Class C5		tonnes CO ₂ -e/ha
Land clearing - Vegetation Class D1		tonnes CO ₂ -e/ha
Land clearing - Vegetation Class D2		tonnes CO ₂ -e/ha
Land clearing - Vegetation Class D3		tonnes CO ₂ -e/ha

Resource	Quantity	Unit
Land clearing - Vegetation Class E1		tonnes CO ₂ -e/ha
Land clearing - Vegetation Class E2		tonnes CO ₂ -e/ha
Land clearing - Vegetation Class E3		tonnes CO ₂ -e/ha
Land clearing - Vegetation Class F1		tonnes CO ₂ -e/ha
Land clearing - Vegetation Class F2		tonnes CO ₂ -e/ha
Land clearing - Vegetation Class G2		tonnes CO ₂ -e/ha
Land clearing - Vegetation Class H1		tonnes CO ₂ -e/ha
Land clearing - Vegetation Class H2		tonnes CO ₂ -e/ha
Land clearing - Vegetation Class I		tonnes CO ₂ -e/ha
Large tree (50cm<DBH<100cm) – Eucalypt		kg CO ₂ -e/tree
Medium tree (20cm<DBH<50cm) – Eucalypt		kg CO ₂ -e/tree
Small tree (5cm<DBH<20cm) - Shrub		kg CO ₂ -e/tree

Table A1.7 Jurisdiction-specific standard conversion factors

Input/activity	Quantity	Unit	Source
Diesel oil			
Liquefied petroleum gas		a	
Petroleum based greases			
Biodiesel			

Default assumptions for the transport of materials (A4) and waste (A5)

Note: Jurisdictions may wish to specify more regionally representative calculation assumptions in Table A1.8 in cases where this is relevant.

Table A1.8 Jurisdiction-specific assumptions for the transport of materials (A4) and waste (A5)

Product / material	Truck distance (km)	Rail distance (km)	Sea distance (km)
Material transport distances			
Aggregate			
Aluminium			
Asphalt			

Bitumen Binders			
Bricks			
Cement			
Concrete			
Copper			
Electrical Bulk			
Fibreglass			
Girders			
Glass			
Insulation			
Linemarking & Road Furnitures			
Paint			
Plasterboard			
Plastics and Polymeric materials			
Plywood			
PV Panels			
Rail Track			
Rock/Bluestone			
Sand			
Steel - Structural Elements			
Steel - Transmission Cable			
Steel Re-inforcement			
Timber			
Waste transport distances			
Waste to landfill			
Waste to recycling			

Appendix 2: Supporting tools and resources

This Guide aims to improve consistency in data and assumptions used by all Australian infrastructure agencies. A range of embodied carbon calculation guidance documents and tools are available to support the carbon assessments process. It is anticipated that more tools that align with this guide will be available over time. These are outlined below in Table A2.1. Jurisdiction-specific Addendum might detail jurisdiction-specific tools and specific requirements applicable to tools, if any.

The principles in this Guide can be used to support carbon calculations through the various tools available. Projects undertaking Green Star and Infrastructure Sustainability Ratings should be able to align well with the reporting requirements of this Guide.

Table A2.1 Sector specific guidance and tools for carbon measurement

Document	Author	Relevant content
Carbon Calculators		
Infrastructure Sustainability Materials Calculator	Infrastructure Sustainability Council	Calculator and user guide for the measurement of embodied (material related) carbon emissions and other environmental impacts for infrastructure projects.
Upfront Carbon Calculator	Green Building Council of Australia (GBCA)	Calculator and interim guide for the measurement of upfront emissions in buildings projects during design and at practical completion.
Embodied Emissions Tool – under development	NABERS	Calculator (in development) to measure embodied carbon in new buildings and major refurbishments.
Other guidance covering carbon estimation and management		
Australian Transport Assessment and Planning (ATAP) Economic Analysis Framework and Parameter Values	Australian Transport Assessment and Planning (ATAP)	The economic analysis framework provides guidance on the inclusion of environmental externalities in business cases and cost-benefit analysis for transport projects. The PV5 Environmental Parameter Values provide fuel consumption and carbon emission conversion factors.
Guide to assessing greenhouse gas emissions	Infrastructure Australia	A guide which sets recommendations for assessing greenhouse gas emissions in infrastructure proposals.
Guidance note – Valuing emissions for economic analysis	Infrastructure Australia	The guidance note sets out the monetised value of GHG emissions for use in economic analysis, including cost-benefit analysis and cost effectiveness analysis. The values will support more transparent and consistent decision making for decarbonisation initiatives as well as other projects with emissions impacts.
PAS2080:2023 <i>Carbon management in buildings and infrastructure</i>	BSI Group	A global standard which specifies requirements for the management of whole life carbon in buildings and infrastructure

Document	Author	Relevant content
Whole life carbon assessment (WLCA) for the built environment	RICS	A global standard for carbon measurement in the built environment.

Appendix 3: Default emission factors

The following section provides default emission factors which can be used for embodied carbon assessments. As emission factors are likely to change over time, it is recommended that agencies refer to the source of the emission factors for the latest figures.

Product stage emission factors (A1-A3)

The following sets of emission factors should be used when you don't have product-specific data:

- *AusLCI Carbon Emission Factors* (use the Carbon Neutrality Assumption method, excluding infrastructure)⁴⁵
- *NABERS Embodied Emission Tool* (once available)
- *Infrastructure Australia's Embodied Carbon Projections for Australian Infrastructure and Buildings* study⁴⁶

Emission factors can also be sourced from the carbon calculators in Appendix 2.

When the specific supplier of a product or material is known, data can be sourced from verified Environmental Product Declarations (see Appendix 6 for which standards these must comply with).

Default transport emission factors (A4)

Recommended emission factors for the transport stage are provided in Table A3.1 below. These have been derived from the *AusLCI Carbon Emission Factors*.

Table A3.1 Default emission factors for the transport stage

Transport mode	Quantity	Unit
Articulated Truck	0.00007	tonnes CO ₂ -e/tonnes.km transport (tkm)
Concrete Agitator Truck	0.00013	tonnes CO ₂ -e/tkm
Light Commercial Vehicles	0.00120	tonnes CO ₂ -e/tkm
Rail, Bulk Transport	0.00002	tonnes CO ₂ -e/tkm
Rigid Truck	0.00022	tonnes CO ₂ -e/tkm
Shipping	0.00001	tonnes CO ₂ -e/tkm

⁴⁵ ALCAS, <https://www.alcas.asn.au/auslci-emissions-factors> (n.d).

⁴⁶ Forthcoming as of February 2024

Default construction emission factors (A5)

Default emission factors for the construction stage are provided in Table A3.2 below. These emission factors have been derived from the following sources:

- *Australian National Greenhouse Account (NGA) Factors* for July 2023 (or latest available)
- *Transport Authorities Greenhouse Group Greenhouse Gas Assessment Workbook for Road Projects*
- Journal articles.

As it is common for emission factors to change over time, it is strongly encouraged that the latest version of the Australian NGA Factors is used when seeking emission factors. All editions can be found on the National Greenhouse Account Factors website.⁴⁷

The NGA Factors for electricity are location-based emission factors and based on the state's mix of renewable and non-renewable energy. The purchase of Greenpower, power purchase agreements (PPAs), large-scale generation certificates (LGCs) or behind the meter renewables (e.g., onsite solar PV) can adopt a 0 kg CO₂-e/kWh for the portion of energy supplied by these sources.

While jurisdiction-specific NGA Factors for electricity use are available in Table A2.2, the national average should be used when using a market-based approach to estimating electricity emissions. For example, ACT have a Jurisdictional Renewable Power Purchase (JRPP) factor and might use a market-based method. Please refer to the guide to using NGA Factors for when to select location-based or market-based approaches.⁴⁸

Where there are separate factors for scope 1, scope 2 and scope 3 emissions, these should be added together.

Table A3.2 Default construction (A5) emission factors

Input/activity	Quantity	Unit	Source
Energy Use (Jurisdiction-specific)			
Grid electricity used on site in NSW/ACT (Scope 2)	0.68	kg CO ₂ -e/kWh	NGA 2023 ^a <i>Grid emission factors will change over time</i>
Grid electricity used on site in NSW/ACT (Scope 3)	0.05	kg CO ₂ -e/kWh	NGA 2023 ^a <i>Grid emission factors will change over time</i>
Grid electricity used on site in Victoria (Scope 2)	0.79	kg CO ₂ -e/kWh	NGA 2023 ^a <i>Grid emission factors will change over time</i>
Grid electricity used on site in Victoria (Scope 3)	0.07	kg CO ₂ -e/kWh	NGA 2023 ^a <i>Grid emission factors will change over time</i>
Grid electricity used on site in Queensland (Scope 2)	0.73	kg CO ₂ -e/kWh	NGA 2023 ^a <i>Grid emission factors will change over time</i>
Grid electricity used on site in Queensland (Scope 3)	0.15	kg CO ₂ -e/kWh	NGA 2023 ^a

⁴⁷ Department of Climate Change, Energy, the Environment and Water, [National Greenhouse Accounts Factors](#), Australian Government website, 17 August 2023, accessed 19 January 2024.

⁴⁸ Department of Climate Change, Energy, the Environment and Water, [National Greenhouse Accounts Factors: 2023](#), Australian Government website, 6 October 2023, accessed 19 January 2024.

Input/activity	Quantity	Unit	Source
			<i>Grid emission factors will change over time</i>
Grid electricity used on site in South Australia (Scope 2)	0.25	kg CO ₂ -e/kWh	NGA 2023 ^a <i>Grid emission factors will change over time</i>
Grid electricity used on site in South Australia (Scope 3)	0.08	kg CO ₂ -e/kWh	NGA 2023 ^a <i>Grid emission factors will change over time</i>
Grid electricity used on site in WA – South West Interconnected System (Scope 2)	0.53	kg CO ₂ -e/kWh	NGA 2023 ^a <i>Grid emission factors will change over time</i>
Grid electricity used on site in WA – South West Interconnected System (Scope 3)	0.04	kg CO ₂ -e/kWh	NGA 2023 ^a <i>Grid emission factors will change over time</i>
Grid electricity used on site in WA – North Western Interconnected System (Scope 2)	0.62	kg CO ₂ -e/kWh	NGA 2023 ^a <i>Grid emission factors will change over time</i>
Grid electricity used on site in WA – North Western Interconnected System (Scope 3)	0.07	kg CO ₂ -e/kWh	NGA 2023 ^a <i>Grid emission factors will change over time</i>
Grid electricity used on site in Tasmania (Scope 2)	0.12	kg CO ₂ -e/kWh	NGA 2023 ^a <i>Grid emission factors will change over time</i>
Grid electricity used on site in Tasmania (Scope 3)	0.01	kg CO ₂ -e/kWh	NGA 2023 ^a <i>Grid emission factors will change over time</i>
Grid electricity used on site in Northern Territory (Scope 2)	0.54	kg CO ₂ -e/kWh	NGA 2023 ^a <i>Grid emission factors will change over time</i>
Grid electricity used on site in Northern Territory (Scope 3)	0.07	kg CO ₂ -e/kWh	NGA 2023 ^a <i>Grid emission factors will change over time</i>
Grid electricity used on site in Northern Territory – Darwin Katherine Interconnected System (Scope 2)	0.54	kg CO ₂ -e/kWh	NGA 2023 ^a <i>Grid emission factors will change over time</i>
Grid electricity used on site in Northern Territory – Darwin Katherine Interconnected System (Scope 3)	0.07	kg CO ₂ -e/kWh	NGA 2023 ^a <i>Grid emission factors will change over time</i>
Grid electricity used on site – National (Scope 2)	0.65	kg CO ₂ -e/kWh	NGA 2023 ^a <i>Grid emission factors will change over time</i>
Grid electricity used on site – National (Scope 3)	0.08	kg CO ₂ -e/kWh	NGA 2023 ^a

Input/activity	Quantity	Unit	Source
			<i>Grid emission factors will change over time</i>
Energy use (national)			
Diesel combusted on site (Scope 1)	70.2	kg CO ₂ -e/GJ	NGA 2023 ^a
Diesel combusted on site (Scope 3)	17.3	kg CO ₂ -e/GJ	NGA 2023 ^a
Liquified petroleum gas (LPG) (Scope 1)	60.60	kg CO ₂ -e/GJ	NGA 2023 ^a
Liquified petroleum gas (LPG) (Scope 3)	20.2	kg CO ₂ -e/GJ	NGA 2023 ^a
Petroleum based greases (Scope 1)	3.5	kg CO ₂ -e/GJ	NGA 2023 ^a
Petroleum based greases (Scope 3)	18	kg CO ₂ -e/GJ	NGA 2023 ^a
Biodiesel (Scope 1)	0.28	kg CO ₂ -e/GJ	NGA 2023 ^a
Waste treatment			
Waste to landfill – inert waste (concrete/metals/plastics/glass)	0	tonnes CO ₂ -e/tonne	NGA 2023 ^a
Waste to landfill – food	2.1	tonnes CO ₂ -e/tonne	NGA 2023 ^a
Waste to landfill – paper and cardboard	3.3	tonnes CO ₂ -e/tonne	NGA 2023 ^a
Waste to landfill – garden and green	1.6	tonnes CO ₂ -e/tonne	NGA 2023 ^a
Waste to landfill – wood	0.7	tonnes CO ₂ -e/tonne	NGA 2023 ^a
Waste to landfill – textiles	2.0	tonnes CO ₂ -e/tonne	NGA 2023 ^a
Waste to landfill- sludge	0.4	tonnes CO ₂ -e/tonne	NGA 2023 ^a
Waste to landfill – rubber and leather	3.3	tonnes CO ₂ -e/tonne	NGA 2023 ^a
Waste to landfill – overall construction and demolition waste	0.2	tonnes CO ₂ -e/tonne	NGA 2023 ^a
Land use and land use change			
Land clearing – Vegetation Class A3	227		TAGG Workbook (2013)
Land clearing – Vegetation Class A4	384	tonnes CO ₂ -e/ha	TAGG Workbook (2013)
Land clearing – Vegetation Class A5	532	tonnes CO ₂ -e/ha	TAGG Workbook (2013)

