Australian Government | Infrastructure Australia

Supporting Appendices: Embodied Carbon Projections for Australian Infrastructure and Buildings

Contents

Appendix A

Greenhouse gas emissions from the built environment

This appendix calculates the contribution of the built environment to Australia's total GHG emissions at the national level.

Emissions are broken into three categories:

1. Embodied carbon emissions, which is itself broken into three categories:
    a. Upfront embodied carbon emissions: Emissions at the start of the asset's life cycle, up to practical completion.
    b. Use phase embodied carbon emissions: Emissions from maintenance and refurbishment.
    c. End-of-life embodied carbon emissions: Emissions from waste treatment during demolition of the asset.
2. Operational carbon emissions: All GHG emissions associated with the use of buildings and infrastructure.
3. Enabled carbon emissions: All GHG emissions enabled by the existence of the built environment, such as vehicles driving over roads.

In this analysis, the industries *not* considered to either be part of the built environment or enabled by the built environment are:

- Mining.
- Agriculture, including livestock production, horticulture, aquaculture, fisheries and forestry.
- Defence/military installations and assets.

The primary sources of data for this analysis were:

- "National Inventory Report 2021" (DCCEEW, 2023c), specifically the "Common Reporting Table (CRT)" for the 2021 year (DCCEEW, 2023d)
- "National Inventory by Economic Sector 2021 - Data Tables (Excel)" (DCCEEW, 2023e)
- "Energy Account, Australia, 2020-21" (ABS, 2023b).

This analysis blends embodied carbon data from 2022-23 (FY 2023, as calculated in this report) with national carbon emissions from 2020-21 (FY 2021, as published by the Australian Government) due to the availability of data. As such, the analysis in this section assumes that there are no significant differences between years. While it is reasonable to assume the COVID-19 pandemic would have more significantly affected FY 2021 than FY 2023, it is notable that total gross emissions are similar in both years: no (DCCEEW, 2023d) versus in 529,100 kt CO_2e in FY 2023 (DCCEEW, 2023a).

A-1 Pipeline Analysis

Table 1 presents a summary of results for the Pipeline Analysis. Table 2 breaks emissions down by life cycle module. Table 3 breaks emissions down further to key contributors.

Table 1: Summary of emissions related to the built environment (Pipeline Analysis)

Life cycle module	Emissions (kt CO_2e)	Share of life cycle, excluding B8	Share of life cycle, including B8	Share of national total
Upfront embodied emissions	35,169	21.2%	11.6%	6.7%
Use phase embodied emissions	17,754	10.7%	5.9%	3.4%
End-of-life embodied carbon emissions	1,484	0.9%	0.5%	0.3%
Operational emissions	111,560	67.2%	36.8%	21.2%
Enabled emissions	137,152	0.0%	45.2%	26.1%
Total	**303,119**	**100.0%**	**100.0%**	**57.6%**

Table 2: Emissions related to the built environment, by life cycle module (Pipeline Analysis)

Life cycle module	Emissions (kt CO_2e)	Share of life cycle, excluding B8	Share of life cycle, including B8	Share of national total
A1-A3	26,976	16.3%	8.9%	5.1%
A4	1,570	0.9%	0.5%	0.3%
A5	6,623	4.0%	2.2%	1.3%
B1	8,548	5.2%	2.8%	1.6%
B2-B5	17,754	10.7%	5.9%	3.4%
B6	100,044	60.3%	33.0%	19.0%
B7	2,968	1.8%	1.0%	0.6%
B8	137,152	0.0%	45.2%	26.1%
C1	203	0.1%	0.1%	0.0%
C2	313	0.2%	0.1%	0.1%
C3	104	0.1%	0.0%	0.0%
C4	863	0.5%	0.3%	0.2%
Total	**303,119**	**100.0%**	**100.0%**	**57.6%**

Table 3: Emissions related to the built environment, by item (Pipeline Analysis)

Life cycle module	Source	Emissions (kt CO_2e)	Share of life cycle, excluding B8	Share of life cycle, including B8	Share of national total
A1-A3	New-build construction products	26,976	16.3%	8.9%	5.1%
A4	Transport of construction products	1,570	0.9%	0.5%	0.3%
A5	Construction waste	1,085	0.7%	0.4%	0.2%
A5	Construction energy	2,826	1.7%	0.9%	0.5%
A5	Commissioning energy	1,285	0.8%	0.4%	0.2%
A5	Land use change	1,427	0.9%	0.5%	0.3%
B1	Stationary air conditioning	4,761	2.9%	1.6%	0.9%
B1	Commercial refrigeration	3,787	2.3%	1.2%	0.7%
B2-B5	Construction products for renovation	17,754	10.7%	5.9%	3.4%
B6	Residential building fossil fuel use	10,714	6.5%	3.5%	2.0%
B6	Residential building electricity use	41,449	25.0%	13.7%	7.9%
B6	Non-residential building fossil fuel use	5,176	3.1%	1.7%	1.0%
B6	Non-residential building electricity use	37,143	22.4%	12.3%	7.1%
B6	Transport electricity use	2,692	1.6%	0.9%	0.5%
B6	Utilities electricity use	2,871	1.7%	0.9%	0.5%
B7	Wastewater treatment fugitive emissions	2,968	1.8%	1.0%	0.6%
B8	Road transport	76,845	0.0%	25.4%	14.6%
B8	Rail transport	4,069	0.0%	1.3%	0.8%
B8	Air transport (domestic)	4,389	0.0%	1.4%	0.8%
B8	Sea transport (domestic)	2,093	0.0%	0.7%	0.4%
B8	Other transportation	913	0.0%	0.3%	0.2%
B8	Industrial electricity use	49,524	0.0%	16.3%	9.4%
B8	Industrial thermal energy use	78,022	0.0%	25.7%	14.8%
B8	Industrial process emissions	21,587	0.0%	7.1%	4.1%
B8	Fugitive emissions from fuels	46,631	0.0%	15.4%	8.9%

Life cycle module	Source	Emissions (kt CO_2e)	Share of life cycle, excluding B8	Share of life cycle, including B8	Share of national total
B8	Emissions from CO_2 capture	2	0.0%	0.0%	0.0%
B8	Building product adjustment	-45,815	0.0%	-15.1%	-8.7%
B8	Construction emissions adjustment	-4,314	0.0%	-1.4%	-0.8%
B8	Other refrigerant emissions	2,857	0.0%	0.9%	0.5%
B8	Mining adjustment	-99,651	0.0%	-32.9%	-18.9%
C1	Demolition and deconstruction	203	0.1%	0.1%	0.0%
C2	Transport of demolition waste	313	0.2%	0.1%	0.1%
C3	Waste processing	104	0.1%	0.0%	0.0%
C4	Waste disposal	863	0.5%	0.3%	0.2%
Total		**303,119**	**100.0%**	**100.0%**	**57.6%**

A-2 Hybrid Analysis

Table 4 presents a summary of results for the Hybrid Analysis. Table 5 breaks emissions down by life cycle module. Table 6 breaks emissions down further to key contributors.

Table 4: Summary of emissions related to the built environment (Hybrid Analysis)

Life cycle module	Emissions (kt CO_2e)	Share of life cycle, excluding B8	Share of life cycle, including B8	Share of national total
Upfront embodied emissions	38,150	22.6%	12.5%	7.2%
Use phase embodied emissions	17,754	10.5%	5.8%	3.4%
End-of-life embodied carbon emissions	1,484	0.9%	0.5%	0.3%
Operational emissions	111,560	66.0%	36.6%	21.2%
Enabled emissions	135,922	0.0%	44.6%	25.8%
Total	**304,871**	**100.0%**	**100.0%**	**57.9%**

Table 5: Emissions related to the built environment, by life cycle module (Pipeline Analysis)

Life cycle module	Emissions (kt CO_2e)	Share of life cycle, excluding B8	Share of life cycle, including B8	Share of national total
A1-A3	28,226	16.7%	9.3%	5.4%
A4	1,467	0.9%	0.5%	0.3%
A5	8,458	5.0%	2.8%	1.6%
B1	8,548	5.1%	2.8%	1.6%
B2-B5	17,754	10.5%	5.8%	3.4%
B6	100,044	59.2%	32.8%	19.0%
B7	2,968	1.8%	1.0%	0.6%
B8	135,922	0.0%	44.6%	25.8%
C1	203	0.1%	0.1%	0.0%
C2	313	0.2%	0.1%	0.1%
C3	104	0.1%	0.0%	0.0%
C4	863	0.5%	0.3%	0.2%
Total	**304,871**	**100.0%**	**100.0%**	**57.9%**

Table 6: Emissions related to the built environment, by item (Pipeline Analysis)

Life cycle module	Source	Emissions (kt CO_2e)	Share of life cycle, excluding B8	Share of life cycle, including B8	Share of national total
A1-A3	New-build construction products	28,226	16.7%	9.3%	5.4%
A4	Transport of construction products	1,467	0.9%	0.5%	0.3%
A5	Construction waste	1,079	0.6%	0.4%	0.2%
A5	Construction energy	3,234	1.9%	1.1%	0.6%
A5	Commissioning energy	967	0.6%	0.3%	0.2%
A5	Land use change	3,178	1.9%	1.0%	0.6%
B1	Stationary air conditioning	4,761	2.8%	1.6%	0.9%
B1	Commercial refrigeration	3,787	2.2%	1.2%	0.7%
B2-B5	Construction products for renovation	17,754	10.5%	5.8%	3.4%
B6	Residential building fossil fuel use	10,714	6.3%	3.5%	2.0%
B6	Residential building electricity use	41,449	24.5%	13.6%	7.9%
B6	Non-residential building fossil fuel use	5,176	3.1%	1.7%	1.0%
B6	Non-residential building electricity use	37,143	22.0%	12.2%	7.1%
B6	Transport electricity use	2,692	1.6%	0.9%	0.5%
B6	Utilities electricity use	2,871	1.7%	0.9%	0.5%
B7	Wastewater treatment fugitive emissions	2,968	1.8%	1.0%	0.6%
B8	Road transport	76,948	0.0%	25.2%	14.6%
B8	Rail transport	4,069	0.0%	1.3%	0.8%
B8	Air transport (domestic)	4,389	0.0%	1.4%	0.8%
B8	Sea transport (domestic)	2,093	0.0%	0.7%	0.4%
B8	Other transportation	913	0.0%	0.3%	0.2%
B8	Industrial electricity use	49,524	0.0%	16.2%	9.4%
B8	Industrial thermal energy use	78,022	0.0%	25.6%	14.8%
B8	Industrial process emissions	21,587	0.0%	7.1%	4.1%
B8	Fugitive emissions from fuels	46,631	0.0%	15.3%	8.9%

Life cycle module	Source	Emissions (kt CO_2e)	Share of life cycle, excluding B8	Share of life cycle, including B8	Share of national total
B8	Emissions from CO_2 capture	2	0.0%	0.0%	0.0%
B8	Building product adjustment	-47,059	0.0%	-15.4%	-8.9%
B8	Construction emissions adjustment	-4,404	0.0%	-1.4%	-0.8%
B8	Other refrigerant emissions	2,857	0.0%	0.9%	0.5%
B8	Mining adjustment	-99,651	0.0%	-32.7%	-18.9%
C1	Demolition and deconstruction	203	0.1%	0.1%	0.0%
C2	Transport of demolition waste	313	0.2%	0.1%	0.1%
C3	Waste processing	104	0.1%	0.0%	0.0%
C4	Waste disposal	863	0.5%	0.3%	0.2%
Total		**304,871**	**100.0%**	**100.0%**	**57.9%**

Appendix B

Decarbonisation strategies

Table 7 presents a summary of the decarbonisation strategies applied in this report. The "Applies to" column describes the typecast(s) or material that the strategy focuses on. The "Roadblocks to uptake" column provides a summary of reasons why uptake within Australia is not already higher.

Only the strategies that were selected are included in Table 7. The remainder of this appendix discusses the strategies in more detail, including those that were considered but were not selected for the analysis.

Table 7: Summary of decarbonisation strategies

Name	Description	Applies to	Roadblocks to uptake
RAP replaces primary aggregate and bitumen in asphalt	Increased use of Reclaimed Asphalt Pavement (RAP) to replace primary asphalt in road pavements.	• Low Use Road • Low Use Road Rehabilitation Maintenance • Routine Road Maintenance • State Road (Highway/Freeway) • State Road (Highway/Freeway) Rehabilitation Maintenance	• Availability of RAP (not always available in regions; use of overlays rather than relays means RAP is not produced) • Availability of asphalt batching plants that can process high-RAP asphalt mixes • State limits on the use of RAP, particularly in the wearing course
Liquid antistrip agent replaces hydrated lime in asphalt	Hydrated lime is currently mandated in most state mixes at 1-1.5% of the total mix. It significantly increases the carbon footprint of the mix. Liquid adhesion (antistrip) additives can be used in small quantities to replace hydrated lime.	• State Road (Highway/Freeway) • State Road (Highway/Freeway) Rehabilitation Maintenance	• Prescriptive mix designs require the use of hydrated lime
RCC replaces gravel in pavement subbase	Recycled Crushed Concrete (RCC) is used to replace primary aggregates (gravel and sand) in the granular subbase of road pavements.	• Low Use Road • Low Use Road Rehabilitation Maintenance • Routine Road Maintenance • State Road (Highway/Freeway)	• RCC perceived to offer lower performance in some cases • RCC is not always available and must be sourced locally due to its weight

Name	Description	Applies to	Roadblocks to uptake
		• State Road (Highway/Freeway) Rehabilitation Maintenance	
RCC replaces gravel in concrete	Recycled Crushed Concrete (RCC) is used to replace primary aggregates (gravel and sand) in the production of new concrete.	• All typecasts using "Aggregate"	• Concerns from industry regarding its technical performance, with industry believing it should be restricted to temporary works, low-strength areas and drainage applications • RCC is not always available and must be sourced locally due to its weight
SCMs replace cement in concrete	Supplementary Cementitious Materials (SCMs) – such as fly as ground granulated blast furnace slag – are used to replace some of the Portland cement in concrete mixes.	• All typecasts using "Cement"	• Increased use of SCMs can affect curing time, making project more difficult to schedule and potentially lengthening overall project duration • Harder to use in precast as longer residence time in moulds needed before the concrete can be removed • Availability of SCMs varies regionally • Cost barrier in the current market (though SCMs are cheaper than Portland cement in many countries as they are often from waste streams)
EAF with 100% renewable electricity	Steel products (e.g., reinforcing bar) currently produced in Electric Arc Furnaces (EAFs) switch to using renewable electricity.	• All typecasts using "Steel re-inforcement" • All typecasts using "Steel - Transmission Cable"	• Small cost uplift • Australian EAFs have historic used grid average electricity, but plan to switch to 100% renewables in 2025
Lightweight reinforcing steel replaces conventional reinforcing steel	High strength reinforcing steel replaces conventional strength reinforcing steel, reducing the weight of the steel needed to achieve the same function.	• All typecasts using "Steel re-inforcement"	• Product not historically available and only launched in late 2023

Name	Description	Applies to	Roadblocks to uptake
Steel fibre reinforcing replaces steel mesh/bar reinforcing	Steel fibres are mixed through the concrete instead of using standard reinforcing steel bar and mesh, significantly reducing the amount of reinforcing steel needed.	• Data Centre • Warehouse	• Some construction firms are reluctant to move away from historic practice because warehouse floor slabs must be very smooth
Engineered structural steel replaces conventional structural steel (i.e., lightweighting).	Structural steel mass is reduced by design, using engineered beams and tapered beams rather than parallel I-beams. The steel is put where it is needed.	• All typecasts using "Steel - Structural Elements"	• Potential extension to project timeline • Requires bespoke design by a structural engineer rather than just working from parallel beams with well-known mechanical properties
Substitution of smelting electricity with 100% renewable electricity	Primary aluminium is produced using electrolysis powered by renewable electricity.	• All typecasts using "Aluminium"	• Highly unlikely in Australia before the late 2020s due to lock-in of smelters to old electricity supply agreements • Currently only available for imported aluminium billet
Biodiesel replaces fossil-derived diesel in construction and commissioning	Biodiesel is used instead of fossil-derived diesel during the construction process and asset commissioning.	• All	• Unreliable supply of biodiesel • High price of biodiesel compared to conventional diesel • Some trucks and machines will only warrant low blends of first-generation biodiesel, e.g. BD5
Renewable electricity replaces average grid electricity in construction and commissioning	Renewable electricity is used instead of grid average electricity during the construction process and asset commissioning.	• All	• Small price increase compared to conventional electricity

B-1 Asphalt pavements

B-1-1 Overview

Asphalt pavements typically consist of a granular subbase (i.e., aggregate), an asphalt base course and an asphalt wearing course. Australia also has many spray-sealed pavements where one or more layers of bitumen are sprayed onto the road surface followed by one or more layers of aggregate. Asphalt pavements are common in high traffic and (sub)urban areas, while spray-seal is common in lower traffic rural areas. This section considers strategies relevant to both types of pavements and to all parts of the pavement (i.e., the binder and the aggregates).

The carbon footprint of granular materials (construction aggregates) is largely determined by the energy required to move them, crush them and grade them. The primary energy sources are diesel and electricity. Electricity can be decarbonised by using renewable electricity. Diesel can be decarbonised by using biodiesel now or by alternative energy sources in the future. Primary (virgin) aggregates can also be replaced entirely by secondary (recycled) aggregates in many cases.

The carbon footprint of asphalt is determined by five components:

1. **Bitumen:** Bitumen binds together the aggregates to create asphalt. Despite making up only 4-6% of a typical asphalt mix, it is one of the largest contributors to asphalt's carbon footprint. Bitumen is produced from fractional distillation of crude oil. Historically, bitumen used in Australia was produced domestically (Neaylon, 2013). However, as Australian oil refineries have closed and/or become import-only terminals, bitumen is increasingly being imported from countries such as Singapore, Malaysia, Thailand and China. The only remaining domestic manufacturer is Viva Energy in Victoria (Viva Energy, 2023). Differences in carbon footprint between suppliers is relatively small as all oil refineries use the same core manufacturing process. While bio-based bitumen does exist, it is still in development and will not be available at scale by FY 2027. As such, the main way to reduce the use of bitumen is through recycling of existing pavement (i.e., increasing the use of RAP).
2. **Aggregates:** Aggregates (sand, gravel and reclaimed materials) make up the bulk of the mass of asphalt; however, their carbon footprint is less significant than bitumen as they have a very low carbon footprint per tonne. The carbon footprint of recycling aggregates is comparable to producing virgin aggregates. However, following the definition of the end-of-waste state in EN 15804+A2 (CEN, 2021), the carbon footprint of recycling aggregates is typically counted at the end-of-life of an asset (e.g., at demolition of a building or bridge) and therefore counted as having a carbon footprint of zero (or near zero) at the start of the next asset's life. As such, the primary strategy for reducing the carbon footprint of aggregates is to recycle them. While recycling more aggregates is unlikely to reduce GHG emissions at a national level (due to comparable emissions to virgin aggregates), it is nevertheless an important strategy to reduce the amount of virgin aggregate that must be extracted, contributing to a more circular economy.
3. **Additives:** Depending on the asphalt mix, different additives can be used to achieve certain properties. These additives often have a relatively high carbon footprint per tonne but are typically used in small quantities. An exception is hydrated lime which is typically specified in state road mixes and can contribute up to one-quarter of the carbon footprint of an asphalt mix, despite making up only 1.5% of the mass (Distin, 2023).
4. **Transport of raw materials to the plant:** This is a relatively small share of the total carbon footprint of asphalt. The carbon footprint primarily comes due to the transport of aggregates (shorter distance, but >90% of the composition) and bitumen (longer distance, but <10% of the composition). The primary strategy to decarbonise transport is electrification, but it is unlikely to be implemented to a significant extent by FY 2027. In the short-term, biodiesel can be used to replace fossil-derived diesel; however, supply is limited.
5. **Plant/manufacturing impacts:** Asphalt is typically produced using either a hot mix process (at temperatures between 150 and 190°C) or warm mix process (at temperatures of between 100 and 150°C). The carbon footprint of the thermal energy is significant. Electricity impacts for mixing can also be significant, but to a lesser extent than the thermal energy. The main

strategies to reduce the carbon footprint of manufacturing are to move towards a warm mix process and to change energy sources (e.g., using renewable electricity).

B-1-2 Strategies

The following decarbonisation strategies were considered for asphalt pavement:

- Reclaimed asphalt pavement (RAP) replaces primary aggregate and bitumen in asphalt
- Liquid antistrip agent replaces hydrated lime in asphalt
- Recycled crushed concrete (RCC) replaces gravel in pavement subbase
- RCC replaces gravel in pavement base course
- RCC replaces gravel in pavement wearing course
- Recycled crushed glass (RCG) replaces sand
- Crumb rubber replaces polymer in polymer-modified bitumen
- Renewable process heat for asphalt plants
- Renewable electricity for asphalt plants
- Electrification of transport

Each strategy was evaluated against the selection criteria - see Table 8.

Table 8: Review of decarbonisation strategies for asphalt against selection criteria

Strategy	Targets upfront carbon	Like-for-like replacement	Additionality	Already available	Potential for decarbonisation
RAP replaces primary aggregate and bitumen in asphalt	✓	✓	✓	✓	✓
Liquid antistrip agent replaces hydrated lime in asphalt	✓	✓	✓	✓	✓
RCC replaces gravel in pavement subbase	✓	✓	✓	✓	✓
RCC replaces gravel in pavement base course	✓	✓	✓	?	?
RCC replaces gravel in pavement wearing course	✓	✓	✓	?	?
RCG replaces sand	✓	✓	?	✓	✕
Crumb rubber replaces polymer in polymer-modified bitumen	✓	✓	✓	✓	?
Renewable process heat for asphalt plants	✓	✓	?	✕	✓
Renewable electricity for asphalt plants	✓	✓	?	✓	✓
Electrification of transport	✓	✓	?	✕	✓

Of the initial list of strategies, only three were taken forward into the detailed analysis:

- RAP replaces primary aggregate and bitumen in asphalt
- Liquid antistrip agent replaces hydrated lime in asphalt
- RCC replaces gravel in pavement subbase

The following strategies were not taken forward for the reasons below:

- **RCC replaces gravel in pavement base course** and
  RCC replaces gravel in pavement wearing course
  Feedback from the pavement industry suggested that the use of RCC – while possible – was perhaps best restricted to the granular subbase and drainage applications where the consequences of changes in material performance compared to virgin aggregates were less important. As such, these two strategies were eliminated.
- **RCG replaces sand**
  Feedback received from suppliers indicated recycled glass was increasingly being used for recycled glass products, with a diminishing percentage of RCG remaining available for inclusion in asphalt or aggregate. Most recycled material suppliers either did not stock RCG or received very small quantities and did not incorporate it into a recycled aggregate blend. From an LCA perspective, using RCG to displace primary container glass (a material with relatively high GHG emissions) is preferable to using it to displace primary sand (a material with relatively low GHG emissions).
- **Crumb rubber replaces polymer in polymer-modified bitumen**
  The use of crumb rubber to replace conventional polymers in polymer-modified bitumen was thought to be a promising strategy by several stakeholders. However, given that it affects a relatively small portion of the total upfront carbon footprint from infrastructure, this strategy was not explored further.
- **Renewable process heat for asphalt plants**
  This strategy was not considered practical by FY 2027 given that an alternative (e.g., biogas or green hydrogen) would first have to be tested and then rolled out to the >100 asphalt plants across Australia. It is a strategy that would likely have considerable benefits, but these benefits are unlikely to be realised within the time horizon for this study.
- **Renewable electricity for asphalt plants**
  This strategy can be applied immediately by any asphalt plant through the purchase of renewable electricity certificates such as Green Power. However, given that electricity makes up a relatively small percentage of the total carbon footprint of asphalt, it is unlikely that this strategy would be additional to the overall decarbonisation of the grid unless it was a specific focus on purchasing strategy.
- **Electrification of transport**
  It was not considered feasible to have any significant uptake of heavy electric trucks (often >40 tonne gross vehicle weight for aggregates) by FY 2027. Further, any electrification of the heavy truck fleet would likely not be additional and simply part of decarbonising the wider transport fleet.

B-1-3 Strategy effectiveness and uptake rates

A summary of the decarbonisation strategies considered for asphalt is presented below in Table 9. In this table:

- **Material affected** is the raw material category affected by the strategy (if applicable).
- **Labour affected** is the labour category affected by the strategy (if applicable).
- **Effective from** is the start date used for the strategy, ranging from FY 2023 (the first year for this report) to FY 2027 (the final year for this report).
- **Reduction of** describes what is being decarbonised. Namely, does the strategy work by reducing the emission factor per unit, or does it work by reducing the number of units required to achieve the same function)?

All strategies in Table 9 work by reducing the emission factor of the material. All strategies except replacing hydrated lime with a liquid anti-strip agent can be implemented immediately. The hydrated lime replacement strategy would require changes to specification and is only considered to be available anywhere in Australia from FY 2025, with uptake building to FY 2027.

Table 9: Summary of decarbonisation strategies considered for asphalt pavements

Strategy	Material affected	Labour affected	Effective from	Reduction of
RAP replaces asphalt in base course	Asphalt (Urban), Asphalt (Highway)	n/a	FY 2023	Material emission factor
RAP replaces asphalt in wearing course	Asphalt (Urban), Asphalt (Highway)	n/a	FY 2023	Material emission factor
Hydrated lime replaced in asphalt	Asphalt (Highway)	n/a	FY 2025	Material emission factor
RCC replaces aggregates in subbase	Aggregate	n/a	FY 2023	Material emission factor

The carbon footprint emission factor (EF) for each strategy and cost uplift (where a negative number represents a cost saving) are shown below in Table 10. Note that all costs are for material costs only and do not include other plant-, labour- or equipment-related costs.

The uptake rate in the base year (FY 2023) and maximum uptake by the end of the study period (FY 2027) in the Mid-level Decarbonisation Scenario and Maximum Decarbonisation Scenario are presented below in Table 11. The current and future uptake rates were determined through workshops with industry, supplemented with research by the authors. The "Effectiveness" column determines what proportion of the material in the asset is affected by the strategy, with 0% meaning that none of the material in the asset is affected and 100% meaning that all the material in the asset is affected.

This Maximum Decarbonisation scenario includes replacement of virgin asphalt by RAP in the base course at rates up to 40%. This is ambitious. The USA – a leader in the use of RAP – achieved a national average replacement of virgin asphalt by RAP of 21.9% in 2021 (NAPA, 2021). Achieving rates of 20-40% RAP replacement in the base course will only be achieved if there is both demand (from roading authorities) and supply (increased availability of RAP together with increased ability to process high levels of RAP in asphalt batching plants). One strategy to increase RAP supply when rehabilitating road pavements is a greater focus on milling and relaying the pavement, with fewer overlays. However, this strategy needs to be evaluated on a case-by-case basis to ensure that it doesn't just shift the carbon footprint to other parts of the pavement life cycle (e.g., increased fuel burn, either from construction machinery during laying or from vehicles driving over the road).

Table 10: Carbon footprint and cost of decarbonisation strategies for asphalt pavements at different levels of uptake

Strategy	Material affected	Labour affected	Uptake	EF (kg Unit CO_2e/unit)	Material cost uplift	Labour cost uplift	Energy cost uplift
RAP replaces asphalt in base course	Asphalt (Highway)	n/a	0%	73.4 t	0.0%	n/a	n/a
RAP replaces asphalt in base course	Asphalt (Highway)	n/a	10%	69.2 t	-3.3%	n/a	n/a
RAP replaces asphalt in base course	Asphalt (Highway)	n/a	20%	65.0 t	-6.7%	n/a	n/a
RAP replaces asphalt in base course	Asphalt (Highway)	n/a	30%	60.7 t	-10.0%	n/a	n/a
RAP replaces asphalt in base course	Asphalt (Highway)	n/a	40%	56.5 t	-13.3%	n/a	n/a
RAP replaces asphalt in base course	Asphalt (Highway)	n/a	50%	52.3 t	-16.7%	n/a	n/a
RAP replaces asphalt in base course	Asphalt (Highway)	n/a	60%	48.1 t	-16.7%	n/a	n/a
RAP replaces asphalt in base course	Asphalt (Highway)	n/a	70%	43.9 t	-16.7%	n/a	n/a
RAP replaces asphalt in base course	Asphalt (Highway)	n/a	80%	39.7 t	-16.7%	n/a	n/a
RAP replaces asphalt in base course	Asphalt (Highway)	n/a	90%	35.5 t	-16.7%	n/a	n/a
RAP replaces asphalt in base course	Asphalt (Highway)	n/a	100%	31.3 t	-16.7%	n/a	n/a
RAP replaces asphalt in base course	Asphalt (Urban)	n/a	0%	60.5 t	0.0%	n/a	n/a
RAP replaces asphalt in base course	Asphalt (Urban)	n/a	10%	57.5 t	-3.3%	n/a	n/a
RAP replaces asphalt in base course	Asphalt (Urban)	n/a	20%	54.6 t	-6.7%	n/a	n/a
RAP replaces asphalt in base course	Asphalt (Urban)	n/a	30%	51.7 t	-10.0%	n/a	n/a
RAP replaces asphalt in base course	Asphalt (Urban)	n/a	40%	48.8 t	-13.3%	n/a	n/a
RAP replaces asphalt in base course	Asphalt (Urban)	n/a	50%	45.9 t	-16.7%	n/a	n/a

Strategy	Material affected	Labour affected	Uptake	EF (kg Unit CO_2e/unit)	Material cost uplift	Labour cost uplift	Energy cost uplift
RAP replaces asphalt in base course	Asphalt (Urban)	n/a	60%	42.9 t	-16.7%	n/a	n/a
RAP replaces asphalt in base course	Asphalt (Urban)	n/a	70%	40.0 t	-16.7%	n/a	n/a
RAP replaces asphalt in base course	Asphalt (Urban)	n/a	80%	37.1 t	-16.7%	n/a	n/a
RAP replaces asphalt in base course	Asphalt (Urban)	n/a	90%	34.2 t	-16.7%	n/a	n/a
RAP replaces asphalt in base course	Asphalt (Urban)	n/a	100%	31.3 t	-16.7%	n/a	n/a
RAP replaces asphalt in wearing course	Asphalt (Highway)	n/a	0%	73.4 t	0.0%	n/a	n/a
RAP replaces asphalt in wearing course	Asphalt (Highway)	n/a	10%	69.2 t	-3.3%	n/a	n/a
RAP replaces asphalt in wearing course	Asphalt (Highway)	n/a	20%	65.0 t	-6.7%	n/a	n/a
RAP replaces asphalt in wearing course	Asphalt (Highway)	n/a	30%	60.7 t	-10.0%	n/a	n/a
RAP replaces asphalt in wearing course	Asphalt (Highway)	n/a	40%	56.5 t	-13.3%	n/a	n/a
RAP replaces asphalt in wearing course	Asphalt (Highway)	n/a	50%	52.3 t	-16.7%	n/a	n/a
RAP replaces asphalt in wearing course	Asphalt (Highway)	n/a	60%	48.1 t	-16.7%	n/a	n/a
RAP replaces asphalt in wearing course	Asphalt (Highway)	n/a	70%	43.9 t	-16.7%	n/a	n/a

Strategy	Material affected	Labour affected	Uptake	EF (kg CO_2e/unit)	Unit	Material cost uplift	Labour cost uplift	Energy cost uplift
RAP replaces asphalt in wearing course	Asphalt (Highway)	n/a	80%	39.7	t	-16.7%	n/a	n/a
RAP replaces asphalt in wearing course	Asphalt (Highway)	n/a	90%	35.5	t	-16.7%	n/a	n/a
RAP replaces asphalt in wearing course	Asphalt (Highway)	n/a	100%	31.3	t	-16.7%	n/a	n/a
RAP replaces asphalt in wearing course	Asphalt (Urban)	n/a	0%	60.5	t	0.0%	n/a	n/a
RAP replaces asphalt in wearing course	Asphalt (Urban)	n/a	10%	57.5	t	-3.3%	n/a	n/a
RAP replaces asphalt in wearing course	Asphalt (Urban)	n/a	20%	54.6	t	-6.7%	n/a	n/a
RAP replaces asphalt in wearing course	Asphalt (Urban)	n/a	30%	51.7	t	-10.0%	n/a	n/a
RAP replaces asphalt in wearing course	Asphalt (Urban)	n/a	40%	48.8	t	-13.3%	n/a	n/a
RAP replaces asphalt in wearing course	Asphalt (Urban)	n/a	50%	45.9	t	-16.7%	n/a	n/a
RAP replaces asphalt in wearing course	Asphalt (Urban)	n/a	60%	42.9	t	-16.7%	n/a	n/a
RAP replaces asphalt in wearing course	Asphalt (Urban)	n/a	70%	40.0	t	-16.7%	n/a	n/a