Input/activity	Quantity	Unit	Source
Land clearing – Vegetation Class A6	594	tonnes CO2-e/ha	TAGG Workbook (2013)
Land clearing – Vegetation Class A7	768	tonnes CO2-e/ha	TAGG Workbook (2013)
Land clearing – Vegetation Class B3	237	tonnes CO2-e/ha	TAGG Workbook (2013)
Land clearing – Vegetation Class B4	401	tonnes CO2-e/ha	TAGG Workbook (2013)
Land clearing – Vegetation Class B5	554	tonnes CO2-e/ha	TAGG Workbook (2013)
Land clearing – Vegetation Class B6	618	tonnes CO2-e/ha	TAGG Workbook (2013)
Land clearing – Vegetation Class C1	77	tonnes CO2-e/ha	TAGG Workbook (2013)
Land clearing – Vegetation Class C2	209	tonnes CO2-e/ha	TAGG Workbook (2013)
Land clearing – Vegetation Class C3	307	tonnes CO2-e/ha	TAGG Workbook (2013)
Land clearing – Vegetation Class C4	521	tonnes CO2-e/ha	TAGG Workbook (2013)
Land clearing – Vegetation Class C5	718	tonnes CO2-e/ha	TAGG Workbook (2013)
Land clearing – Vegetation Class D1	77	tonnes CO2-e/ha	TAGG Workbook (2013)
Land clearing – Vegetation Class D2	209	tonnes CO2-e/ha	TAGG Workbook (2013)
Land clearing – Vegetation Class D3	307	tonnes CO2-e/ha	TAGG Workbook (2013)
Land clearing – Vegetation Class E1	80	tonnes CO2-e/ha	TAGG Workbook (2013)
Land clearing – Vegetation Class E2	217	tonnes CO2-e/ha	TAGG Workbook (2013)
Land clearing – Vegetation Class E3	316	tonnes CO2-e/ha	TAGG Workbook (2013)
Land clearing – Vegetation Class F1	106	tonnes CO2-e/ha	TAGG Workbook (2013)
Land clearing – Vegetation Class F2	287	tonnes CO2-e/ha	TAGG Workbook (2013)

Input/activity	Quantity	Unit	Source
Land clearing – Vegetation Class G2	113	tonnes CO ₂ -e/ha	TAGG Workbook (2013)
Land clearing – Vegetation Class H1	115	tonnes CO ₂ -e/ha	TAGG Workbook (2013)
Land clearing – Vegetation Class H2	309	tonnes CO ₂ -e/ha	TAGG Workbook (2013)
Land clearing – Vegetation Class I	110	tonnes CO ₂ -e/ha	TAGG Workbook (2013)
Very large tree (DBH > 100cm) – Eucalypt	47,505	kg CO ₂ -e/tree	Paul, K.I et al. (2016) ⁴⁹ Paul, K.I et al. (2019) ⁵⁰
Large tree (50cm<DBH<100cm) – Eucalypt	18,660	kg CO ₂ -e/tree	Paul, K.I et al. (2016) Paul, K.I et al. (2019)
Medium tree (20cm<DBH<50cm) – Eucalypt	4,287	kg CO ₂ -e/tree	Paul, K.I et al. (2016) Paul, K.I et al. (2019)
Small tree (5cm<DBH<20cm) – Shrub	192	kg CO ₂ -e/tree	Paul, K.I et al. (2016) Paul, K.I et al. (2019)
Notes: a – refer to the latest Australian National Greenhouse Account Factors for updated emission factors b – NE = not estimated. No data available to support the provision for a scope 3 factor for this grid.			

Standard conversions

Standard conversions which are typically during the carbon calculation process are provided in Table A3.3 below.

Table A3.3 Standard conversion factors

Input/activity	Quantity	Unit	Source
Diesel oil	38.6	GJ/kL	NGA 2023 ^a
Liquefied petroleum gas	25.7	GJ/kL	NGA 2023 ^a
Petroleum based greases	38.8	GJ/kL	NGA 2023 ^a
Biodiesel	34.6	GJ/kL	NGA 2023 ^a
Notes: a – refer to the latest Australian National Greenhouse Account Factors for updated conversion factors			

⁴⁹ Paul, K.I et al, *Testing the generality of above-ground biomass allometry across plant functional types at the content scale* (2016)

⁵⁰ Paul, K.I et al, *Testing the generality of above-ground biomass allometry across plant functional types* (2019)

Decarbonisation of the electricity grid over time

As the shift towards renewable electricity continues, the emission factor of the Australian grid is steadily declining. This should be considered when conducting operational carbon calculations (B6-B7), particularly for operational energy use calculations (B6).

Table A3.4 and Figure A3.1 below show the emission factor projections for the NSW electricity network. These are outlined in Appendix C of the *Australian Emission Projections 2022* report⁵¹, and are regularly updated.

Project teams are advised to refer to the most recent *Australian Emission Projections* report for updated emission factors, as the projections are regularly changing. For projects with a long or delayed construction phase, it is recommended to use these factors to represent the most likely electricity grid intensity at time of consumption (through use of a representative middle point or by averaging estimated electricity consumption over the construction program and applying relevant factors).

⁵¹ Department of Climate Change, Energy, the Environment and Water, [Australia's emissions projections 2022](#), Australian Government, 2022.

Table A3.4 Projected Australian electricity grid emission factors over time

Grid	23	24	25	26	27	28	29	30	31	32	33	34	35
Australia	0.77	0.65	0.56	0.51	0.47	0.41	0.35	0.29	0.27	0.25	0.24	0.21	0.20

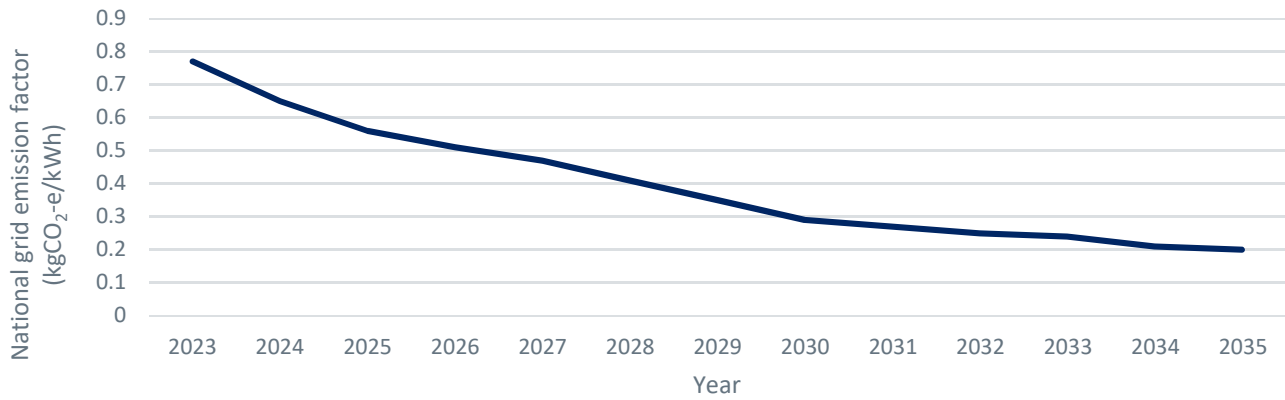


Figure A3.1 Projected Australian grid decarbonisation over time

Appendix 4: Detailed worked example – social infrastructure

The following section provides an example of how carbon measurement and reporting can take place at each project stage (focused on upfront carbon only). This **example is hypothetical only** and aims to demonstrate the practical application of the guidance in this document.

Stage 1 – Strategic Options and Business Case

With a growing and aging population, the demand for health services is increasing. Health Infrastructure NSW and a Local Health District are exploring options to increase the provision of hospital capacity to meet this growing demand in urban areas. At the Strategic Options phase, the project team are exploring options outlined in Table A4.1 below, including a new build hospital, the expansion of existing hospitals, and a non-build option.

Table A4.1 Worked example: Potential strategic options to cater for growing demand in health services

New build	Upgrade and expansion of existing hospitals	Non build option
Development of a new hospital on a greenfield site: <ul style="list-style-type: none"> - 400 beds - 100,000 m² GFA - Approx. \$600m 	Refurbishment and expansion of existing hospitals on brownfield sites: <ul style="list-style-type: none"> - 400 beds - 100,000 m² GFA - Approx. \$600m 	Improve efficiency of the current capacity within hospitals through provision of virtual services and improved outpatient care

The non-build option was investigated, and due to space limitations in existing hospitals, it was determined that this option would not be able to meet the forecast increase in demand for services.

The option to refurbish and expand existing hospitals was seen as an opportunity to reduce embodied carbon by utilising existing site infrastructure, and potentially some existing building structures.

Step 1 – Define the system boundary

To understand the carbon emissions associated with each option, the agency first outlined the lifecycle stages which were to be included in the assessment (also known as the **system boundary**). The following modules were included in the system boundary:

- Product Stage (A1-A3)
- Transport (A4)
- Construction and installation processes (A5)

The project team had limited data available for estimating other modules such as In-Use (B1-B5) or Operational Carbon (B6-B7). However, they will consider these at a high-level when developing options and exploring trade-offs.

Step 2 – Consider potential trade-offs

Potential trade-offs between upfront carbon, in-use carbon and operational carbon were identified and

qualitatively considered when exploring the following options for the hospital development:

- **Electrification of building systems** (e.g. heat pumps instead of gas boilers) – resulting in a higher upfront carbon due to additional materials required, but reducing in-use carbon due to the avoided use of gas.
- **Inclusion of rooftop solar photovoltaic (PV)** – increasing upfront and in-use carbon from greater initial and replacement materials required, but lowering the amount of grid-based electricity the building will consume, lowering the associated operational carbon emissions.

When the preferred option is selected, these trade-offs will be considered further and integrated into the future stages of the project design.

Step 3 – Assess carbon emissions and removals

The agency reviewed the data available to determine the most suitable methodology for conducting the carbon assessment. At this stage, the agency had access to the predicted capital spend for each option. However, no further estimates of material quantities or area breakdowns were available. For this reason, the agency used the asset-level carbon intensity benchmarks for the initial assessment, which are based on predicted capital spend.

There were no suitable sub-asset level benchmarks available. However, the team did find that some had been developed by the UK National Health Service, as part of the ‘carbon limits’ in the *Net Zero Building Standard User Guide*, and noted that similar could be developed for Australia in the future.

The carbon associated with each option was estimated using the following approach:

Worked example: Initial carbon assessment using asset-level benchmarks

Inputs:

- Predicted CAPEX for each option
- Default material share of CAPEX estimations (provided in Appendix 7). The new-build option applied the mid-range estimate for material share of CAPEX (29%), whilst the upgrade and expansion option applied the low-range scenario for material share of CAPEX to reflect the higher costs of labour involved (22%)
- Asset-level carbon intensity benchmarks (provided in Appendix 7)

Equation:

$$\text{Estimated carbon per module (kg CO}_2\text{-e)} = \text{CAPEX (\$)} \times \text{Material share of CAPEX (\%)} \times \text{Carbon intensity benchmark (kgCO}_2\text{-e/\$)}$$

The above equation was used to calculate the product stage (A1-A3), transport (A4) and construction (A5) stage emissions separately.

For the option to expand existing hospitals, consultation with a quantity surveyor determined that labour constituted a larger portion of the overall project cost. For this reason, the default benchmarks provided in Appendix 7 were revised to account for higher labour costs, reducing the total material share of the project CAPEX (as per inputs above).

As recommended, **low, mid and high scenario** carbon intensity benchmarks were used to account for the uncertainty involved.

Results:

The following table shows the predicted carbon intensity of each option. As the carbon intensity benchmarks exclude land-use change, this was calculated separately using site-specific data regarding the location and level of vegetation present.

	New build (tonnes CO ₂ e) [uncertainty range low high]	Expansion of existing hospitals (tonnes CO ₂ e) [uncertainty range low high]
Product Stage (A1-A3)	87,500 [65,000 – 109,500]	66,500 [49,500 – 83,000]
Transport (A4)	3,800 [2,800 – 4,500]	2,900 [2,100 – 3,500]
Construction (A5)	12,500 [9,200 – 15,500]	9,400 [7,000 – 11,500]
Land-use change (A5)	600	0
Total estimated upfront carbon	104,400 [78,100 – 130,100]	78,800 [58,600 – 98,000]
Note – carbon emissions have been approximated for simplicity.		

This high-level carbon assessment was considered as part of the cost-benefit analysis, noting these results have limited accuracy and offer high-level indications of carbon only.

Following the strategic options assessment, the expansion of existing hospitals was selected as the preferred option. The assessment concluded that current hospitals had sufficient space on-site to expand the current buildings and accommodate rising service demands. Moreover, the potential to utilise existing structures for the expansion can reduce the materials required for the works and associated carbon emissions.

Stage 2 – Planning Approval, Design and Procurement

At concept design, the project team are developing the details of the ‘expansion of existing hospitals’. Carbon measurement was important to identify areas of focus for the design development. Leading up to the planning submission, in a jurisdiction where this may be required, the project also prepared a carbon assessment to inform the planning consent application and confirm that low-carbon options were explored as part of the submission.

Step 1 – Define the system boundary

The project team reviewed the **system boundary** and confirmed the same life-cycle modules would be explored. These are:

- Product Stage (A1-A3)
- Transport (A4)
- Construction and installation processes (A5)

Step 2 – Considering trade-offs

The trade-offs highlighted at the Strategic Options phase were included in the design, such that:

- The ‘expansion of hospitals’ option will include an upgrade to all electric systems
- Rooftop solar PV was included in the design

Additional design options and potential trade-offs were identified at Stage 2 and qualitatively assessed. These are:

- **Improved building fabric for higher operational energy efficiency** – requiring more materials and increasing upfront carbon, but resulting in lower operational energy use and associated carbon emissions.
- **Batteries for back-up energy storage instead of generators** – resulting in a higher upfront carbon and replacement carbon due to the additional materials required, but reducing in-use carbon from the avoided use of diesel fuel.

Step 3 – Assess carbon emissions and removals

Product Stage (A1-A3)

At this stage, the project team had access to high-level material quantity estimates for the expansion of existing hospitals, including the additional structure, foundation, and building envelope required. The project teams were able to utilise approximately 15% of the existing hospitals' structure and envelope for the new expansion works, reducing the materials required and associated carbon emissions.

The team then used the **emission factor hierarchy** in section 5.4.1, and recommended emission factor sources outlined in Appendix 3 to understand the best emission factors to use for this data.

Finally, the product stage (A1-A3) calculations were conducted using the below approach.

Worked example: Product stage (A1-A3) carbon calculations using material quantity estimates

Inputs:

- Material quantity estimates
- Emission factors (EFs) selected using the **emission factor hierarchy** provided in section 5.4.1, and approved emission sources outlined in **Appendix 3**.

Equation:

$$\text{Total product stage carbon (kg CO}_2\text{-e)} = \text{material quantity (unit)} \times \text{product stage EF (kgCO}_2\text{-e/unit)}$$

Results:

Element	Material	Quantity	Total product stage emissions (tonnes CO ₂ e) ¹
Earthworks	Aggregates	2,000 t	5
Structure	Concrete	48,800 m ³	22,000
	Reinforcing Steel	7,000 t	11,000
	Structural Steel	170 t	450
Foundation	Concrete	12,000 m ³	6,500
	Reinforcing Steel	960 t	1,500
Envelope	Façade aluminium	425 t	8,000
	Glazing	3,850 m ²	200
	Steel roof sheeting	30,000 m ²	350
	Insulation	10,000 m ²	200
Total			50,205 t CO₂-e

Notes: 1 - Estimated carbon has been approximated for simplicity

Transport to site (A4)

At this stage of the project, the material suppliers had not been selected, and specific transport distances for each material were not available. For this reason, the **default transport distances** provided in Appendix 9 were used alongside the **default transport emission factors** in Appendix 3.

Worked example: Transport (A4) carbon calculations using material quantity estimates

Inputs:

- Material quantity estimates
- Default transport distances (provided in Appendix 6) as no better estimations were available
- Default transport emission factors (EFs) in Appendix 3

Equation:

$$\text{Total transport carbon (kg CO}_2\text{-e)} = \text{material quantity (tonnes)} \times \text{distance (km)} \times \text{transport EF (kgCO}_2\text{-e/tonnes.km)}$$

Results:

Element	Material	Total transport emissions (tonnes CO ₂ e) ¹
Earthworks	Aggregates	30
Structure	Concrete	250
	Reinforcing Steel	1,000
...
...
Total		1,500 tonnes CO₂-e

Notes: 1 - Estimated carbon has been approximated for simplicity

Construction and installation process (A5)

For the construction emissions, the project team included estimations for the following:

- Construction electricity and fuel use
- Waste generated on site & transport of waste to end-destination
- Commissioning energy

For construction electricity and fuel use, the project team had access to high level estimations benchmarked off previous projects. These were multiplied by emission factors for electricity and fuel use provided in Appendix 3 to understand the carbon emissions associated with construction activities.

As the developments were on existing brownfield sites, there was no land clearing required to accommodate the hospital expansions.

To understand the amount of waste which will be generated during construction, the project team applied the **default waste generation factors** in Appendix 9 to the product stage (A1-A3) material estimates.

The total waste quantity could then be multiplied by the transport emission factors and end-of-life treatment emissions factors in Appendix 3 to understand the total waste-related carbon emissions from the project.

Overall, the emissions calculated for the construction and installation processes are outlined below.

Worked example: Construction and installation processes (A5) carbon assessment

Inputs:

- Outlined in the table below

Equation:

The following equations were used for the transport and end of life treatment of waste:

- *Transport of waste (kg CO₂-e) = waste quantity (tonnes) × transport EF (kgCO₂-e/tonnes.km) × default transport distance (km)*
- *End-of-life treatment of waste = waste quantity (tonnes) × waste treatment EF (kgCO₂-e/tonnes)*

Results:

Key inputs	Quantity	Emission factor	Emission factor source	Estimated carbon emissions ²
NSW Grid Electricity	576,000 kWh	0.73 kg CO ₂ -e/kWh ¹	NGA 2023	420 tonnes CO ₂ -e
Diesel	1,700 kL	87.5 kg CO ₂ -e/GJ ¹ - 38.6 GJ/kL	NGA 2023	5,740 tonnes CO ₂ -e
Waste treatment – landfill	8,000 t	0.2 tCO ₂ -e/t	NGA 2023	1,600 tonnes CO ₂ -e
Waste transport – landfill	8,000 t x 50km	0.0002 tCO ₂ -e/t.km	TfNSW Carbon Tool	80 tonnes CO ₂ -e
Total				7,840 tonnes CO₂-e

Notes: 1 – Emission factor includes Scope 3 emissions, 2 – Estimated carbon has been approximated for simplicity

As the material estimates included in the carbon assessment cover all of the minimum inclusions outlined for social infrastructure in Appendix 8, the project was able to assume the **default completeness rate of 80%**, and upscale the carbon calculation to account for the remaining 20%.

Worked example: Upscaling for completeness

Inputs:

- Calculated product stage emissions (a) and completeness (80%)
- Calculated transport emissions (b) and completeness (80%)
- Calculated construction energy and waste emissions I and completeness (80%)
- Calculated land-use change emissions (d) (completeness should be 100%)

Equation:

$$\text{Total Upfront Carbon (tCO}_2\text{-e)} = \frac{a}{80\%} + \frac{b}{80\%} + \frac{c}{80\%} + d$$

(Note – the completeness of land-use change carbon assessments are assumed to be 100%, and do not need to be upscaled)

Results:

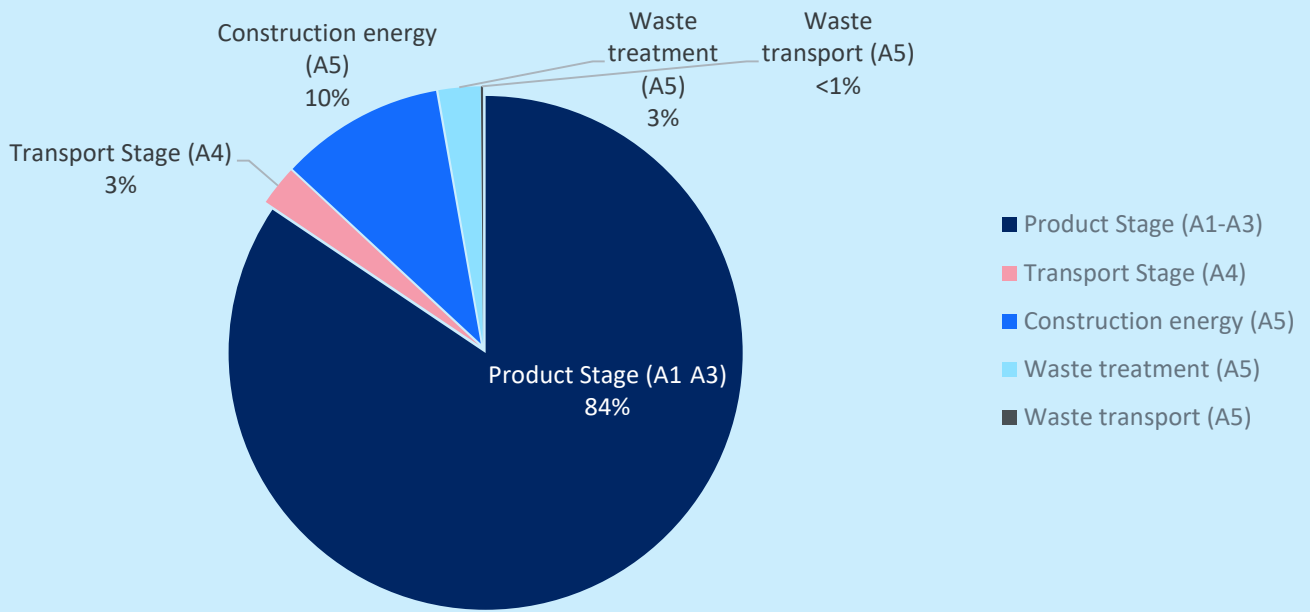
	Calculated emissions ¹	Upscaled emissions
Product Stage (A1-A3)	50,205	62,750
Transport (A4)	1,500	1,875
Construction (A5)	7,840	9,800
Total	59,545	74,430

Notes: 1 - Estimated carbon has been approximated for simplicity

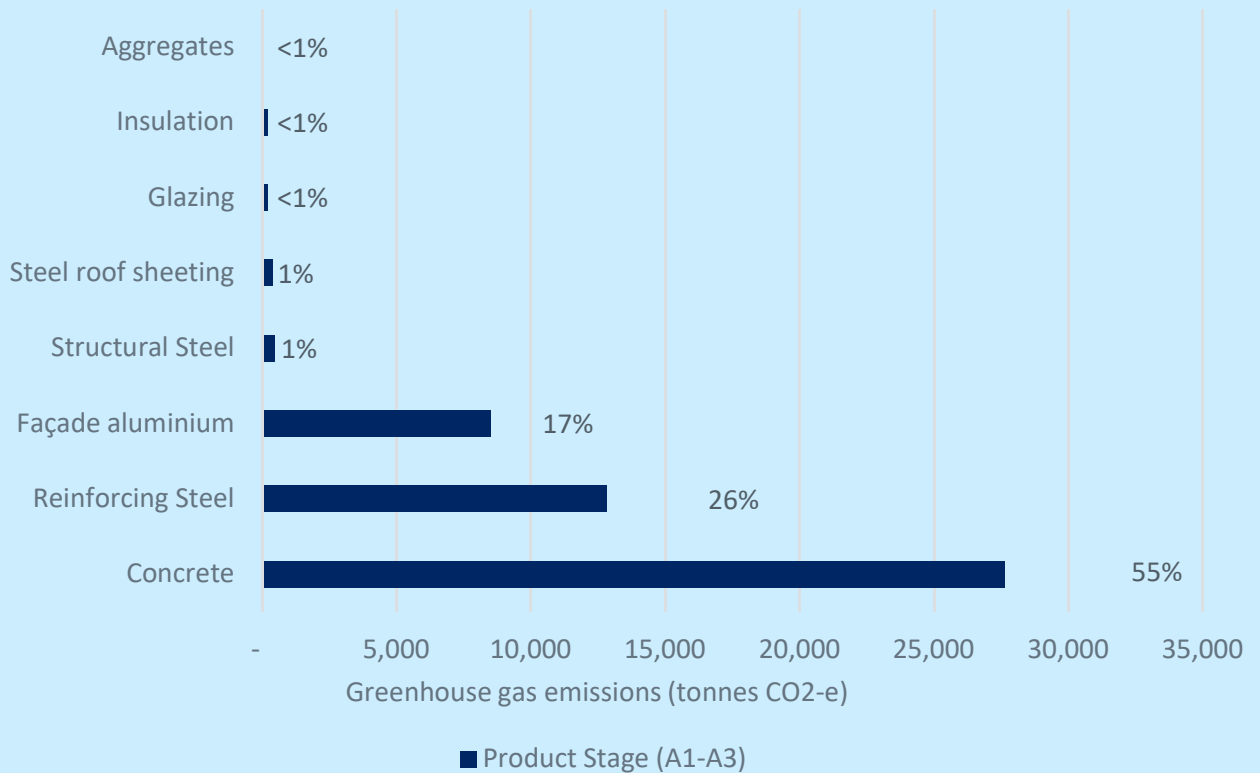
Final results

Using the results above, the project team developed the following results chart and contribution analysis to display the main sources of carbon for the project (over page).

Worked example: Total upfront carbon



Worked example: Product stage contribution analysis



Stage 3 – Construction and Practical Completion

At practical completion, the project is updating the design phase carbon calculations with actual data gathered during construction.

Firstly, the team reviewed the design phase carbon calculations to understand the scope and life cycle boundary included, and identify any changes to the design which may have taken place since the assessment.

With no scope or boundary changes occurring since the previous assessment, the project proceeded to update the design phase carbon assessment with actual data.

Step 1 – Define the system boundary

The project confirmed there will be no changes to the system boundary between the two carbon calculations, and the product stage (A1-A3), transport (A4) and construction (A5) modules will be included.

Step 2 – Consider trade-offs

The trade-offs identified at planning approvals were included in the design, such that:

- The hospital expansions included the improved building fabric to increase operational energy efficiency
- Batteries were chosen for back-up energy storage to realise operational carbon savings.

Step 3 – Updating the assessment with available actual quantities

During construction, the project collected the material use data on the key materials (concrete and steel), transport distance data on the heaviest products (concrete and aggregates), and tracked all construction clearing, energy and fuel use. For the remaining inputs, the design based estimations were used.

Worked example: Updating the assessment with available actual quantities

Key inputs	Designs estimates (Stage 2)	Actual construction data (Stage 3)
Product Stage (A1-A3)		
Concrete	60,800 m ³	62,000 m ³
Structural Steel	170 t	200 t
Reinforcing Steel	7,960 t	8,000 t
...
Transport (A4)		
Concrete	18km	30km
Aggregates	62km	50km
Construction and installation processes (A5)		
NSW grid electricity	576,000 kWh	600,000 kWh
Diesel	1,700 kL	2,000 kL
Waste treatment – construction and demolition	8,000 t	8,000 t

For the remaining inputs, the design-based estimations were used.

Step 4 – Reporting on final emissions

The following report was created at practical completion.