Strategy	Material affected	Labour affected	Uptake	EF (kg CO_2e/unit)	Unit	Material cost uplift	Labour cost uplift	Energy cost uplift
RAP replaces asphalt in wearing course	Asphalt (Urban)	n/a	80%	37.1	t	-16.7%	n/a	n/a
RAP replaces asphalt in wearing course	Asphalt (Urban)	n/a	90%	34.2	t	-16.7%	n/a	n/a
RAP replaces asphalt in wearing course	Asphalt (Urban)	n/a	100%	31.3	t	-16.7%	n/a	n/a
RCC replaces aggregates in subbase	Aggregate	n/a	0%	8.70	t	0.0%	n/a	n/a
RCC replaces aggregates in subbase	Aggregate	n/a	10%	7.83	t	-3.3%	n/a	n/a
RCC replaces aggregates in subbase	Aggregate	n/a	20%	6.96	t	-6.7%	n/a	n/a
RCC replaces aggregates in subbase	Aggregate	n/a	30%	6.09	t	-10.0%	n/a	n/a
RCC replaces aggregates in subbase	Aggregate	n/a	40%	5.22	t	-13.3%	n/a	n/a
RCC replaces aggregates in subbase	Aggregate	n/a	50%	4.35	t	-16.7%	n/a	n/a
RCC replaces aggregates in subbase	Aggregate	n/a	60%	3.48	t	-20.0%	n/a	n/a
RCC replaces aggregates in subbase	Aggregate	n/a	70%	2.61	t	-23.3%	n/a	n/a
RCC replaces aggregates in subbase	Aggregate	n/a	80%	1.74	t	-26.7%	n/a	n/a
RCC replaces aggregates in subbase	Aggregate	n/a	90%	0.87	t	-30.0%	n/a	n/a
RCC replaces aggregates in subbase	Aggregate	n/a	100%	0.00	t	-33.3%	n/a	n/a
Hydrated lime replaced in asphalt	Asphalt (Highway)	n/a	0%	73.4	t	0.0%	n/a	n/a
Hydrated lime replaced in asphalt	Asphalt (Highway)	n/a	10%	72.2	t	-0.1%	n/a	n/a

Strategy	Material affected	Labour affected	Uptake	EF (kg Unit CO_2e/unit)	Material cost uplift	Labour cost uplift	Energy cost uplift
Hydrated lime replaced in asphalt	Asphalt (Highway)	n/a	20%	71.0 t	-0.3%	n/a	n/a
Hydrated lime replaced in asphalt	Asphalt (Highway)	n/a	30%	69.9 t	-0.4%	n/a	n/a
Hydrated lime replaced in asphalt	Asphalt (Highway)	n/a	40%	68.7 t	-0.5%	n/a	n/a
Hydrated lime replaced in asphalt	Asphalt (Highway)	n/a	50%	67.5 t	-0.7%	n/a	n/a
Hydrated lime replaced in asphalt	Asphalt (Highway)	n/a	60%	66.3 t	-0.8%	n/a	n/a
Hydrated lime replaced in asphalt	Asphalt (Highway)	n/a	70%	65.2 t	-0.9%	n/a	n/a
Hydrated lime replaced in asphalt	Asphalt (Highway)	n/a	80%	64.0 t	-1.1%	n/a	n/a
Hydrated lime replaced in asphalt	Asphalt (Highway)	n/a	90%	62.8 t	-1.2%	n/a	n/a
Hydrated lime replaced in asphalt	Asphalt (Highway)	n/a	100%	61.6 t	-1.3%	n/a	n/a

Table 11: Uptake rate per strategy for asphalt pavements

Strategy	Material affected	Grouped asset class	State	Effectiveness	Uptake FY 2023	Uptake FY 2027 Mid	Uptake FY 2027 Max
RAP replaces asphalt in base course	Asphalt (Highway)	Transport, road, highway/freeway	ACT	100%	10%	40%	40%
RAP replaces asphalt in base course	Asphalt (Highway)	Transport, road, highway/freeway	NSW	100%	20%	40%	40%
RAP replaces asphalt in base course	Asphalt (Highway)	Transport, road, highway/freeway	NT	100%	5%	15%	40%
RAP replaces asphalt in base course	Asphalt (Highway)	Transport, road, highway/freeway	QLD	100%	10%	40%	40%
RAP replaces asphalt in base course	Asphalt (Highway)	Transport, road, highway/freeway	SA	100%	20%	40%	40%
RAP replaces asphalt in base course	Asphalt (Highway)	Transport, road, highway/freeway	TAS	100%	10%	40%	40%
RAP replaces asphalt in base course	Asphalt (Highway)	Transport, road, highway/freeway	VIC	100%	20%	40%	40%
RAP replaces asphalt in base course	Asphalt (Highway)	Transport, road, highway/freeway	WA	100%	5%	10%	40%
RAP replaces asphalt in base course	Asphalt (Urban)	Transport, road, minor, rural	ACT	100%	5%	20%	20%
RAP replaces asphalt in base course	Asphalt (Urban)	Transport, road, minor, rural	NSW	100%	10%	20%	20%
RAP replaces asphalt in base course	Asphalt (Urban)	Transport, road, minor, rural	NT	100%	0%	15%	20%
RAP replaces asphalt in base course	Asphalt (Urban)	Transport, road, minor, rural	QLD	100%	5%	20%	20%
RAP replaces asphalt in base course	Asphalt (Urban)	Transport, road, minor, rural	SA	100%	10%	20%	20%

Strategy	Material affected	Grouped asset class	State	Effectiveness	Uptake FY 2023	Uptake FY 2027 Mid	Uptake FY 2027 Max
RAP replaces asphalt in base course	Asphalt (Urban)	Transport, road, minor, rural	TAS	100%	5%	20%	20%
RAP replaces asphalt in base course	Asphalt (Urban)	Transport, road, minor, rural	VIC	100%	10%	20%	20%
RAP replaces asphalt in base course	Asphalt (Urban)	Transport, road, minor, rural	WA	100%	5%	10%	20%
RAP replaces asphalt in base course	Asphalt (Urban)	Transport, road, minor, urban	ACT	100%	10%	40%	40%
RAP replaces asphalt in base course	Asphalt (Urban)	Transport, road, minor, urban	NSW	100%	20%	40%	40%
RAP replaces asphalt in base course	Asphalt (Urban)	Transport, road, minor, urban	NT	100%	5%	15%	40%
RAP replaces asphalt in base course	Asphalt (Urban)	Transport, road, minor, urban	QLD	100%	10%	40%	40%
RAP replaces asphalt in base course	Asphalt (Urban)	Transport, road, minor, urban	SA	100%	20%	40%	40%
RAP replaces asphalt in base course	Asphalt (Urban)	Transport, road, minor, urban	TAS	100%	10%	40%	40%
RAP replaces asphalt in base course	Asphalt (Urban)	Transport, road, minor, urban	VIC	100%	20%	40%	40%
RAP replaces asphalt in base course	Asphalt (Urban)	Transport, road, minor, urban	WA	100%	5%	10%	40%
RAP replaces asphalt in wearing course	Asphalt (Highway)	Transport, road, highway/freeway	ACT	100%	5%	20%	25%
RAP replaces asphalt in wearing course	Asphalt (Highway)	Transport, road, highway/freeway	NSW	100%	10%	20%	25%

Strategy	Material affected	Grouped asset class	State	Effectiveness	Uptake FY 2023	Uptake FY 2027 Mid	Uptake FY 2027 Max
RAP replaces asphalt in wearing course	Asphalt (Highway)	Transport, road, highway/freeway	NT	100%	0%	10%	25%
RAP replaces asphalt in wearing course	Asphalt (Highway)	Transport, road, highway/freeway	QLD	100%	5%	20%	25%
RAP replaces asphalt in wearing course	Asphalt (Highway)	Transport, road, highway/freeway	SA	100%	5%	10%	25%
RAP replaces asphalt in wearing course	Asphalt (Highway)	Transport, road, highway/freeway	TAS	100%	5%	25%	25%
RAP replaces asphalt in wearing course	Asphalt (Highway)	Transport, road, highway/freeway	VIC	100%	10%	25%	25%
RAP replaces asphalt in wearing course	Asphalt (Highway)	Transport, road, highway/freeway	WA	100%	0%	0%	25%
RAP replaces asphalt in wearing course	Asphalt (Urban)	Transport, road, minor, rural	ACT	100%	5%	10%	15%
RAP replaces asphalt in wearing course	Asphalt (Urban)	Transport, road, minor, rural	NSW	100%	5%	10%	15%
RAP replaces asphalt in wearing course	Asphalt (Urban)	Transport, road, minor, rural	NT	100%	0%	5%	15%
RAP replaces asphalt in wearing course	Asphalt (Urban)	Transport, road, minor, rural	QLD	100%	0%	10%	15%
RAP replaces asphalt in wearing course	Asphalt (Urban)	Transport, road, minor, rural	SA	100%	5%	10%	15%
RAP replaces asphalt in wearing course	Asphalt (Urban)	Transport, road, minor, rural	TAS	100%	0%	10%	15%
RAP replaces asphalt in wearing course	Asphalt (Urban)	Transport, road, minor, rural	VIC	100%	5%	10%	15%

Strategy	Material affected	Grouped asset class	State	Effectiveness	Uptake FY 2023	Uptake FY 2027 Mid	Uptake FY 2027 Max
RAP replaces asphalt in wearing course	Asphalt (Urban)	Transport, road, minor, rural	WA	100%	0%	0%	15%
RAP replaces asphalt in wearing course	Asphalt (Urban)	Transport, road, minor, urban	ACT	100%	5%	20%	25%
RAP replaces asphalt in wearing course	Asphalt (Urban)	Transport, road, minor, urban	NSW	100%	10%	20%	25%
RAP replaces asphalt in wearing course	Asphalt (Urban)	Transport, road, minor, urban	NT	100%	0%	10%	25%
RAP replaces asphalt in wearing course	Asphalt (Urban)	Transport, road, minor, urban	QLD	100%	5%	20%	25%
RAP replaces asphalt in wearing course	Asphalt (Urban)	Transport, road, minor, urban	SA	100%	5%	10%	25%
RAP replaces asphalt in wearing course	Asphalt (Urban)	Transport, road, minor, urban	TAS	100%	5%	25%	25%
RAP replaces asphalt in wearing course	Asphalt (Urban)	Transport, road, minor, urban	VIC	100%	10%	25%	25%
RAP replaces asphalt in wearing course	Asphalt (Urban)	Transport, road, minor, urban	WA	100%	0%	0%	25%
RCC replaces aggregates in subbase	Aggregate	Transport, road, highway/freeway	ACT	100%	5%	20%	30%
RCC replaces aggregates in subbase	Aggregate	Transport, road, highway/freeway	NSW	100%	5%	20%	30%
RCC replaces aggregates in subbase	Aggregate	Transport, road, highway/freeway	NT	100%	0%	20%	30%
RCC replaces aggregates in subbase	Aggregate	Transport, road, highway/freeway	QLD	100%	5%	20%	30%

Strategy	Material affected	Grouped asset class	State	Effectiveness	Uptake FY 2023	Uptake FY 2027 Mid	Uptake FY 2027 Max
RCC replaces aggregates in subbase	Aggregate	Transport, road, highway/freeway	SA	100%	5%	20%	30%
RCC replaces aggregates in subbase	Aggregate	Transport, road, highway/freeway	TAS	100%	0%	20%	30%
RCC replaces aggregates in subbase	Aggregate	Transport, road, highway/freeway	VIC	100%	5%	20%	30%
RCC replaces aggregates in subbase	Aggregate	Transport, road, highway/freeway	WA	100%	0%	20%	30%
RCC replaces aggregates in subbase	Aggregate	Transport, road, minor, rural	ACT	100%	0%	5%	10%
RCC replaces aggregates in subbase	Aggregate	Transport, road, minor, rural	NSW	100%	0%	5%	10%
RCC replaces aggregates in subbase	Aggregate	Transport, road, minor, rural	NT	100%	0%	5%	10%
RCC replaces aggregates in subbase	Aggregate	Transport, road, minor, rural	QLD	100%	0%	5%	10%
RCC replaces aggregates in subbase	Aggregate	Transport, road, minor, rural	SA	100%	0%	5%	10%
RCC replaces aggregates in subbase	Aggregate	Transport, road, minor, rural	TAS	100%	0%	5%	10%
RCC replaces aggregates in subbase	Aggregate	Transport, road, minor, rural	VIC	100%	0%	5%	10%
RCC replaces aggregates in subbase	Aggregate	Transport, road, minor, rural	WA	100%	0%	5%	10%
RCC replaces aggregates in subbase	Aggregate	Transport, road, minor, urban	ACT	100%	5%	20%	30%

Strategy	Material affected	Grouped asset class	State	Effectiveness	Uptake FY 2023	Uptake FY 2027 Mid	Uptake FY 2027 Max
RCC replaces aggregates in subbase	Aggregate	Transport, road, minor, urban	NSW	100%	5%	20%	30%
RCC replaces aggregates in subbase	Aggregate	Transport, road, minor, urban	NT	100%	0%	20%	30%
RCC replaces aggregates in subbase	Aggregate	Transport, road, minor, urban	QLD	100%	5%	20%	30%
RCC replaces aggregates in subbase	Aggregate	Transport, road, minor, urban	SA	100%	5%	20%	30%
RCC replaces aggregates in subbase	Aggregate	Transport, road, minor, urban	TAS	100%	0%	20%	30%
RCC replaces aggregates in subbase	Aggregate	Transport, road, minor, urban	VIC	100%	5%	20%	30%
RCC replaces aggregates in subbase	Aggregate	Transport, road, minor, urban	WA	100%	0%	20%	30%
Hydrated lime replaced in asphalt	Asphalt (Highway)	Transport, road, highway/freeway	ACT	100%	0%	100%	100%
Hydrated lime replaced in asphalt	Asphalt (Highway)	Transport, road, highway/freeway	NSW	100%	0%	100%	100%
Hydrated lime replaced in asphalt	Asphalt (Highway)	Transport, road, highway/freeway	NT	100%	0%	100%	100%
Hydrated lime replaced in asphalt	Asphalt (Highway)	Transport, road, highway/freeway	QLD	100%	0%	100%	100%
Hydrated lime replaced in asphalt	Asphalt (Highway)	Transport, road, highway/freeway	SA	100%	0%	100%	100%
Hydrated lime replaced in asphalt	Asphalt (Highway)	Transport, road, highway/freeway	TAS	100%	0%	100%	100%

Strategy	Material affected	Grouped asset class	State	Effectiveness	Uptake FY 2023	Uptake FY 2027 Mid	Uptake FY 2027 Max
Hydrated lime replaced in asphalt	Asphalt (Highway)	Transport, road, highway/freeway	VIC	100%	0%	100%	100%
Hydrated lime replaced in asphalt	Asphalt (Highway)	Transport, road, highway/freeway	WA	100%	0%	100%	100%

B-2 Concrete

B-2-1 Overview

The carbon footprint of concrete is determined by five components:

1. **Cementitious materials:** Cementitious materials bind together the aggregates to create concrete. Despite cementitious materials making up only 10-15% of a typical concrete mix, virgin cement is one of the largest contributors to concrete's carbon footprint, contributing up to 90% of the total carbon footprint. Virgin cement is produced by grinding cement clinker – a nodular grey manufactured mineral – together with gypsum. The carbon footprint of cement comes primarily from the clinker. Clinker is produced by heating crushed limestone and other minerals to around 1,400-1,500°C in a kiln. Around one-third of the emissions from clinker production come from burning fuels for thermal energy, with the remaining two-thirds from process emissions, primarily from the chemical reaction $CaCO_3 \rightarrow CaO + CO_2$. The Australian cement industry has reduced the GHG emissions from cement manufacture by 25% over the last two decades (VDZ, 2021). While this process is expected to continue incrementally over time, it is unlikely that there will be any major step stages before FY 2027 that can be influenced through purchasing decisions. Instead, further use of supplementary cementitious materials (SCMS), such as fly ash and ground granulated blast furnace slag, are likely to offer the greatest potential for additional decarbonisation before FY 2027.
2. **Aggregates:** Aggregates (sand, gravel and reclaimed materials) make up the bulk of the mass of concrete; however, their carbon footprint is less significant than cement as they have a very low carbon footprint per tonne. Recycled aggregates are one potential strategy to reduce the carbon footprint of concrete.
3. **Admixtures:** Admixtures alter the properties of the concrete. These can have a relatively high carbon footprint per tonne but are typically used in small quantities (often 1% or less).
4. **Transport of raw materials to the plant:** This is a relatively small share of the total carbon footprint of concrete. The carbon footprint primarily comes due to the transport of aggregates (shorter distance, but around 80% of the composition) and cementitious materials (longer distance, but only around 15% of the composition). The primary strategy to decarbonise transport is electrification, but it is unlikely to be implemented to a significant extent by FY 2027. In the short-term, biodiesel can be used to replace fossil-derived diesel; however, supply is limited.
5. **Plant/manufacturing impacts:** Concrete can be batched either in a central mixing plant or by blending directly in agitator trucks. Central mixing plants are electric. Trucks are virtually all diesel at present, though they can transition to electric over time. Concrete batching is a small part of the carbon footprint of concrete.

B-2-2 Strategies

The following decarbonisation strategies were considered for concrete:

- SCMs replace cement in concrete
- RCC replaces gravel in concrete
- Electrification of transport.

Each strategy was evaluated against the selection criteria – see Table 12.

Table 12: Review of decarbonisation strategies for concrete against selection criteria

Strategy	Targets upfront carbon	Like-for-like replacement	Additionality	Already available	Potential for decarbonisation
SCMs replace cement in concrete	✓	✓	✓	✓	✓
RCC replaces gravel in concrete	✓	✓	✓	✓	✓
Electrification of transport	✓	✓	?	✕	✓

Of the initial list of strategies, two were taken forward into the detailed analysis:

- SCMs replace cement in concrete
- RCC replaces gravel in concrete.

Electrification of transport was not taken forward. It was not considered feasible to have any significant uptake of heavy electric trucks (often >40 tonne gross vehicle weight for aggregates) by FY 2027. Further, any electrification of the heavy truck fleet would likely not be additional and simply part of decarbonising the wider transport fleet. While it is much more plausible to electrify agitator trucks (concrete mixers) due to shorter transport distances, this was also considered implausible to any significant extent by FY 2027.

B-2-3 Strategy effectiveness and uptake rates

A summary of the decarbonisation strategies considered for concrete is presented below in Table 13. All strategies work by reducing the emission factor of the material. All strategies are already available (with varying levels of uptake) and can be further implemented immediately.

Table 13: Summary of decarbonisation strategies considered for concrete

Strategy	Material affected	Labour affected	Effective from	Reduction of
SCMs replace cement	Cement	n/a	FY 2023	Material emission factor
RCC replaces aggregates in concrete	Aggregate	n/a	FY 2023	Material emission factor

Table 14 shows the carbon footprint emission factor (EF) for each strategy along with its cost uplift. Note that a negative cost uplift represents a cost saving at the project level.

Table 15 presents uptake in the base year (FY 2023) and maximum uptake by the end of the study period (FY 2027) in both the Mid-level Decarbonisation Scenario and the Maximum Decarbonisation Scenario. The current and future uptake rates were determined through workshops with industry. Through these workshops, the “RCC replaces gravel in concrete” strategy received similar feedback to asphalt and has been limited to a low uptake rate, within its main use cases being in temporary works and low-strength areas.

Table 14: Carbon footprint and cost of decarbonisation strategies for concrete at different levels of uptake

Strategy	Material affected	Labour affected	Uptake	EF (kg CO_2e/unit)	Unit	Material cost uplift	Labour cost uplift	Energy cost uplift
SCMs replace cement	Cement	n/a	0%	831	t	0.0%	n/a	n/a
SCMs replace cement	Cement	n/a	10%	749	t	4.0%	n/a	n/a
SCMs replace cement	Cement	n/a	20%	668	t	8.0%	n/a	n/a
SCMs replace cement	Cement	n/a	30%	586	t	12.0%	n/a	n/a
SCMs replace cement	Cement	n/a	40%	520	t	16.0%	n/a	n/a
SCMs replace cement	Cement	n/a	50%	454	t	20.0%	n/a	n/a
SCMs replace cement	Cement	n/a	60%	388	t	24.0%	n/a	n/a
SCMs replace cement	Cement	n/a	70%	322	t	28.0%	n/a	n/a
SCMs replace cement	Cement	n/a	80%	256	t	32.0%	n/a	n/a
SCMs replace cement	Cement	n/a	90%	190	t	36.0%	n/a	n/a
SCMs replace cement	Cement	n/a	100%	124	t	40.0%	n/a	n/a
RCC replaces aggregates in concrete	Aggregate	n/a	0%	8.70	t	0.0%	n/a	n/a
RCC replaces aggregates in concrete	Aggregate	n/a	10%	7.83	t	-3.3%	n/a	n/a
RCC replaces aggregates in concrete	Aggregate	n/a	20%	6.96	t	-6.7%	n/a	n/a
RCC replaces aggregates in concrete	Aggregate	n/a	30%	6.09	t	-10.0%	n/a	n/a
RCC replaces aggregates in concrete	Aggregate	n/a	40%	5.22	t	-13.3%	n/a	n/a
RCC replaces aggregates in concrete	Aggregate	n/a	50%	4.35	t	-16.7%	n/a	n/a

Strategy	Material affected	Labour affected	Uptake	EF (kg CO_2e/unit)	Unit	Material cost uplift	Labour cost uplift	Energy cost uplift
RCC replaces aggregates in concrete	Aggregate	n/a	60%	3.48	t	-20.0%	n/a	n/a
RCC replaces aggregates in concrete	Aggregate	n/a	70%	2.61	t	-23.3%	n/a	n/a
RCC replaces aggregates in concrete	Aggregate	n/a	80%	1.74	t	-26.7%	n/a	n/a
RCC replaces aggregates in concrete	Aggregate	n/a	90%	0.87	t	-30.0%	n/a	n/a
RCC replaces aggregates in concrete	Aggregate	n/a	100%	0.00	t	-33.3%	n/a	n/a

Table 15: Uptake rate per strategy for concrete

Strategy	Material affected	Grouped asset class	State	Effectiveness	Uptake FY 2023	Uptake FY 2027 Mid	Uptake FY 2027 Max
SCMs replace cement	Cement	Building, high-rise, non-residential	ACT	100%	25%	40%	50%
SCMs replace cement	Cement	Building, high-rise, non-residential	NSW	100%	25%	40%	50%
SCMs replace cement	Cement	Building, high-rise, non-residential	NT	100%	5%	40%	50%
SCMs replace cement	Cement	Building, high-rise, non-residential	QLD	100%	35%	40%	50%
SCMs replace cement	Cement	Building, high-rise, non-residential	SA	100%	20%	40%	50%
SCMs replace cement	Cement	Building, high-rise, non-residential	TAS	100%	10%	40%	50%
SCMs replace cement	Cement	Building, high-rise, non-residential	VIC	100%	20%	40%	50%
SCMs replace cement	Cement	Building, high-rise, non-residential	WA	100%	20%	40%	50%
SCMs replace cement	Cement	Building, high-rise, residential	ACT	100%	15%	40%	50%
SCMs replace cement	Cement	Building, high-rise, residential	NSW	100%	15%	40%	50%
SCMs replace cement	Cement	Building, high-rise, residential	NT	100%	5%	40%	50%
SCMs replace cement	Cement	Building, high-rise, residential	QLD	100%	15%	40%	50%
SCMs replace cement	Cement	Building, high-rise, residential	SA	100%	15%	40%	50%
SCMs replace cement	Cement	Building, high-rise, residential	TAS	100%	5%	40%	50%
SCMs replace cement	Cement	Building, high-rise, residential	VIC	100%	10%	40%	50%
SCMs replace cement	Cement	Building, high-rise, residential	WA	100%	15%	40%	50%
SCMs replace cement	Cement	Building, low-rise, civic/commercial	ACT	100%	15%	40%	50%
SCMs replace cement	Cement	Building, low-rise, civic/commercial	NSW	100%	15%	40%	50%
SCMs replace cement	Cement	Building, low-rise, civic/commercial	NT	100%	5%	40%	50%
SCMs replace cement	Cement	Building, low-rise, civic/commercial	QLD	100%	15%	40%	50%
SCMs replace cement	Cement	Building, low-rise, civic/commercial	SA	100%	15%	40%	50%

Strategy	Material affected	Grouped asset class	State	Effectiveness	Uptake FY 2023	Uptake FY 2027 Mid	Uptake FY 2027 Max
SCMs replace cement	Cement	Building, low-rise, civic/commercial	TAS	100%	5%	40%	50%
SCMs replace cement	Cement	Building, low-rise, civic/commercial	VIC	100%	15%	40%	50%
SCMs replace cement	Cement	Building, low-rise, civic/commercial	WA	100%	15%	40%	50%
SCMs replace cement	Cement	Building, low-rise, residential, attached	ACT	100%	10%	40%	50%
SCMs replace cement	Cement	Building, low-rise, residential, attached	NSW	100%	10%	40%	50%
SCMs replace cement	Cement	Building, low-rise, residential, attached	NT	100%	5%	40%	50%
SCMs replace cement	Cement	Building, low-rise, residential, attached	QLD	100%	10%	40%	50%
SCMs replace cement	Cement	Building, low-rise, residential, attached	SA	100%	10%	40%	50%
SCMs replace cement	Cement	Building, low-rise, residential, attached	TAS	100%	5%	40%	50%
SCMs replace cement	Cement	Building, low-rise, residential, attached	VIC	100%	10%	40%	50%
SCMs replace cement	Cement	Building, low-rise, residential, attached	WA	100%	10%	40%	50%
SCMs replace cement	Cement	Building, low-rise, residential, detached	ACT	100%	10%	40%	50%
SCMs replace cement	Cement	Building, low-rise, residential, detached	NSW	100%	10%	40%	50%
SCMs replace cement	Cement	Building, low-rise, residential, detached	NT	100%	5%	40%	50%

Strategy	Material affected	Grouped asset class	State	Effectiveness	Uptake FY 2023	Uptake FY 2027 Mid	Uptake FY 2027 Max
SCMs replace cement	Cement	Building, low-rise, residential, detached	QLD	100%	10%	40%	50%
SCMs replace cement	Cement	Building, low-rise, residential, detached	SA	100%	10%	40%	50%
SCMs replace cement	Cement	Building, low-rise, residential, detached	TAS	100%	5%	40%	50%
SCMs replace cement	Cement	Building, low-rise, residential, detached	VIC	100%	10%	40%	50%
SCMs replace cement	Cement	Building, low-rise, residential, detached	WA	100%	10%	40%	50%
SCMs replace cement	Cement	Building, low-rise, warehouse-type	ACT	100%	15%	40%	50%
SCMs replace cement	Cement	Building, low-rise, warehouse-type	NSW	100%	15%	40%	50%
SCMs replace cement	Cement	Building, low-rise, warehouse-type	NT	100%	5%	40%	50%
SCMs replace cement	Cement	Building, low-rise, warehouse-type	QLD	100%	15%	40%	50%
SCMs replace cement	Cement	Building, low-rise, warehouse-type	SA	100%	15%	40%	50%
SCMs replace cement	Cement	Building, low-rise, warehouse-type	TAS	100%	5%	40%	50%
SCMs replace cement	Cement	Building, low-rise, warehouse-type	VIC	100%	15%	40%	50%
SCMs replace cement	Cement	Building, low-rise, warehouse-type	WA	100%	15%	40%	50%
SCMs replace cement	Cement	Data transmission	ACT	100%	10%	40%	50%
SCMs replace cement	Cement	Data transmission	NSW	100%	15%	40%	50%
SCMs replace cement	Cement	Data transmission	NT	100%	10%	40%	50%
SCMs replace cement	Cement	Data transmission	QLD	100%	20%	40%	50%
SCMs replace cement	Cement	Data transmission	SA	100%	15%	40%	50%

Strategy	Material affected	Grouped asset class	State	Effectiveness	Uptake FY 2023	Uptake FY 2027 Mid	Uptake FY 2027 Max
SCMs replace cement	Cement	Data transmission	TAS	100%	10%	40%	50%
SCMs replace cement	Cement	Data transmission	VIC	100%	15%	40%	50%
SCMs replace cement	Cement	Data transmission	WA	100%	10%	40%	50%
SCMs replace cement	Cement	Electricity generation, fossil	ACT	100%	10%	40%	50%
SCMs replace cement	Cement	Electricity generation, fossil	NSW	100%	10%	40%	50%
SCMs replace cement	Cement	Electricity generation, fossil	NT	100%	5%	40%	50%
SCMs replace cement	Cement	Electricity generation, fossil	QLD	100%	10%	40%	50%
SCMs replace cement	Cement	Electricity generation, fossil	SA	100%	10%	40%	50%
SCMs replace cement	Cement	Electricity generation, fossil	TAS	100%	5%	40%	50%
SCMs replace cement	Cement	Electricity generation, fossil	VIC	100%	10%	40%	50%
SCMs replace cement	Cement	Electricity generation, fossil	WA	100%	5%	40%	50%
SCMs replace cement	Cement	Electricity generation, renewable	ACT	100%	10%	40%	50%
SCMs replace cement	Cement	Electricity generation, renewable	NSW	100%	10%	40%	50%
SCMs replace cement	Cement	Electricity generation, renewable	NT	100%	5%	40%	50%
SCMs replace cement	Cement	Electricity generation, renewable	QLD	100%	10%	40%	50%
SCMs replace cement	Cement	Electricity generation, renewable	SA	100%	10%	40%	50%
SCMs replace cement	Cement	Electricity generation, renewable	TAS	100%	5%	40%	50%
SCMs replace cement	Cement	Electricity generation, renewable	VIC	100%	10%	40%	50%
SCMs replace cement	Cement	Electricity generation, renewable	WA	100%	5%	40%	50%
SCMs replace cement	Cement	Electricity transmission	ACT	100%	10%	40%	50%
SCMs replace cement	Cement	Electricity transmission	NSW	100%	10%	40%	50%

Strategy	Material affected	Grouped asset class	State	Effectiveness	Uptake FY 2023	Uptake FY 2027 Mid	Uptake FY 2027 Max
SCMs replace cement	Cement	Electricity transmission	NT	100%	5%	40%	50%
SCMs replace cement	Cement	Electricity transmission	QLD	100%	10%	40%	50%
SCMs replace cement	Cement	Electricity transmission	SA	100%	10%	40%	50%
SCMs replace cement	Cement	Electricity transmission	TAS	100%	5%	40%	50%
SCMs replace cement	Cement	Electricity transmission	VIC	100%	10%	40%	50%
SCMs replace cement	Cement	Electricity transmission	WA	100%	5%	40%	50%
SCMs replace cement	Cement	Gas transmission	ACT	100%	10%	40%	50%
SCMs replace cement	Cement	Gas transmission	NSW	100%	10%	40%	50%
SCMs replace cement	Cement	Gas transmission	NT	100%	5%	40%	50%
SCMs replace cement	Cement	Gas transmission	QLD	100%	10%	40%	50%
SCMs replace cement	Cement	Gas transmission	SA	100%	10%	40%	50%
SCMs replace cement	Cement	Gas transmission	TAS	100%	5%	40%	50%
SCMs replace cement	Cement	Gas transmission	VIC	100%	10%	40%	50%
SCMs replace cement	Cement	Gas transmission	WA	100%	5%	40%	50%
SCMs replace cement	Cement	Transport, bridge	ACT	100%	15%	40%	50%
SCMs replace cement	Cement	Transport, bridge	NSW	100%	20%	40%	50%
SCMs replace cement	Cement	Transport, bridge	NT	100%	5%	40%	50%
SCMs replace cement	Cement	Transport, bridge	QLD	100%	15%	40%	50%
SCMs replace cement	Cement	Transport, bridge	SA	100%	10%	40%	50%
SCMs replace cement	Cement	Transport, bridge	TAS	100%	5%	40%	50%
SCMs replace cement	Cement	Transport, bridge	VIC	100%	20%	40%	50%

Strategy	Material affected	Grouped asset class	State	Effectiveness	Uptake FY 2023	Uptake FY 2027 Mid	Uptake FY 2027 Max
SCMs replace cement	Cement	Transport, bridge	WA	100%	5%	40%	50%
SCMs replace cement	Cement	Transport, rail	ACT	100%	15%	40%	50%
SCMs replace cement	Cement	Transport, rail	NSW	100%	15%	40%	50%
SCMs replace cement	Cement	Transport, rail	NT	100%	5%	40%	50%
SCMs replace cement	Cement	Transport, rail	QLD	100%	15%	40%	50%
SCMs replace cement	Cement	Transport, rail	SA	100%	5%	40%	50%
SCMs replace cement	Cement	Transport, rail	TAS	100%	5%	40%	50%
SCMs replace cement	Cement	Transport, rail	VIC	100%	20%	40%	50%
SCMs replace cement	Cement	Transport, rail	WA	100%	5%	40%	50%
SCMs replace cement	Cement	Transport, road, highway/freeway	ACT	100%	15%	40%	50%
SCMs replace cement	Cement	Transport, road, highway/freeway	NSW	100%	20%	40%	50%
SCMs replace cement	Cement	Transport, road, highway/freeway	NT	100%	5%	40%	50%
SCMs replace cement	Cement	Transport, road, highway/freeway	QLD	100%	20%	40%	50%
SCMs replace cement	Cement	Transport, road, highway/freeway	SA	100%	15%	40%	50%
SCMs replace cement	Cement	Transport, road, highway/freeway	TAS	100%	10%	40%	50%
SCMs replace cement	Cement	Transport, road, highway/freeway	VIC	100%	10%	40%	50%
SCMs replace cement	Cement	Transport, road, highway/freeway	WA	100%	15%	40%	50%
SCMs replace cement	Cement	Transport, road, minor, rural	ACT	100%	10%	40%	50%
SCMs replace cement	Cement	Transport, road, minor, rural	NSW	100%	10%	40%	50%
SCMs replace cement	Cement	Transport, road, minor, rural	NT	100%	0%	40%	50%
SCMs replace cement	Cement	Transport, road, minor, rural	QLD	100%	10%	40%	50%

Strategy	Material affected	Grouped asset class	State	Effectiveness	Uptake FY 2023	Uptake FY 2027 Mid	Uptake FY 2027 Max
SCMs replace cement	Cement	Transport, road, minor, rural	SA	100%	10%	40%	50%
SCMs replace cement	Cement	Transport, road, minor, rural	TAS	100%	0%	40%	50%
SCMs replace cement	Cement	Transport, road, minor, rural	VIC	100%	10%	40%	50%
SCMs replace cement	Cement	Transport, road, minor, rural	WA	100%	10%	40%	50%
SCMs replace cement	Cement	Transport, road, minor, urban	ACT	100%	15%	40%	50%
SCMs replace cement	Cement	Transport, road, minor, urban	NSW	100%	20%	40%	50%
SCMs replace cement	Cement	Transport, road, minor, urban	NT	100%	5%	40%	50%
SCMs replace cement	Cement	Transport, road, minor, urban	QLD	100%	20%	40%	50%
SCMs replace cement	Cement	Transport, road, minor, urban	SA	100%	15%	40%	50%
SCMs replace cement	Cement	Transport, road, minor, urban	TAS	100%	10%	40%	50%
SCMs replace cement	Cement	Transport, road, minor, urban	VIC	100%	10%	40%	50%
SCMs replace cement	Cement	Transport, road, minor, urban	WA	100%	15%	40%	50%
SCMs replace cement	Cement	Transport, tunnel	ACT	100%	15%	40%	50%
SCMs replace cement	Cement	Transport, tunnel	NSW	100%	25%	40%	50%
SCMs replace cement	Cement	Transport, tunnel	NT	100%	5%	40%	50%
SCMs replace cement	Cement	Transport, tunnel	QLD	100%	15%	40%	50%
SCMs replace cement	Cement	Transport, tunnel	SA	100%	10%	40%	50%
SCMs replace cement	Cement	Transport, tunnel	TAS	100%	5%	40%	50%
SCMs replace cement	Cement	Transport, tunnel	VIC	100%	20%	40%	50%
SCMs replace cement	Cement	Transport, tunnel	WA	100%	5%	40%	50%
SCMs replace cement	Cement	Water transmission	ACT	100%	10%	40%	50%

Strategy	Material affected	Grouped asset class	State	Effectiveness	Uptake FY 2023	Uptake FY 2027 Mid	Uptake FY 2027 Max
SCMs replace cement	Cement	Water transmission	NSW	100%	15%	40%	50%
SCMs replace cement	Cement	Water transmission	NT	100%	10%	40%	50%
SCMs replace cement	Cement	Water transmission	QLD	100%	20%	40%	50%
SCMs replace cement	Cement	Water transmission	SA	100%	15%	40%	50%
SCMs replace cement	Cement	Water transmission	TAS	100%	10%	40%	50%
SCMs replace cement	Cement	Water transmission	VIC	100%	15%	40%	50%
SCMs replace cement	Cement	Water transmission	WA	100%	10%	40%	50%
SCMs replace cement	Cement	Water treatment	ACT	100%	10%	40%	50%
SCMs replace cement	Cement	Water treatment	NSW	100%	15%	40%	50%
SCMs replace cement	Cement	Water treatment	NT	100%	10%	40%	50%
SCMs replace cement	Cement	Water treatment	QLD	100%	20%	40%	50%
SCMs replace cement	Cement	Water treatment	SA	100%	15%	40%	50%
SCMs replace cement	Cement	Water treatment	TAS	100%	10%	40%	50%
SCMs replace cement	Cement	Water treatment	VIC	100%	15%	40%	50%
SCMs replace cement	Cement	Water treatment	WA	100%	10%	40%	50%
RCC replaces aggregates in concrete	Aggregate	All	ACT	100%	0%	5%	10%
RCC replaces aggregates in concrete	Aggregate	All	NSW	100%	0%	5%	10%
RCC replaces aggregates in concrete	Aggregate	All	NT	100%	0%	5%	10%
RCC replaces aggregates in concrete	Aggregate	All	QLD	100%	0%	5%	10%

Strategy	Material affected	Grouped asset class	State	Effectiveness	Uptake FY 2023	Uptake FY 2027 Mid	Uptake FY 2027 Max
RCC replaces aggregates in concrete	Aggregate	All	SA	100%	0%	5%	10%
RCC replaces aggregates in concrete	Aggregate	All	TAS	100%	0%	5%	10%
RCC replaces aggregates in concrete	Aggregate	All	VIC	100%	0%	5%	10%
RCC replaces aggregates in concrete	Aggregate	All	WA	100%	0%	5%	10%

B-3 Steel

B-3-1 Overview

Crude steel is typically manufactured using one of two main manufacturing routes:

- Virgin steel (primary steel) is manufactured primarily from virgin iron. The most common manufacturing route is the BF-BOF route where a Blast Furnace (BF) converts iron ore to pig iron and then a Basic Oxygen Furnace (BOF) converts pig iron to steel. Virgin iron/steel makes up the bulk of the product, though some scrap is always used. The GHG emissions from virgin steel primarily come from the metallurgical coal needed for ironmaking. Coal is used to chemically reduce iron ore to metallic iron (i.e., a direct process emission), while coal gases are combusted to produce most of the energy needed by the manufacturing process. Australia has two primary steel manufacturing plants: Port Kembla (BlueScope Steel) and Whyalla (Liberty).
- Recycled steel (secondary steel) is manufactured primarily from steel scrap. The most common manufacturing route is an Electric Arc Furnace (EAF). While steel scrap is the main raw material, other alloying elements – including virgin iron – may be used to achieve the desired alloy composition. As such, recycled steel does not always contain 100% recycled content. The emissions of recycled steel are primarily due to electricity use by the EAF and the upstream emissions of the alloying elements. Australia has two EAFs, both operated by InfraBuild: Laverton, Melbourne and Rooty Hill, Sydney.

Final steel products require further manufacturing, such as rolling, bending and welding. Many steel products are metal-coated (typically in zinc, zinc-aluminium or zinc-aluminium-magnesium). Cladding products are typically metal coated and painted. Structural steel often requires intumescent paint or galvanising.

B-3-2 Strategies

The decarbonisation strategies available for steel depend on the manufacturing route:

- Virgin steel is difficult to decarbonise ("hard to abate"). A blast furnace is optimised to use coal. The main alternative is to use a different process to produce iron from iron ore, known as Direct Reduced Iron (DRI). The fuel supply for DRI is much more flexible than a blast furnace and can be coal, natural gas or hydrogen. Coal- and gas-fired DRI is a mature technology with approximately 5% market share globally (MPP, 2022), though DRI is not currently used in Australia. DRI using natural gas reduces the carbon footprint of crude steel by approximately 40% (MPP, 2022). It is possible to produce steel with nearly zero direct GHG emissions by replacing natural gas with green hydrogen, and by pairing the DRI (iron) plant with an EAF running on renewable electricity to produce steel. In 2020, Liberty announced plans to transition its Whyalla steelworks from BF-BOS to DRI-EAF in the future (GFG, 2020). Liberty expects to have the EAF operational by 2025 and the DRI operational before 2030 (GFG, 2023). However, without strong carbon pricing, DRI-EAF steel from renewable energy sources may cost up to 40% more than conventional BF-BOS steel – a significant green premium (MPP, 2022). Globally, the DRI-EAF route is currently considered to start becoming available from the 2030s and may become the dominant primary steelmaking technology by 2050 (MPP, 2022).
- Recycled steel is much easier to decarbonise than primary steel. The primary source of emissions from recycled steel is electricity. Electricity can be decarbonised by purchasing renewable electricity using guarantee of origin certificates. Imported recycled steel produced from 100% renewable electricity is already available on the Australian market. Domestically, InfraBuild has committed to purchasing 100% renewable electricity by approximately 2025.

A strategy that applies to both virgin steel and recycled steel is lightweighting. Lightweighting can be achieved in two main ways:

1. Increase the strength of the steel, meaning that less steel is needed to deliver a specific amount of performance.
2. Put the steel only in places where strength is needed, rather than having sections of uniform size and structural members placed in a uniform pattern.

InfraBuild released a new lightweight reinforcing steel product in late 2023 (InfraBuild, 2023b). Lightweighting strategies for structural steel were already available in 2023. Replacement of reinforcing steel by steel fibres was already widely used – particularly in warehouses – in 2023.

The following decarbonisation strategies were considered for steel:

- DRI-EAF replaces BF-BOS to produce primary steel
- Increasing recycled content in steel
- EAF with 100% renewable electricity
- Lightweight reinforcing steel replaces conventional reinforcing steel
- Steel fibre reinforcing replaces steel mesh/bar reinforcing
- Engineered structural steel replaces conventional structural steel (i.e., lightweighting).

Each strategy was evaluated against the selection criteria - see Table 16.

Table 16: Review of decarbonisation strategies for concrete against selection criteria

Strategy	Targets upfront carbon	Like-for-like replacement	Additionality	Already available	Potential for decarbonisation
DRI-EAF replaces BF-BOS to produce primary steel	✓	✓	✓	✕	✓
Increasing recycled content in steel	✓	✓	✕	✓	?
EAF with 100% renewable electricity	✓	✓	✓	✓	✓
Lightweight reinforcing steel replaces conventional reinforcing steel	✓	✓	✓	✓	✓
Steel fibre reinforcing replaces steel mesh/bar reinforcing	✓	✓	✓	✓	✓
Engineered structural steel replaces conventional structural steel (i.e., lightweighting)	✓	✓	✓	✓	✓

Of the initial list of strategies, four were taken into detailed analysis:

- EAF with 100% renewable electricity
- Lightweight reinforcing steel replaces conventional reinforcing steel
- Steel fibre reinforcing replaces steel mesh/bar reinforcing
- Engineered structural steel replaces conventional structural steel (i.e., lightweighting).

Two strategies were eliminated based on the review in Table 16:

- **DRI-EAF replaces BF-BOS to produce primary steel**
  While gas-fired DRI will likely already be available on the Australian market before FY 2027 – whether through domestic production, imports, or both – it is unclear to what extent. This

strategy has extremely strong decarbonisation potential; however, most sources believe that it will only be widely available from the 2030s onward, e.g., (MPP, 2022).

- **Increasing recycled content in steel**
  After conversations with steel producers, it became clear that defining the recycled content of steel was not realistic by FY 2027. The four steelworks in Australia all make different steel products, with little or no overlap between them. Domestic structural steel is made by the two blast furnaces (Port Kembla and Whyalla). Domestic reinforcing steel and smaller structural steel members are manufactured by InfraBuild, incorporating high quantities of scrap steel using an EAF (with some supplementary production from Whyalla). This means that the product required for the job dictates the price, the percentage of recycled content and whether it is produced with an EAF or BF-BOS. Reinforcing steel already has high recycled content. While it is possible to specify high recycled content for structural steel in imported products, doing so will likely mean that other projects nearer to the exporting steelworks will miss out. As the world's population and economy continue to grow, there is simply not enough steel scrap available worldwide to manufacture all products from scrap and this trend is likely to continue for at least several decades. This strategy therefore fails the additionality test at the global level (which is the level that matters for climate change).

B-3-3 Strategy effectiveness and uptake rates

A summary of the decarbonisation strategies considered for steel is presented below in Table 17. Three of the strategies work by reducing the amount of steel required to deliver the same function, while one strategy (EAF with 100% renewable electricity) reduces the emission factor per tonne of the material. While there was a small amount of recycled steel from 100% renewable electricity in FY 2023, it is currently a niche product and it is likely that it will only be available at scale within the Australian market when InfraBuild transitions to 100% renewable electricity in the 2025 calendar year (FY 2026).

Table 17: Summary of decarbonisation strategies considered for steel

Strategy	Material affected	Labour affected	Effective from	Reduction of
EAF with 100% renewable electricity	Steel Re-inforcement Steel - Transmission Cable	n/a	FY 2026	Material emission factor
Lightweight reinforcing steel replaces conventional reinforcing steel	Steel Re-inforcement	n/a	FY 2024	Material quantity
Steel fibre reinforcing replaces steel mesh/bar reinforcing	Steel Re-inforcement	n/a	FY 2023	Material quantity
Engineered structural steel replaces conventional structural steel (i.e., lightweighting)	Steel - Structural Elements	n/a	FY 2023	Material quantity

Table 14 shows the carbon footprint emission factor (EF) for each strategy along with its cost uplift. Note that a negative cost uplift represents a cost saving at the project level.

Table 15 presents uptake in the base year (FY 2023) and maximum uptake by the end of the study period (FY 2027) in both the Mid-level Decarbonisation Scenario and the Maximum Decarbonisation Scenario. The current and future uptake rates were determined through workshops with industry. The FY 2023 uptake of 30% for steel fibre reinforcing replacing conventional reinforcing steel is an estimate as no data was available.

Table 18: Carbon footprint and cost of decarbonisation strategies for steel at different levels of uptake

Strategy	Material affected	Labour affected	Uptake	EF (kg Unit CO_2e/unit)	Material cost uplift	Labour cost uplift	Energy cost uplift
Steel EAF 100% renewable electricity	Steel - Transmission Cable	n/a	0%	1,580 t	0.0%	n/a	n/a
Steel EAF 100% renewable electricity	Steel - Transmission Cable	n/a	10%	1,471 t	0.2%	n/a	n/a
Steel EAF 100% renewable electricity	Steel - Transmission Cable	n/a	20%	1,362 t	0.4%	n/a	n/a
Steel EAF 100% renewable electricity	Steel - Transmission Cable	n/a	30%	1,253 t	0.5%	n/a	n/a
Steel EAF 100% renewable electricity	Steel - Transmission Cable	n/a	40%	1,144 t	0.7%	n/a	n/a
Steel EAF 100% renewable electricity	Steel - Transmission Cable	n/a	50%	1,035 t	0.9%	n/a	n/a
Steel EAF 100% renewable electricity	Steel - Transmission Cable	n/a	60%	926 t	1.1%	n/a	n/a
Steel EAF 100% renewable electricity	Steel - Transmission Cable	n/a	70%	817 t	1.2%	n/a	n/a
Steel EAF 100% renewable electricity	Steel - Transmission Cable	n/a	80%	708 t	1.4%	n/a	n/a
Steel EAF 100% renewable electricity	Steel - Transmission Cable	n/a	90%	599 t	1.6%	n/a	n/a
Steel EAF 100% renewable electricity	Steel - Transmission Cable	n/a	100%	490 t	1.8%	n/a	n/a

Strategy	Material affected	Labour affected	Uptake	EF (kg Unit CO_2e/unit)	Material cost uplift	Labour cost uplift	Energy cost uplift
Reinforcing steel lightweighting	Steel Re-inforcement	n/a	0%	1,580 t	0.0%	n/a	n/a
Reinforcing steel lightweighting	Steel Re-inforcement	n/a	10%	1,454 t	0.0%	n/a	n/a
Reinforcing steel lightweighting	Steel Re-inforcement	n/a	20%	1,327 t	0.0%	n/a	n/a
Reinforcing steel lightweighting	Steel Re-inforcement	n/a	30%	1,201 t	0.0%	n/a	n/a
Reinforcing steel lightweighting	Steel Re-inforcement	n/a	40%	1,074 t	0.0%	n/a	n/a
Reinforcing steel lightweighting	Steel Re-inforcement	n/a	50%	948 t	0.0%	n/a	n/a
Reinforcing steel lightweighting	Steel Re-inforcement	n/a	60%	822 t	0.0%	n/a	n/a
Reinforcing steel lightweighting	Steel Re-inforcement	n/a	70%	695 t	0.0%	n/a	n/a
Reinforcing steel lightweighting	Steel Re-inforcement	n/a	80%	569 t	0.0%	n/a	n/a
Reinforcing steel lightweighting	Steel Re-inforcement	n/a	90%	442 t	0.0%	n/a	n/a
Reinforcing steel lightweighting	Steel Re-inforcement	n/a	100%	316 t	0.0%	n/a	n/a

Strategy	Material affected	Labour affected	Uptake	EF (kg Unit CO_2e/unit)	Material cost uplift	Labour cost uplift	Energy cost uplift
Fibre reinforcing replaces mesh/bar	Steel Re-inforcement	n/a	0%	1,580 t	0.0%	n/a	n/a
Fibre reinforcing replaces mesh/bar	Steel Re-inforcement	n/a	10%	1,454 t	2.0%	n/a	n/a
Fibre reinforcing replaces mesh/bar	Steel Re-inforcement	n/a	20%	1,327 t	4.0%	n/a	n/a
Fibre reinforcing replaces mesh/bar	Steel Re-inforcement	n/a	30%	1,201 t	6.0%	n/a	n/a
Fibre reinforcing replaces mesh/bar	Steel Re-inforcement	n/a	40%	1,074 t	8.0%	n/a	n/a
Fibre reinforcing replaces mesh/bar	Steel Re-inforcement	n/a	50%	948 t	10.0%	n/a	n/a
Fibre reinforcing replaces mesh/bar	Steel Re-inforcement	n/a	60%	822 t	12.0%	n/a	n/a
Fibre reinforcing replaces mesh/bar	Steel Re-inforcement	n/a	70%	695 t	14.0%	n/a	n/a
Fibre reinforcing replaces mesh/bar	Steel Re-inforcement	n/a	80%	569 t	16.0%	n/a	n/a
Fibre reinforcing replaces mesh/bar	Steel Re-inforcement	n/a	90%	442 t	18.0%	n/a	n/a
Fibre reinforcing replaces mesh/bar	Steel Re-inforcement	n/a	100%	316 t	20.0%	n/a	n/a

Strategy	Material affected	Labour affected	Uptake	EF (kg Unit CO_2e/unit)	Material cost uplift	Labour cost uplift	Energy cost uplift
Structural steel lightweighting	Steel - Structural Elements	Structural Engineer	0%	3,090 t	0.0%	0.0%	n/a
Structural steel lightweighting	Steel - Structural Elements	Structural Engineer	10%	2,997 t	-1.0%	3.0%	n/a
Structural steel lightweighting	Steel - Structural Elements	Structural Engineer	20%	2,905 t	-2.0%	6.0%	n/a
Structural steel lightweighting	Steel - Structural Elements	Structural Engineer	30%	2,812 t	-3.0%	9.0%	n/a
Structural steel lightweighting	Steel - Structural Elements	Structural Engineer	40%	2,719 t	-4.0%	12.0%	n/a
Structural steel lightweighting	Steel - Structural Elements	Structural Engineer	50%	2,627 t	-5.0%	15.0%	n/a
Structural steel lightweighting	Steel - Structural Elements	Structural Engineer	60%	2,534 t	-6.0%	18.0%	n/a
Structural steel lightweighting	Steel - Structural Elements	Structural Engineer	70%	2,441 t	-7.0%	21.0%	n/a
Structural steel lightweighting	Steel - Structural Elements	Structural Engineer	80%	2,348 t	-8.0%	24.0%	n/a
Structural steel lightweighting	Steel - Structural Elements	Structural Engineer	90%	2,256 t	-9.0%	27.0%	n/a
Structural steel lightweighting	Steel - Structural Elements	Structural Engineer	100%	2,163 t	-10.0%	30.0%	n/a

Table 19: Uptake rate per strategy for steel

Strategy	Material affected	Reduction of	Grouped asset class	State	Effectiveness	Uptake FY 2023	Uptake FY 2027 Mid	Uptake FY 2027 Max
Steel EAF 100% renewable electricity	Steel - Transmission Cable	Material emission factor	All	ACT	100%	0%	50%	100%
Steel EAF 100% renewable electricity	Steel - Transmission Cable	Material emission factor	All	NSW	100%	0%	50%	100%
Steel EAF 100% renewable electricity	Steel - Transmission Cable	Material emission factor	All	NT	100%	0%	50%	100%
Steel EAF 100% renewable electricity	Steel - Transmission Cable	Material emission factor	All	QLD	100%	0%	50%	100%
Steel EAF 100% renewable electricity	Steel - Transmission Cable	Material emission factor	All	SA	100%	0%	50%	100%
Steel EAF 100% renewable electricity	Steel - Transmission Cable	Material emission factor	All	TAS	100%	0%	50%	100%
Steel EAF 100% renewable electricity	Steel - Transmission Cable	Material emission factor	All	VIC	100%	0%	50%	100%
Steel EAF 100% renewable electricity	Steel - Transmission Cable	Material emission factor	All	WA	100%	0%	50%	100%
Steel EAF 100% renewable electricity	Steel Re-inforcement	Material emission factor	All	ACT	100%	0%	50%	100%
Steel EAF 100% renewable electricity	Steel Re-inforcement	Material emission factor	All	NSW	100%	0%	50%	100%
Steel EAF 100% renewable electricity	Steel Re-inforcement	Material emission factor	All	NT	100%	0%	50%	100%
Steel EAF 100% renewable electricity	Steel Re-inforcement	Material emission factor	All	QLD	100%	0%	50%	100%

Strategy	Material affected	Reduction of	Grouped asset class	State	Effectiveness	Uptake FY 2023	Uptake FY 2027 Mid	Uptake FY 2027 Max
Steel EAF 100% renewable electricity	Steel Re-inforcement	Material emission factor	All	SA	100%	0%	50%	100%
Steel EAF 100% renewable electricity	Steel Re-inforcement	Material emission factor	All	TAS	100%	0%	50%	100%
Steel EAF 100% renewable electricity	Steel Re-inforcement	Material emission factor	All	VIC	100%	0%	50%	100%
Steel EAF 100% renewable electricity	Steel Re-inforcement	Material emission factor	All	WA	100%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Building, high-rise, non-residential	ACT	50%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Building, high-rise, non-residential	NSW	50%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Building, high-rise, non-residential	NT	50%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Building, high-rise, non-residential	QLD	50%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Building, high-rise, non-residential	SA	50%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Building, high-rise, non-residential	TAS	50%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Building, high-rise, non-residential	VIC	50%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Building, high-rise, non-residential	WA	50%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Building, high-rise, residential	ACT	50%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Building, high-rise, residential	NSW	50%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Building, high-rise, residential	NT	50%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Building, high-rise, residential	QLD	50%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Building, high-rise, residential	SA	50%	0%	50%	100%

Strategy	Material affected	Reduction of	Grouped asset class	State	Effectiveness	Uptake FY 2023	Uptake FY 2027 Mid	Uptake FY 2027 Max
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Building, high-rise, residential	TAS	50%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Building, high-rise, residential	VIC	50%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Building, high-rise, residential	WA	50%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Building, low-rise, civic/commercial	ACT	33%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Building, low-rise, civic/commercial	NSW	33%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Building, low-rise, civic/commercial	NT	33%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Building, low-rise, civic/commercial	QLD	33%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Building, low-rise, civic/commercial	SA	33%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Building, low-rise, civic/commercial	TAS	33%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Building, low-rise, civic/commercial	VIC	33%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Building, low-rise, civic/commercial	WA	33%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Building, low-rise, residential, attached	ACT	33%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Building, low-rise, residential, attached	NSW	33%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Building, low-rise, residential, attached	NT	33%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Building, low-rise, residential, attached	QLD	33%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Building, low-rise, residential, attached	SA	33%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Building, low-rise, residential, attached	TAS	33%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Building, low-rise, residential, attached	VIC	33%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Building, low-rise, residential, attached	WA	33%	0%	50%	100%

Strategy	Material affected	Reduction of	Grouped asset class	State	Effectiveness	Uptake FY 2023	Uptake FY 2027 Mid	Uptake FY 2027 Max
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Building, low-rise, residential, detached	ACT	25%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Building, low-rise, residential, detached	NSW	25%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Building, low-rise, residential, detached	NT	25%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Building, low-rise, residential, detached	QLD	25%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Building, low-rise, residential, detached	SA	25%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Building, low-rise, residential, detached	TAS	25%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Building, low-rise, residential, detached	VIC	25%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Building, low-rise, residential, detached	WA	25%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Building, low-rise, warehouse-type	ACT	25%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Building, low-rise, warehouse-type	NSW	25%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Building, low-rise, warehouse-type	NT	25%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Building, low-rise, warehouse-type	QLD	25%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Building, low-rise, warehouse-type	SA	25%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Building, low-rise, warehouse-type	TAS	25%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Building, low-rise, warehouse-type	VIC	25%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Building, low-rise, warehouse-type	WA	25%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Electricity generation, fossil	ACT	50%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Electricity generation, fossil	NSW	50%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Electricity generation, fossil	NT	50%	0%	50%	100%

Strategy	Material affected	Reduction of	Grouped asset class	State	Effectiveness	Uptake FY 2023	Uptake FY 2027 Mid	Uptake FY 2027 Max
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Electricity generation, fossil	QLD	50%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Electricity generation, fossil	SA	50%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Electricity generation, fossil	TAS	50%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Electricity generation, fossil	VIC	50%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Electricity generation, fossil	WA	50%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Electricity generation, renewable	ACT	50%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Electricity generation, renewable	NSW	50%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Electricity generation, renewable	NT	50%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Electricity generation, renewable	QLD	50%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Electricity generation, renewable	SA	50%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Electricity generation, renewable	TAS	50%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Electricity generation, renewable	VIC	50%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Electricity generation, renewable	WA	50%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Electricity transmission	ACT	50%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Electricity transmission	NSW	50%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Electricity transmission	NT	50%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Electricity transmission	QLD	50%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Electricity transmission	SA	50%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Electricity transmission	TAS	50%	0%	50%	100%

Strategy	Material affected	Reduction of	Grouped asset class	State	Effectiveness	Uptake FY 2023	Uptake FY 2027 Mid	Uptake FY 2027 Max
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Electricity transmission	VIC	50%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Electricity transmission	WA	50%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Transport, bridge	ACT	20%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Transport, bridge	NSW	20%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Transport, bridge	NT	20%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Transport, bridge	QLD	20%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Transport, bridge	SA	20%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Transport, bridge	TAS	20%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Transport, bridge	VIC	20%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Transport, bridge	WA	20%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Transport, tunnel	ACT	50%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Transport, tunnel	NSW	50%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Transport, tunnel	NT	50%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Transport, tunnel	QLD	50%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Transport, tunnel	SA	50%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Transport, tunnel	TAS	50%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Transport, tunnel	VIC	50%	0%	50%	100%
Reinforcing steel lightweighting	Steel Re-inforcement	Material quantity	Transport, tunnel	WA	50%	0%	50%	100%
Fibre reinforcing replaces mesh/bar	Steel Re-inforcement	Material quantity	Building, low-rise, warehouse-type	ACT	75%	30%	60%	100%

Strategy	Material affected	Reduction of	Grouped asset class	State	Effectiveness	Uptake FY 2023	Uptake FY 2027 Mid	Uptake FY 2027 Max
Fibre reinforcing replaces mesh/bar	Steel Re-inforcement	Material quantity	Building, low-rise, warehouse-type	NSW	75%	30%	60%	100%
Fibre reinforcing replaces mesh/bar	Steel Re-inforcement	Material quantity	Building, low-rise, warehouse-type	NT	75%	30%	60%	100%
Fibre reinforcing replaces mesh/bar	Steel Re-inforcement	Material quantity	Building, low-rise, warehouse-type	QLD	75%	30%	60%	100%
Fibre reinforcing replaces mesh/bar	Steel Re-inforcement	Material quantity	Building, low-rise, warehouse-type	SA	75%	30%	60%	100%
Fibre reinforcing replaces mesh/bar	Steel Re-inforcement	Material quantity	Building, low-rise, warehouse-type	TAS	75%	30%	60%	100%
Fibre reinforcing replaces mesh/bar	Steel Re-inforcement	Material quantity	Building, low-rise, warehouse-type	VIC	75%	30%	60%	100%
Fibre reinforcing replaces mesh/bar	Steel Re-inforcement	Material quantity	Building, low-rise, warehouse-type	WA	75%	30%	60%	100%
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Building, high-rise, non-residential	ACT	50%	0%	50%	100%
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Building, high-rise, non-residential	NSW	50%	0%	50%	100%
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Building, high-rise, non-residential	NT	50%	0%	50%	100%
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Building, high-rise, non-residential	QLD	50%	0%	50%	100%
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Building, high-rise, non-residential	SA	50%	0%	50%	100%
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Building, high-rise, non-residential	TAS	50%	0%	50%	100%
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Building, high-rise, non-residential	VIC	50%	0%	50%	100%
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Building, high-rise, non-residential	WA	50%	0%	50%	100%
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Building, high-rise, residential	ACT	50%	0%	50%	100%
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Building, high-rise, residential	NSW	50%	0%	50%	100%
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Building, high-rise, residential	NT	50%	0%	50%	100%
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Building, high-rise, residential	QLD	50%	0%	50%	100%

Strategy	Material affected	Reduction of	Grouped asset class	State	Effectiveness	Uptake FY 2023	Uptake FY 2027 Mid	Uptake FY 2027 Max
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Building, high-rise, residential	SA	50%	0%	50%	100%
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Building, high-rise, residential	TAS	50%	0%	50%	100%
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Building, high-rise, residential	VIC	50%	0%	50%	100%
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Building, high-rise, residential	WA	50%	0%	50%	100%
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Building, low-rise, civic/commercial	ACT	33%	0%	50%	100%
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Building, low-rise, civic/commercial	NSW	33%	0%	50%	100%
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Building, low-rise, civic/commercial	NT	33%	0%	50%	100%
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Building, low-rise, civic/commercial	QLD	33%	0%	50%	100%
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Building, low-rise, civic/commercial	SA	33%	0%	50%	100%
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Building, low-rise, civic/commercial	TAS	33%	0%	50%	100%
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Building, low-rise, civic/commercial	VIC	33%	0%	50%	100%
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Building, low-rise, civic/commercial	WA	33%	0%	50%	100%
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Building, low-rise, residential, attached	ACT	33%	0%	50%	100%
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Building, low-rise, residential, attached	NSW	33%	0%	50%	100%
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Building, low-rise, residential, attached	NT	33%	0%	50%	100%
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Building, low-rise, residential, attached	QLD	33%	0%	50%	100%
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Building, low-rise, residential, attached	SA	33%	0%	50%	100%
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Building, low-rise, residential, attached	TAS	33%	0%	50%	100%
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Building, low-rise, residential, attached	VIC	33%	0%	50%	100%

Strategy	Material affected	Reduction of	Grouped asset class	State	Effectiveness	Uptake FY 2023	Uptake FY 2027 Mid	Uptake FY 2027 Max
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Building, low-rise, residential, attached	WA	33%	0%	50%	100%
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Building, low-rise, residential, detached	ACT	25%	0%	50%	100%
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Building, low-rise, residential, detached	NSW	25%	0%	50%	100%
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Building, low-rise, residential, detached	NT	25%	0%	50%	100%
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Building, low-rise, residential, detached	QLD	25%	0%	50%	100%
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Building, low-rise, residential, detached	SA	25%	0%	50%	100%
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Building, low-rise, residential, detached	TAS	25%	0%	50%	100%
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Building, low-rise, residential, detached	VIC	25%	0%	50%	100%
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Building, low-rise, residential, detached	WA	25%	0%	50%	100%
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Building, low-rise, warehouse-type	ACT	50%	0%	50%	100%
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Building, low-rise, warehouse-type	NSW	50%	0%	50%	100%
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Building, low-rise, warehouse-type	NT	50%	0%	50%	100%
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Building, low-rise, warehouse-type	QLD	50%	0%	50%	100%
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Building, low-rise, warehouse-type	SA	50%	0%	50%	100%
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Building, low-rise, warehouse-type	TAS	50%	0%	50%	100%
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Building, low-rise, warehouse-type	VIC	50%	0%	50%	100%
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Building, low-rise, warehouse-type	WA	50%	0%	50%	100%
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Electricity generation, fossil	ACT	50%	0%	50%	100%
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Electricity generation, fossil	NSW	50%	0%	50%	100%

Strategy	Material affected	Reduction of	Grouped asset class	State	Effectiveness	Uptake FY 2023	Uptake FY 2027 Mid	Uptake FY 2027 Max
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Electricity generation, fossil	NT	50%	0%	50%	100%
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Electricity generation, fossil	QLD	50%	0%	50%	100%
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Electricity generation, fossil	SA	50%	0%	50%	100%
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Electricity generation, fossil	TAS	50%	0%	50%	100%
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Electricity generation, fossil	VIC	50%	0%	50%	100%
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Electricity generation, fossil	WA	50%	0%	50%	100%
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Electricity generation, renewable	ACT	50%	0%	50%	100%
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Electricity generation, renewable	NSW	50%	0%	50%	100%
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Electricity generation, renewable	NT	50%	0%	50%	100%
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Electricity generation, renewable	QLD	50%	0%	50%	100%
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Electricity generation, renewable	SA	50%	0%	50%	100%
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Electricity generation, renewable	TAS	50%	0%	50%	100%
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Electricity generation, renewable	VIC	50%	0%	50%	100%
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Electricity generation, renewable	WA	50%	0%	50%	100%
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Electricity transmission	ACT	50%	0%	50%	100%
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Electricity transmission	NSW	50%	0%	50%	100%
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Electricity transmission	NT	50%	0%	50%	100%
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Electricity transmission	QLD	50%	0%	50%	100%
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Electricity transmission	SA	50%	0%	50%	100%

Strategy	Material affected	Reduction of	Grouped asset class	State	Effectiveness	Uptake FY 2023	Uptake FY 2027 Mid	Uptake FY 2027 Max
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Electricity transmission	TAS	50%	0%	50%	100%
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Electricity transmission	VIC	50%	0%	50%	100%
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Electricity transmission	WA	50%	0%	50%	100%
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Transport, bridge	ACT	50%	0%	50%	100%
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Transport, bridge	NSW	50%	0%	50%	100%
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Transport, bridge	NT	50%	0%	50%	100%
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Transport, bridge	QLD	50%	0%	50%	100%
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Transport, bridge	SA	50%	0%	50%	100%
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Transport, bridge	TAS	50%	0%	50%	100%
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Transport, bridge	VIC	50%	0%	50%	100%
Structural steel lightweighting	Steel - Structural Elements	Material quantity	Transport, bridge	WA	50%	0%	50%	100%

B-4 Aluminium

B-4-1 Overview

The primary uses of aluminium in the built environment are:

- Framing for windows and doors in buildings.
- Framing and opaque panels for curtain wall and façade systems in buildings.
- Lightweight structural framing, particularly for roof-mounted solar photovoltaic installations.
- Balustrades and other ancillary uses.