Table A4.2 General project data

Input	Project Details
Project or contract name	Hospital refurbishment and expansion program
Government agency	Health Infrastructure NSW
Applicable reporting requirements	Sustainable Buildings SEPP, Green Star
Date of assessment undertaken	February 2024
Primary asset class (IA Master Type)	Education, health and justice
Primary asset type (IA Typecast)	Hospital
Other sub-assets included within the scope (IA Typecast)	Not applicable

Table A4.3 General asset level or sub-asset level data

Input	Project details
Declared unit	m ² GFA
Project scale (quantity in declared unit)	100,000 m ² GFA
Data sources (optional)	<ul style="list-style-type: none"> Actual construction data Design estimates
Emission factor sources (EPDs, bill of quantities etc) or carbon intensity benchmark (optional)	<ul style="list-style-type: none"> Aus LCI emission factors EPD's

Table A4.4 Reporting carbon by life cycle module for asset and sub-asset level reporting

Life cycle module	Final design	
	Absolute (tonnes CO ₂ -e)	Per declared unit (tonnes CO ₂ -e/unit)
Product stage (A1-A3)	64,500	0.65
Transport to site (A4)	2,000	0.02
Construction (A5)	9,500	0.095
Total upfront carbon (A1-A5)	76,000	0.76

Appendix 5: Data required and potential sources

The most typical data needed to complete an embodied carbon assessment at each stage of measurement, and potential sources of these data are provided in Table A5.1 below.

Table A5.1 Data inputs required for an upfront carbon assessment and potential sources

Data input	Description	Potential data source
General Information		
Project scope information	The project type in line with the Infrastructure Australia’s classification system (mastertypes and typecasts) to facilitate the use of carbon intensity benchmarks and for accurate reporting and carbon disclosure.	<ul style="list-style-type: none"> These are defined in the Infrastructure Australia’s Market Capacity report 2022.
Design life of the asset and elements	The number of years the overall asset is being designed for as well as the design life of each element to determine rates of replacement.	<ul style="list-style-type: none"> Design specifications / standards Contract documentation
Use, Maintenance and Refurbishment activity data	The quantities of materials, energy, waste used during routine maintenance activities. Fugitive and process emissions included in definition (B1)	<ul style="list-style-type: none"> Asset operator or benchmarked from other operating assets
Stage 1 – Using Carbon Intensity Benchmarks		
Total project cost and expected spend on material	This is important when using carbon intensity benchmarks (which will be provided in tonnes of carbon per total spend on materials), and to assist the development of future carbon intensity benchmarks.	<ul style="list-style-type: none"> Project quantity surveyor
Carbon intensity benchmarks	Carbon emission benchmarks per asset level (typecast) or sub-asset or element specific benchmarks.	<ul style="list-style-type: none"> Asset level (typecast) have been developed by Infrastructure Australia and provided in Appendix 7. Agencies may develop their own sub-asset or element specific benchmarks (preferred data source if available).
Stage 2 and Stage 3 – Using construction quantities and emission factors		
Construction quantities	The quantities of materials, energy, waste and land used to construct the asset are required for the upfront carbon	<ul style="list-style-type: none"> Bill of quantities from quantity surveyor Material take off from digital model Equipment schedules from quantity surveyor/ cost estimator

Data input	Description	Potential data source
	assessment. These quantities are often referred to as the activity data.	<ul style="list-style-type: none"> Actual construction quantities.
Emissions factors	The carbon footprint per unit of resource use or construction activity (or activity data)	<ul style="list-style-type: none"> There are a range of emission factor sources available to use. Refer to Appendix 3 for more information.

Appendix 6: How to source emission factor data from literature

Impact assessment methods for Global Warming Potential

When sourcing emission factor data from literature, it is important to interrogate the impact assessment methods used to ensure that the appropriate emission factor is selected. All embodied carbon calculations must be performed using Global Warming Potential (GWP) over a 100-year time horizon (GWP100) in line with ISO 14067:2018. The most recent characterisation factors from the Intergovernmental Panel on Climate Change (IPCC) should be used where possible. At the time of writing, the *IPCC Sixth Assessment Report (AR6)* contains the most recent factors. However, GWP100 factors following older assessment reports may also be used.

Following EN 15804:2012+A2:2019, the total carbon footprint (**GWP-Total**) is the sum of three constituent parts:

- **GWP-Fossil**: Carbon emissions arising from fossil sources.
- **GWP-Biogenic**: Carbon emissions arising from biogenic sources (net of emissions and removals).
- **GWP-LULUC**: Carbon emissions due to land use and land use change.

Emissions and removals should be clearly separated in line with PAS2080:2023 (e.g., biogenic carbon uptake from land use and carbonation of concrete). This is particularly important for the following types of projects:

- Projects where biogenic carbon is significant (e.g., buildings with timber structure). In this case, GWP-Biogenic and GWP-Fossil should be reported separately along with total carbon emissions.
- Linear infrastructure with significant land use change impacts like land clearing or revegetation (e.g., greenfield linear infrastructure projects). In this case, GWP-LULUC or 'land clearing' impacts should be reported separately along with total carbon emissions.

Example of sourcing data from an Environmental Product Declarations (EPD)

An Environmental Product Declaration (EPD) presents the results of a Life Cycle Assessment (LCA) conducted to a certain set of rules, known as a PCR (Product Category Rules).

EPD data must be third-party verified in line with one of these Product Category Rules, unless being used in the absence of no other representative data of higher quality. While all EPDs should follow ISO 14025, the international standard for EPDs, they do not all follow the same PCR.

Project teams should only choose EPDs that comply with one of the following PCR documents:

- **EN 15804:2012+A2:2019**: European standard EN 15804+A2 replaced EN 15804+A1 (see below). It separates GWP into its component parts.
 - **ISO 21930:2017**: This PCR is broadly aligned with EN 15804+A1, while making changes to make its rules and indicators more applicable to other jurisdictions. It is widely used in North America.
-

- **EN 15804:2012+A1:2013:** European standard EN 15804+A1 was the first widely accepted PCR for construction products internationally. It did not require carbon footprint (GWP) to be separated into its component parts, so carbon footprint results are often just reported as GWP. While this standard is no longer valid, thousands of EPDs worldwide were produced to it so it is still often seen today.

All three PCR documents above use the same base life cycle modules, i.e., A1-A5, B1-B6, C1-C4 and D. All three sets of rules also have a similar system boundary and underlying approach.

When reading an EPD, focus on the results for modules A1-A3. These are the cradle-to-gate results and include all life cycle stages from extraction of raw materials through to manufacture of the finished product. Results for downstream life cycle stages are typically calculated at the material group level (e.g., total concrete and total timber), rather than product-by-product.

Table A6.1 below presents an example of the results for 1 m³ of a concrete product. Table A6.2 presents similar results for 1 m³ of a timber product. The column for A1-A3 has been highlighted in both tables.

Based upon the example in Table A6.1:

- GWP-Total = 255 kg CO₂-e/m³. Because the concrete product does not contain stored carbon, this is also the total gross GHG emissions.
- GWP-Fossil = 250 kg CO₂-e/m³
- GWP-Biogenic = 4 kg CO₂-e/m³
- GWP-LULUC = 1 kg CO₂-e/m³

Table A6.1 Example EPD results for 1 m³ of a concrete product, assuming 100% recycling at end-of-life following EN 15804+A2

Indicator	Abbr.	Unit	A1-A3	C1	C2	C3	C4	D
Global warming potential	GWP	kg CO ₂ e	255	10	5	8	0	6
Global warming potential (fossil)	GWPf	kg CO ₂ e	250	10	5	8	0	6
Global warming potential (biogenic)	GWPb	kg CO ₂ e	4	0	0	0	0	0
Global warming potential (land use change)	GWPluc	kg CO ₂ e	1	0	0	0	0	0
...

Based upon the example in Table A6.2:

- GWP-Total = -715 kg CO₂-e/m³. This number is negative because of stored carbon in the timber. It can only be used if you plan to release (part of) this stored carbon later in the life cycle. It cannot be used like this in upfront carbon calculations because upfront carbon does not include end-of-life.
- GWP-Fossil = 100 kg CO₂-e/m³
- GWP-Biogenic = -815 kg CO₂-e/m³
- GWP-LULUC = 0 kg CO₂-e/m³
- Following PAS2080:2023, GHG emissions and GHG removals must be reported separately.

- Total GHG removals (when expressed as a negative number)
 - = $-1 \times \text{biogenic carbon content} \times (44/12)$
 - = $-1 \times 225 \times (44/12)$
 - = $-825 \text{ kg CO}_2\text{-e/m}^3$
- Total GHG emissions
 - = $\text{GWP-Fossil} + (\text{GWP-Biogenic} - \text{GHG removals}) + \text{GWP-LULUC}$
 - = $100 + (-815 - -825) + 0$
 - = $100 + 10 + 0$
 - = $110 \text{ kg CO}_2\text{-e/m}^3$
- Note: You can sense-check your calculations, as $\text{GWP-Total} = \text{GHG removals} + \text{GHG emissions}$.
- Note: If using an EPD for timber that does not declare biogenic carbon content, you can approximate it as follows: $\text{stored biogenic carbon} = \text{mass} \times (1 - \text{water content}) \times 50\%$. In the example in Table A6.2, the density of the timber is 500 kg/m^3 and the water content (on a wet basis) is 10%. $\text{Stored biogenic carbon} = 500 \times (100\% - 10\%) \times 50\% = 225 \text{ kg carbon/ m}^3$.

Table A6.2 Example EPD results for 1 m³ of a timber product, assuming 100% landfill at end-of-life following EN 15804+A2

Indicator	Abbr.	Unit	A1-A3	C1	C2	C3	C4	D
Global warming potential	GWP	kg CO ₂ e	-715	1	2	0	926	-1
Global warming potential (fossil)	GWPf	kg CO ₂ e	100	1	2	0	50	-1
Global warming potential (biogenic)	GWPb	kg CO ₂ e	- 815	0	0	0	875	0
Global warming potential (land use change)	GWPluc	kg CO ₂ e	0	0	0	0	1	0
...
Biogenic carbon content – product	BCC-prod	kg C	225	0	0	0	0	-225

Appendix 7: Asset level carbon intensity benchmarks

Emissions intensities are provided for each typecast using a physical unit (where available) in Table A7.1. Where no physical unit is available, emissions intensities are provided per dollar of material spend. Emissions intensities per dollar are provided for all typecasts in Table A7.2.

These emissions intensities are based on calculations developed for Infrastructure Australia's *Embodied Carbon Projections for Australian Infrastructure and Buildings* study⁵², with additional analysis applied to meet the specific requirements of this technical guidance. Cost intensities are in FY2021 dollars and relate to material spend only, excluding labour, professional services, plant, equipment and GST. When applying these benchmarks to projects in future years, costs should be adjusted to account for inflation and escalation from the FY2021 base year.

For buildings, these carbon intensity benchmarks have a warm shell scope and include external paved areas related to the building (carparks, driveways and hardstands). The GBCA's (2020) definition of "warm shell" is applied: "Finishes and services are applied to common areas. Tenancies are delivered with ceilings, floor coverings and lighting systems; and ducts from air supply and return risers, electrical and hydraulic services are installed above the ceiling from the riser throughout the tenancy areas."⁵³ All other elements of the fitout should be excluded.

When using the default assumptions for "material share of capex":

- Multiply the total project cost by the "Material share of capex" column. Low, mid and high values are provided. The midpoint should be used as a default, while the low and high values provide a range. Labour-intensive projects (such as a refurbishment of a heritage building) are likely to have a low material share of capex. Projects that are more standardised (such as construction of a warehouse) are likely have a higher material share of capex.
- The total project cost of construction should exclude the costs of land acquisition, departmental administration, and the head contractor's profit margin. Where these values are not known, the total project cost can be estimated by taking the declared project value (excluding land acquisition costs) and multiplying by 90%.
- For buildings, the total cost is that for a warm shell scope only but should include external paved areas related to the building.
- Where you have no better available information, the following should be used:

⁵² Forthcoming as of February 2024

⁵³ Green Building Council of Australia (GBCA). *Fitout Scope: Guidance for Cold Shell, Warm Shell and Integrated Fitouts*. GBCA. 2020.

- Mid range values for new builds (on either greenfield or brownfield sites)
- Low range values for refurbishment options (where there is substantial reuse of existing assets)

When developing and using your own estimates of material spend:

- For services used in assets, it is recommended to align with the methodology in the tables below which assume:
 - 40% of total cost is material-related for mechanical services, vertical transportation services (lifts and escalators) and plumbing/hydraulic services.
 - 20% of total cost is material-related for electrical services, fire services and other services.
- For buildings, please include a warm shell scope only (including external paved areas), for assumed total project costs. Fitout and services beyond a warm shell scope should be excluded.

Note that these emission intensities will be subject to review periodically and updated overtime.

Table A7.1 Emission intensities based on typecast unit

Super sector	Mastertype	Typecast	Product stage (A1-A3) Emission intensity (kg CO ₂ e/unit)			Transport (A4) Emission intensity (kg CO ₂ e/unit)			Construction (A5) Emission intensity (kg CO ₂ e/unit)			Typecast unit
			Low	Mid	High	Low	Mid	High	Low	Mid	High	
Building	Aviation	Airport Building	542	722	903	20.6	27.5	34.4	77.5	103	129	m ² GFA
Building	Education	Higher Education	494	658	823	20.4	27.2	33.9	112	149	186	m ² GFA
Building	Education	School	590	787	984	21.2	28.3	35.4	98.2	131	164	m ² GFA
Building	Health	Aged Care Facility	250	333	417	14.4	19.1	23.9	29.1	38.8	48.5	m ² GFA
Building	Health	Health Facility	566	755	944	21.5	28.7	35.9	73.8	98.3	123	m ² GFA
Building	Health	Hospital	483	645	806	20.8	27.8	34.7	67.8	90.4	113	m ² GFA
Building	Justice	Correctional Centre	585	780	974	22.6	30.1	37.6	193	258	322	m ² GFA
Building	Justice	Courthouse	615	820	1,025	23	30.7	38.4	68.6	91.5	114	m ² GFA

Super sector	Mastertype	Typecast	Product stage (A1-A3) Emission intensity (kg CO ₂ e/unit)			Transport (A4) Emission intensity (kg CO ₂ e/unit)			Construction (A5) Emission intensity (kg CO ₂ e/unit)			Typecast unit
			Low	Mid	High	Low	Mid	High	Low	Mid	High	
Building	Justice	Fire and Emergency Facility	615	820	1,025	23	30.7	38.4	77.9	104	130	m ² GFA
Building	Justice	Police Facility	615	820	1,025	23	30.7	38.4	54.2	72.2	90.3	m ² GFA
Building	Other building	Arts Facility	615	819	1,024	22	29.3	36.6	106	141	176	m ² GFA
Building	Other building	Civic/Convention Centre	518	690	863	21	28	35	110	146	183	m ² GFA
Building	Other building	Laboratory	518	691	863	22	29.3	36.6	49.6	66.2	82.7	m ² GFA
Building	Other building	Office	362	482	603	19.2	25.6	32	93.4	125	156	m ² GFA
Building	Residential	Accommodation	289	386	482	17.1	22.8	28.5	76.9	102.6	128	m ² GFA
Building	Residential	Detached Residential	233	310	388	13.5	17.9	22.4	32.6	43.4	54.3	m ² GFA
Building	Residential	Multi Residential	315	419	524	17.3	23.1	28.8	65.1	86.8	108	m ² GFA
Building	Residential	Semi-detached Residential	233	310	388	13.5	18	22.5	34.1	45.5	56.8	m ² GFA
Building	Retail	Retail Store	566	755	944	21.5	28.7	35.8	75.4	101	126	m ² GFA
Building	Sports Facility	Arena/Sporting Facility	615	819	1,024	22	29.3	36.6	226	301	376	m ² GFA
Buildings	Telecommunications	Data Centre	259	346	432	14.2	18.9	23.7	81.6	109	136	m ² GFA

Super sector	Mastertype	Typecast	Product stage (A1-A3) Emission intensity (kg CO ₂ e/unit)			Transport (A4) Emission intensity (kg CO ₂ e/unit)			Construction (A5) Emission intensity (kg CO ₂ e/unit)			Typecast unit
			Low	Mid	High	Low	Mid	High	Low	Mid	High	
	and Digital											
Buildings	Transport Building	Parking Facility	362	482	603	19.1	25.5	31.9	54.1	72.1	90.1	m ² GFA
Buildings	Transport Building	Warehouse	260	346	433	14.6	19.5	24.4	36.6	48.8	61	m ² GFA
Transport	Aviation	Airport Runway	0.552	0.736	0.92	0.033	0.044	0.055	0.123	0.164	0.204	\$ material spend
Transport	Rail	Bridge (Rail)	1.27	1.7	2.12	0.061	0.081	0.102	0.134	0.179	0.224	\$ material spend
Transport	Rail	Light Rail	0.478	0.637	0.797	0.035	0.047	0.059	0.175	0.234	0.292	\$ material spend
Transport	Rail	Light Rail, Stabling, and Signalling Works	0.48	0.64	0.8	0.039	0.052	0.065	0.115	0.154	0.192	\$ material spend
Transport	Rail	Main Line Works (Rail)	0.228	0.304	0.38	0.02	0.027	0.034	0.173	0.231	0.289	\$ material spend
Transport	Rail	Station (Rail)	0.684	0.911	1.14	0.037	0.05	0.062	0.104	0.139	0.173	\$ material spend
Transport	Rail	Tunnel (Rail)	0.646	0.861	1.08	0.04	0.053	0.067	0.171	0.227	0.284	\$ material spend
Transport	Road	Bridge (Road)	1.27	1.7	2.12	0.054	0.073	0.091	0.122	0.163	0.203	\$ material spend

Super sector	Mastertype	Typecast	Product stage (A1-A3) Emission intensity (kg CO ₂ e/unit)			Transport (A4) Emission intensity (kg CO ₂ e/unit)			Construction (A5) Emission intensity (kg CO ₂ e/unit)			Typecast unit
			Low	Mid	High	Low	Mid	High	Low	Mid	High	
Transport	Road	Low Use Road	0.343	0.457	0.572	0.033	0.045	0.056	0.152	0.203	0.253	\$ material spend
Transport	Road	Low Use Road Rehabilitation Maintenance	0.104	0.138	0.173	0.028	0.037	0.046	0.175	0.234	0.292	\$ material spend
Transport	Road	Routine Road Maintenance	0.137	0.183	0.229	0.025	0.033	0.041	0.209	0.278	0.348	\$ material spend
Transport	Road	State Road (Highway/Freeway)	0.431	0.517	0.718	0.036	0.043	0.06	0.179	0.215	0.299	\$ material spend
Transport	Road	State Road (Highway/Freeway) Rehabilitation Maintenance	0.115	0.153	0.191	0.026	0.035	0.043	0.142	0.189	0.236	\$ material spend
Transport	Road	Tunnel (Road)	0.516	0.688	0.86	0.037	0.049	0.061	0.192	0.256	0.32	\$ material spend
Transport	Road/Rail	Level Crossing	0.694	0.926	1.16	0.033	0.044	0.056	0.137	0.183	0.228	\$ material spend
Utilities	Energy and Fuels	CCGT	No data	No data	No data	No data	No data	No data	No data	No data	No data	kW
Utilities	Energy and Fuels	Coal	n/a	1.6	n/a	n/a	0.049	n/a	n/a	0.183	n/a	\$ material spend

Super sector	Mastertype	Typecast	Product stage (A1-A3) Emission intensity (kg CO ₂ e/unit)			Transport (A4) Emission intensity (kg CO ₂ e/unit)			Construction (A5) Emission intensity (kg CO ₂ e/unit)			Typecast unit
			Low	Mid	High	Low	Mid	High	Low	Mid	High	
Utilities	Energy and Fuels	Gas and Liquids	n/a	3,312	n/a	n/a	74.4	n/a	n/a	568	n/a	kW
Utilities	Energy and Fuels	Gas Pipeline	0.151	0.202	0.252	0.014	0.018	0.023	0.099	0.132	0.165	\$ material spend
Utilities	Energy and Fuels	Hydro	No data	No data	No data	No data	No data	No data	No data	No data	No data	kW
Utilities	Energy and Fuels	Pumped Hydro	n/a	508	n/a	n/a	32.1	n/a	n/a	131	n/a	kW
Utilities	Energy and Fuels	Transmission (other)	n/a	1.8	n/a	n/a	0.083	n/a	n/a	0.223	n/a	\$ material spend
Utilities	Energy and Fuels	Transmission Line: Double Circuit	n/a	709,633	n/a	n/a	9,435	n/a	n/a	23,757	n/a	'000 km
Utilities	Energy and Fuels	Transmission Line: Single Circuit	n/a	376,661	n/a	n/a	4,647	n/a	n/a	11,743	n/a	'000 km
Utilities	Energy and Fuels	Utility Solar	n/a	4,203	n/a	n/a	71.9	n/a	n/a	146	n/a	kW
Utilities	Energy and Fuels	Wind	n/a	554	n/a	n/a	16.9	n/a	n/a	50	n/a	kW
Utilities	Telecommunications and Digital	Telecommunications	0.52	0.693	0.866	0.137	0.183	0.229	0.157	0.21	0.262	\$ material spend
Utilities	Water and Sewerage	Dam	0.616	0.821	1.026	0.064	0.085	0.106	0.21	0.28	0.35	\$ material spend

Super sector	Mastertype	Typecast	Product stage (A1-A3) Emission intensity (kg CO ₂ e/unit)			Transport (A4) Emission intensity (kg CO ₂ e/unit)			Construction (A5) Emission intensity (kg CO ₂ e/unit)			Typecast unit
			Low	Mid	High	Low	Mid	High	Low	Mid	High	
Utilities	Water and Sewerage	Water Pipeline	0.147	0.197	0.246	0.016	0.021	0.026	0.063	0.084	0.105	\$ material spend
Utilities	Water and Sewerage	Water Treatment Plant	0.649	0.865	1.082	0.054	0.072	0.09	0.222	0.296	0.37	\$ material spend

Table A7.2: Emissions intensities based on material spend

Super Sector	Mastertype	Typecast	Material share of capex			Product stage (A1-A3) Emission intensity (kg CO ₂ e/\$ material spend)			Transport (A4) Emission intensity (kg CO ₂ e/\$ material spend)			Construction (A5) Emission intensity (kg CO ₂ e/\$ material spend)		
			Low	Mid	High	Low	Mid	High	Low	Mid	High	Low	Mid	High
Building	Aviation	Airport Building	23%	30%	38%	0.396	0.528	0.66	0.015	0.02	0.025	0.057	0.076	0.094
Building	Education	Higher Education	22%	29%	36%	0.386	0.514	0.643	0.016	0.021	0.027	0.087	0.117	0.146
Building	Education	School	24%	32%	40%	0.405	0.54	0.676	0.015	0.019	0.024	0.067	0.09	0.112
Building	Health	Aged Care Facility	26%	34%	43%	0.348	0.465	0.581	0.02	0.027	0.033	0.041	0.054	0.068
Building	Health	Health Facility	23%	31%	39%	0.401	0.535	0.668	0.015	0.02	0.025	0.052	0.07	0.087
Building	Health	Hospital	22%	29%	36%	0.378	0.504	0.63	0.016	0.022	0.027	0.053	0.071	0.088
Building	Justice	Correctional Centre	24%	32%	41%	0.403	0.538	0.672	0.016	0.021	0.026	0.134	0.178	0.223

Super Sector	Mastertype	Typecast	Material share of capex			Product stage (A1-A3) Emission intensity (kg CO ₂ e/\$ material spend)			Transport (A4) Emission intensity (kg CO ₂ e/\$ material spend)			Construction (A5) Emission intensity (kg CO ₂ e/\$ material spend)		
				Mid	High		Mid	High	Low		High	Low		High
Building	Justice	Courthouse	24%	32%	40%	0.41	0.546	0.683	0.015	0.02	0.026	0.046	0.061	0.076
Building	Justice	Fire and Emergency Facility	24%	32%	40%	0.41	0.546	0.683	0.015	0.02	0.026	0.052	0.069	0.087
Building	Justice	Police Facility	24%	32%	40%	0.41	0.546	0.683	0.015	0.02	0.026	0.036	0.048	0.06
Building	Other building	Arts Facility	24%	32%	40%	0.41	0.546	0.683	0.015	0.02	0.024	0.071	0.094	0.118
Building	Other building	Civic/Convention Centre	22%	30%	37%	0.391	0.521	0.652	0.016	0.021	0.026	0.083	0.111	0.138
Building	Other building	Laboratory	22%	30%	37%	0.391	0.522	0.652	0.017	0.022	0.028	0.037	0.05	0.062
Building	Other building	Office	19%	26%	32%	0.341	0.455	0.569	0.018	0.024	0.03	0.088	0.118	0.147
Building	Residential	Accommodation	25%	34%	42%	0.326	0.435	0.544	0.019	0.026	0.032	0.087	0.116	0.145
Building	Residential	Detached Residential	26%	35%	43%	0.358	0.477	0.597	0.021	0.028	0.034	0.05	0.067	0.083
Building	Residential	Multi Residential	25%	33%	42%	0.318	0.424	0.531	0.018	0.023	0.029	0.066	0.088	0.11
Building	Residential	Semi-detached Residential	26%	35%	43%	0.358	0.477	0.597	0.021	0.028	0.035	0.052	0.07	0.087
Building	Retail	Retail Store	23%	31%	39%	0.401	0.535	0.668	0.015	0.02	0.025	0.053	0.071	0.089
Building	Sports Facility	Arena/Sporting Facility	24%	32%	40%	0.41	0.546	0.683	0.015	0.02	0.024	0.151	0.201	0.251

Super Sector	Mastertype	Typecast	Material share of capex			Product stage (A1-A3) Emission intensity (kg CO ₂ e/\$ material spend)			Transport (A4) Emission intensity (kg CO ₂ e/\$ material spend)			Construction (A5) Emission intensity (kg CO ₂ e/\$ material spend)		
			Low	Mid	High	Low	Mid	High	Low	Mid	High	Low	Mid	High
Buildings	Telecommunications and Digital	Data Centre	29%	38%	48%	0.403	0.538	0.672	0.022	0.029	0.037	0.127	0.169	0.212
Buildings	Transport Building	Parking Facility	19%	26%	32%	0.341	0.455	0.569	0.018	0.024	0.03	0.051	0.068	0.085
Buildings	Transport Building	Warehouse	29%	38%	48%	0.404	0.538	0.673	0.023	0.03	0.038	0.057	0.076	0.095
Transport	Aviation	Airport Runway	21%	28%	35%	0.552	0.736	0.92	0.033	0.044	0.055	0.123	0.164	0.204
Transport	Rail	Bridge (Rail)	23%	31%	39%	1.27	1.7	2.12	0.061	0.081	0.102	0.134	0.179	0.224
Transport	Rail	Light Rail	30%	40%	50%	0.478	0.637	0.797	0.035	0.047	0.059	0.175	0.234	0.292
Transport	Rail	Light Rail, Stabling, and Signalling Works	31%	41%	51%	0.48	0.64	0.8	0.039	0.052	0.065	0.115	0.154	0.192
Transport	Rail	Main Line Works (Rail)	14%	18%	23%	0.228	0.304	0.38	0.02	0.027	0.034	0.173	0.231	0.289
Transport	Rail	Station (Rail)	33%	45%	56%	0.684	0.911	1.14	0.037	0.05	0.062	0.104	0.139	0.173
Transport	Rail	Tunnel (Rail)	13%	18%	22%	0.646	0.861	1.08	0.04	0.053	0.067	0.171	0.227	0.284
Transport	Road	Bridge (Road)	23%	31%	39%	1.27	1.7	2.12	0.054	0.073	0.091	0.122	0.163	0.203
Transport	Road	Low Use Road	18%	23%	29%	0.343	0.457	0.572	0.033	0.045	0.056	0.152	0.203	0.253
Transport	Road	Low Use Road Rehabilitation Maintenance	20%	27%	34%	0.104	0.138	0.173	0.028	0.037	0.046	0.175	0.234	0.292