The aluminium in these applications is extruded and typically anodised or powder coated. The crude aluminium used may be either from a virgin source, a recycled source or any blend of the two. Most aluminium used in Australia's built environment in FY 2023 was from virgin sources.

The carbon footprint of extruded virgin aluminium is determined by four main processing steps (listed below by their order in the supply chain, not by environmental relevance):

1. **Bauxite mining:** Bauxite is the primary mineral used to produce primary aluminium. Bauxite mining makes up a very small share of the carbon footprint of aluminium (IAI, 2022).
2. **Alumina production:** Bauxite is first processed into alumina. Alumina production is environmentally relevant, but to a much lesser extent than electrolysis (IAI, 2022).
3. **Electrolysis of aluminium metal:** Electrolysis is used to convert alumina into aluminium metal. Electrolysis contributes the largest share of the carbon footprint of primary aluminium (IAI, 2022). This contribution comes from several sources: direct electricity use, consumption of carbon electrodes (releasing CO_2 to air) and production of perfluorocarbons (PFCs). Electricity is typically the single-largest contributor to the carbon footprint of primary aluminium; however, its contribution depends on the type of electricity. Typically, an aluminium smelter is co-located with a large electricity generator that can supply a continuous base load. The type of electricity (coal, natural gas, hydro power or a grid average) is what determines the carbon footprint of crude aluminium, with hydro-powered aluminium having a carbon footprint of approximately 5 kg CO_2e/kg and coal-fired aluminium having a carbon footprint over 20 kg CO_2e/kg (IAI, 2022).
4. **Extrusion, powder coating and/or anodising:** The raw aluminium billet must first be heated and extruded into a profile (e.g., a window frame). The aluminium will then be protected using either a powder-coated (paint) finish or an anodised finish.

Unlike other materials in this report, the built environment is not the predominant user of aluminium. Other industries (e.g. aircraft, automotive, boats, beverage cans and aluminium foil packaging) are more significant end users, both in Australia and globally. This lessens the significance of the built environment as a driver for change in the aluminium industry.

Australia is a major producer of bauxite and alumina globally. Australia has four aluminium smelters: Bell Bay (Tas), Boyne Island (QLD), Portland (Vic) and Tomago (NSW). Only two of these smelters produce billet (Boyne and Tomago) meaning that the aluminium from Bell Bay and Portland are not used for aluminium framing in the construction sector. (They are used in zinc-aluminium coatings for steel roofing and cladding products.) There are no large-scale aluminium recycling plants in Australia, meaning that recycled aluminium billet must be imported, typically from China.

B-4-2 Strategies

The following decarbonisation strategies were considered for aluminium:

- Substitution of smelting electricity with 100% renewable electricity. In this strategy, aluminium is either imported from a smelter supplied using hydro power (e.g., from Canada or New Zealand) or renewable electricity is purchased from the regional electricity grid using guarantee of origin certificates.

- Carbon-free smelting. In this strategy, the carbon electrodes are replaced with a different process. Carbon-free smelting eliminates all direct GHG emissions from aluminium smelting.

Each strategy was evaluated against the selection criteria – see Table 20.

Table 20: Review of decarbonisation strategies for concrete against selection criteria

Strategy	Targets upfront carbon	Like-for-like replacement	Additionality	Already available	Potential for decarbonisation
Substitution of smelting electricity with 100% renewable electricity	✓	✓	✓	✓	✓
Carbon-free smelting	✓	✓	✓	×	✓

Carbon-free smelting was not taken to detailed analysis. While this technology is expected to be available in the global market by FY 2027, it will not be widely available. Feedback from the aluminium industry is that it will go into computers, smartphones and other consumer products first, followed perhaps by cars and aircraft. As it will likely take several years to convert each smelter, it is unlikely the technology will be available for building products in Australia until well into the 2030s.

Substitution of smelting electricity with 100% renewable electricity was the only strategy considered. These products are already available on the Australian market in FY 2023; however, the aluminium billet must be imported into Australia. Australia's only smelter powered predominantly by hydro power (Bell Bay, Tasmania) does not produce billet. It is important to recognise that the adoption of this strategy in the short-term would disadvantage Australian smelters until their electricity contracts roll over and they can negotiate a higher share of renewable electricity using guarantee of origin certificates. Tomago's electricity contract comes up for renewal in 2028 and Boyne's in 2029, both of which are beyond the timescale for this project.

B-4-3 Strategy effectiveness and uptake rates

The only decarbonisation strategy considered for aluminium is presented below in Table 21. This strategy works by reducing the emission factor of the material.

Table 21: Summary of decarbonisation strategies considered for aluminium

Strategy	Material affected	Labour affected	Effective from	Reduction of
Substitution of smelting electricity with 100% renewable electricity	Aluminium	n/a	FY 2023	Material emission factor

Table 22 shows the carbon footprint emission factor (EF) for this strategy along with its cost uplift. The EF of aluminium billet was calculated as a weighted average of the EF for average domestic production from the Australian Aluminium Council (AAC, 2023) and the EF for world average aluminium production from the International Aluminium Institute (IAI, 2022). A 50% market share for domestic billet (and 50% imported billet) was assumed as no better information was available. Imports are thought to make up more than 50% of the non-residential market, but likely much less of the residential market due to turnaround times and minimum order quantities (Harrington, 2021). An EF for extrusion, powder coating and anodising was then added based on (AEC, 2022).

Table 23 presents uptake in the base year (FY 2023) and maximum uptake by the end of the study period (FY 2027) in both the Mid-level Decarbonisation Scenario and the Maximum Decarbonisation Scenario. The current and future uptake rates were determined through workshops with industry.

Table 22: Carbon footprint and cost of decarbonisation strategies for aluminium at different levels of uptake

Strategy	Material affected	Labour affected	Uptake	EF (kg CO_2e/unit)	Unit	Material cost uplift	Labour cost uplift	Energy cost uplift
Aluminium 100% renewable electricity	Aluminium	n/a	0%	17,245	t	0.0%	n/a	n/a
Aluminium 100% renewable electricity	Aluminium	n/a	10%	16,275	t	0.7%	n/a	n/a
Aluminium 100% renewable electricity	Aluminium	n/a	20%	15,304	t	1.3%	n/a	n/a
Aluminium 100% renewable electricity	Aluminium	n/a	30%	14,334	t	2.0%	n/a	n/a
Aluminium 100% renewable electricity	Aluminium	n/a	40%	13,363	t	2.6%	n/a	n/a
Aluminium 100% renewable electricity	Aluminium	n/a	50%	12,393	t	3.3%	n/a	n/a
Aluminium 100% renewable electricity	Aluminium	n/a	60%	11,422	t	3.9%	n/a	n/a
Aluminium 100% renewable electricity	Aluminium	n/a	70%	10,452	t	4.6%	n/a	n/a
Aluminium 100% renewable electricity	Aluminium	n/a	80%	9,481	t	5.3%	n/a	n/a
Aluminium 100% renewable electricity	Aluminium	n/a	90%	8,511	t	5.9%	n/a	n/a
Aluminium 100% renewable electricity	Aluminium	n/a	100%	7,540	t	6.6%	n/a	n/a

Table 23: Uptake rate per strategy for aluminium

Strategy	Material affected	Reduction of	Grouped asset class	State	Effectiveness	Uptake FY 2023	Uptake FY 2027 Mid	Uptake FY 2027 Max
Aluminium 100% renewable electricity	Aluminium	Material emission factor	All	ACT	100%	0%	25%	50%
Aluminium 100% renewable electricity	Aluminium	Material emission factor	All	NSW	100%	0%	25%	50%
Aluminium 100% renewable electricity	Aluminium	Material emission factor	All	NT	100%	0%	25%	50%
Aluminium 100% renewable electricity	Aluminium	Material emission factor	All	QLD	100%	0%	25%	50%
Aluminium 100% renewable electricity	Aluminium	Material emission factor	All	SA	100%	0%	25%	50%
Aluminium 100% renewable electricity	Aluminium	Material emission factor	All	TAS	100%	0%	25%	50%
Aluminium 100% renewable electricity	Aluminium	Material emission factor	All	VIC	100%	0%	25%	50%
Aluminium 100% renewable electricity	Aluminium	Material emission factor	All	WA	100%	0%	25%	50%

B-5 Transportation

B-5-1 Overview

The carbon footprint of transportation is due to the energy source used. This is diesel at present.

B-5-2 Strategies

The following decarbonisation strategies were considered for transportation:

- Electrification of transport.
- Biodiesel replaces fossil-derived diesel in transport.

Each strategy was evaluated against the selection criteria – see Table 24.

Table 24: Review of decarbonisation strategies for transportation against selection criteria

Strategy	Targets upfront carbon	Like-for-like replacement	Additionality	Already available	Potential for decarbonisation
Electrification of transport	✓	✓	?	✕	✓
Biodiesel replaces fossil-derived diesel in transport	✓	✓	✕	✓	✓

Neither strategy was taken forward due to the huge numbers of different trucks on the road transporting construction materials. Electrification of heavy trucks was not considered feasible to any significant extent by FY 2027. Biodiesel was not considered to go beyond business-as-usual. In both cases, there would be too many trucks to cause any meaningful change by FY 2027.

B-6 Construction Energy

B-6-1 Overview

The carbon footprint of construction energy is due to the energy source used. Most construction machines (excavators, graders, etc.) use diesel. Some are electric, e.g., tower cranes. Energy used during commissioning may also be a mixture of diesel (testing backup diesel generators and/or for sites that don't have a grid connection during the commissioning phase) or electricity.

The primary strategies to decarbonise energy to use renewable electricity and biodiesel. While other fuels (such as green hydrogen) may also be viable in future, it is highly unlikely that there will be any significant adoption before FY 2027.

B-6-2 Strategies

The following decarbonisation strategies were considered for construction energy:

- Biodiesel replaces fossil-derived diesel in construction.
- Renewable electricity replaces average grid electricity in construction.

Each strategy was evaluated against the selection criteria – see Table 25.

Table 25: Review of decarbonisation strategies for construction energy against selection criteria

Strategy	Targets upfront carbon	Like-for-like replacement	Additionality	Already available	Potential for decarbonisation
Biodiesel replaces fossil-derived diesel in construction and commissioning	✓	✓	✓	✓	✓
Renewable electricity replaces average grid electricity in construction and commissioning	✓	✓	✓	✓	✓

Both strategies were considered viable. Some large building and infrastructure projects are already using biodiesel and renewable electricity as of FY 2027.

B-6-3 Strategy effectiveness and uptake rates

A summary of the decarbonisation strategies considered for construction energy is presented below in Table 26. Both strategies work by reducing the emission factor of the energy source. Both strategies are already available and can be further implemented immediately.

Table 26: Summary of decarbonisation strategies considered for construction energy

Strategy	Material affected	Labour affected	Effective from	Reduction of
Biodiesel replaces fossil-derived diesel in construction and commissioning	n/a	n/a	FY 2023	Energy emission factor
Renewable electricity replaces average grid electricity in construction and commissioning	n/a	n/a	FY 2023	Energy emission factor

Table 27 shows the carbon footprint emission factor (EF) for each strategy along with its cost uplift.

Table 28 presents uptake in the base year (FY 2023) and maximum uptake by the end of the study period (FY 2027) in both the Mid-level Decarbonisation Scenario and the Maximum Decarbonisation Scenario. The current and future uptake rates were determined through workshops with industry.

Table 27: Carbon footprint and cost of decarbonisation strategies for construction energy at different levels of uptake

Strategy	Material affected	Labour affected	Uptake	EF (kg CO_2e/unit)	Unit	Material cost uplift	Labour cost uplift	Energy cost uplift
Biodiesel in construction	n/a	n/a	0%	3.38	L	n/a	n/a	0.0%
Biodiesel in construction	n/a	n/a	10%	3.17	L	n/a	n/a	5.5%
Biodiesel in construction	n/a	n/a	20%	2.97	L	n/a	n/a	11.1%
Biodiesel in construction	n/a	n/a	30%	2.76	L	n/a	n/a	16.6%
Biodiesel in construction	n/a	n/a	40%	2.55	L	n/a	n/a	22.1%
Biodiesel in construction	n/a	n/a	50%	2.35	L	n/a	n/a	27.7%
Biodiesel in construction	n/a	n/a	60%	2.14	L	n/a	n/a	33.2%
Biodiesel in construction	n/a	n/a	70%	1.93	L	n/a	n/a	38.8%
Biodiesel in construction	n/a	n/a	80%	1.73	L	n/a	n/a	44.3%
Biodiesel in construction	n/a	n/a	90%	1.52	L	n/a	n/a	49.8%
Biodiesel in construction	n/a	n/a	100%	1.32	L	n/a	n/a	55.4%
Renewable electricity in construction	n/a	n/a	0%	0.770	kWh	n/a	n/a	0.0%
Renewable electricity in construction	n/a	n/a	10%	0.702	kWh	n/a	n/a	2.3%
Renewable electricity in construction	n/a	n/a	20%	0.634	kWh	n/a	n/a	4.6%
Renewable electricity in construction	n/a	n/a	30%	0.566	kWh	n/a	n/a	7.0%

Strategy	Material affected	Labour affected	Uptake	EF (kg CO_2e/unit)	Unit	Material cost uplift	Labour cost uplift	Energy cost uplift
Renewable electricity in construction	n/a	n/a	40%	0.498	kWh	n/a	n/a	9.3%
Renewable electricity in construction	n/a	n/a	50%	0.430	kWh	n/a	n/a	11.6%
Renewable electricity in construction	n/a	n/a	60%	0.362	kWh	n/a	n/a	13.9%
Renewable electricity in construction	n/a	n/a	70%	0.294	kWh	n/a	n/a	16.3%
Renewable electricity in construction	n/a	n/a	80%	0.226	kWh	n/a	n/a	18.6%
Renewable electricity in construction	n/a	n/a	90%	0.158	kWh	n/a	n/a	20.9%
Renewable electricity in construction	n/a	n/a	100%	0.090	kWh	n/a	n/a	23.2%

Table 28: Uptake rate per strategy for construction energy

Strategy	Material affected	Reduction of	Grouped asset class	State	Effectiveness	Uptake FY 2023	Uptake FY 2027 Mid	Uptake FY 2027 Max
Biodiesel in construction	n/a	Energy emission factor	All	ACT	100%	1%	1%	20%
Biodiesel in construction	n/a	Energy emission factor	All	NSW	100%	1%	1%	20%
Biodiesel in construction	n/a	Energy emission factor	All	NT	100%	0%	0%	20%
Biodiesel in construction	n/a	Energy emission factor	All	QLD	100%	1%	1%	20%
Biodiesel in construction	n/a	Energy emission factor	All	SA	100%	1%	1%	20%
Biodiesel in construction	n/a	Energy emission factor	All	TAS	100%	1%	1%	20%
Biodiesel in construction	n/a	Energy emission factor	All	VIC	100%	1%	1%	20%
Biodiesel in construction	n/a	Energy emission factor	All	WA	100%	1%	1%	20%
Renewable electricity in construction	n/a	Energy emission factor	All	ACT	100%	5%	30%	100%
Renewable electricity in construction	n/a	Energy emission factor	All	NSW	100%	5%	30%	100%
Renewable electricity in construction	n/a	Energy emission factor	All	NT	100%	0%	0%	100%
Renewable electricity in construction	n/a	Energy emission factor	All	QLD	100%	5%	30%	100%
Renewable electricity in construction	n/a	Energy emission factor	All	SA	100%	5%	30%	100%
Renewable electricity in construction	n/a	Energy emission factor	All	TAS	100%	5%	30%	100%
Renewable electricity in construction	n/a	Energy emission factor	All	VIC	100%	5%	30%	100%
Renewable electricity in construction	n/a	Energy emission factor	All	WA	100%	5%	30%	100%

Appendix C

Results of the Pipeline Analysis

This appendix presents detailed results of the Pipeline Analysis to support the main results in the body of this report. The results in this appendix may not match the corresponding results in the body of the report due to rounding.

C-1 Results for the 5-year pipeline

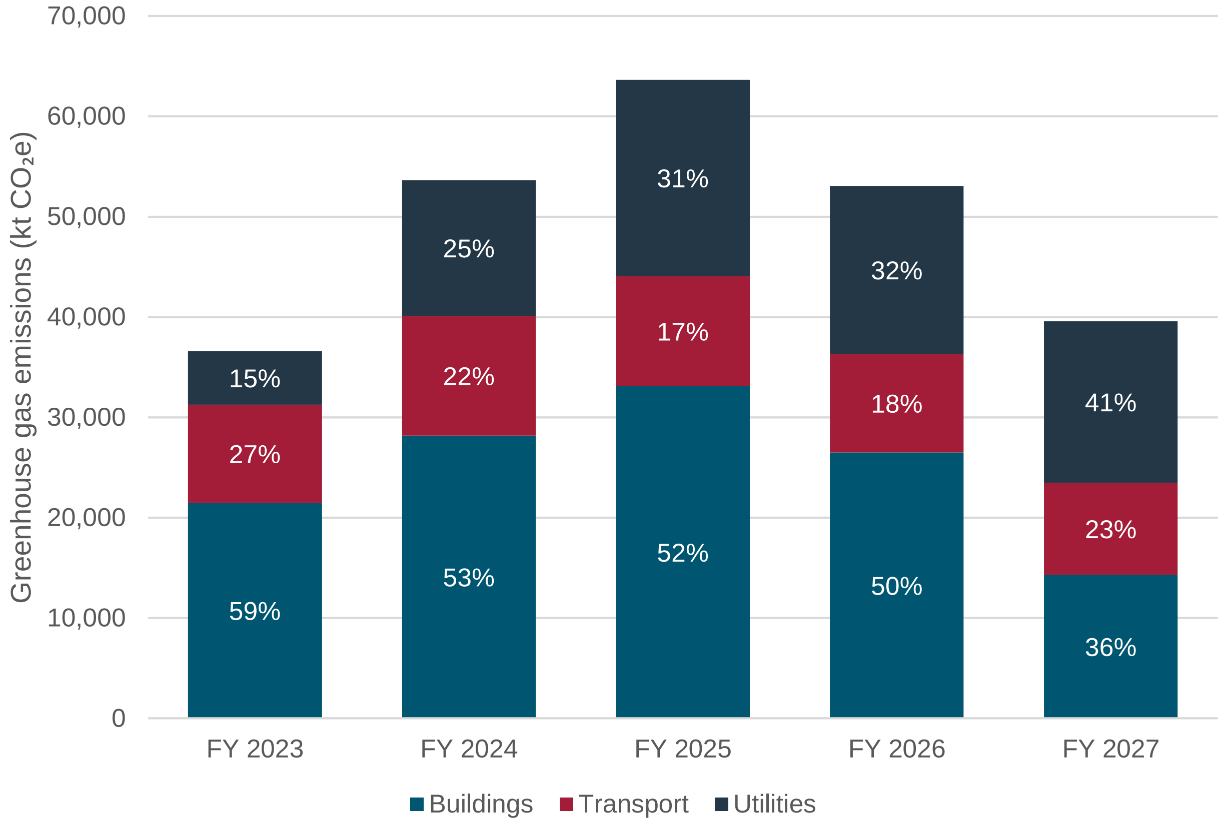

Figure 1 Embodied carbon in Australia's pipeline of infrastructure and buildings (Pipeline Analysis)

Table 29: Embodied carbon (kt CO_2e) in Australia's pipeline of infrastructure and buildings (Pipeline Analysis)

Super sector	FY 2023	FY 2024	FY 2025	FY 2026	FY 2027	Total
Buildings	21,488	28,193	33,115	26,502	14,315	**123,613**
Transport	9,778	11,895	10,942	9,815	9,156	**51,585**
Utilities	5,319	13,569	19,598	16,737	16,120	**71,343**
Total	**36,585**	**53,657**	**63,654**	**53,054**	**39,591**	**246,541**

Table 30: Carbon stored in timber products (kt CO_2e) in Australia's pipeline of infrastructure and buildings (Pipeline Analysis)

Super sector	FY 2023	FY 2024	FY 2025	FY 2026	FY 2027	Total
Total	**-830**	**-1,231**	**-1,556**	**-1,262**	**-690**	**-5,569**

C-2 Results in baseline year and final year

C-2-1 Baseline Scenario in FY 2023

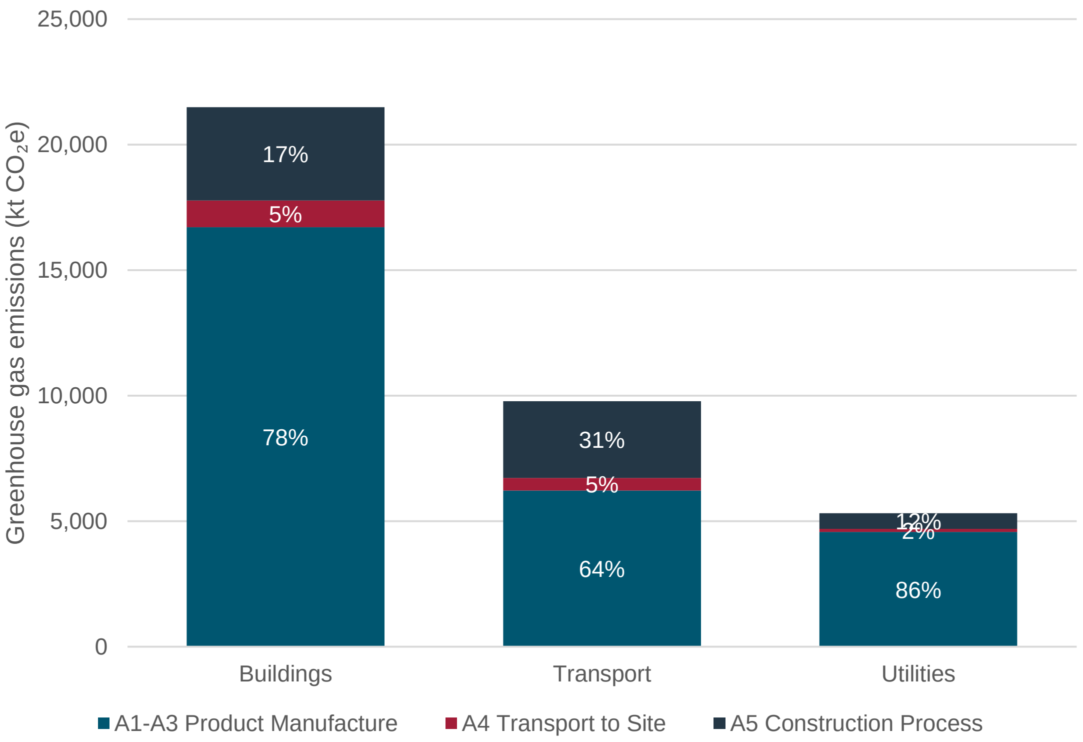

Figure 2: Embodied carbon per super sector for Baseline Scenario by life cycle module in baseline year FY 2023 (Pipeline Analysis)

Table 31: Embodied carbon (kt CO_2e) per super sector for Baseline Scenario by life cycle module in baseline year FY 2023 (Pipeline Analysis)

Super sector	A1-A3 Product Manufacture	A4 Transport to Site	A5 Construction Waste	A5 Construction	A5 Land Use Change	A5 Commissioning	Total embodied carbon
Buildings	16,715	1,055	734	1,342	738	904	**21,488**
Transport	6,222	500	326	1,945	498	287	**9,778**
Utilities	4,566	123	77	267	191	94	**5,319**
Total	**27,504**	**1,678**	**1,137**	**3,555**	**1,427**	**1,285**	**36,585**

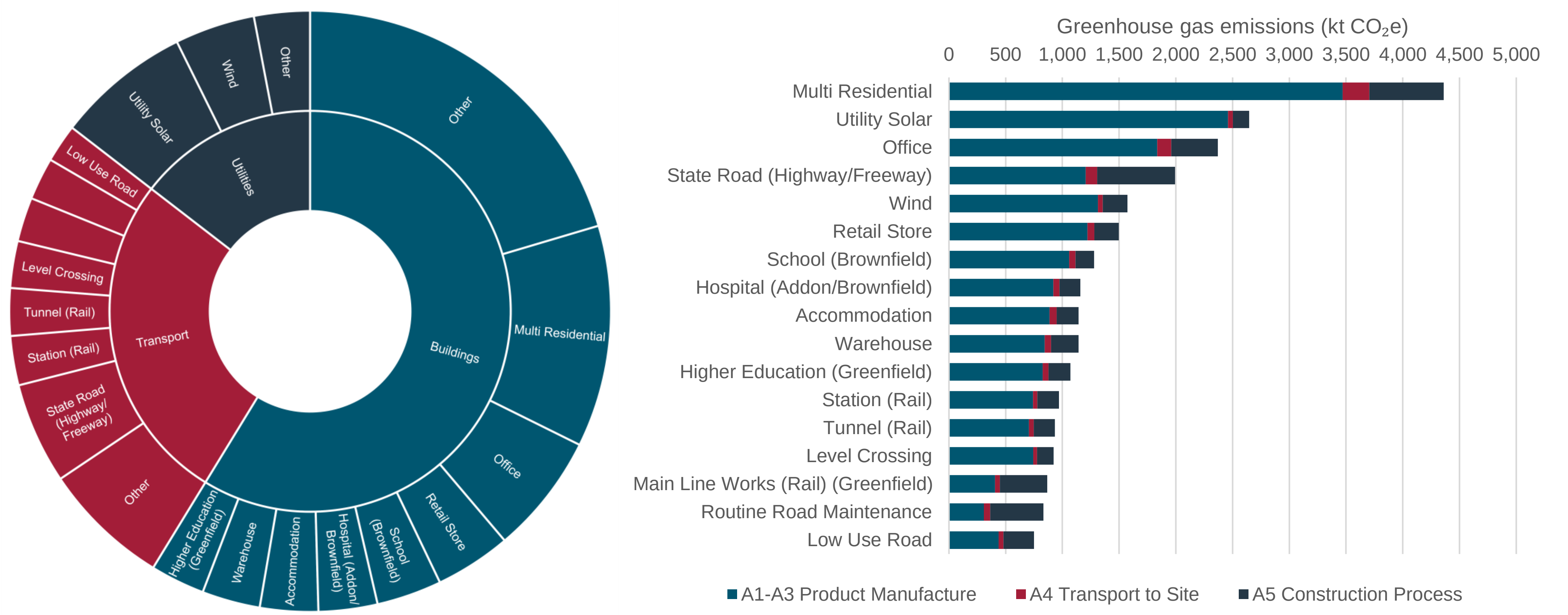

Figure 3: Embodied carbon for the 10 highest contributing typecasts for Baseline Scenario in baseline year FY 2023 (Pipeline Analysis)