Super Sector	Mastertype	Typecast	Material share of capex			Product stage (A1-A3) Emission intensity (kg CO ₂ e/\$ material spend)			Transport (A4) Emission intensity (kg CO ₂ e/\$ material spend)			Construction (A5) Emission intensity (kg CO ₂ e/\$ material spend)		
				Mid	High		Mid	High	Low		High	Low		High
Transport	Road	Routine Road Maintenance	25%	33%	42%	0.137	0.183	0.229	0.025	0.033	0.041	0.209	0.278	0.348
Transport	Road	State Road (Highway/Freeway)	17%	20%	28%	0.431	0.517	0.718	0.036	0.043	0.06	0.179	0.215	0.299
Transport	Road	State Road (Highway/Freeway) Rehabilitation Maintenance	23%	31%	38%	0.115	0.153	0.191	0.026	0.035	0.043	0.142	0.189	0.236
Transport	Road	Tunnel (Road)	20%	26%	33%	0.516	0.688	0.86	0.037	0.049	0.061	0.192	0.256	0.32
Transport	Road/Rail	Level Crossing	23%	30%	38%	0.694	0.926	1.16	0.033	0.044	0.056	0.137	0.183	0.228
Utilities	Energy and Fuels	CCGT	n/a	n/a	n/a	No data	No data	No data	No data	No data	No data	No data	No data	No data
Utilities	Energy and Fuels	Coal	n/a	n/a	n/a	n/a	1.6	n/a	n/a	0.049	n/a	n/a	0.183	n/a
Utilities	Energy and Fuels	Gas and Liquids	n/a	n/a	n/a	n/a	1.56	n/a	n/a	0.035	n/a	n/a	0.268	n/a
Utilities	Energy and Fuels	Gas Pipeline	17%	23%	29%	0.151	0.202	0.252	0.014	0.018	0.023	0.099	0.132	0.165
Utilities	Energy and Fuels	Hydro	n/a	n/a	n/a	No data	No data	No data	No data	No data	No data	No data	No data	No data
Utilities	Energy and Fuels	Pumped Hydro	n/a	n/a	n/a	n/a	0.873	n/a	n/a	0.055	n/a	n/a	0.225	n/a

Super Sector	Mastertype	Typecast	Material share of capex			Product stage (A1-A3) Emission intensity (kg CO ₂ e/\$ material spend)			Transport (A4) Emission intensity (kg CO ₂ e/\$ material spend)			Construction (A5) Emission intensity (kg CO ₂ e/\$ material spend)		
			Low	Mid	High	Low	Mid	High	Low	Mid	High	Low	Mid	High
Utilities	Energy and Fuels	Transmission (other)	n/a	n/a	n/a	n/a	1.8	n/a	n/a	0.083	n/a	n/a	0.223	n/a
Utilities	Energy and Fuels	Transmission Line: Double Circuit	n/a	n/a	n/a	n/a	3.9	n/a	n/a	0.052	n/a	n/a	0.13	n/a
Utilities	Energy and Fuels	Transmission Line: Single Circuit	n/a	n/a	n/a	n/a	4.1	n/a	n/a	0.051	n/a	n/a	0.128	n/a
Utilities	Energy and Fuels	Utility Solar	n/a	n/a	n/a	n/a	4.85	n/a	n/a	0.083	n/a	n/a	0.168	n/a
Utilities	Energy and Fuels	Wind	n/a	n/a	n/a	n/a	1.77	n/a	n/a	0.054	n/a	n/a	0.158	n/a
Utilities	Telecommunications and Digital	Telecommunications	22%	29%	36%	0.52	0.693	0.866	0.137	0.183	0.229	0.157	0.21	0.262
Utilities	Water and Sewerage	Dam	18%	23%	29%	0.616	0.821	1.03	0.064	0.085	0.106	0.21	0.28	0.35
Utilities	Water and Sewerage	Water Pipeline	17%	23%	29%	0.147	0.197	0.246	0.016	0.021	0.026	0.063	0.084	0.105
Utilities	Water and Sewerage	Water Treatment Plant	20%	27%	33%	0.649	0.865	1.08	0.054	0.072	0.09	0.222	0.296	0.37

Appendix 8: Asset specific minimum inclusions

Where carbon is being estimated from material quantities and sub-asset or element carbon intensity benchmarks, assessments should aim to cover at least 80% of the project elements (by material spend). The following section provides guidance on the asset elements that are to be included in the embodied carbon assessment for major infrastructure types and sub-types where an asset-level carbon intensity benchmark is not used. Construction stage (A4-A5) minimum inclusions, applicable to all asset types, are also provided at the end of this appendix in Table A8.6.

For the remaining 20% an upscaling approach should be undertaken as discussed in Section 5.6.2.

In-use (B1-B5) minimum inclusions have been provided to quantify the carbon associated with routine maintenance, replacement and refurbishment of key elements that have a shorter design life than the asset. An example on how to calculate the in-use embodied carbon has been provided in Case Study 7 below.

This guidance on minimum inclusions does not cover all asset types. For example, many transport projects and programs would fall outside of the ‘road’ and ‘rail’ major asset types, such as transport interchanges, wharfs, fleet and access upgrades, depot and maintenance facilities. Where these are a significant source of emissions for road and rail projects, these should form part of minimum inclusions as part of the 80% minimum scope.

While conveyances (e.g., rolling stock, light rail vehicles, bus fleet, ferries) can also be a significant source of embodied carbon emissions, the Guide focuses on fixed and permanent infrastructure assets. As such, conveyances do not feature as part of the minimum inclusions for transport assets. However, where relevant to agency investments and programs, agencies are encouraged to consider their embodied carbon. To help in measuring this source of embodied carbon, agencies may consider requesting manufacturer Environmental Product Declarations when procuring conveyances.

Social Infrastructure

This section provides the minimum product stage (A1-A3) and in-use embodied carbon (B1-B5) inclusions for the following asset typecasts:

- Schools and higher education
- Hospitals
- Correctional centres



The following elements represent 80% scope for A1-A3 and B1-B5 stages for social infrastructure. Refer to Table A8.6 at the end of Appendix 8 for construction stage (A4-A5) minimum inclusions. Where information on a project element is unavailable, the predicted material quantity can be estimated using an informed methodology (such as material-use benchmarks derived from similar projects).

Table A8.1 Minimum inclusions for social infrastructure projects

Asset Typecast	Product stage (A1 A3)	In use embodied carbon (B1 B5)
School and higher education, Hospital, Correction centre	<ul style="list-style-type: none"> • Structure • Foundation • Envelope – façade, cladding, glazing, roof, insulation • Temporary civil and structural works 	<ul style="list-style-type: none"> • Façade replacement <p>Note: operational emissions from refrigerant leakage (B1) are also significant,</p>

	<ul style="list-style-type: none"> Associated infrastructure (where relevant): roads and pavements, car parks, and site civil works e.g. drainage and retaining structures 	but not considered in the definition of embodied carbon used in this Guide.
--	---	---

Roads

The material inputs for road projects can vary depending on the pavement types, and the inclusion of tunnels or bridges (any elevated sections requiring structure). The following section outlines the asset elements that should be included in the embodied carbon calculation for various road projects.

The following Infrastructure Australia’s asset typecasts are covered under this category:

- State Roads (Highway/Freeway)
- Bridges (Road)
- Tunnels (Road)



The following elements represent 80% scope for A1-A3 and B1-B5 stages for roads. Refer to Table A8.6 at the end of Appendix 8 for construction stage (A4-A5) minimum inclusions. Where information on a project element is unavailable, the predicted material quantity can be estimated using an informed methodology (such as material-use benchmarks derived from similar projects).

Table A8.2 Minimum product stage inclusions for State Roads, Bridges and Tunnels

Asset Typecast	Product stage (A1 A3)	In use embodied carbon (B1 B5)
State roads (highways/freeways)	<ul style="list-style-type: none"> Pavement Road base Civil structures Retaining walls Drainage Aggregates Temporary civil and structural works Associated infrastructure (where relevant): major civil and structure components for bus stops, interchanges, and active transport links. 	<ul style="list-style-type: none"> Pavement rehabilitation and resurfacing Drainage structure replacement Aggregates replacement
Road bridges (in addition to the above)	<ul style="list-style-type: none"> Bridge structure (deck, piers, piles/footings) 	
Road tunnels (in addition to the above)	<ul style="list-style-type: none"> Tunnel lining Grout Epoxy Ventilation systems 	<ul style="list-style-type: none"> Replacement of ventilation systems

Rail

The following Infrastructure Australia’s asset typecasts are covered under this category:

- Mainline Works (Rail)
- Tunnels (Rail)
- Bridges (Rail)



The following elements represent 80% scope for A1-A3 and B1-B5 stages for rail. Refer to Table A8.6 at the end of Appendix 8 for construction stage (A4-A5) minimum inclusions. Where information on a project element is unavailable, the predicted material quantity can be estimated using an informed methodology (such as material-use benchmarks derived from similar projects).

Table A8.3 Minimum inclusions for Mainline Works, Bridges and Tunnels

Asset Typecast	Product stage (A1 A3)	In use embodied carbon (B1 B5)
Mainline Works	<ul style="list-style-type: none"> • Rail tracks • Sleepers and fastening system • Track slab • Ballast • Drainage • Aggregates • Major electrical equipment and cabling (including major transformers) • Electrical support structures • Service/access walkways • Temporary civil and structural works • Associated infrastructure (where relevant): major civil and structure components for stations and active transport links. 	<ul style="list-style-type: none"> • Rail tracks replacement, sleepers, and fastening system replacement • Drainage structure replacement • Major electrical equipment and cabling replacement • Electrical support structures replacement
Bridges (in addition to the above for Mainline Works)	<ul style="list-style-type: none"> • Bridge structure (deck, piers, piles/footings) 	
Tunnels (in addition to the above for Mainline Works)	<ul style="list-style-type: none"> • Tunnel lining • Grout • Epoxy • Ventilation system 	<ul style="list-style-type: none"> • Replacement of ventilation system
Stations	<ul style="list-style-type: none"> • Structure • Foundation • Envelope – façade, cladding, glazing, roof, insulation • Temporary civil and structural works • Associated infrastructure (where relevant): roads and pavements, car parks, and site civil works e.g. drainage and retaining structures 	<ul style="list-style-type: none"> • Façade replacement <p>Note: operational emissions from refrigerant leakage (B1) are also significant, but not considered in the definition of embodied carbon used in this Guide.</p>

The following Case Study (Case Study 7) demonstrates the approach to estimating the replacement materials required throughout the asset life cycle. This is a weighted approach to ensure the design life of the asset does

not drastically change the in-use embodied carbon emissions from replacements. It is recommended that if the design life of elements is certain then the replacement rate should be rounded down to the closest whole number. However, if the design life is uncertain and only an estimate is available, it is suggested to adopt the more conservative unrounded rate. Alternatively, project teams may follow the approach for replacements set out in the RICS *Whole life carbon assessment for the built environment* standard.

Case Study 7: Calculating the replacement rate of asset elements

An electrified rail project identified that cabling is a significant source of in-use stage embodied carbon. The project team calculates the in-use embodied emissions which will result from the replacement of materials over the asset lifespan (module B4).

The **asset life is 100 years**, whilst the project knows the estimated **design life of its cabling components is only 30 years**, meaning they will need to be replaced during the asset life cycle. To calculate the replacement rate for the cabling component, the following equation was used:

$$\text{Replacement rate} = \frac{(c) \text{ asset design life}}{(d) \text{ element design life}} = \frac{100}{30} = 3.33$$

Note: Round down to a replacement rate of 3 if design life of the element is certain.

Initially, **50 tonnes** of cabling will be needed to construct the asset (module A1-A3), and the project team expects that the cabling will likely need to be replaced after 30 years and multiple times over the asset life. To calculate the materials required for cabling replacements (B4), the following equation was used:

$$\text{Replacement Quantity} = 50 \text{ tonnes} \times 3.33 = 166.5 \text{ tonnes}$$

This calculation shows that an additional **166.5 tonnes of cabling** will be required during the in-use stage of the asset.

Water and Sewerage

This section provides the minimum product stage (A1-A3) and in-use embodied carbon (B1-B5) inclusions for the following asset typecasts:

- Water pipelines
- Water Recycling / Treatment Plants
- Dams and reservoirs



The following elements represent 80% scope for A1-A3 and B1-B5 stages for water and sewerage projects. Refer to Table A8.6 at the end of Appendix 8 for construction stage (A4-A5) minimum inclusions. Where information on a project element is unavailable, the predicted material quantity can be estimated using an informed methodology (such as material-use benchmarks derived from similar projects).

Table A8.4 Minimum product stage inclusions for water pipelines, water recycling/treatment plans and dams

Asset Typecast	Product stage (A1 A3)	In use embodied carbon (B1 B5)
Water Pipeline (including associated network infrastructure)	<ul style="list-style-type: none"> • Major pipes (>DN100) • Foundations and structures for pipes, pumping stations and maintenance shafts (e.g., above ground support structures and footings) • Major mechanical and electrical equipment and cabling (e.g., pumps and transformers) • Aggregates • Access/service roads • Temporary civil and structural works 	<ul style="list-style-type: none"> • Major mechanical and electrical equipment and cabling replacement (e.g., pumps) • Pipe replacement and slip lining (refurbishment)
Water Recycling / Treatment Plants (in addition to the above)	<ul style="list-style-type: none"> • Above ground structures (e.g., bioreactors, screening, sedimentation and clarification tanks) 	<p>Note: Operational emission sources of fugitive emissions (B1), use of treatment chemicals (B2), and biosolids transfer/disposal (B2) are significant, but not considered in the definition of embodied carbon used in this Guide.</p>
Dams (in addition to the above)	<ul style="list-style-type: none"> • Crest/roadway • Spillway • Foundation • Embankments • Intake and outlet towers • Temporary civil and structural works 	<p>Note: operational emission sources of fugitive emissions (B1) from decomposition of vegetation are significant, but not considered in the definition of embodied carbon used in this Guide.</p>

Energy

This section provides the minimum product stage (A1-A3) and in-use embodied carbon (B1-B5) inclusions for the following asset typecasts:

- Transmission lines



- Wind
- Utility (solar)

The following elements represent 80% scope for A1-A3 and B1-B5 stages for energy projects. Refer to Table A8.6 at the end of Appendix 8 for construction stage (A4-A5) minimum inclusions. Where information on a project element is unavailable, the predicted material quantity can be estimated using an informed methodology (such as material-use benchmarks derived from similar projects).