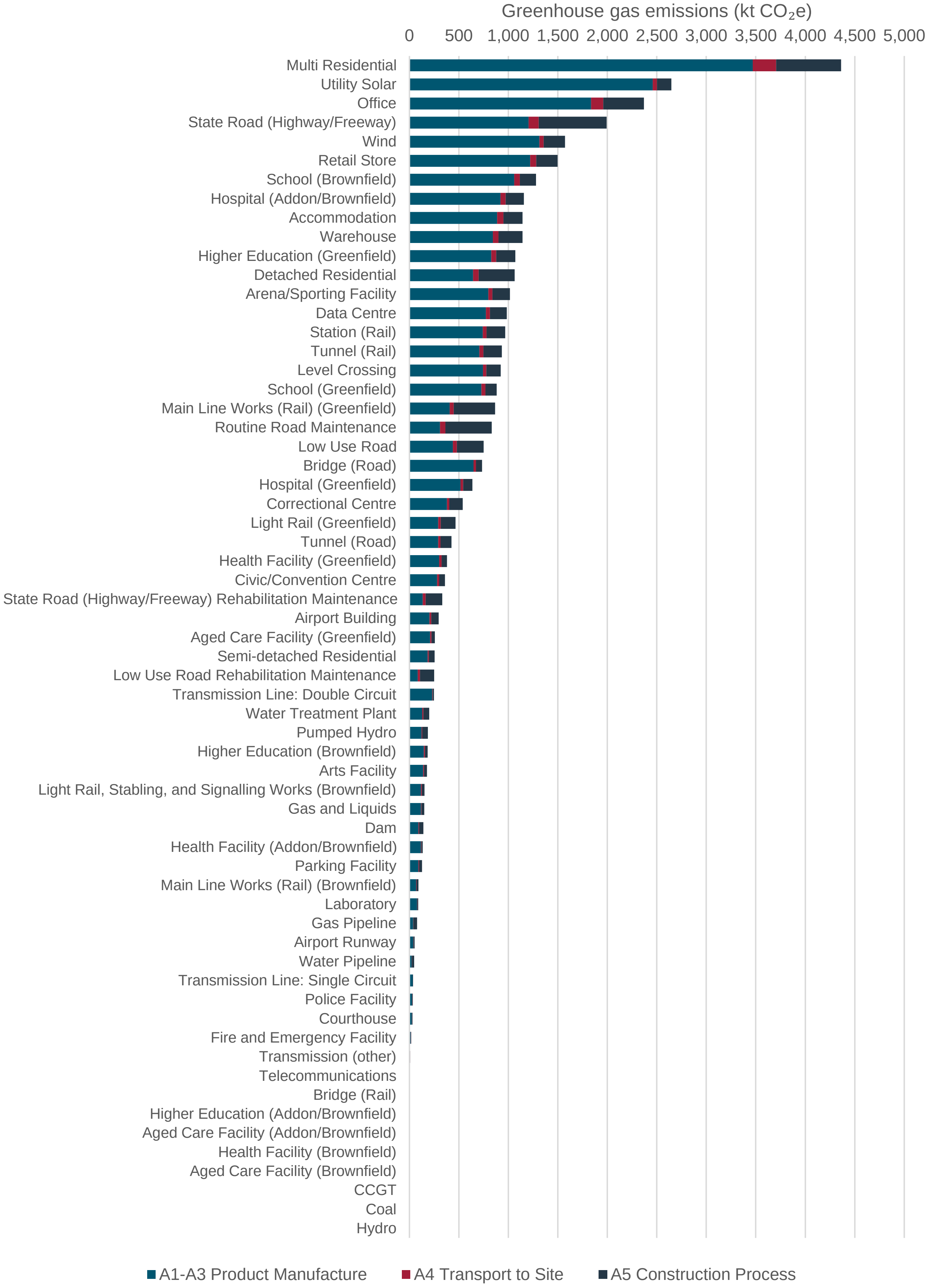

Figure 4: Embodied carbon per typecast for Baseline Scenario by life cycle module in baseline year FY 2023 (Pipeline Analysis)

Table 32: Embodied carbon (kt CO_2e) per typecast for Baseline Scenario by life cycle module in baseline year FY 2023 (Pipeline Analysis)

Project type (typecast)	A1-A3 Product Manufacture	A4 Transport to Site	A5 Construction Waste	A5 Construction	A5 Land Use Change	A5 Commissioning	Total embodied carbon
Multi Residential	3,469	237	168	323	0	165	**4,362**
Utility Solar	2,459	42	27	58	48	12	**2,647**
Office	1,835	124	87	156	0	168	**2,370**
State Road (Highway/Freeway)	1,205	102	66	415	184	21	**1,993**
Wind	1,313	43	24	106	66	22	**1,573**
Retail Store	1,221	61	44	46	101	24	**1,497**
School (Brownfield)	1,059	57	42	82	0	40	**1,279**
Hospital (Addon/Brownfield)	920	53	35	60	0	88	**1,158**
Accommodation	887	64	43	73	6	71	**1,144**
Warehouse	844	56	40	70	120	14	**1,143**
Higher Education (Greenfield)	827	49	33	44	74	43	**1,071**
Detached Residential	644	56	35	98	231	0	**1,063**
Arena/Sporting Facility	797	41	32	98	0	48	**1,015**
Data Centre	774	41	31	71	0	69	**985**
Station (Rail)	740	40	31	41	77	41	**969**
Tunnel (Rail)	706	42	38	104	0	43	**934**
Level Crossing	744	34	31	110	0	6	**924**
School (Greenfield)	727	42	29	39	28	19	**883**
Main Line Works (Rail) (Greenfield)	407	41	23	219	110	67	**867**
Routine Road Maintenance	309	55	28	441	0	0	**833**
Low Use Road	438	42	25	159	78	8	**751**
Bridge (Road)	647	26	15	41	0	4	**734**
Hospital (Greenfield)	516	26	20	14	42	20	**637**
Correctional Centre	381	23	15	47	27	46	**539**
Light Rail (Greenfield)	291	25	16	45	44	46	**467**
Tunnel (Road)	292	23	18	51	0	41	**424**
Health Facility (Greenfield)	301	23	12	8	24	11	**379**

Project type (typecast)	A1-A3 Product Manufacture	A4 Transport to Site	A5 Construction Waste	A5 Construction	A5 Land Use Change	A5 Commissioning	Total embodied carbon
Civic/Convention Centre	279	20	13	23	0	23	**358**
State Road (Highway/Freeway) Rehabilitation Maintenance	134	30	14	153	0	0	**331**
Airport Building	203	18	10	17	31	16	**295**
Aged Care Facility (Greenfield)	210	12	8	5	18	3	**256**
Semi-detached Residential	185	12	9	29	21	0	**256**
Low Use Road Rehabilitation Maintenance	85	23	9	134	0	0	**252**
Transmission Line: Double Circuit	231	3	3	5	5	2	**248**
Water Treatment Plant	131	10	7	25	14	12	**200**
Pumped Hydro	123	8	5	19	14	20	**188**
Higher Education (Brownfield)	147	10	6	11	0	11	**185**
Arts Facility	139	10	7	12	0	11	**178**
Light Rail, Stabling, and Signalling Works (Brownfield)	116	9	6	18	0	4	**153**
Gas and Liquids	117	3	2	11	6	11	**150**
Dam	91	8	5	24	12	2	**142**
Health Facility (Addon/Brownfield)	117	5	4	3	0	4	**134**
Parking Facility	91	7	4	8	13	4	**127**
Main Line Works (Rail) (Brownfield)	69	5	4	11	0	3	**91**
Laboratory	77	4	3	2	2	2	**90**
Gas Pipeline	36	3	2	11	14	11	**77**
Airport Runway	39	2	2	3	4	3	**54**
Water Pipeline	24	2	1	7	11	1	**48**
Transmission Line: Single Circuit	34	0	0	1	1	0	**36**
Police Facility	27	2	1	2	0	2	**35**
Courthouse	25	2	1	2	0	1	**31**
Fire and Emergency Facility	14	1	1	1	0	1	**18**
Transmission (other)	4	0	0	0	0	0	**5**

Project type (typecast)	A1-A3 Product Manufacture	A4 Transport to Site	A5 Construction Waste	A5 Construction	A5 Land Use Change	A5 Commissioning	Total embodied carbon
Telecommunications	2	0	0	0	0	0	**3**
Bridge (Rail)	1	0	0	0	0	0	**1**
Higher Education (Addon/Brownfield)	0	0	0	0	0	0	**0**
Aged Care Facility (Addon/Brownfield)	0	0	0	0	0	0	**0**
Health Facility (Brownfield)	0	0	0	0	0	0	**0**
Aged Care Facility (Brownfield)	0	0	0	0	0	0	**0**
CCGT	0	0	0	0	0	0	**0**
Coal	0	0	0	0	0	0	**0**
Hydro	0	0	0	0	0	0	**0**
Total	**27,504**	**1,678**	**1,137**	**3,555**	**1,427**	**1,285**	**36,585**

Table 33: Stored carbon (kt CO_2e) in timber for Baseline Scenario in baseline year FY 2023 (Pipeline Analysis)

GHG removals stored in wood products (kt CO_2 eq)	-830

Table 34: Embodied carbon (kt CO_2e) per state for Baseline Scenario by life cycle module in baseline year FY 2023 (Pipeline Analysis)

Super sector	NSW	VIC	QLD	WA	SA	TAS	ACT	NT	Total
Buildings	7,994	5,812	4,280	1,464	732	332	517	358	**21,488**
Transport	3,359	2,895	2,036	834	303	193	46	113	**9,778**
Utilities	1,744	527	2,349	351	184	164	0	0	**5,319**
Total	**13,097**	**9,234**	**8,664**	**2,649**	**1,219**	**689**	**563**	**471**	**36,585**

Table 35: Embodied carbon per capita (kt CO_2e pc) per state for Baseline Scenario by life cycle module in baseline year FY 2023 (Pipeline Analysis)

Super sector	NSW	VIC	QLD	WA	SA	TAS	ACT	NT	Total
Buildings	0.922	0.809	0.785	0.530	0.407	0.607	1.114	1.359	**0.792**
Transport	0.387	0.403	0.374	0.302	0.168	0.353	0.099	0.429	**0.360**
Utilities	0.201	0.073	0.431	0.127	0.102	0.300	0.000	0.000	**0.196**
Total	**1.510**	**1.285**	**1.590**	**0.958**	**0.677**	**1.260**	**1.213**	**1.788**	**1.348**

C-2-2 Baseline Scenario in FY 2027

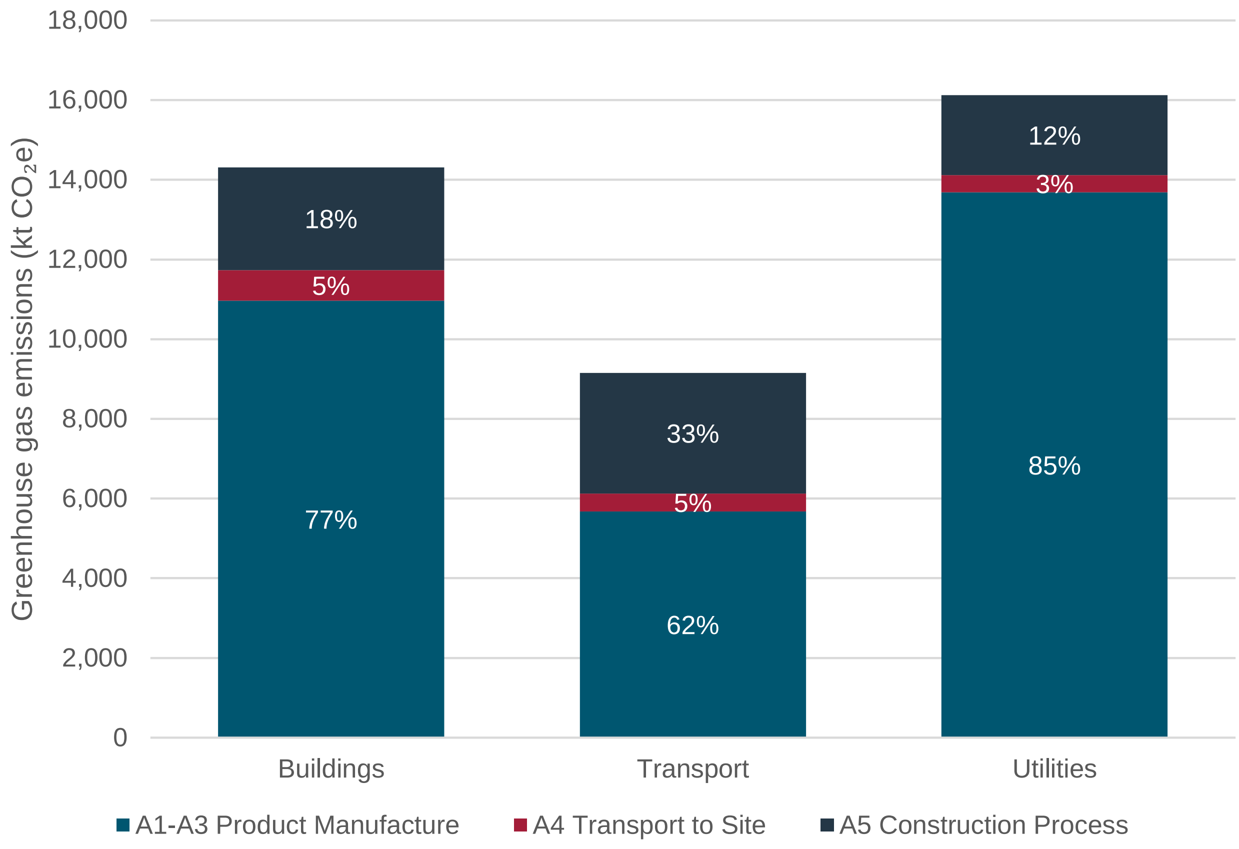

Figure 31: Embodied carbon per super sector for Baseline Scenario by life cycle module in FY 2027 (Pipeline Analysis)

Table 36: Embodied carbon (kt CO_2e) per super sector for Baseline Scenario by life cycle module in FY 2027 (Pipeline Analysis)

Super sector	A1-A3 Product Manufacture	A4 Transport to Site	A5 Construction Waste	A5 Construction	A5 Land Use Change	A5 Commissioning	Total embodied carbon
Buildings	10,967	765	496	877	624	584	**14,315**
Transport	5,678	450	306	1,757	620	345	**9,156**
Utilities	13,684	433	254	715	807	227	**16,120**
Total	**30,328**	**1,648**	**1,056**	**3,350**	**2,052**	**1,156**	**39,591**

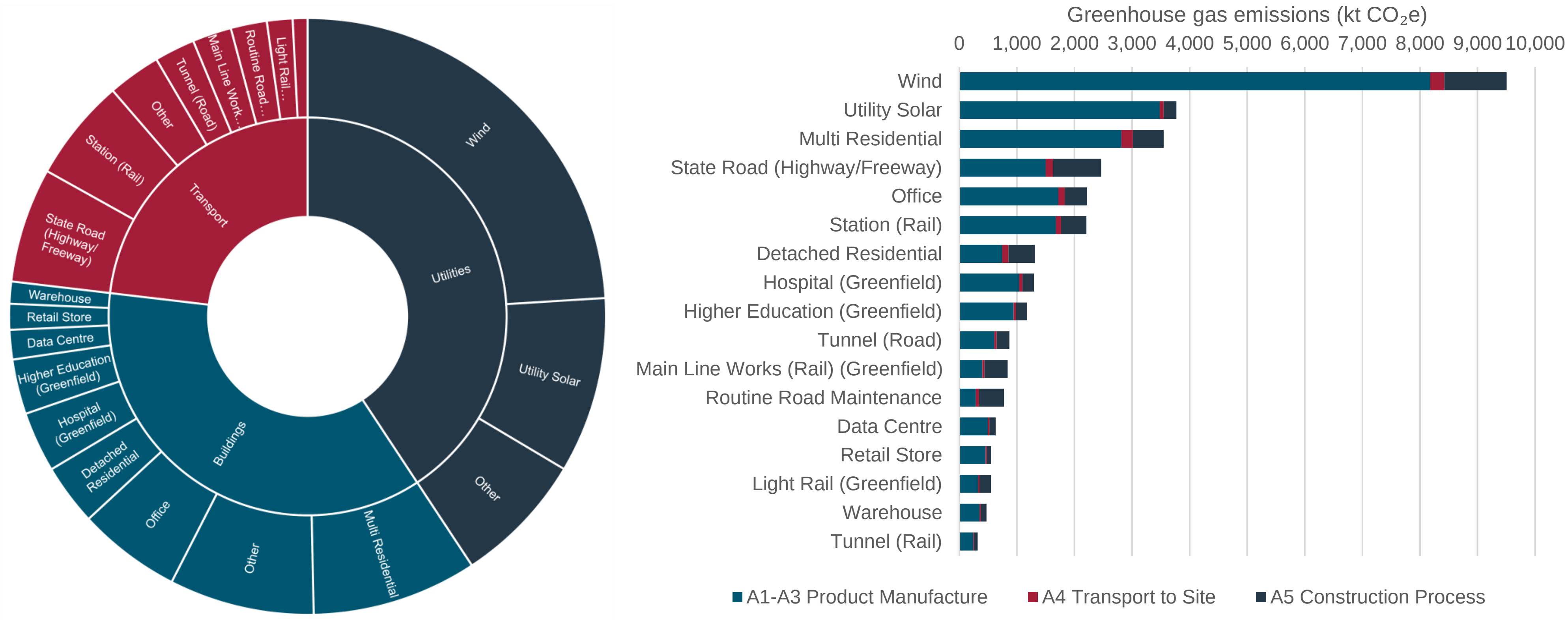

Figure 32: Embodied carbon for the 10 highest contributing typecasts for Baseline Scenario in FY 2027 (Pipeline Analysis)

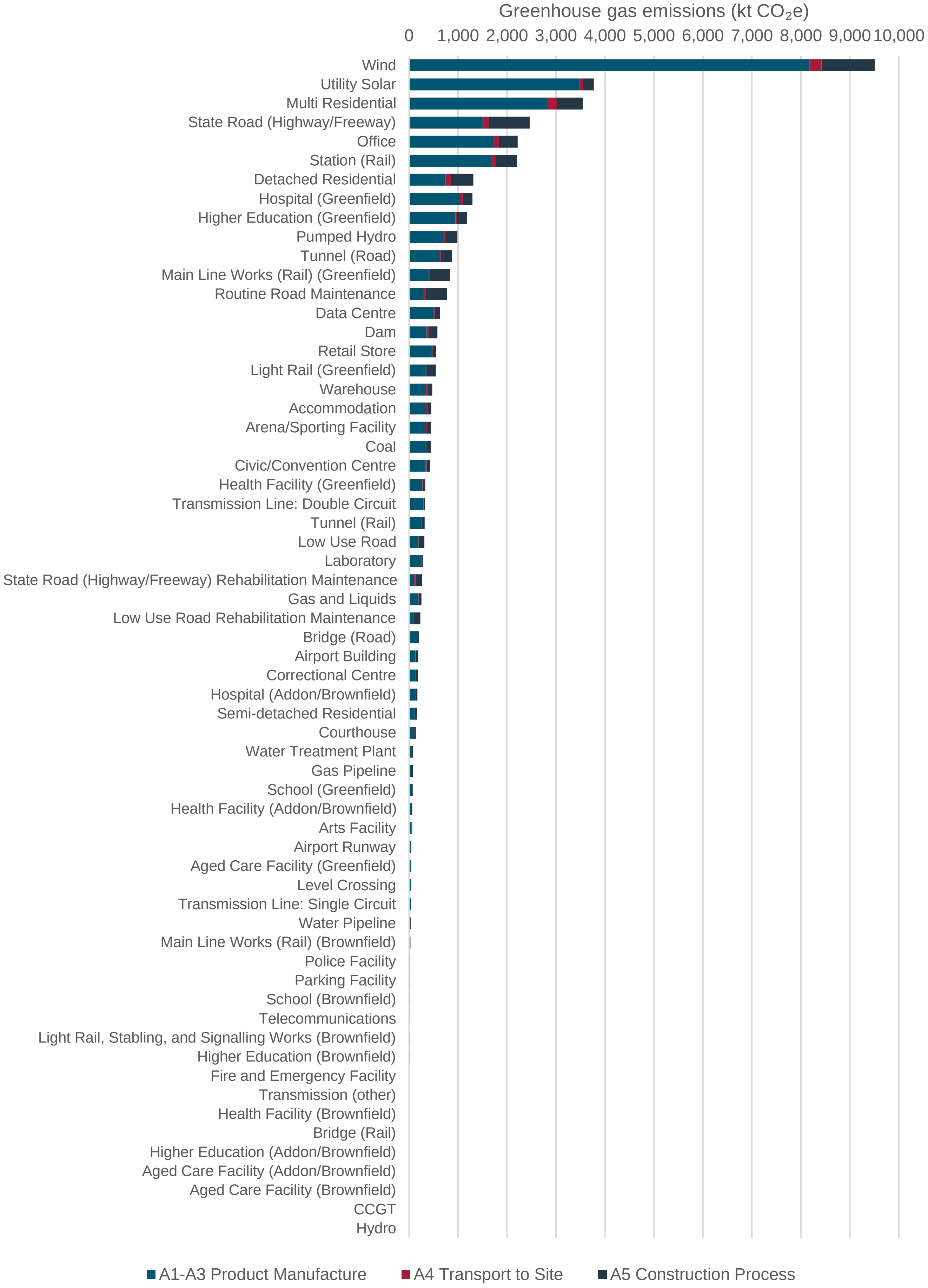

Figure 33: Embodied carbon per typecast for Baseline Scenario by life cycle module in FY 2027 (Pipeline Analysis)

Table 37: Embodied carbon (kt CO_2e) per typecast for Baseline Scenario by life cycle module in FY 2027 (Pipeline Analysis)

Project type (typecast)	A1-A3 Product Manufacture	A4 Transport to Site	A5 Construction Waste	A5 Construction	A5 Land Use Change	A5 Commissioning	Total embodied carbon
Wind	8,178	246	151	437	408	89	**9,508**
Utility Solar	3,478	71	39	61	110	12	**3,772**
Multi Residential	2,816	198	137	262	0	134	**3,546**
State Road (Highway/Freeway)	1,501	124	82	514	217	26	**2,464**
Office	1,716	113	82	146	0	157	**2,215**
Station (Rail)	1,679	88	69	92	183	94	**2,206**
Detached Residential	745	106	43	113	304	0	**1,312**
Hospital (Greenfield)	1,037	59	39	28	92	40	**1,295**
Higher Education (Greenfield)	945	39	37	50	59	49	**1,179**
Pumped Hydro	696	46	27	64	88	66	**986**
Tunnel (Road)	606	41	37	103	0	84	**871**
Main Line Works (Rail) (Greenfield)	402	32	22	218	98	67	**838**
Routine Road Maintenance	287	52	26	409	0	0	**775**
Data Centre	494	29	20	45	0	44	**632**
Dam	357	42	20	92	61	9	**581**
Retail Store	455	22	16	17	34	9	**553**
Light Rail (Greenfield)	327	21	18	51	81	52	**549**
Warehouse	348	25	17	29	50	6	**473**
Accommodation	345	33	17	28	2	28	**454**
Arena/Sporting Facility	345	23	14	42	0	20	**444**
Coal	339	10	5	17	55	17	**443**
Civic/Convention Centre	337	23	16	28	0	27	**431**
Health Facility (Greenfield)	271	13	10	7	21	10	**332**
Transmission Line: Double Circuit	296	4	3	3	16	2	**324**
Tunnel (Rail)	242	13	13	35	0	15	**318**
Low Use Road	178	18	10	66	38	3	**314**
Laboratory	241	11	9	6	10	6	**282**

Project type (typecast)	A1-A3 Product Manufacture	A4 Transport to Site	A5 Construction Waste	A5 Construction	A5 Land Use Change	A5 Commissioning	Total embodied carbon
State Road (Highway/Freeway) Rehabilitation Maintenance	107	25	11	121	0	0	**264**
Gas and Liquids	190	4	3	14	30	14	**254**
Low Use Road Rehabilitation Maintenance	78	21	9	122	0	0	**230**
Bridge (Road)	178	8	4	12	0	1	**204**
Airport Building	130	10	6	11	19	10	**187**
Correctional Centre	121	19	5	15	12	14	**187**
Hospital (Addon/Brownfield)	135	8	5	9	0	13	**170**
Semi-detached Residential	117	7	6	18	16	0	**164**
Courthouse	113	8	5	9	0	5	**140**
Water Treatment Plant	54	5	3	10	9	5	**86**
Gas Pipeline	36	3	2	11	18	11	**81**
School (Greenfield)	61	4	2	3	2	2	**74**
Health Facility (Addon/Brownfield)	56	3	2	1	0	2	**64**
Arts Facility	49	4	2	4	0	4	**63**
Airport Runway	32	2	2	3	4	3	**45**
Aged Care Facility (Greenfield)	34	2	1	1	3	0	**41**
Level Crossing	32	2	1	5	0	0	**40**
Transmission Line: Single Circuit	34	0	0	0	1	0	**37**
Water Pipeline	15	1	1	5	9	1	**32**
Main Line Works (Rail) (Brownfield)	20	2	1	3	0	1	**27**
Police Facility	15	4	1	1	0	1	**23**
Parking Facility	11	1	1	1	1	0	**16**
School (Brownfield)	12	1	1	1	0	0	**15**
Telecommunications	8	1	0	1	3	1	**14**
Light Rail, Stabling, and Signalling Works (Brownfield)	9	1	1	1	0	0	**12**
Higher Education (Brownfield)	9	1	0	1	0	1	**12**
Fire and Emergency Facility	7	1	0	1	0	1	**9**

Project type (typecast)	A1-A3 Product Manufacture	A4 Transport to Site	A5 Construction Waste	A5 Construction	A5 Land Use Change	A5 Commissioning	Total embodied carbon
Transmission (other)	2	0	0	0	0	0	**2**
Health Facility (Brownfield)	1	0	0	0	0	0	**1**
Bridge (Rail)	0	0	0	0	0	0	**0**
Higher Education (Addon/Brownfield)	0	0	0	0	0	0	**0**
Aged Care Facility (Addon/Brownfield)	0	0	0	0	0	0	**0**
Aged Care Facility (Brownfield)	0	0	0	0	0	0	**0**
CCGT	0	0	0	0	0	0	**0**
Hydro	0	0	0	0	0	0	**0**
Total	**30,328**	**1,648**	**1,056**	**3,350**	**2,052**	**1,156**	**39,591**

Table 38: Stored carbon (kt CO_2e) in timber for Baseline Scenario in FY 2027 (Pipeline Analysis)

GHG removals stored in wood products (kt CO_2 eq)	-690

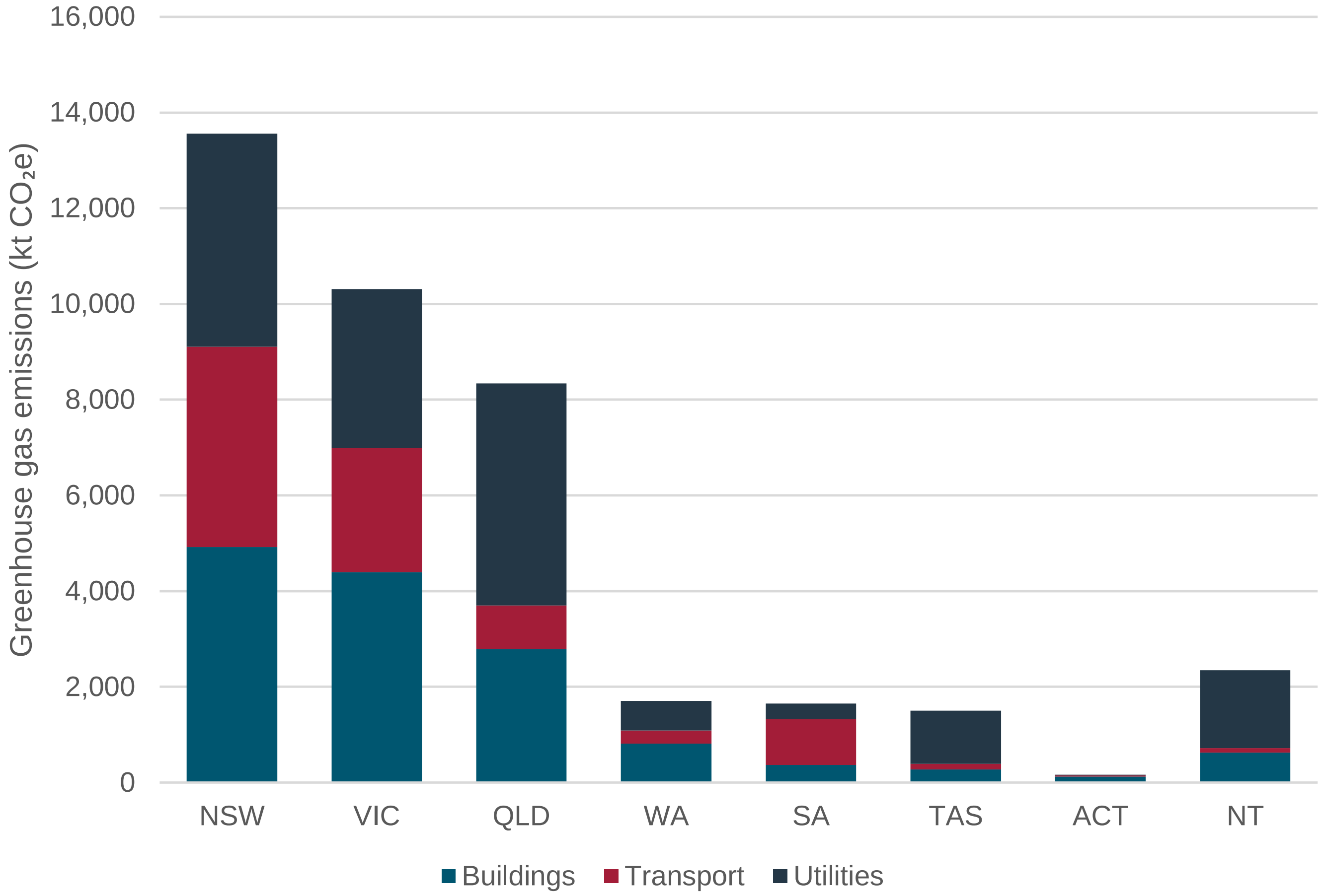

Figure 34:Embodied carbon per state for Baseline Scenario in FY 2027 (Pipeline Analysis)

Table 39: Embodied carbon (kt CO_2e) per state for Baseline Scenario by life cycle module in FY 2027 (Pipeline Analysis)

Super sector	NSW	VIC	QLD	WA	SA	TAS	ACT	NT	Total
Buildings	4,920	4,396	2,790	814	364	275	127	627	**14,315**
Transport	4,190	2,589	909	272	962	116	25	92	**9,156**
Utilities	4,452	3,329	4,641	620	327	1,109	11	1,631	**16,120**
Total	**13,562**	**10,314**	**8,340**	**1,706**	**1,653**	**1,501**	**164**	**2,350**	**39,591**

C-2-3 Mid-level Decarbonisation Scenario in FY 2027

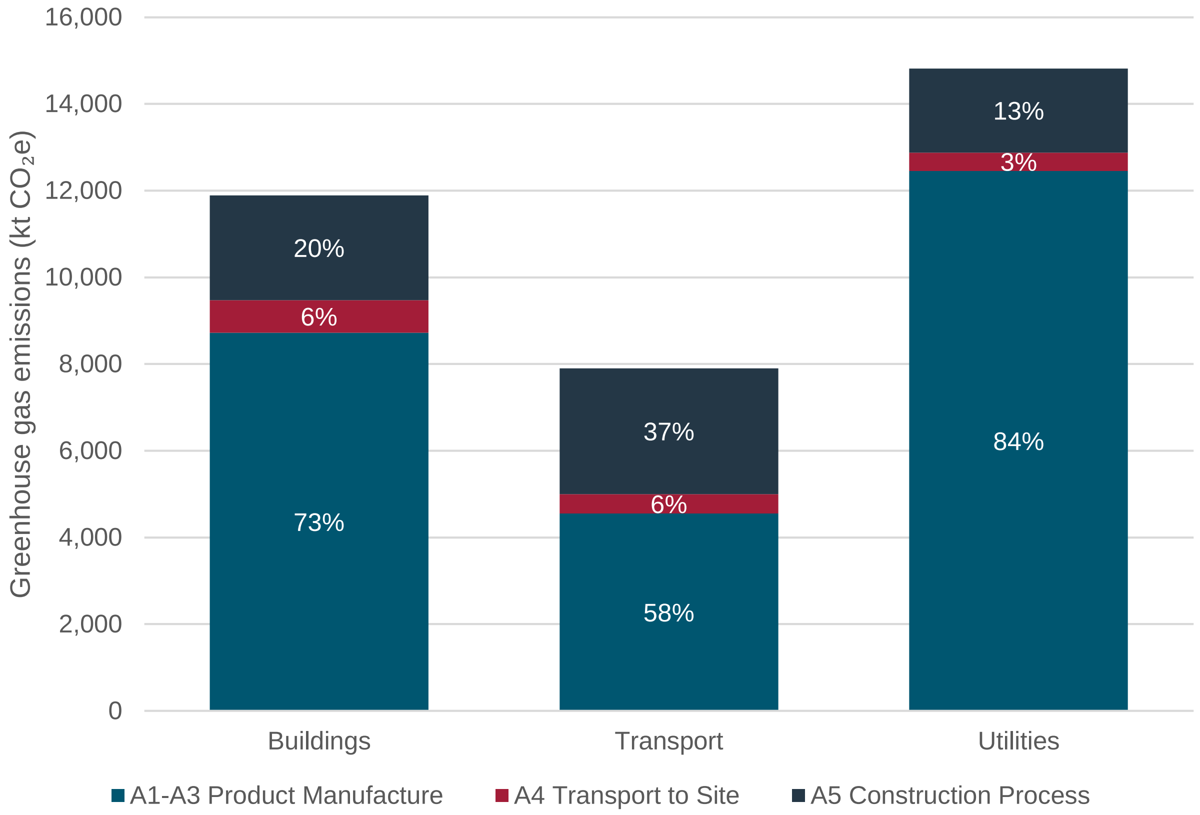

Figure 35: Embodied carbon per super sector for Mid-level Decarbonisation Scenario by life cycle module in FY 2027 (Pipeline Analysis)

Table 40: Embodied carbon (kt CO_2e) per super sector for Mid-level Decarbonisation Scenario by life cycle module in FY 2027 (Pipeline Analysis)

Super sector	A1-A3 Product Manufacture	A4 Transport to Site	A5 Construction Waste	A5 Construction	A5 Land Use Change	A5 Commissioning	Total embodied carbon
Buildings	8,726	750	393	838	624	556	**11,888**
Transport	4,553	448	249	1,706	620	328	**7,904**
Utilities	12,458	421	226	691	807	216	**14,820**
Total	**25,737**	**1,619**	**869**	**3,235**	**2,052**	**1,100**	**34,612**

C-2-4 Maximum Decarbonisation Scenario in FY 2027

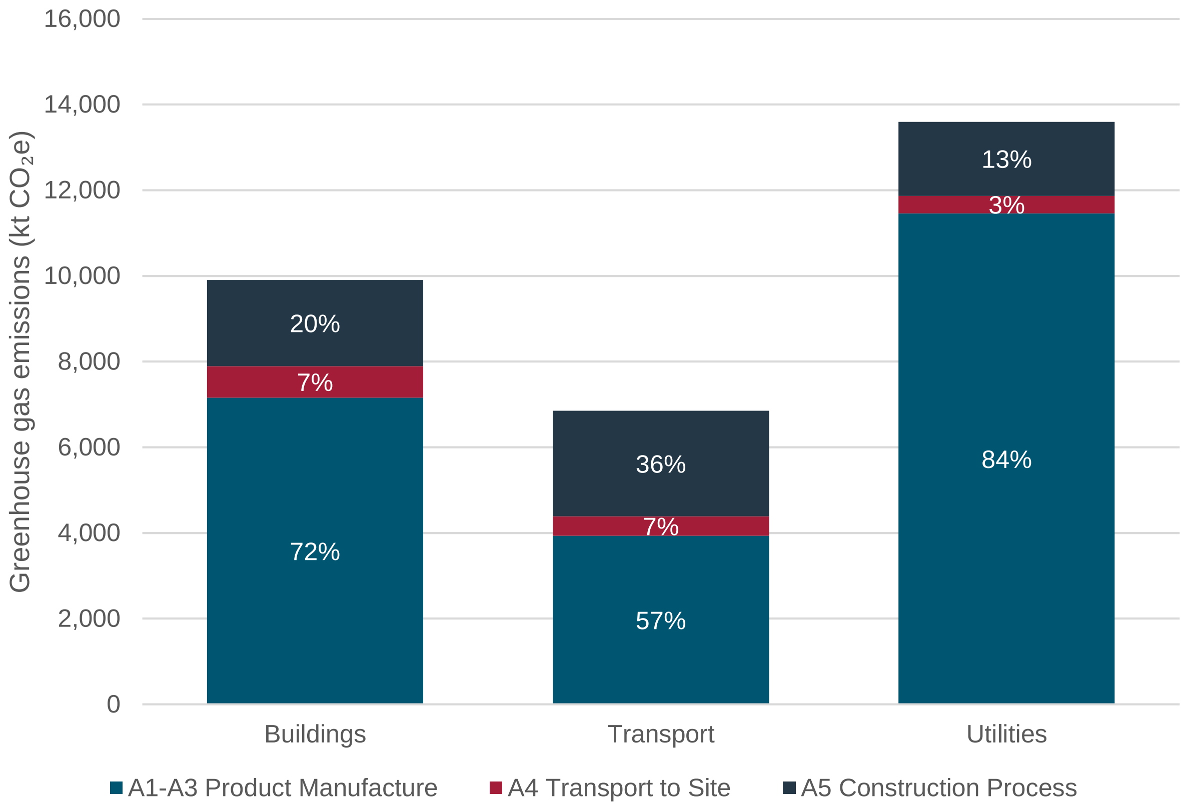

Figure 36 Embodied carbon per super sector for Maximum Decarbonisation Scenario by life cycle module in FY 2027 (Pipeline Analysis)

Table 41: Embodied carbon (kt CO_2e) per super sector for Maximum Decarbonisation Scenario by life cycle module in FY 2027 (Pipeline Analysis)

Super sector	A1-A3 Product Manufacture	A4 Transport to Site	A5 Construction Waste	A5 Construction	A5 Land Use Change	A5 Commissioning	Total embodied carbon
Buildings	7,160	734	324	639	624	421	**9,903**
Transport	3,938	446	219	1,381	620	249	**6,854**
Utilities	11,461	408	211	546	807	164	**13,598**
Total	**22,560**	**1,589**	**754**	**2,566**	**2,052**	**833**	**30,354**

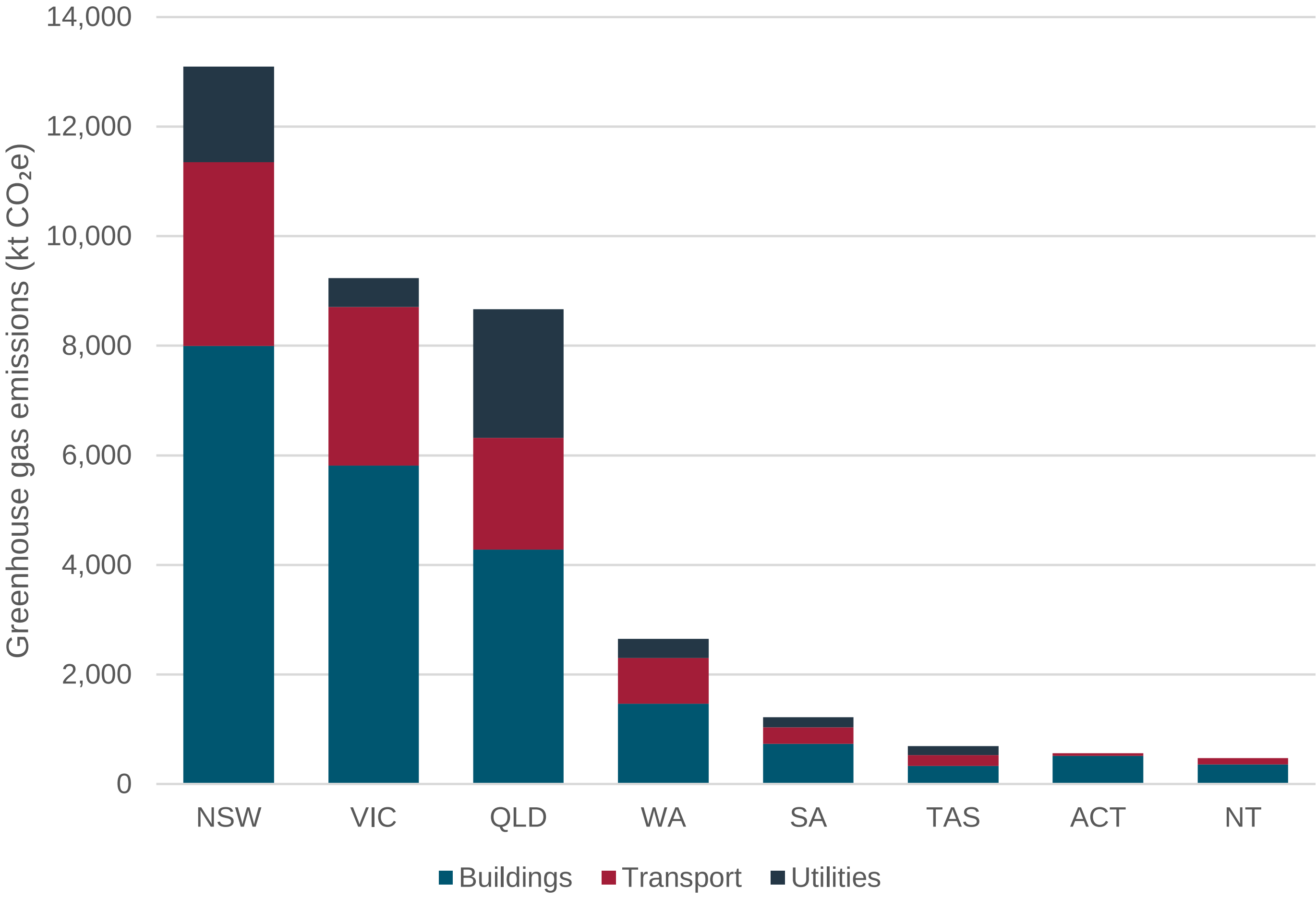

Figure 37: Embodied carbon per state for Baseline Scenario in baseline year FY 2023 (Pipeline Analysis)

Appendix D

Results of the Hybrid Analysis

This appendix presents detailed results of the Hybrid Analysis to support the main results in the body of this report. The results in this appendix may not match the corresponding results in the body of the report due to rounding.

D-1 Results for the 5-year pipeline

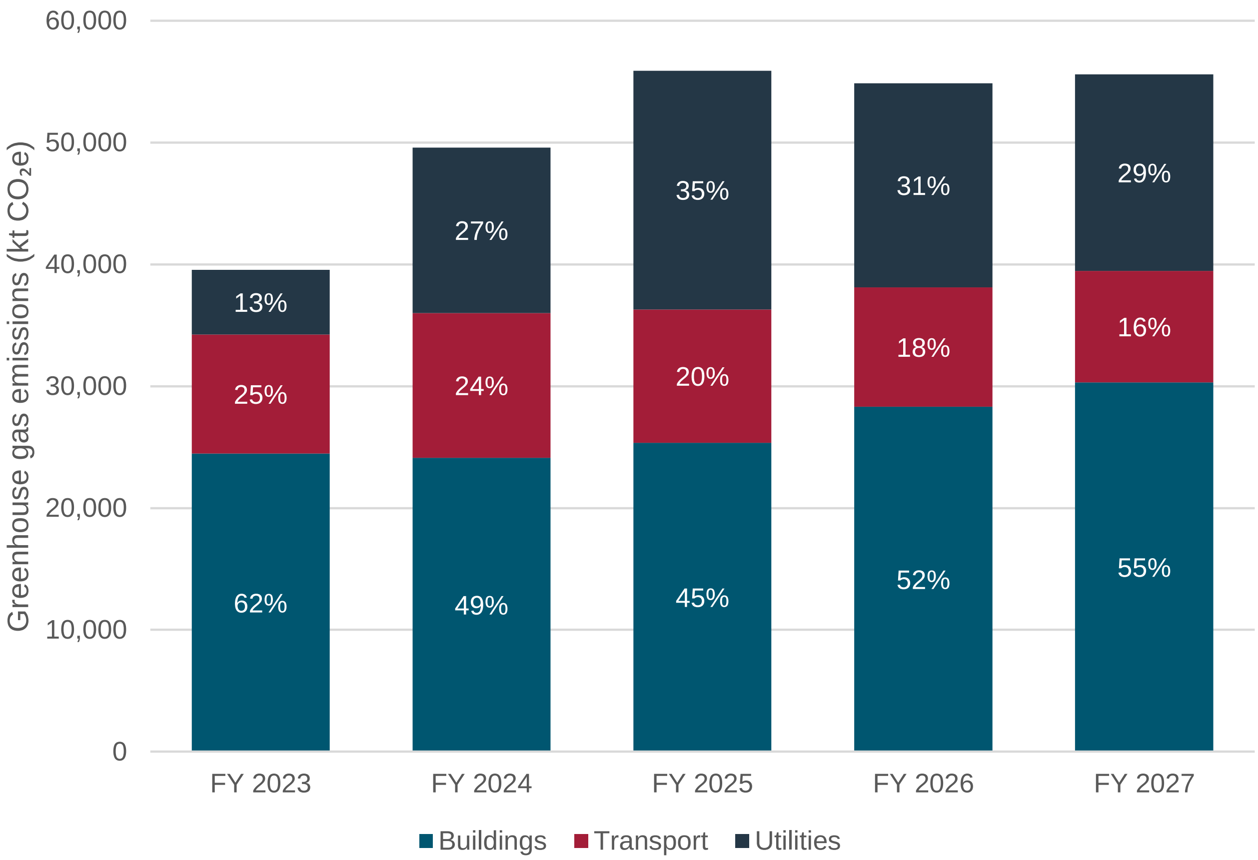

Figure 5: Embodied carbon in Australia's pipeline of infrastructure and buildings (Hybrid Analysis)

Table 42: Embodied carbon (kt CO_2e) in Australia's pipeline of infrastructure and buildings (Hybrid Analysis)

Super sector	FY 2023	FY 2024	FY 2025	FY 2026	FY 2027	Total
Buildings	24,469	24,125	25,366	28,310	30,319	**132,590**
Transport	9,778	11,895	10,942	9,815	9,156	**51,585**
Utilities	5,319	13,569	19,598	16,737	16,120	**71,343**
Total	**39,566**	**49,589**	**55,906**	**54,862**	**55,595**	**255,518**

Table 43: Carbon stored in timber products (kt CO_2e) in Australia's pipeline of infrastructure and buildings (Hybrid Analysis)

Super sector	FY 2023	FY 2024	FY 2025	FY 2026	FY 2027	Total
Total	**-2,459**	**-2,377**	**-2,522**	**-2,859**	**-3,094**	**-13,312**

D-2 Results in baseline year and final year

D-2-1 Baseline Scenario in FY 2023

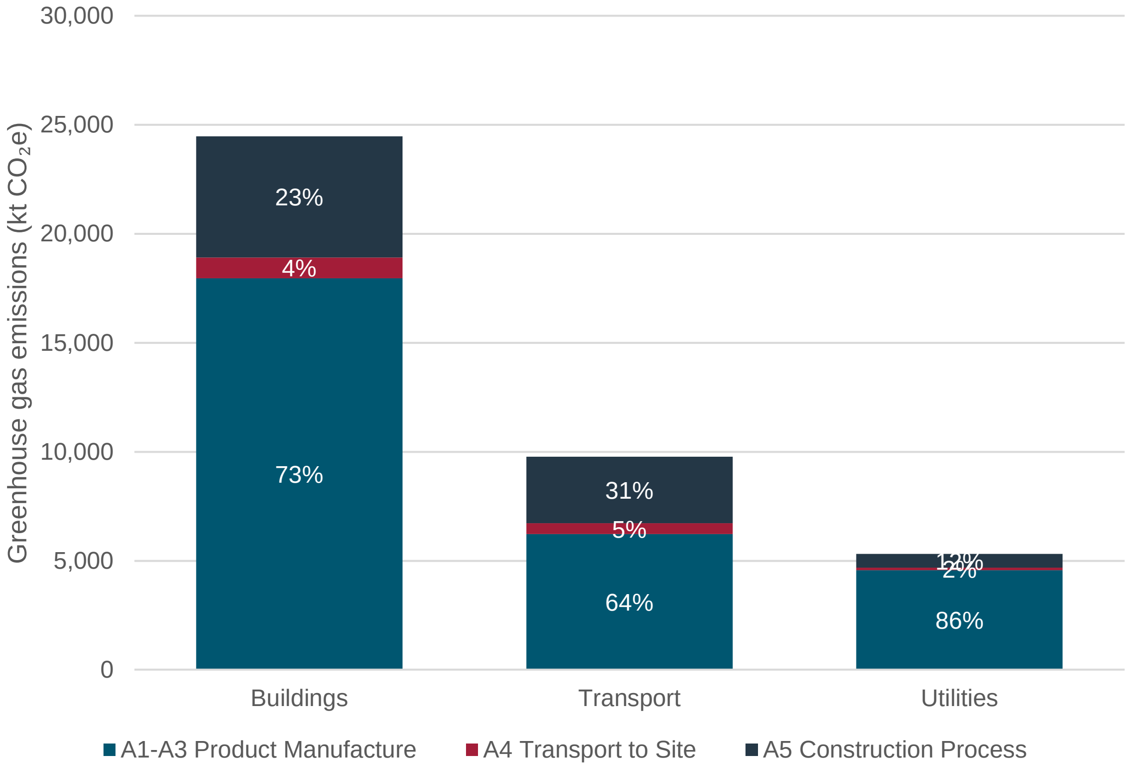

Figure 6: Embodied carbon per super sector for Baseline Scenario by life cycle module in baseline year FY 2023 (Hybrid Analysis)

Table 44: Embodied carbon (kt CO_2e) per super sector for Baseline Scenario by life cycle module in baseline year FY 2023 (Hybrid Analysis)

Super sector	A1-A3 Product Manufacture	A4 Transport to Site	A5 Construction Waste	A5 Construction	A5 Land Use Change	A5 Commissioning	Total embodied carbon
Buildings	17,965	951	728	1,750	2,490	586	**24,469**
Transport	6,222	500	326	1,945	498	287	**9,778**
Utilities	4,566	123	77	267	191	94	**5,319**
Total	**28,754**	**1,575**	**1,130**	**3,962**	**3,178**	**967**	**39,566**

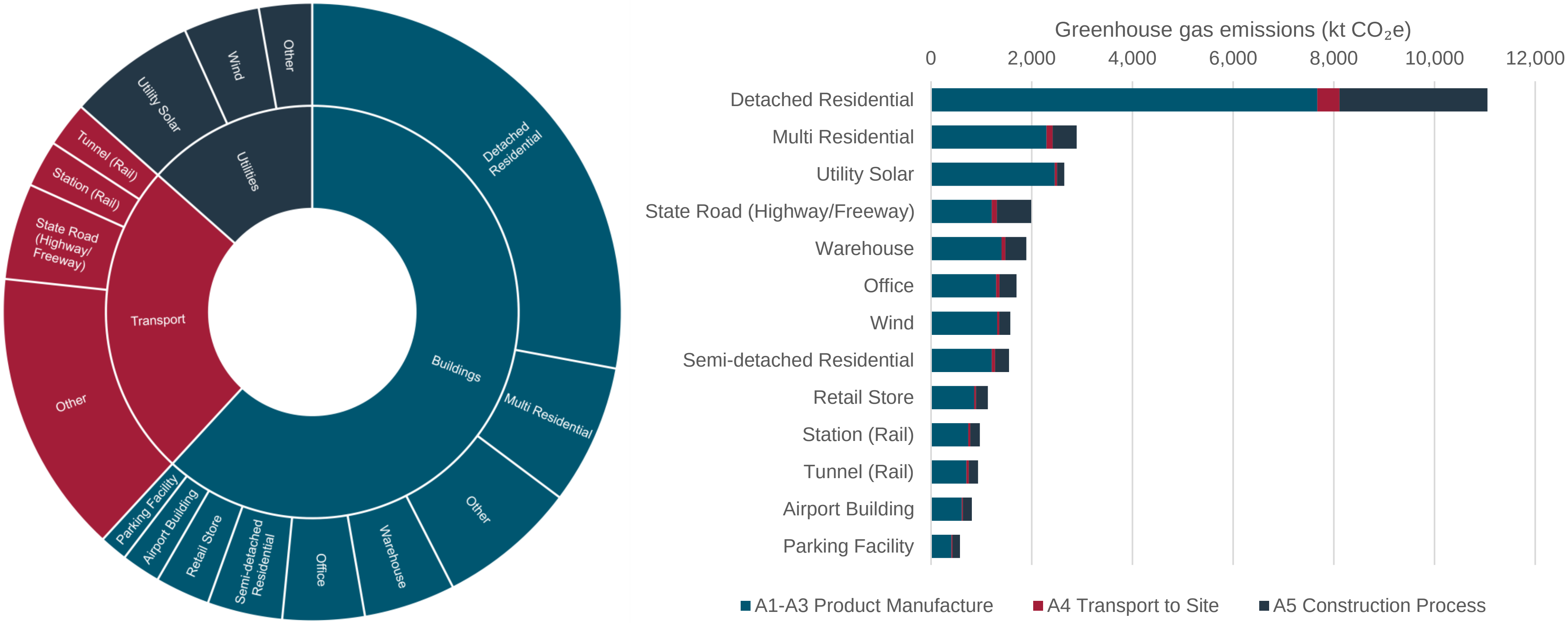

Figure 7: Embodied carbon for the 10 highest contributing typecasts for Baseline Scenario in baseline year FY 2023 (Hybrid Analysis)

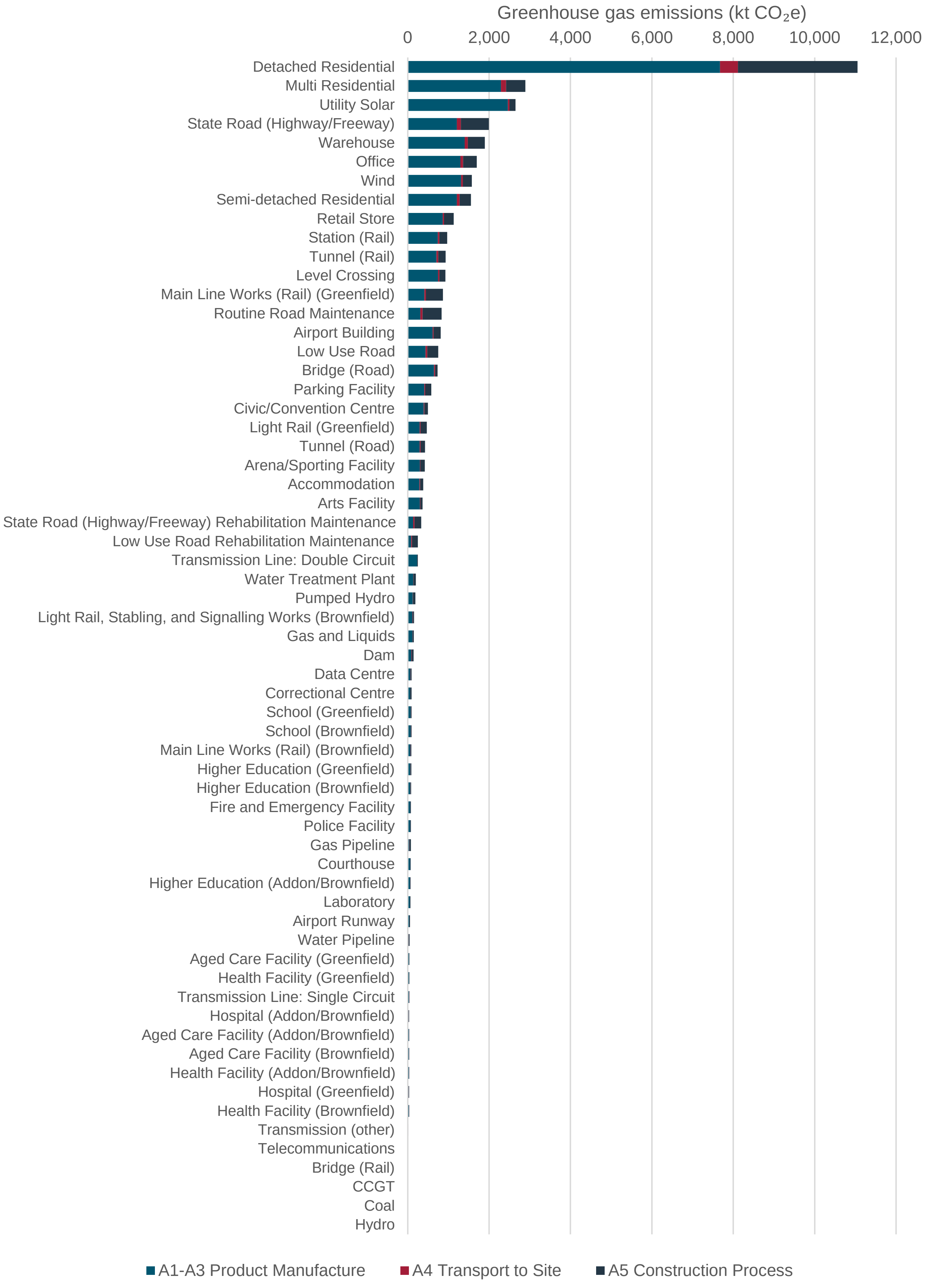

Figure 8: Embodied carbon per typecast for Baseline Scenario by life cycle module in baseline year FY 2023 (Hybrid Analysis)

Table 45: Materials with the highest contribution to carbon footprint per typecast (Hybrid Analysis)

Super sector	Project type (typecast)	Materials with highest impact
Buildings	Detached Residential	Cement, Aluminium, Building Services
Utilities	Utility Solar	PV Panels, Aluminium, Steel - Structural Elements
Buildings	Multi Residential	Cement, Steel Re-inforcement, Building Services
Utilities	Wind	Steel - Structural Elements, Plastics and Polymeric Materials, Aluminium
Transport	State Road (Highway/Freeway)	Cement, Asphalt (Highway), Steel - Structural Elements
Buildings	Warehouse	Cement, Steel - Structural Elements, Steel Re-inforcement
Buildings	Office	Cement, Aluminium, Steel Re-inforcement
Buildings	Semi-detached Residential	Cement, Aluminium, Building Services
Transport	Level Crossing	Cement, Steel - Structural Elements, Steel Re-inforcement
Transport	Bridge (Road)	Girders, Steel Re-inforcement, Cement
Transport	Tunnel (Rail)	Cement, Steel Re-inforcement, Steel - Structural Elements
Buildings	Retail Store	Steel - Structural Elements, Aluminium, Cement
Transport	Main Line Works (Rail) (Greenfield)	Cement, Steel - Structural Elements, Rock/Bluestone
Transport	Low Use Road	Cement, Steel - Structural Elements, Asphalt (Urban)
Buildings	Airport Building	Steel - Structural Elements, Aluminium, Cement
Transport	Main Line Works (Rail) (Brownfield)	Cement, Steel Re-inforcement, Steel - Structural Elements
Transport	Routine Road Maintenance	Asphalt (Urban), Aggregate, Bitumen Binders
Buildings	Parking Facility	Cement, Aluminium, Steel Re-inforcement
Transport	Tunnel (Road)	Cement, Steel Re-inforcement, Asphalt (Urban)
Transport	Station (Rail)	Cement, Steel - Structural Elements, Steel Re-inforcement
Buildings	Civic/Convention Centre	Steel - Structural Elements, Aluminium, Cement
Buildings	Arena/Sporting Facility	Steel - Structural Elements, Aluminium, Cement
Buildings	Accommodation	Cement, Building Services, Steel Re-inforcement
Buildings	Arts Facility	Steel - Structural Elements, Aluminium, Cement
Utilities	Water Treatment Plant	Cement, Steel Re-inforcement, Steel - Structural Elements
Transport	State Road (Highway/Freeway) Rehabilitation Maintenance	Asphalt (Highway), Aggregate, Bitumen Binders
Utilities	Gas and Liquids	Steel - Structural Elements, Aluminium, Cement
Transport	Light Rail (Greenfield)	Cement, Steel Re-inforcement, Steel - Structural Elements
Transport	Low Use Road Rehabilitation Maintenance	Asphalt (Urban), Aggregate, Bitumen Binders
Transport	Airport Runway	Cement, Steel Re-inforcement, Steel - Structural Elements
Utilities	Pumped Hydro	Steel - Structural Elements, Cement, Aggregate
Utilities	Gas Pipeline	Cement, Steel - Structural Elements, Steel Re-inforcement
Utilities	Transmission Line: Double Circuit	Aluminium, Steel - Structural Elements, Steel - Transmission Cable
Utilities	Dam	Cement, Steel Re-inforcement, Steel - Structural Elements

Super sector	Project type (typecast)	Materials with highest impact
Transport	Light Rail, Stabling, and Signalling Works (Brownfield)	Cement, Steel Re-inforcement, Steel - Structural Elements
Utilities	Transmission Line: Single Circuit	Aluminium, Steel - Structural Elements, Steel - Transmission Cable
Buildings	Data Centre	Cement, Steel - Structural Elements, Steel Re-inforcement
Buildings	Correctional Centre	Steel - Structural Elements, Aluminium, Cement
Buildings	School (Greenfield)	Steel - Structural Elements, Aluminium, Cement
Buildings	School (Brownfield)	Steel - Structural Elements, Aluminium, Cement
Utilities	Water Pipeline	Cement, Steel - Structural Elements, Steel Re-inforcement
Buildings	Higher Education (Greenfield)	Steel - Structural Elements, Aluminium, Cement
Buildings	Higher Education (Brownfield)	Steel - Structural Elements, Aluminium, Cement
Buildings	Fire and Emergency Facility	Steel - Structural Elements, Aluminium, Cement
Buildings	Courthouse	Steel - Structural Elements, Aluminium, Cement
Buildings	Police Facility	Steel - Structural Elements, Aluminium, Cement
Buildings	Higher Education (Addon/Brownfield)	Steel - Structural Elements, Aluminium, Cement
Buildings	Laboratory	Steel - Structural Elements, Aluminium, Cement
Buildings	Aged Care Facility (Greenfield)	Cement, Building Services, Aluminium
Buildings	Health Facility (Greenfield)	Steel - Structural Elements, Aluminium, Cement
Buildings	Aged Care Facility (Addon/Brownfield)	Cement, Building Services, Aluminium
Buildings	Hospital (Addon/Brownfield)	Steel - Structural Elements, Aluminium, Cement
Buildings	Health Facility (Addon/Brownfield)	Steel - Structural Elements, Aluminium, Cement
Buildings	Aged Care Facility (Brownfield)	Cement, Building Services, Aluminium
Buildings	Hospital (Greenfield)	Steel - Structural Elements, Aluminium, Cement
Buildings	Health Facility (Brownfield)	Steel - Structural Elements, Aluminium, Cement
Utilities	Telecommunications	Cement, Steel Re-inforcement, Steel - Structural Elements
Utilities	Transmission (other)	Copper, Cement, Aluminium
Transport	Bridge (Rail)	Girders, Steel Re-inforcement, Cement
Utilities	CCGT	No data
Utilities	Coal	No data
Utilities	Hydro	No data

Table 46: Embodied carbon (kt CO_2e) per typecast for Baseline Scenario by life cycle module in baseline year FY 2023 (Hybrid Analysis)

Project type (typecast)	A1-A3 Product Manufacture	A4 Transport to Site	A5 Construction Waste	A5 Construction	A5 Land Use Change	A5 Commissioning	Total embodied carbon
Detached Residential	7,674	441	354	725	1,858	0	**11,053**
Multi Residential	2,293	124	90	254	0	130	**2,891**
Utility Solar	2,459	42	27	58	48	12	**2,647**
State Road (Highway/Freeway)	1,205	102	66	415	184	21	**1,993**
Warehouse	1,400	79	59	127	204	25	**1,894**
Office	1,293	69	45	140	0	150	**1,697**
Wind	1,313	43	24	106	66	22	**1,573**
Semi-detached Residential	1,206	67	56	124	99	0	**1,552**
Retail Store	859	33	24	59	126	31	**1,131**
Station (Rail)	740	40	31	41	77	41	**969**
Tunnel (Rail)	706	42	38	104	0	43	**934**
Level Crossing	744	34	31	110	0	6	**924**
Main Line Works (Rail) (Greenfield)	407	41	23	219	110	67	**867**
Routine Road Maintenance	309	55	28	441	0	0	**833**
Airport Building	611	23	17	35	90	34	**810**
Low Use Road	438	42	25	159	78	8	**751**
Bridge (Road)	647	26	15	41	0	4	**734**
Parking Facility	408	22	14	44	69	21	**578**
Civic/Convention Centre	395	16	12	38	0	37	**497**
Light Rail (Greenfield)	291	25	16	45	44	46	**467**
Tunnel (Road)	292	23	18	51	0	41	**424**
Arena/Sporting Facility	299	11	8	69	0	34	**421**
Accommodation	286	17	12	33	3	32	**381**
Arts Facility	299	11	8	25	0	24	**367**
State Road (Highway/Freeway) Rehabilitation Maintenance	134	30	14	153	0	0	**331**