Table A8.5 Minimum product stage inclusions for transmission lines, wind and utility (solar)

Asset Type	Product stage (A1 A3)	In use embodied carbon (B1 B5)
Transmission lines	<ul style="list-style-type: none"> • Foundations • Lattice towers / structure • Conductor system • Aggregate • Insulation system • Earthing system • Substation transformer • Substation switchgear • Access/service road • Temporary civil and structural works 	<ul style="list-style-type: none"> • Major electrical equipment and cabling replacements
Wind	<ul style="list-style-type: none"> • Foundations • Wind tower • Nacelle (fibreglass shell for drive shaft and gearbox) • Rotor and blades • Aggregate • Power cables • Turbine transformer • Turbine switchgear • Substation transformer • Substation switchgear • Access/service roads • Temporary civil and structural works 	<ul style="list-style-type: none"> • Major electrical equipment and cabling replacements
Solar (utility)	<ul style="list-style-type: none"> • Solar PV Cells • Racking System • Electrical cabling • Inverters • Batteries • Aggregate • Substation transformer • Substation switchgear • Transformer foundation • Access/service roads • Temporary civil and structural works 	<ul style="list-style-type: none"> • Solar PV cell replacement • Major electrical equipment and cabling

Construction stage (A4-A5)

Additional guidance for construction stage minimum inclusions is provided in Table A8.6 below. This is applicable to all asset types.

Table A8.6 Minimum inclusions for the construction stage

Asset Type/cast	Construction (A4 A5)
All	<ul style="list-style-type: none">• Electricity purchased• Fuel consumption associated with plant, equipment and site vehicles• Land use change (stored carbon and loss of future sequestration from vegetation removal)• Transport of materials to site• Waste generated during construction (on-site)<ul style="list-style-type: none">○ Inert waste from earthworks○ Construction material wastage○ Vegetation waste○ Site office waste• Transport of waste to end destination

Appendix 9: Default calculation assumptions

Default transport distance assumptions (A4)

Default assumptions for the transport of materials and waste are provided in Table A9.1 below. These transport distances were used in the calculations for Infrastructure Australia’s *Embodied Carbon Projections for Australian Infrastructure and Buildings* study.⁵⁴

These distances are designed to represent a market-weighted average product in each State and Territory. The distances start from the primary producer and include all downstream manufacturing stages to get the product to the local market. For example:

- transport of a steel product starts at the steel mill (the primary producer) and includes the fabricator (the manufacturer) before being transported to the job site.
- transport for a timber product starts at the forest (the primary producer) and then goes to a sawmill (the manufacturer) before being transported to a local timber yard or directly to the job site.

The distances are weighted to account for imports. This means that international sea freight is included, weighted by the market share of imports. The market share of imports was calculated based on trade statistics for some materials (structural steel, reinforcing steel, cement, aluminium) and estimated for others.

The starting point for all calculations was state-specific data from CSIRO’s Transport Network Strategic Investment Tool (TraNSIT) provided directly to Infrastructure Australia.

The data supplied from CSIRO’s TraNSIT model:

- applies to domestic freight only (i.e., doesn’t include imports)
- covers truck and rail freight only (i.e., does not include coastal sea freight)
- covers most (but not all) of the key materials included in Infrastructure Australia’s study
- focuses primarily on transport from the manufacturer but does not necessarily include transport from the primary producer.

As such, the CSIRO TraNSIT data was supplemented to include:

- weighted average product on the market, accounting for transport of imported products.
- international sea freight and domestic coastal shipping.
- additional materials that were not in the TraNSIT dataset.
- upstream transport from the primary producer to the secondary producer / manufacturer.

Table A9.1 Default assumptions for the transport of materials (A4) and waste (A5)

Material	State	Truck (km)	Rail (km)	Sea (km)
Aggregate	ACT	90	0	0
Aggregate	NSW	62	0	0
Aggregate	NT	450	0	0

⁵⁴ Forthcoming as of February 2024

Material	State	Truck (km)	Rail (km)	Sea (km)
Aggregate	QLD	61	0	0
Aggregate	SA	87	0	0
Aggregate	TAS	50	0	0
Aggregate	VIC	38	0	0
Aggregate	WA	80	0	0
Aluminium	ACT	689	0	7,426
Aluminium	NSW	444	0	7,372
Aluminium	NT	1,130	0	4,587
Aluminium	QLD	542	0	6,764
Aluminium	SA	531	0	8,498
Aluminium	TAS	204	0	8,605
Aluminium	VIC	396	0	8,316
Aluminium	WA	1,058	0	6,535
Asphalt (Highway)	ACT	110	0	0
Asphalt (Highway)	NSW	57	0	0
Asphalt (Highway)	NT	345	0	0
Asphalt (Highway)	QLD	52	0	0
Asphalt (Highway)	SA	156	0	0
Asphalt (Highway)	TAS	120	0	0
Asphalt (Highway)	VIC	40	0	0
Asphalt (Highway)	WA	143	0	0
Asphalt (Urban)	ACT	110	0	0
Asphalt (Urban)	NSW	57	0	0
Asphalt (Urban)	NT	345	0	0
Asphalt (Urban)	QLD	52	0	0
Asphalt (Urban)	SA	156	0	0
Asphalt (Urban)	TAS	120	0	0
Asphalt (Urban)	VIC	40	0	0
Asphalt (Urban)	WA	143	0	0
Bathroom Fitout	ACT	280	0	10,000
Bathroom Fitout	NSW	50	0	10,000
Bathroom Fitout	NT	200	0	10,000
Bathroom Fitout	QLD	50	0	10,000
Bathroom Fitout	SA	50	0	10,000
Bathroom Fitout	TAS	50	0	10,000
Bathroom Fitout	VIC	50	0	10,000
Bathroom Fitout	WA	50	0	10,000
Bitumen Binders	ACT	414	18	6,000
Bitumen Binders	NSW	165	18	6,000
Bitumen Binders	NT	465	18	6,000
Bitumen Binders	QLD	221	18	6,000

Material	State	Truck (km)	Rail (km)	Sea (km)
Bitumen Binders	SA	252	18	6,000
Bitumen Binders	TAS	111	18	6,000
Bitumen Binders	VIC	124	18	6,000
Bitumen Binders	WA	314	18	6,000
Bricks	ACT	290	0	0
Bricks	NSW	100	0	0
Bricks	NT	3,750	0	0
Bricks	QLD	100	0	0
Bricks	SA	100	0	0
Bricks	TAS	100	0	0
Bricks	VIC	100	0	0
Bricks	WA	100	0	0
Building Services	ACT	280	0	10,000
Building Services	NSW	50	0	10,000
Building Services	NT	200	0	10,000
Building Services	QLD	50	0	10,000
Building Services	SA	50	0	10,000
Building Services	TAS	50	0	10,000
Building Services	VIC	50	0	10,000
Building Services	WA	50	0	10,000
Carpet	ACT	500	0	2,000
Carpet	NSW	500	0	2,000
Carpet	NT	1,000	0	2,000
Carpet	QLD	500	0	2,000
Carpet	SA	500	0	2,000
Carpet	TAS	500	0	2,000
Carpet	VIC	500	0	2,000
Carpet	WA	500	0	2,000
Cement	ACT	311	10	694
Cement	NSW	324	10	704
Cement	NT	1,478	10	1,322
Cement	QLD	546	10	817
Cement	SA	117	10	818
Cement	TAS	102	10	1,787
Cement	VIC	263	10	716
Cement	WA	213	10	1,011
Ceramic Tiles	ACT	200	0	500
Ceramic Tiles	NSW	200	0	500
Ceramic Tiles	NT	1,000	0	1,000
Ceramic Tiles	QLD	200	0	500
Ceramic Tiles	SA	200	0	500

Material	State	Truck (km)	Rail (km)	Sea (km)
Ceramic Tiles	TAS	200	0	1,000
Ceramic Tiles	VIC	200	0	500
Ceramic Tiles	WA	200	0	500
Copper	ACT	280	0	10,000
Copper	NSW	50	0	10,000
Copper	NT	200	0	10,000
Copper	QLD	50	0	10,000
Copper	SA	50	0	10,000
Copper	TAS	50	0	10,000
Copper	VIC	50	0	10,000
Copper	WA	50	0	10,000
Electrical Bulk	ACT	280	0	10,000
Electrical Bulk	NSW	50	0	10,000
Electrical Bulk	NT	200	0	10,000
Electrical Bulk	QLD	50	0	10,000
Electrical Bulk	SA	50	0	10,000
Electrical Bulk	TAS	50	0	10,000
Electrical Bulk	VIC	50	0	10,000
Electrical Bulk	WA	50	0	10,000
Fiberglass	ACT	280	0	20,000
Fiberglass	NSW	50	0	20,000
Fiberglass	NT	200	0	20,000
Fiberglass	QLD	50	0	20,000
Fiberglass	SA	50	0	20,000
Fiberglass	TAS	50	0	20,000
Fiberglass	VIC	50	0	20,000
Fiberglass	WA	50	0	20,000
Girders	ACT	196	980	893
Girders	NSW	303	686	886
Girders	NT	770	3,095	552
Girders	QLD	475	1,576	813
Girders	SA	229	964	1,022
Girders	TAS	319	2	2,163
Girders	VIC	149	1,026	1,000
Girders	WA	335	3,121	786
Glass	ACT	200	0	10,000
Glass	NSW	200	0	10,000
Glass	NT	1,000	0	10,000
Glass	QLD	200	0	10,000
Glass	SA	200	0	10,000
Glass	TAS	200	0	10,000

Material	State	Truck (km)	Rail (km)	Sea (km)
Glass	VIC	200	0	10,000
Glass	WA	200	0	10,000
Glass (HV Insulators)	ACT	280	0	10,000
Glass (HV Insulators)	NSW	50	0	10,000
Glass (HV Insulators)	NT	200	0	10,000
Glass (HV Insulators)	QLD	50	0	10,000
Glass (HV Insulators)	SA	50	0	10,000
Glass (HV Insulators)	TAS	50	0	10,000
Glass (HV Insulators)	VIC	50	0	10,000
Glass (HV Insulators)	WA	50	0	10,000
Insulation	ACT	500	0	2,000
Insulation	NSW	500	0	2,000
Insulation	NT	1,000	0	2,000
Insulation	QLD	500	0	2,000
Insulation	SA	500	0	2,000
Insulation	TAS	500	0	2,000
Insulation	VIC	500	0	2,000
Insulation	WA	500	0	2,000
Kitchen Fitout	ACT	307	0	2,000
Kitchen Fitout	NSW	307	0	2,000
Kitchen Fitout	NT	3,750	0	2,000
Kitchen Fitout	QLD	307	0	2,000
Kitchen Fitout	SA	307	0	2,000
Kitchen Fitout	TAS	307	0	2,000
Kitchen Fitout	VIC	307	0	2,000
Kitchen Fitout	WA	307	0	2,000
Linemarking & Road Furnitures	ACT	500	0	500
Linemarking & Road Furnitures	NSW	500	0	500
Linemarking & Road Furnitures	NT	3,750	0	500
Linemarking & Road Furnitures	QLD	500	0	500
Linemarking & Road Furnitures	SA	500	0	500
Linemarking & Road Furnitures	TAS	500	0	500
Linemarking & Road Furnitures	VIC	500	0	500
Linemarking & Road Furnitures	WA	500	0	500
Paint	ACT	500	0	500
Paint	NSW	500	0	500
Paint	NT	1,000	0	1,000
Paint	QLD	500	0	500
Paint	SA	500	0	500
Paint	TAS	500	0	1,000
Paint	VIC	500	0	500

Material	State	Truck (km)	Rail (km)	Sea (km)
Paint	WA	500	0	500
Plasterboard	ACT	500	0	0
Plasterboard	NSW	500	0	0
Plasterboard	NT	3,750	0	0
Plasterboard	QLD	500	0	0
Plasterboard	SA	500	0	0
Plasterboard	TAS	500	0	0
Plasterboard	VIC	500	0	0
Plasterboard	WA	500	0	0
Plastics and Polymeric materials	ACT	500	0	10,000
Plastics and Polymeric materials	NSW	500	0	10,000
Plastics and Polymeric materials	NT	3,750	0	10,000
Plastics and Polymeric materials	QLD	500	0	10,000
Plastics and Polymeric materials	SA	500	0	10,000
Plastics and Polymeric materials	TAS	500	0	10,000
Plastics and Polymeric materials	VIC	500	0	10,000
Plastics and Polymeric materials	WA	500	0	10,000
Plywood	ACT	89	51	500
Plywood	NSW	88	51	500
Plywood	NT	1,389	51	1,000
Plywood	QLD	167	51	500
Plywood	SA	581	51	500
Plywood	TAS	388	51	1,000
Plywood	VIC	201	51	500
Plywood	WA	56	51	500
PV Panels	ACT	280	0	10,000
PV Panels	NSW	50	0	10,000
PV Panels	NT	200	0	10,000
PV Panels	QLD	50	0	10,000
PV Panels	SA	50	0	10,000
PV Panels	TAS	50	0	10,000
PV Panels	VIC	50	0	10,000
PV Panels	WA	50	0	10,000
Rail Track	ACT	738	18	2,619
Rail Track	NSW	877	18	2,600
Rail Track	NT	3,256	18	1,618
Rail Track	QLD	1,572	18	2,386
Rail Track	SA	732	18	2,997
Rail Track	TAS	2,797	18	2,305
Rail Track	VIC	598	18	2,933
Rail Track	WA	2,931	18	2,305