Project type (typecast)	A1-A3 Product Manufacture	A4 Transport to Site	A5 Construction Waste	A5 Construction	A5 Land Use Change	A5 Commissioning	Total embodied carbon
Low Use Road Rehabilitation Maintenance	85	23	9	134	0	0	**252**
Transmission Line: Double Circuit	231	3	3	5	5	2	**248**
Water Treatment Plant	131	10	7	25	14	12	**200**
Pumped Hydro	123	8	5	19	14	20	**188**
Light Rail, Stabling, and Signalling Works (Brownfield)	116	9	6	18	0	4	**153**
Gas and Liquids	117	3	2	11	6	11	**150**
Dam	91	8	5	24	12	2	**142**
Data Centre	67	4	3	12	0	12	**97**
Correctional Centre	62	2	2	11	9	10	**97**
School (Greenfield)	75	3	2	8	5	4	**96**
School (Brownfield)	75	3	2	10	0	5	**95**
Main Line Works (Rail) (Brownfield)	69	5	4	11	0	3	**91**
Higher Education (Greenfield)	63	3	2	7	9	7	**90**
Higher Education (Brownfield)	63	3	2	9	0	9	**85**
Fire and Emergency Facility	66	2	2	4	0	4	**78**
Police Facility	66	2	2	4	0	4	**77**
Gas Pipeline	36	3	2	11	14	11	**77**
Courthouse	66	2	2	4	0	2	**75**
Higher Education (Addon/Brownfield)	63	3	2	2	0	2	**70**
Laboratory	55	2	2	2	4	2	**67**
Airport Runway	39	2	2	3	4	3	**54**
Water Pipeline	24	2	1	7	11	1	**48**
Aged Care Facility (Greenfield)	30	2	1	1	5	1	**40**
Health Facility (Greenfield)	29	1	1	1	4	2	**38**
Transmission Line: Single Circuit	34	0	0	1	1	0	**36**

Project type (typecast)	A1-A3 Product Manufacture	A4 Transport to Site	A5 Construction Waste	A5 Construction	A5 Land Use Change	A5 Commissioning	Total embodied carbon
Hospital (Addon/Brownfield)	24	1	1	3	0	4	**33**
Aged Care Facility (Addon/Brownfield)	30	2	1	0	0	0	**33**
Aged Care Facility (Brownfield)	30	2	1	0	0	0	**33**
Health Facility (Addon/Brownfield)	29	1	1	1	0	1	**33**
Hospital (Greenfield)	24	1	1	1	4	2	**33**
Health Facility (Brownfield)	29	1	1	0	0	0	**30**
Transmission (other)	4	0	0	0	0	0	**5**
Telecommunications	2	0	0	0	0	0	**3**
Bridge (Rail)	1	0	0	0	0	0	**1**
CCGT	0	0	0	0	0	0	**0**
Coal	0	0	0	0	0	0	**0**
Hydro	0	0	0	0	0	0	**0**
	28,754	**1,575**	**1,130**	**3,962**	**3,178**	**967**	**39,566**

Table 47: Stored carbon (kt CO_2e) in timber for Baseline Scenario in baseline year FY 2023 (Hybrid Analysis)

GHG removals stored in wood products (kt CO_2 eq)	-2,459

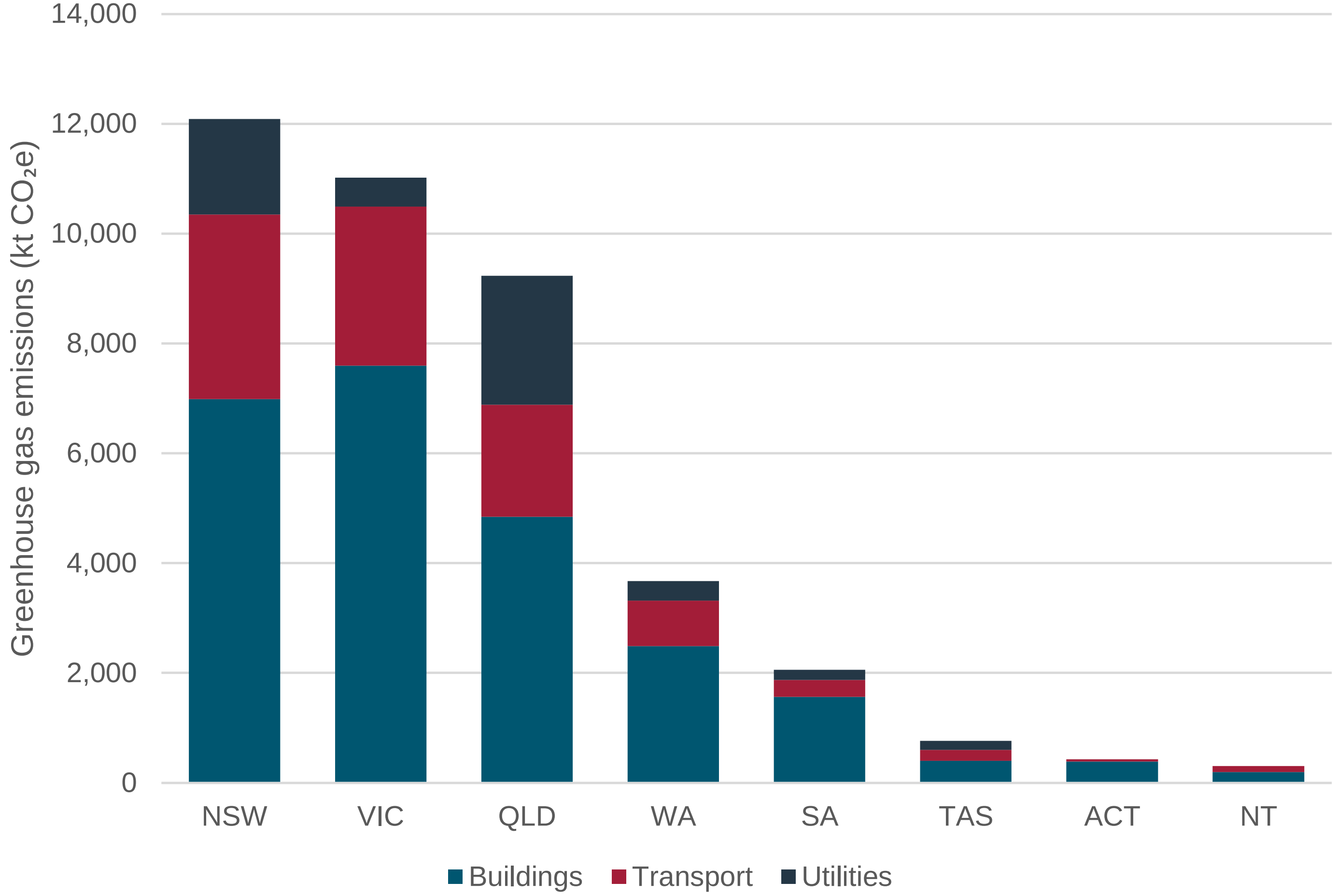

Figure 9: Embodied carbon per state for Baseline Scenario in baseline year FY 2023 (Hybrid Analysis)

Table 48: Embodied carbon (kt CO_2e) per state for Baseline Scenario by life cycle module in baseline year FY 2023 (Hybrid Analysis)

Super sector	NSW	VIC	QLD	WA	SA	TAS	ACT	NT	Total
Buildings	6,986	7,598	4,847	2,487	1,568	403	386	195	**24,469**
Transport	3,359	2,895	2,036	834	303	193	46	113	**9,778**
Utilities	1,744	527	2,349	351	184	164	0	0	**5,319**
Total	**12,089**	**11,019**	**9,231**	**3,672**	**2,055**	**761**	**432**	**308**	**39,566**

Table 49: Embodied carbon per capita (kt CO_2e pc) per state for Baseline Scenario by life cycle module in baseline year FY 2023 (Hybrid Analysis)

Super sector	NSW	VIC	QLD	WA	SA	TAS	ACT	NT	Total
Buildings	0.806	1.058	0.889	0.900	0.871	0.737	0.831	0.740	**0.902**
Transport	0.387	0.403	0.374	0.302	0.168	0.353	0.099	0.429	**0.360**
Utilities	0.201	0.073	0.431	0.127	0.102	0.300	0.000	0.000	**0.196**
Total	**1.394**	**1.534**	**1.694**	**1.329**	**1.142**	**1.390**	**0.930**	**1.169**	**1.458**

D-2-2 Baseline Scenario in FY 2027

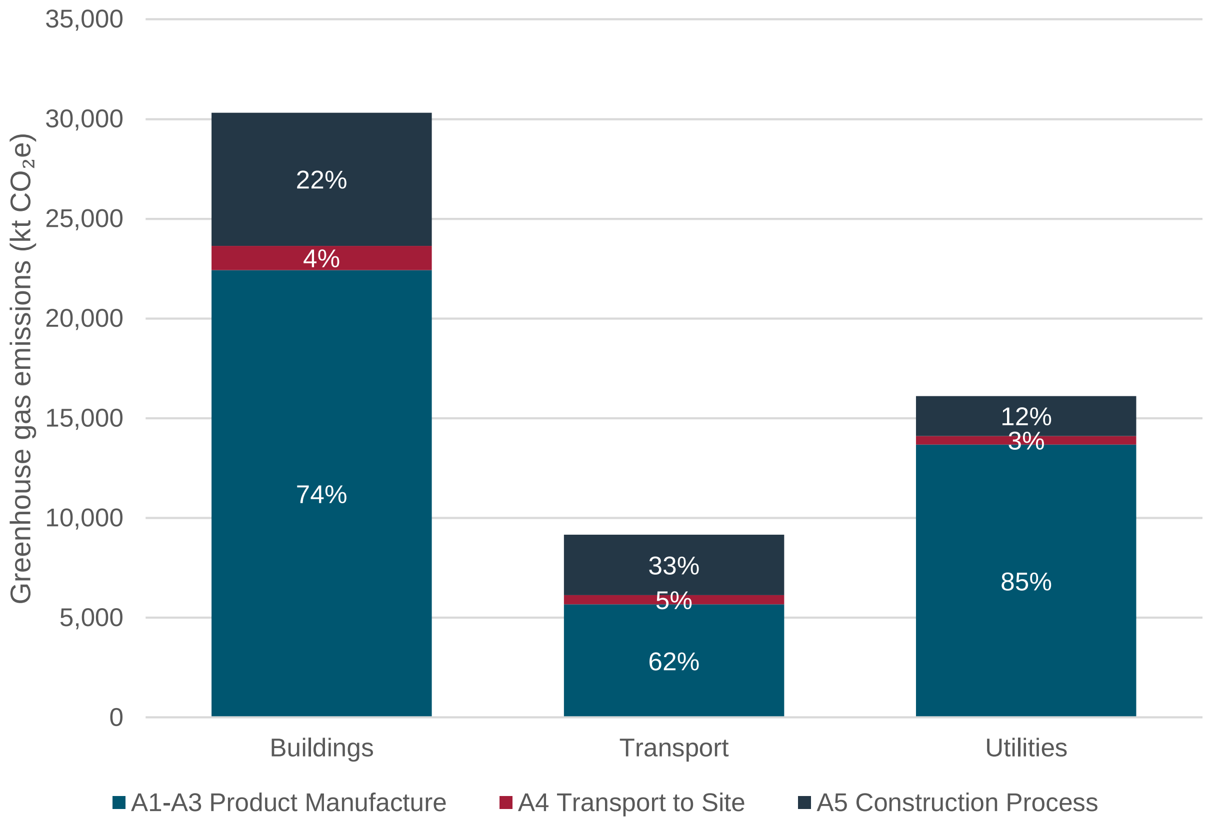

Figure 10: Embodied carbon per super sector for Baseline Scenario by life cycle module in FY 2027 (Hybrid Analysis)

Table 50: Embodied carbon (kt CO_2e) per super sector for Baseline Scenario by life cycle module in FY 2027 (Hybrid Analysis)

Super sector	A1-A3 Product Manufacture	A4 Transport to Site	A5 Construction Waste	A5 Construction	A5 Land Use Change	A5 Commissioning	Total embodied carbon
Buildings	22,429	1,214	920	2,058	3,067	632	**30,319**
Transport	5,678	450	306	1,757	620	345	**9,156**
Utilities	13,684	433	254	715	807	227	**16,120**
Total	**41,791**	**2,097**	**1,479**	**4,530**	**4,495**	**1,204**	**55,595**

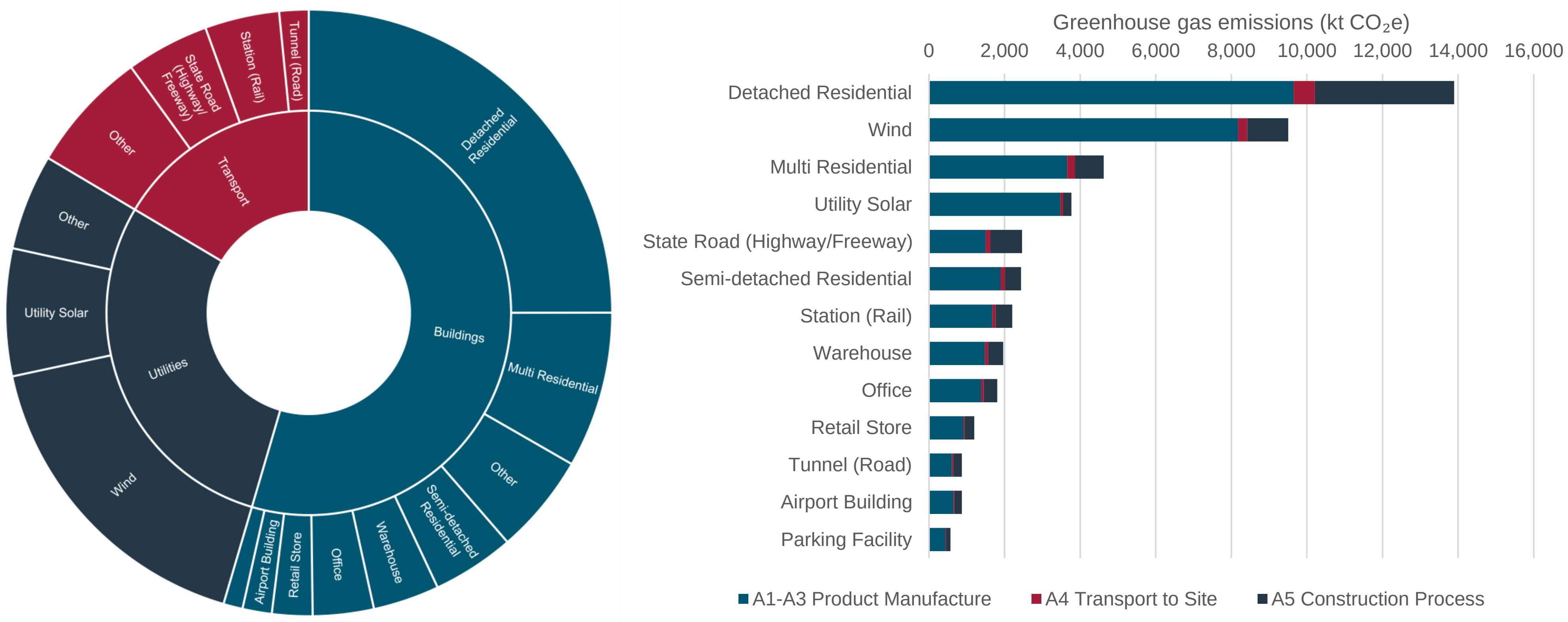

Figure 11: Embodied carbon for the 10 highest contributing typecasts for Baseline Scenario in FY 2027 (Hybrid Analysis)

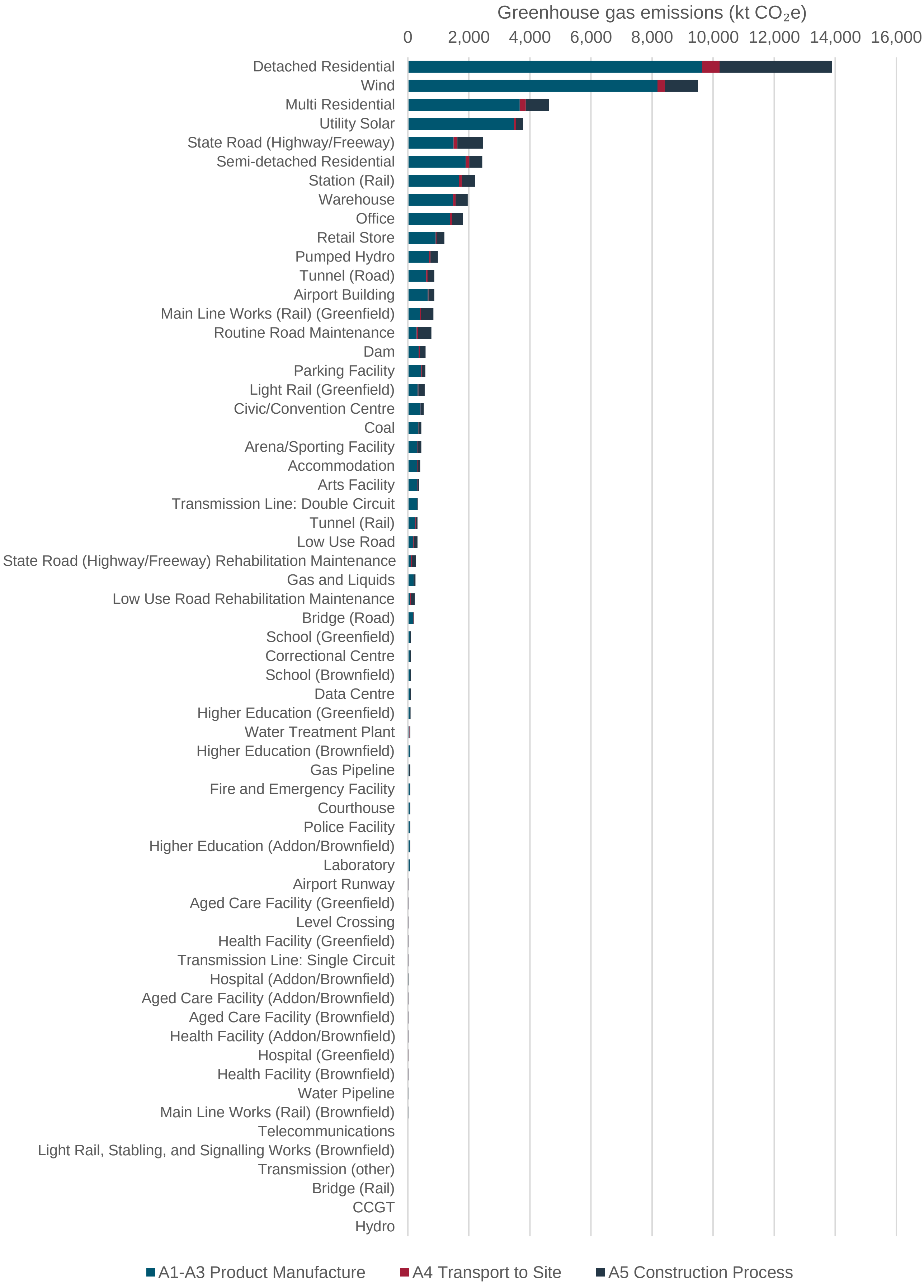

Figure 12: Embodied carbon per typecast for Baseline Scenario by life cycle module in FY 2027 (Hybrid Analysis)

Table 51: Embodied carbon (kt CO_2e) per typecast for Baseline Scenario by life cycle module in FY 2027 (Hybrid Analysis)

Project type (typecast)	A1-A3 Product Manufacture	A4 Transport to Site	A5 Construction Waste	A5 Construction	A5 Land Use Change	A5 Commissioning	Total embodied carbon
Detached Residential	9,648	560	446	895	2,343	0	**13,892**
Wind	8,178	246	151	437	408	89	**9,508**
Multi Residential	3,663	203	144	406	0	208	**4,624**
Utility Solar	3,478	71	39	61	110	12	**3,772**
State Road (Highway/Freeway)	1,501	124	82	514	217	26	**2,464**
Semi-detached Residential	1,897	112	88	179	159	0	**2,435**
Station (Rail)	1,679	88	69	92	183	94	**2,206**
Warehouse	1,482	83	62	100	216	20	**1,963**
Office	1,380	73	48	147	0	158	**1,806**
Retail Store	910	35	25	62	133	32	**1,197**
Pumped Hydro	696	46	27	64	88	66	**986**
Tunnel (Road)	606	41	37	103	0	84	**871**
Airport Building	654	25	19	38	96	37	**868**
Main Line Works (Rail) (Greenfield)	402	32	22	218	98	67	**838**
Routine Road Maintenance	287	52	26	409	0	0	**775**
Dam	357	42	20	92	61	9	**581**
Parking Facility	436	23	15	15	74	7	**571**
Light Rail (Greenfield)	327	21	18	51	81	52	**549**
Civic/Convention Centre	419	17	12	37	0	36	**522**
Coal	339	10	5	17	55	17	**443**
Arena/Sporting Facility	318	11	8	69	0	34	**441**
Accommodation	303	18	12	34	3	33	**403**
Arts Facility	318	11	8	19	0	18	**375**
Transmission Line: Double Circuit	296	4	3	3	16	2	**324**
Tunnel (Rail)	242	13	13	35	0	15	**318**
Low Use Road	178	18	10	66	38	3	**314**

Project type (typecast)	A1-A3 Product Manufacture	A4 Transport to Site	A5 Construction Waste	A5 Construction	A5 Land Use Change	A5 Commissioning	Total embodied carbon
State Road (Highway/Freeway) Rehabilitation Maintenance	107	25	11	121	0	0	**264**
Gas and Liquids	190	4	3	14	30	14	**254**
Low Use Road Rehabilitation Maintenance	78	21	9	122	0	0	**230**
Bridge (Road)	178	8	4	12	0	1	**204**
School (Greenfield)	80	3	2	5	6	3	**98**
Correctional Centre	66	3	2	8	10	8	**95**
School (Brownfield)	80	3	2	7	0	4	**95**
Data Centre	72	4	3	8	0	8	**95**
Higher Education (Greenfield)	67	3	2	6	10	6	**92**
Water Treatment Plant	54	5	3	10	9	5	**86**
Higher Education (Brownfield)	67	3	2	5	0	5	**81**
Gas Pipeline	36	3	2	11	18	11	**81**
Fire and Emergency Facility	69	3	2	3	0	3	**80**
Courthouse	69	3	2	4	0	2	**80**
Police Facility	69	3	2	1	0	1	**76**
Higher Education (Addon/Brownfield)	67	3	2	0	0	0	**71**
Laboratory	58	2	2	2	4	2	**71**
Airport Runway	32	2	2	3	4	3	**45**
Aged Care Facility (Greenfield)	31	2	1	2	5	1	**42**
Level Crossing	32	2	1	5	0	0	**40**
Health Facility (Greenfield)	30	1	1	1	4	2	**39**
Transmission Line: Single Circuit	34	0	0	0	1	0	**37**
Hospital (Addon/Brownfield)	26	1	1	3	0	4	**35**
Aged Care Facility (Addon/Brownfield)	31	2	1	0	0	0	**35**
Aged Care Facility (Brownfield)	31	2	1	0	0	0	**35**
Health Facility (Addon/Brownfield)	30	1	1	1	0	1	**34**
Hospital (Greenfield)	26	1	1	1	4	1	**34**

Project type (typecast)	A1-A3 Product Manufacture	A4 Transport to Site	A5 Construction Waste	A5 Construction	A5 Land Use Change	A5 Commissioning	Total embodied carbon
Health Facility (Brownfield)	30	1	1	0	0	0	**32**
Water Pipeline	15	1	1	5	9	1	**32**
Main Line Works (Rail) (Brownfield)	20	2	1	3	0	1	**27**
Telecommunications	8	1	0	1	3	1	**14**
Light Rail, Stabling, and Signalling Works (Brownfield)	9	1	1	1	0	0	**12**
Transmission (other)	2	0	0	0	0	0	**2**
Bridge (Rail)	0	0	0	0	0	0	**0**
CCGT	0	0	0	0	0	0	**0**
Hydro	0	0	0	0	0	0	**0**
Total	**41,791**	**2,097**	**1,479**	**4,530**	**4,495**	**1,204**	**55,595**

Table 52: Stored carbon (kt CO_2e) in timber for Baseline Scenario in FY 2027 (Hybrid Analysis)

GHG removals stored in wood products (kt CO_2 eq)	-3,094

Table 53: Embodied carbon (kt CO_2e) per state for Baseline Scenario by life cycle module in FY 2027 (Hybrid Analysis)

Super sector	NSW	VIC	QLD	WA	SA	TAS	ACT	NT	Total
Buildings	8,527	8,747	6,848	3,558	1,523	408	460	250	**30,319**
Transport	4,190	2,589	909	272	962	116	25	92	**9,156**
Utilities	4,452	3,329	4,641	620	327	1,109	11	1,631	**16,120**
Total	**17,168**	**14,665**	**12,398**	**4,449**	**2,812**	**1,633**	**496**	**1,973**	**55,595**

D-2-3 Mid-level Decarbonisation Scenario in FY 2027

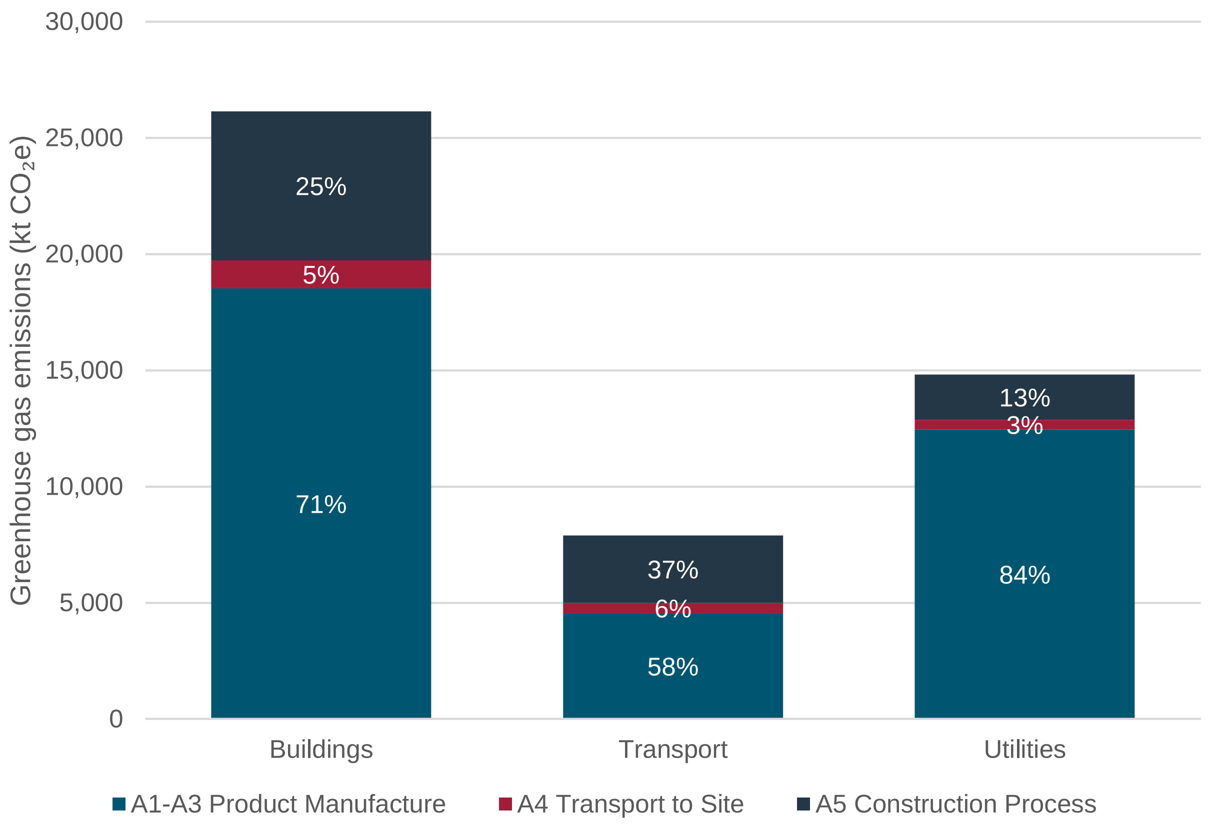

Figure 46:: Embodied carbon per super sector for Mid-level Decarbonisation Scenario by life cycle module in FY 2027 (Hybrid Analysis)

Table 54: Embodied carbon (kt CO_2e) per super sector for Mid-level Decarbonisation Scenario by life cycle module in FY 2027 (Hybrid Analysis)

Super sector	A1-A3 Product Manufacture	A4 Transport to Site	A5 Construction Waste	A5 Construction	A5 Land Use Change	A5 Commissioning	Total embodied carbon
Buildings	18,533	1,201	746	2,002	3,067	601	**26,150**
Transport	4,553	448	249	1,706	620	328	**7,904**
Utilities	12,458	421	226	691	807	216	**14,820**
Total	**35,544**	**2,070**	**1,221**	**4,399**	**4,495**	**1,145**	**48,874**

D-2-4 Maximum Decarbonisation Scenario in FY 2027

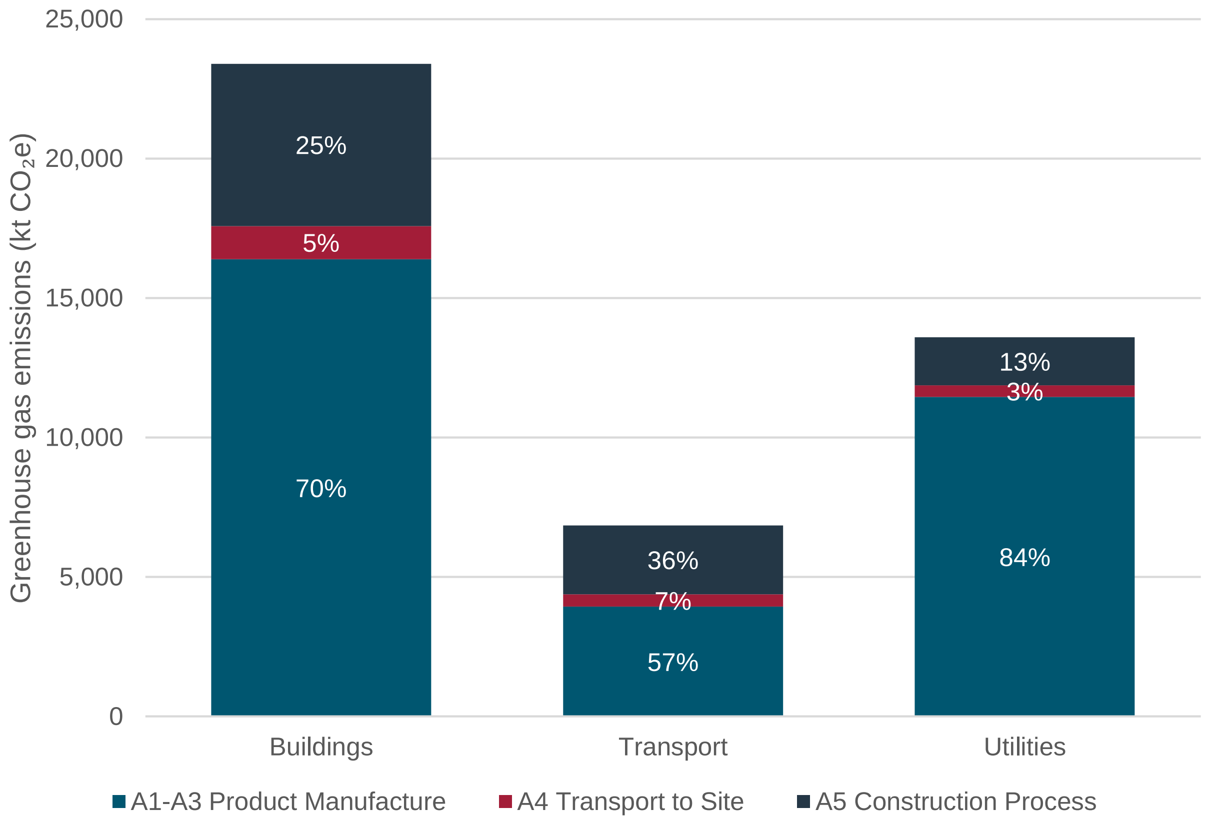

Figure 47: Embodied carbon per super sector for Maximum Decarbonisation Scenario by life cycle module in FY 2027 (Hybrid Analysis)

Table 55: Embodied carbon (kt CO_2e) per super sector for Maximum Decarbonisation Scenario by life cycle module in FY 2027 (Hybrid Analysis)

Super sector	A1-A3 Product Manufacture	A4 Transport to Site	A5 Construction Waste	A5 Construction	A5 Land Use Change	A5 Commissioning	Total embodied carbon
Buildings	16,403	1,187	660	1,633	3,067	456	**23,406**
Transport	3,938	446	219	1,381	620	249	**6,854**
Utilities	11,461	408	211	546	807	164	**13,598**
Total	**31,803**	**2,041**	**1,090**	**3,560**	**4,495**	**868**	**43,858**

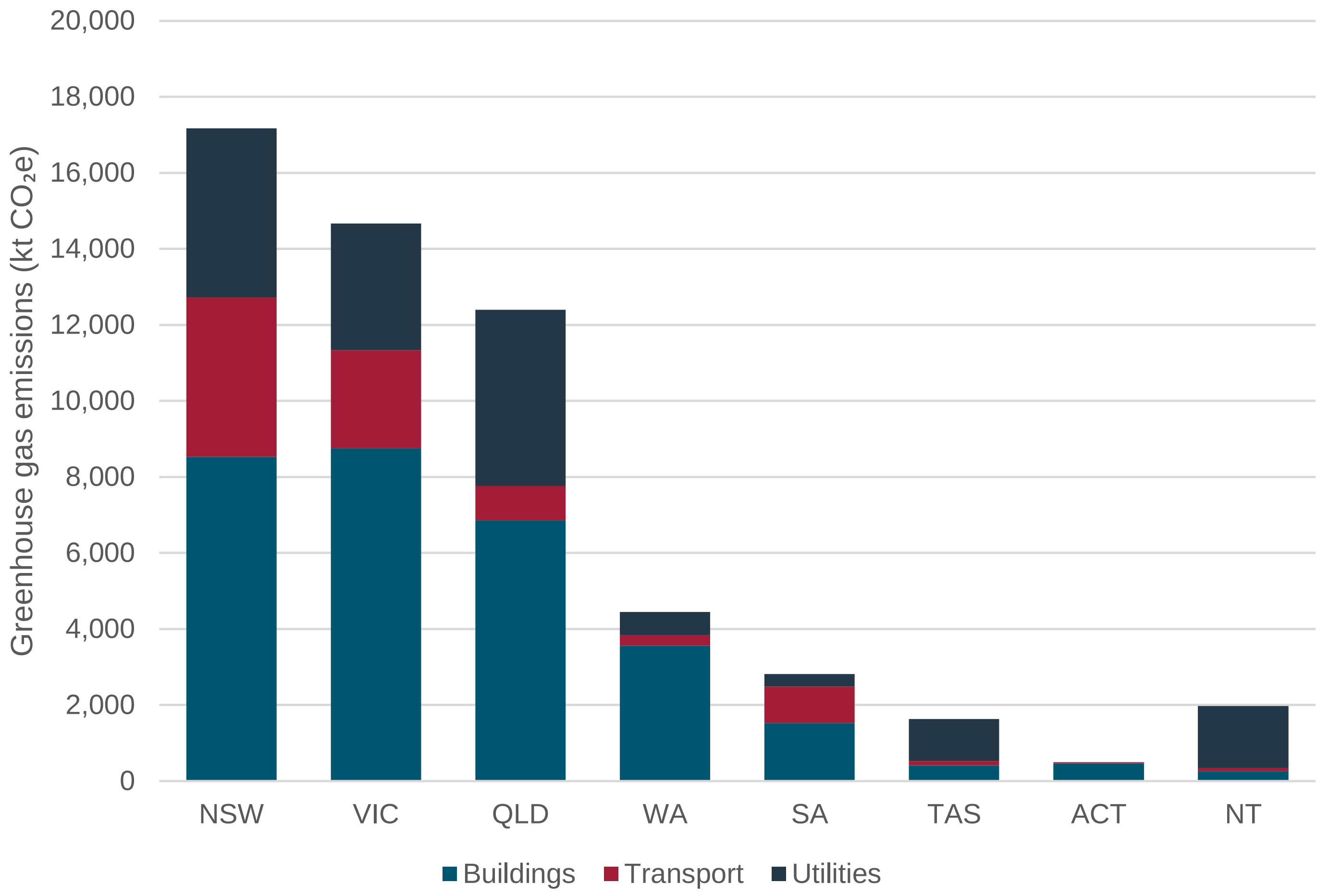

Figure 48: Embodied carbon per state for Baseline Scenario in FY 2027 (Hybrid Analysis)

Appendix E Emission intensities

Emissions intensities are provided for each typecast using a physical unit (where available) in Table 56. 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 57.