Material	State	Truck (km)	Rail (km)	Sea (km)
Rock/Bluestone	ACT	51	4	0
Rock/Bluestone	NSW	36	4	0
Rock/Bluestone	NT	244	4	0
Rock/Bluestone	QLD	51	4	0
Rock/Bluestone	SA	59	4	0
Rock/Bluestone	TAS	28	4	0
Rock/Bluestone	VIC	23	4	0
Rock/Bluestone	WA	81	4	0
Sand	ACT	88	0	0
Sand	NSW	56	0	0
Sand	NT	454	0	0
Sand	QLD	46	0	0
Sand	SA	92	0	0
Sand	TAS	65	0	0
Sand	VIC	40	0	0
Sand	WA	60	0	0
Stainless Steel	ACT	280	0	10,000
Stainless Steel	NSW	50	0	10,000
Stainless Steel	NT	200	0	10,000
Stainless Steel	QLD	50	0	10,000
Stainless Steel	SA	50	0	10,000
Stainless Steel	TAS	50	0	10,000
Stainless Steel	VIC	50	0	10,000
Stainless Steel	WA	50	0	10,000
Steel – Structural Elements	ACT	196	980	893
Steel – Structural Elements	NSW	303	686	886
Steel – Structural Elements	NT	770	3,095	552
Steel – Structural Elements	QLD	475	1,576	813
Steel – Structural Elements	SA	229	964	1,022
Steel – Structural Elements	TAS	319	2	2,163
Steel – Structural Elements	VIC	149	1,026	1,000
Steel – Structural Elements	WA	335	3,121	786
Steel – Transmission Cable	ACT	815	0	2,619
Steel – Transmission Cable	NSW	911	0	2,600
Steel – Transmission Cable	NT	3,213	0	1,618
Steel – Transmission Cable	QLD	1,593	0	2,386
Steel – Transmission Cable	SA	855	0	2,997
Steel – Transmission Cable	TAS	2,677	0	2,305
Steel – Transmission Cable	VIC	620	0	2,933
Steel – Transmission Cable	WA	2,614	0	2,305
Steel Re-inforcement	ACT	815	15	2,619

Material	State	Truck (km)	Rail (km)	Sea (km)
Steel Re-inforcement	NSW	911	15	2,600
Steel Re-inforcement	NT	3,213	15	1,618
Steel Re-inforcement	QLD	1,593	15	2,386
Steel Re-inforcement	SA	855	15	2,997
Steel Re-inforcement	TAS	2,677	15	2,305
Steel Re-inforcement	VIC	620	15	2,933
Steel Re-inforcement	WA	2,614	15	2,305
Timber	ACT	89	51	0
Timber	NSW	88	51	0
Timber	NT	1,389	51	0
Timber	QLD	167	51	0
Timber	SA	581	51	0
Timber	TAS	388	51	0
Timber	VIC	201	51	0
Timber	WA	56	51	0

Default construction waste generation rates and transport offsite (A5)

Default waste generation rates for the construction phase are provided in Table A9.2 below. Where location of waste treatment is unknown, a default 50km transport distance of offsite processing can be assumed. These figures are derived from the *Embodied Carbon Projections for Australian Infrastructure and Buildings* study conducted by Infrastructure Australia.

Please refer to the jurisdiction-specific Addendum for regionally specific considerations.

Table A9.2 Default assumptions for waste generation during construction (A5)

Material	Wastage rate (%)
Aggregate	5%
Aluminium	1%
Asphalt	6%
Bathroom Fitout	6%
Bitumen Binders	6%
Bricks	6%
Building Services	1%
Carpet	6%
Ceramic Tiles	6%
Concrete	5%

Material	Wastage rate (%)
Copper	1%
Electrical Bulk	1%
Fibreglass	1%
Girders	1%
Glass	1%
Glass (HV Insulators)	1%
Insulation	7%
Kitchen Fitout	6%
Linemarking & Road Furnitures	6%
Paint	6%
Plasterboard	15%
Plastics and Polymeric materials	6%
Plywood	10%
PV Panels	1%
Rail Track	1%
Rock/Bluestone	5%
Sand	5%
Stainless Steel	1%
Steel – Structural Elements	1%
Steel – Transmission Cable	1%
Steel Re-inforcement	5%
Timber	2%

Default end-of-life waste treatment (A5)

Default calculation assumptions for the end-of-life treatment of waste are provided in Table A9.3 below. These figures are derived from the *Embodied Carbon Projections for Australian Infrastructure and Buildings* study conducted by Infrastructure Australia. These figures can also apply to end-of-life stage calculations (C1-C4).

Please refer to the jurisdiction-specific Addendum for regionally specific considerations.

Table A9.3 Default end of life waste treatment assumptions (A5)

Waste type	Recycling rate (%)	Landfill rate (%)	Incineration rate (%)
Aggregate	90%	10%	0%

Waste type	Recycling rate (%)	Landfill rate (%)	Incineration rate (%)
Aluminium	50%	50%	0%
Asphalt	100%	0%	0%
Bathroom Fitout	0%	100%	0%
Bitumen Binders	100%	0%	0%
Bricks	90%	10%	0%
Building Services	40%	60%	0%
Carpet	20%	80%	0%
Ceramic Tiles	0%	100%	0%
Concrete	90%	10%	0%
Copper	50%	50%	0%
Electrical Bulk	40%	60%	0%
Fiberglass	0%	100%	0%
Girders	90%	10%	0%
Glass	20%	80%	0%
Glass (HV Insulators)	0%	100%	0%
Insulation	0%	100%	0%
Kitchen Fitout	0%	100%	0%
Linemarking & Road Furnitures	0%	100%	0%
Paint	0%	100%	0%
Plasterboard	17%	83%	0%
Plastics and Polymeric materials	0%	100%	0%
Plywood	25%	70%	5%
PV Panels	0%	100%	0%
Rail Track	90%	10%	0%
Rock/Bluestone	90%	10%	0%
Sand	90%	10%	0%
Stainless Steel	50%	50%	0%
Steel – Structural Elements	90%	10%	0%
Steel – Transmission Cable	90%	10%	0%
Steel Re-enforcement	90%	10%	0%
Timber	25%	70%	5%

Appendix 10: Reporting templates

General project information

Table A10.1 provides an overview of the general project information that should be submitted alongside the calculated carbon emissions for each asset type. This information will enable the identification and categorisation of projects in line with the Infrastructure Australia’s classification system. For an overview of the Infrastructure Australia’s classification system, see Section 5.6.1.

Table A10.1 General project data

Input	Project Details
Project or contract name	
Program (if relevant)	
Project stage	
Government agency	
Applicable reporting requirements (e.g. NABERS, ISC, GreenStar, Organisation carbon reporting tool, Statutory planning policy / assessment requirements, etc.)	
Date of assessment undertaken	
Primary asset class (IA Mastertype)	
Primary asset type (IA Typecast)	
Other sub-assets included within the scope (IA Typecast)	

Reporting template 1 – Carbon emissions and removals by life cycle module

The following reporting templates are recommended to disclose the total asset-level carbon emissions, and the calculated emissions for each distinct sub-asset element. Larger and more complex projects may contain multiple asset types, and it is recommended that the following tables are completed for each asset within the project or contract boundary. For example, a major road project may include portions of road at grade, elevated (bridges, interchanges, and grade separations), and through tunnel. In these cases, investigation of the carbon emissions (absolute and per declared unit) can support options analysis and benchmarking for future projects.

In the following tables, the **grey cells** represent embodied carbon modules that are not covered by this Guide or that are unlikely to be significant. However, these are included in Table A10.3 for completeness, and agencies are encouraged to provide these reporting inputs where the data is available. Please refer to your jurisdiction-specific Addendum and/or jurisdiction-specific policy for mandatory and optional reporting requirements.

Table A10.2 General asset level or sub-asset level data

Input	Project Details
Declared unit	
Project scale (quantity in declared unit)	
Key data sources (optional)	
Key emission factor sources or carbon intensity benchmarks used (optional)	

Table A10.3 Template for presenting carbon by life cycle module for asset and sub-asset level reporting

Life cycle module	Base Case		Option/s	
	Absolute (tCO ₂ e)	Per declared unit (tCO ₂ e/unit)	Absolute (tCO ₂ e)	Per declared unit (tCO ₂ e/unit)
Pre-Construction Activities (A0)				
Product stage (A1-A3)				
Transport to site (A4)				
Construction (A5)				
Land use change (A5)				
Use phase material emissions and removals (B1)				
Maintenance (B2)				
Repair, refurbishment and replacement (B3-B5)				
Deconstruction/Demolition (C1)				
Waste transport (C2)				

Life cycle module	Base Case		Option/s	
	Absolute (tCO ₂ e)	Per declared unit (tCO ₂ e/unit)	Absolute (tCO ₂ e)	Per declared unit (tCO ₂ e/unit)
Waste processing for reuse/recycling (C3)				
Waste disposal (C4)				
Benefits and loads beyond the system boundary (D) ¹				
Total upfront carbon (A1-A5) – excluding biogenic carbon				
Total upfront carbon - including biogenic carbon²				
Total embodied carbon				
Total embodied carbon (including biogenic carbon)²				
<p>1 - Module D is included for completeness</p> <p>2 - Main reporting of carbon emissions should exclude biogenic carbon. For projects with significant biogenic carbon (such as buildings with timber structures), additional reporting of biogenic carbon and modules C1-C4 is recommended.</p>				

Reporting template 2 - Materials (product stage and in-use stage)

The following table shows the material data associated with construction activities to be reported. The disclosure of material inputs for product stage (A1-A3) and in-use (B1-B5) carbon measurement should be reported in a separate tables or columns. Please refer to your jurisdiction-specific addendum and/or jurisdiction-specific policy for mandatory and optional reporting requirements.

Table A10.4 Reporting template for materials used

Product Group	Material	Quantity	Unit
Concrete	Concrete (in situ) - total		m ²
	Precast concrete		tonnes
Steel	Reinforcing steel		tonnes
	Structural steel		tonnes
Asphalt (for road projects)	Asphalt		tonnes
Aggregates	Ballast (rail)		tonnes
	Other aggregates		tonnes
Other materials		
		
		

Reporting template 3 - Construction activities (A5)

The following reporting template is recommended to disclose the activity data that informed the construction stage (A5) carbon calculations. Please refer to your jurisdiction-specific Addendum and/or jurisdiction-specific policy for mandatory and optional reporting requirements.

Table A10.5 Reporting template for construction activity data

Resource	Quantity	Unit
Electricity		
Standard grid electricity		kWh
Renewable electricity (onsite, behind the meter)		kWh
Renewable (offsite, GreenPower, LGCs etc)		kWh
Fuel Use		
Diesel oil		kL
Liquified petroleum gas		kL
Biodiesel (B5)		kL
Biodiesel (B10)		kL

Resource	Quantity	Unit
Biodiesel (B20)		kL
Biodiesel (B100)		kL
Petroleum based greases		kL
...		
Waste generation		
Total waste to landfill		tonnes
Total waste to recycling		tonnes
Waste to landfill - inert waste (concrete/metals/plastics/glass)		tonnes
Waste to landfill - food		tonnes
Waste to landfill - paper and cardboard		tonnes
Waste to landfill - garden and green		tonnes
Waste to landfill - wood		tonnes
Waste to landfill - textiles		tonnes
Waste to landfill- sludge		tonnes
Waste to landfill - rubber and leather		tonnes
Land use and land use change		
Total land cleared		ha
Total trees cleared		no.
Land clearing - Vegetation Class A3		ha
Land clearing - Vegetation Class A4		ha
Land clearing - Vegetation Class A5		ha
Land clearing - Vegetation Class A6		ha
Land clearing - Vegetation Class A7		ha
Land clearing - Vegetation Class B3		ha
Land clearing - Vegetation Class B4		ha
Land clearing - Vegetation Class B5		ha
Land clearing - Vegetation Class B6		ha
Land clearing - Vegetation Class C1		ha
Land clearing - Vegetation Class C2		ha
Land clearing - Vegetation Class C3		ha

Resource	Quantity	Unit
Land clearing - Vegetation Class C4		ha
Land clearing - Vegetation Class C5		ha
Land clearing - Vegetation Class D1		ha
Land clearing - Vegetation Class D2		ha
Land clearing - Vegetation Class D3		ha
Land clearing - Vegetation Class E1		ha
Land clearing - Vegetation Class E2		ha
Land clearing - Vegetation Class E3		ha
Land clearing - Vegetation Class F1		ha
Land clearing - Vegetation Class F2		ha
Land clearing - Vegetation Class G2		ha
Land clearing - Vegetation Class H1		ha
Land clearing - Vegetation Class H2		ha
Land clearing - Vegetation Class I		ha
Large tree (50cm<DBH<100cm) – Eucalypt		No. trees
Medium tree (20cm<DBH<50cm) – Eucalypt		No. trees
Small tree (5cm<DBH<20cm) - Shrub		No. trees

Appendix 11: Recommended declared units

Recommended declared units are provided in Table A11.1 below. These are broken down by Infrastructure Australia's mastertype (asset class) and typecasts (asset type).

Table A11.1 Recommended functional and declared units.

IA Mastertype (asset class)	IA Typecasts (asset type)	Declared units
Higher level declared units (linked to function or service)		
Social Infrastructure	Schools, hospitals, precincts, correctional facilities, other vertical infrastructure	<ul style="list-style-type: none"> Customer service provided for (e.g., patient, student)
Transport	Passenger transport	<ul style="list-style-type: none"> Passenger.km
	Freight transport	<ul style="list-style-type: none"> Tonne.km
Water	Water supply	<ul style="list-style-type: none"> ML supplied
	Wastewater	<ul style="list-style-type: none"> ML/day treated (Average Dry Weather Flow) Equivalent population serviced
	Storage	<ul style="list-style-type: none"> ML storage
Power	Generation	<ul style="list-style-type: none"> MWh provided over asset life
More detailed declared units (more specific)		
Social infrastructure	Schools, hospitals, precincts, correctional facilities, other vertical infrastructure	<ul style="list-style-type: none"> m² GFA
Road	Road - general	<ul style="list-style-type: none"> Lane.km or m² road surface area
	Road - Bridge	<ul style="list-style-type: none"> m² usable bridge deck
	Road - Tunnel	<ul style="list-style-type: none"> Lane.km km at a fixed tunnel diameter
Railway	Railway – Greenfield/Brownfield/Light Rail/Bridge/Tunnel	<ul style="list-style-type: none"> track.km
	Railway - Station	<ul style="list-style-type: none"> m² GFA
Power	Transmission	<ul style="list-style-type: none"> km for a fixed capacity
	Generation	<ul style="list-style-type: none"> MW capacity