Cost intensities are in FY2021 dollars and relate to material spend only, excluding labour, professional services, plant, equipment and GST. 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." All other elements of the fitout should be excluded.

These carbon intensity benchmarks are in FY2021 dollars. They are relative to material spend only, excluding labour, professional services, plant, equipment and GST.

As material-only costs are not always available, the "Material share of capex" column provides a conversion from total project cost to material cost. Within Infrastructure Australia's Market Capacity Intelligence System, the total project must exclude the cost of land, taxes and local council fees. In the absence of specific data per project, Infrastructure Australia applies a multiplier of 90% to a declared project cost to convert it to a suitable total project cost for use in these calculations. For services, this report assumes that 40% of total cost is material-related for mechanical, vertical transportation and plumbing/hydraulic services, with 20% of the cost as material-related for electrical, fire and other services.

Table 56: Emission intensities based on typecast unit

Typecast	Product stage (A1-A3) Emission intensity (kg CO_2e/unit)			Transport (A4) Emission intensity (kg CO_2e/unit)			Construction (A5) Emission intensity (kg CO_2e/unit)			Typecast unit
	Low	**Mid**	**High**	**Low**	**Mid**	**High**	**Low**	**Mid**	**High**	
Airport Building	542	722	903	20.6	27.5	34.4	77.5	103	129	m^2 GFA
Higher Education (Addon/Brownfield)	494	658	823	20.4	27.2	33.9	20.2	26.9	33.6	m^2 GFA
Higher Education (Brownfield)	494	658	823	20.4	27.2	33.9	121	161	202	m^2 GFA
Higher Education (Greenfield)	494	658	823	20.4	27.2	33.9	112	149	186	m^2 GFA
School (Brownfield)	590	787	984	21.2	28.3	35.4	128	171	214	m^2 GFA
School (Greenfield)	590	787	984	21.2	28.3	35.4	98.2	131	164	m^2 GFA
Aged Care Facility (Addon/Brownfield)	250	333	417	14.4	19.1	23.9	14.7	19.6	24.5	m^2 GFA

Typecast	Product stage (A1-A3) Emission intensity (kg CO_2e/unit)			Transport (A4) Emission intensity (kg CO_2e/unit)			Construction (A5) Emission intensity (kg CO_2e/unit)			Typecast unit
Aged Care Facility (Brownfield)	250	333	417	14.4	19.1	23.9	11.1	14.8	18.6	m^2 GFA
Aged Care Facility (Greenfield)	250	333	417	14.4	19.1	23.9	29.1	38.8	48.5	m^2 GFA
Health Facility (Addon/Brownfield)	566	755	944	21.5	28.7	35.9	59.5	79.3	99.1	m^2 GFA
Health Facility (Brownfield)	566	755	944	21.5	28.7	35.9	17.7	23.6	29.5	m^2 GFA
Health Facility (Greenfield)	566	755	944	21.5	28.7	35.9	73.8	98.3	123	m^2 GFA
Hospital (Addon/Brownfield)	483	645	806	20.8	27.8	34.7	156	208	260	m^2 GFA
Hospital (Greenfield)	483	645	806	20.8	27.8	34.7	67.8	90.4	113	m^2 GFA
Correctional Centre	585	780	974	22.6	30.1	37.6	193	258	322	m^2 GFA
Courthouse	615	820	1,025	23.0	30.7	38.4	68.6	91.5	114	m^2 GFA
Fire and Emergency Facility	615	820	1,025	23.0	30.7	38.4	77.9	104	130	m^2 GFA
Police Facility	615	820	1,025	23.0	30.7	38.4	54.2	72.2	90.3	m^2 GFA
Arts Facility	615	819	1,024	22.0	29.3	36.6	106	141	176	m^2 GFA
Civic/Convention Centre	518	690	863	21.0	28.0	35.0	110	146	183	m^2 GFA
Laboratory	518	691	863	22.0	29.3	36.6	49.6	66.2	82.7	m^2 GFA
Office	362	482	603	19.2	25.6	32.0	93.4	125	156	m^2 GFA
Accommodation	289	386	482	17.1	22.8	28.5	76.9	102.6	128	m^2 GFA
Detached Residential	233	310	388	13.5	17.9	22.4	32.6	43.4	54.3	m^2 GFA
Multi Residential	315	419	524	17.3	23.1	28.8	65.1	86.8	108	m^2 GFA
Semi-detached Residential	233	310	388	13.5	18.0	22.5	34.1	45.5	56.8	m^2 GFA
Retail Store	566	755	944	21.5	28.7	35.8	75.4	101	126	m^2 GFA
Arena/Sporting Facility	615	819	1,024	22.0	29.3	36.6	226	301	376	m^2 GFA
Data Centre	259	346	432	14.2	18.9	23.7	81.6	109	136	m^2 GFA
Parking Facility	362	482	603	19.1	25.5	31.9	54.1	72.1	90.1	m^2 GFA
Warehouse	260	346	433	14.6	19.5	24.4	36.6	48.8	61.0	m^2 GFA
Airport Runway	0.552	0.736	0.920	0.033	0.044	0.055	0.123	0.164	0.204	$ material spend
Bridge (Rail)	1.27	1.70	2.12	0.061	0.081	0.102	0.134	0.179	0.224	$ material spend
Light Rail (Greenfield)	0.478	0.637	0.797	0.035	0.047	0.059	0.175	0.234	0.292	$ material spend

Typecast	Product stage (A1-A3) Emission intensity (kg CO_2e/unit)			Transport (A4) Emission intensity (kg CO_2e/unit)			Construction (A5) Emission intensity (kg CO_2e/unit)			Typecast unit
Light Rail, Stabling, and Signalling Works (Brownfield)	0.480	0.640	0.800	0.039	0.052	0.065	0.115	0.154	0.192	$ material spend
Main Line Works (Rail) (Brownfield)	0.478	0.637	0.796	0.031	0.042	0.052	0.122	0.163	0.204	$ material spend
Main Line Works (Rail) (Greenfield)	0.228	0.304	0.380	0.020	0.027	0.034	0.173	0.231	0.289	$ material spend
Station (Rail)	0.684	0.911	1.14	0.037	0.050	0.062	0.104	0.139	0.173	$ material spend
Tunnel (Rail)	0.646	0.861	1.08	0.040	0.053	0.067	0.171	0.227	0.284	$ material spend
Bridge (Road)	1.27	1.70	2.12	0.054	0.073	0.091	0.122	0.163	0.203	$ material spend
Low Use Road	0.343	0.457	0.572	0.033	0.045	0.056	0.152	0.203	0.253	$ material spend
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
Routine Road Maintenance	0.137	0.183	0.229	0.025	0.033	0.041	0.209	0.278	0.348	$ material spend
State Road (Highway/Freeway)	0.431	0.517	0.718	0.036	0.043	0.060	0.179	0.215	0.299	$ material spend
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
Tunnel (Road)	0.516	0.688	0.860	0.037	0.049	0.061	0.192	0.256	0.320	$ material spend
Level Crossing	0.694	0.926	1.16	0.033	0.044	0.056	0.137	0.183	0.228	$ material spend
CCGT	No data	No data	No data	No data	No data	No data	No data	No data	No data	kW
Coal	n/a	1.60	n/a	n/a	0.049	n/a	n/a	0.183	n/a	$ material spend
Gas and Liquids	n/a	3,312	n/a	n/a	74.4	n/a	n/a	568	n/a	kW
Gas Pipeline	0.151	0.202	0.252	0.014	0.018	0.023	0.099	0.132	0.165	$ material spend
Hydro	No data	No data	No data	No data	No data	No data	No data	No data	No data	kW
Pumped Hydro	n/a	508	n/a	n/a	32.1	n/a	n/a	131	n/a	kW
Transmission (other)	n/a	1.80	n/a	n/a	0.083	n/a	n/a	0.223	n/a	$ material spend
Transmission Line: Double Circuit	n/a	709,633	n/a	n/a	9,435	n/a	n/a	23,757	n/a	'000 km
Transmission Line: Single Circuit	n/a	376,661	n/a	n/a	4,647	n/a	n/a	11,743	n/a	'000 km
Utility Solar	n/a	4,203	n/a	n/a	71.9	n/a	n/a	146	n/a	kW
Wind	n/a	554	n/a	n/a	16.9	n/a	n/a	50	n/a	kW
Telecommunications	0.520	0.693	0.866	0.137	0.183	0.229	0.157	0.210	0.262	$ material spend
Dam	0.616	0.821	1.026	0.064	0.085	0.106	0.210	0.280	0.350	$ material spend
Water Pipeline	0.147	0.197	0.246	0.016	0.021	0.026	0.063	0.084	0.105	$ material spend
Water Treatment Plant	0.649	0.865	1.082	0.054	0.072	0.090	0.222	0.296	0.370	$ material spend

Table 57: Emissions intensities based on material spend

Typecast	Material share of capex			Product stage (A1-A3) Emission intensity (kg CO_2e/$ material spend)			Transport (A4) Emission intensity (kg CO_2e/$ material spend)			Construction (A5) Emission intensity (kg CO_2e/$ material spend)		
	Low	Mid	High	Low	Mid	High	Low	Mid	High	Low	Mid	High
Airport Building	23%	30%	38%	0.396	0.528	0.660	0.015	0.020	0.025	0.057	0.076	0.094
Higher Education (Addon/Brownfield)	22%	29%	36%	0.386	0.514	0.643	0.016	0.021	0.027	0.016	0.021	0.026
Higher Education (Brownfield)	22%	29%	36%	0.386	0.514	0.643	0.016	0.021	0.027	0.095	0.126	0.158
Higher Education (Greenfield)	22%	29%	36%	0.386	0.514	0.643	0.016	0.021	0.027	0.087	0.117	0.146
School (Brownfield)	24%	32%	40%	0.405	0.540	0.676	0.015	0.019	0.024	0.088	0.117	0.147
School (Greenfield)	24%	32%	40%	0.405	0.540	0.676	0.015	0.019	0.024	0.067	0.090	0.112
Aged Care Facility (Addon/Brownfield)	26%	34%	43%	0.348	0.465	0.581	0.020	0.027	0.033	0.021	0.027	0.034
Aged Care Facility (Brownfield)	26%	34%	43%	0.348	0.465	0.581	0.020	0.027	0.033	0.016	0.021	0.026
Aged Care Facility (Greenfield)	26%	34%	43%	0.348	0.465	0.581	0.020	0.027	0.033	0.041	0.054	0.068
Health Facility (Addon/Brownfield)	23%	31%	39%	0.401	0.535	0.668	0.015	0.020	0.025	0.042	0.056	0.070
Health Facility (Brownfield)	23%	31%	39%	0.401	0.535	0.668	0.015	0.020	0.025	0.013	0.017	0.021
Health Facility (Greenfield)	23%	31%	39%	0.401	0.535	0.668	0.015	0.020	0.025	0.052	0.070	0.087
Hospital (Addon/Brownfield)	22%	29%	36%	0.378	0.504	0.630	0.016	0.022	0.027	0.122	0.162	0.203
Hospital (Greenfield)	22%	29%	36%	0.378	0.504	0.630	0.016	0.022	0.027	0.053	0.071	0.088
Correctional Centre	24%	32%	41%	0.403	0.538	0.672	0.016	0.021	0.026	0.134	0.178	0.223
Courthouse	24%	32%	40%	0.410	0.546	0.683	0.015	0.020	0.026	0.046	0.061	0.076
Fire and Emergency Facility	24%	32%	40%	0.410	0.546	0.683	0.015	0.020	0.026	0.052	0.069	0.087
Police Facility	24%	32%	40%	0.410	0.546	0.683	0.015	0.020	0.026	0.036	0.048	0.060
Arts Facility	24%	32%	40%	0.410	0.546	0.683	0.015	0.020	0.024	0.071	0.094	0.118
Civic/Convention Centre	22%	30%	37%	0.391	0.521	0.652	0.016	0.021	0.026	0.083	0.111	0.138
Laboratory	22%	30%	37%	0.391	0.522	0.652	0.017	0.022	0.028	0.037	0.050	0.062
Office	19%	26%	32%	0.341	0.455	0.569	0.018	0.024	0.030	0.088	0.118	0.147
Accommodation	25%	34%	42%	0.326	0.435	0.544	0.019	0.026	0.032	0.087	0.116	0.145
Detached Residential	26%	35%	43%	0.358	0.477	0.597	0.021	0.028	0.034	0.050	0.067	0.083
Multi Residential	25%	33%	42%	0.318	0.424	0.531	0.018	0.023	0.029	0.066	0.088	0.110
Semi-detached Residential	26%	35%	43%	0.358	0.477	0.597	0.021	0.028	0.035	0.052	0.070	0.087
Retail Store	23%	31%	39%	0.401	0.535	0.668	0.015	0.020	0.025	0.053	0.071	0.089

Typecast	Material share of capex			Product stage (A1-A3) Emission intensity (kg CO_2e/$ material spend)			Transport (A4) Emission intensity (kg CO_2e/$ material spend)			Construction (A5) Emission intensity (kg CO_2e/$ material spend)		
Arena/Sporting Facility	24%	32%	40%	0.410	0.546	0.683	0.015	0.020	0.024	0.151	0.201	0.251
Data Centre	29%	38%	48%	0.403	0.538	0.672	0.022	0.029	0.037	0.127	0.169	0.212
Parking Facility	19%	26%	32%	0.341	0.455	0.569	0.018	0.024	0.030	0.051	0.068	0.085
Warehouse	29%	38%	48%	0.404	0.538	0.673	0.023	0.030	0.038	0.057	0.076	0.095
Airport Runway	21%	28%	35%	0.552	0.736	0.920	0.033	0.044	0.055	0.123	0.164	0.204
Bridge (Rail)	23%	31%	39%	1.27	1.70	2.12	0.061	0.081	0.102	0.134	0.179	0.224
Light Rail (Greenfield)	30%	40%	50%	0.478	0.637	0.797	0.035	0.047	0.059	0.175	0.234	0.292
Light Rail, Stabling, and Signalling Works (Brownfield)	31%	41%	51%	0.480	0.640	0.800	0.039	0.052	0.065	0.115	0.154	0.192
Main Line Works (Rail) (Brownfield)	31%	41%	51%	0.478	0.637	0.796	0.031	0.042	0.052	0.122	0.163	0.204
Main Line Works (Rail) (Greenfield)	14%	18%	23%	0.228	0.304	0.380	0.020	0.027	0.034	0.173	0.231	0.289
Station (Rail)	33%	45%	56%	0.684	0.911	1.14	0.037	0.050	0.062	0.104	0.139	0.173
Tunnel (Rail)	13%	18%	22%	0.646	0.861	1.08	0.040	0.053	0.067	0.171	0.227	0.284
Bridge (Road)	23%	31%	39%	1.27	1.70	2.12	0.054	0.073	0.091	0.122	0.163	0.203
Low Use Road	18%	23%	29%	0.343	0.457	0.572	0.033	0.045	0.056	0.152	0.203	0.253
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
Routine Road Maintenance	25%	33%	42%	0.137	0.183	0.229	0.025	0.033	0.041	0.209	0.278	0.348
State Road (Highway/Freeway)	17%	20%	28%	0.431	0.517	0.718	0.036	0.043	0.060	0.179	0.215	0.299
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
Tunnel (Road)	20%	26%	33%	0.516	0.688	0.860	0.037	0.049	0.061	0.192	0.256	0.320
Level Crossing	23%	30%	38%	0.694	0.926	1.16	0.033	0.044	0.056	0.137	0.183	0.228
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
Coal	n/a	n/a	n/a	n/a	1.60	n/a	n/a	0.049	n/a	n/a	0.183	n/a
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
Gas Pipeline	17%	23%	29%	0.151	0.202	0.252	0.014	0.018	0.023	0.099	0.132	0.165
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
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
Transmission (other)	n/a	n/a	n/a	n/a	1.80	n/a	n/a	0.083	n/a	n/a	0.223	n/a
Transmission Line: Double Circuit	n/a	n/a	n/a	n/a	3.90	n/a	n/a	0.052	n/a	n/a	0.130	n/a
Transmission Line: Single Circuit	n/a	n/a	n/a	n/a	4.10	n/a	n/a	0.051	n/a	n/a	0.128	n/a

Typecast	Material share of capex			Product stage (A1-A3) Emission intensity (kg CO_2e/$ material spend)			Transport (A4) Emission intensity (kg CO_2e/$ material spend)			Construction (A5) Emission intensity (kg CO_2e/$ material spend)		
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
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
Telecommunications	22%	29%	36%	0.520	0.693	0.866	0.137	0.183	0.229	0.157	0.210	0.262
Dam	18%	23%	29%	0.616	0.821	1.03	0.064	0.085	0.106	0.210	0.280	0.350
Water Pipeline	17%	23%	29%	0.147	0.197	0.246	0.016	0.021	0.026	0.063	0.084	0.105
Water Treatment Plant	20%	27%	33%	0.649	0.865	1.08	0.054	0.072	0.090	0.222	0.296	0.370

Appendix F

IO-LCA comparison

For comparison purposes, upfront embodied carbon emissions for FY 2023 are calculated using an economy-wide input-output LCA (IO-LCA) approach. According to the national IO tables (ABS, 2023), Australia's infrastructure and building sector (new builds only) covers the following industries:

1. Residential Building Construction (Residential)
2. Non-residential Building Construction (Non-residential)
3. Heavy and Civil Engineering Construction (Civil)
4. Construction Services

F-1 Manufacture of building products (modules A1-A3)

Emissions from manufacturing building products are calculated by multiplying the material quantities with the IO-LCA emission factors presented in the Environmental Performance in Construction (EPiC) Database developed by the University of Melbourne (Crawford, Stephan, & Prideaux, 2019).

When emission factors for certain materials are unavailable in the EPiC database, emission factors in the Integrated Carbon Metrics Embodied Carbon Life Cycle Inventory (ICM) Database are used (Wiedmann, Teh, & Yu, 2019). See Table 58 for a complete list of emissions factors.

F-2 Transport to site (module A4)

Transport to site is modelled as a mixture of truck, rail and sea freight to get materials from their original supplier to the construction site. The carbon emissions are same as in the Hybrid Analysis in Appendix D, which uses a consumption-based approach. In other words, all freight is included, including freight that occurs overseas.

F-3 Construction services (module A5)

According to Liersch (2022), the embodied emissions related to Construction Services in FY 2019 were 17,274 kt CO_2e. These emissions are scaled according to the total economic value of Australia's infrastructure and building pipeline in FY 2023 (15,583 kt CO_2e).

The estimated embodied emissions related to Construction Services in FY 2023 are allocated across Residential Building (45%), Non-residential Building (34%), and Heavy and Civil Engineering (21%) – based on their individual contributions to the total economic value of Australia's infrastructure and building pipeline.

Table 58: IO-LCA emission factors for building products

Material	Units	Conversion (t/unit)	Emission factor (kt CO_2e/t)	Variation*	Notes
Aggregate	tonnes	1	3.60E-05	414%	Gravel, EPiC
Aluminium	tonnes	1	2.94E-02	170%	Aluminium extruded, EPiC
Asphalt (Urban)	tonnes	1	2.00E-04	331%	Asphalt, EPiC
Asphalt (Highway)	tonnes	1	2.00E-04	273%	Asphalt, EPiC
Bathroom Fitout	tonnes	1	1.75E-03	133%	Scaled up the process emissions based on sanitary ceramic (Integrated Carbon Metrics (ICM) Embodied Carbon Life Cycle Inventory)
Bitumen Binders	litre	0.001036	8.08E-04	212%	Bitumen, at refinery (Integrated Carbon Metrics (ICM) Embodied Carbon Life Cycle Inventory)
Bricks	tonnes	1	3.20E-04	148%	Clay brick, EPiC
Building Services	square metres	1	8.63E-05	3%	Scaled up the process emissions by 115% (based on ICM Embodied Carbon Life Cycle Inventory - Steel electric)
Carpet	square metres	0.0012	4.72E-02	567%	Average of tufted carpet - wool prestige and quality, EPiC
Cement	tonnes	1	1.30E-03	156%	Portland cement, EPiC
Ceramic Tiles	tonnes	1	1.30E-03	289%	Ceramic tile, EPiC
Copper	tonnes	1	1.01E-02	230%	Copper pipe, EPiC
Electrical Bulk	tonnes	1	1.70E-03	44%	Have scaled up the process emissions by 115% (based on Steel electric)
Fiberglass	tonnes	1	7.53E-04	44%	Scaled up the EPD results based on ICM Embodied Carbon Life Cycle Inventory for Glass Fibre (114%)
Girders	tonnes	1	3.41E-03	110%	Scaled up process LCA EF by 111% based on ICM Embodied Carbon Life Cycle Inventory
Glass	tonnes	1	2.00E-03	102%	Flat glass, EPiC
Glass (HV Insulators)	tonnes	1	2.22E-03	206%	Solar glass (Integrated Carbon Metrics (ICM) Embodied Carbon Life Cycle Inventory)
Insulation	tonnes	1	4.00E-03	256%	Glasswool insulation, EPiC
Kitchen Fitout	tonnes	1	1.75E-03	66%	Assumed as bathroom fitouts
Linemarking & Road Furniture	metre	0.01	3.79E-02	1194%	Scaled up process LCA EF by 111% based on ICM Embodied Carbon Life Cycle Inventory
Paint	tonnes	1	6.80E-03	297%	Water-based paint, EPiC
Plasterboard	square metres	0.00721	8.04E-04	352%	10mm plasterboard, EPiC
Plastics and Polymeric Materials	tonnes	1	4.20E-03	129%	Unplasticised polyvinyl chloride (uPVC), EPiC
Plywood	square metres	0.0074	6.13E-03	600%	Plywood, assumed density = 600 kg/m3, EPiC

Material	Units	Conversion (t/unit)	Emission factor (kt CO_2e/t)	Variation*	Notes
PV Panels	MW	50	1.21E-02	158%	Scaled up the EPD results based on ICM Embodied Carbon Life Cycle Inventory
Rail Track	metre	0.055	3.69E-03	111%	Scaled up EPD results by 111% based on ICM Embodied Carbon Life Cycle Inventory
Rock/Bluestone	tonnes	1	3.60E-05	414%	Assumed as aggregates, which is Gravel in EPiC
Sand	tonnes	1	2.40E-05	668%	Sand, EPiC
Stainless Steel	tonnes	1	7.20E-03	84%	Stainless steel sheet, EPiC
Steel - Structural Elements	tonnes	1	2.90E-03	94%	Hot rolled structural steel, EPiC
Steel - Transmission Cable	tonnes	1	2.10E-03	133%	Steel bar, EPiC
Steel Re-inforcement	tonnes	1	2.10E-03	133%	Steel bar, EPiC
Timber	cubic metres	0.551	1.06E-03	371%	Softwood kiln-dried, EPiC

*compared to process LCA. For example, IO-LCA emission factor for aggregates is x4 compared to process LCA emission factor.

Construction energy, gas, water, and wastes (module A5)

This covers direct emissions from electricity, gas, and water use, as well as construction waste management. Direct emissions are sourced from Australia's National Greenhouse Gas Accounts (DCCEEW, 2023c) and allocated across these services, based on the monetary transactions within the economy. For this analysis, it is assumed that the total direct emissions in FY 2023 and FY 2020 are same.

Table 59: Emissions related to construction services, electricity, gas, water, and construction wastes

Industry	Electricity	Gas	Water	Waste	Construction services	Total
Direct GHG emissions in FY 2020 (kt CO_2e)	152,460	1,888	2,187	10,651		
Residential (kt CO_2e)	95	0	145	207	6,985	7,431
Non-residential (kt CO_2e)	195	0	13	72	5,315	5,596
Civil (kt CO_2e)	950	0	20	266	3,383	4,619

Land use change (module A5)

Land use change includes the GHG emissions caused by converting one land use type to another. It applies to greenfield developments only and is not relevant to brownfield developments (as the land has already been developed and there is no land use change). It is particularly significant where forested areas are cleared, or where wetlands are drained.

All land use change is assumed to occur in module A5. There was some confusion during the stakeholder consultation process as to whether land use change impacts could also occur in module A0 (pre-construction). The GHG emissions are same as in the Hybrid Analysis in Appendix D.

Summary

Upfront carbon emissions in Australia's pipeline of infrastructure and building projects, calculated using an IO-LCA approach, are estimated to be 69 Mt CO_2e in FY 2023 (Table 60). This is nearly twice the upfront emissions calculated in the Pipeline Analysis and Hybrid Analysis using a Process LCA approach. The differences are largely driven by the differences in the emission factors of the building products. IO-LCA considers all monetary transactions within the economy including capital goods and services consumed by a sector including, for example, capital goods, banking and insurance. However, a Process LCA approach typically excludes capital goods and services from the LCA system boundary.

Table 60: Upfront embodied emissions from the built environment in FY 2023 (Input-Output LCA)

	Residential	Non-residential	Civil	Total
A1-A3 Product Manufacture	18,725	9,406	17,983	**46,115**
A4 Transport to Site	649	302	624	**1,575**
A5 Construction Waste	207	72	266	**545**
A5 Construction Services	6,985	5,315	3,383	**15,682**
A5 Electricity, Gas, Water	240	209	970	**1,418**
A5 Land Use Change	1,960	530	688	**3,178**
Total	**28,766**	**15,834**	**23,914**	**68,513**

Appendix G

Supporting data

G-1 Emission factors

Emission factors were sourced from process LCA sources only. Only public datasets were used. Preference was given to construction specific LCA results following EN 15804 or ISO 21930.

Many sources were used, including:

- AusLCI, the national Australian Life Cycle Inventory Database, managed by the Australian Life Cycle Assessment Society (ALCAS, 2023). Version 1.42 of the database was used, available at https://www.auslci.com.au/index.php/EmissionFactors.
- National Greenhouse Accounts (NGA) Factors, managed by the Department of Climate Change, Energy, the Environment and Water (DCCEEW, 2023c). The 2022 version (released in February 2023) was used, available at https://www.dcceew.gov.au/sites/default/files/documents/national-greenhouse-accounts-factors-2022.pdf.
- Environmental Product Declarations (EPDs), primarily from EPD Australasia (https://epd-australasia.com/) and its parent, the International EPD System (https://www.environdec.com/).
- The BRANZ CONSTRUCT Database (BRANZ, 2023), available at https://www.branz.co.nz/environment-zero-carbon-research/framework/branz-co2nstruct/. While this is a New Zealand dataset, it contains data for many imported products which are also applicable to Australia.
- Data from industry associations.

For AusLCI, preference was given to the construction emission factor set (following EN 15804), though the non-construction emission factor set was used where a suitable item wasn't available. For most products, "Climate change - total (Infr Excl)" was used. For biogenic products (e.g., timber), "Climate change - fossil (Infr Excl)" was used instead, as stored biogenic carbon was calculated separately. Infrastructure was excluded as is common practice in many LCA and EPD studies. It typically has a small impact on carbon emissions but can create uncertainty in the results as the assumptions for infrastructure are approximate (Tokede & Rouwette, 2023). In this context, infrastructure is the carbon embodied in the assets used to enable a process. For example, a truck burns fuel to transport goods (main process) but requires a road to travel over (infrastructure). Further, the purpose of this report is to calculate the carbon footprint of infrastructure in Australia, which could lead to double counting if infrastructure was included in the underlying emission factors.

G-1-1 Materials

Emission factors are presented in Table 61. These emission factors are intended to be current, market-weighted averages as of FY 2023. They represent emissions before the application of decarbonisation strategies. For example, the emission factor for cement in Table 61 excludes the use of supplementary cementitious materials.

Table 61: Emission factors for materials

Material	Emission factor (kt CO_2e/t)	Affected by replacement strategy	Notes
Aggregate	8.70E-06	Yes	"Gravel, crushed, at mine" as per AusLCI v1.42 Construction https://www.auslci.com.au/index.php/EmissionFactors
Aluminium	1.72E-02	Yes	Sum of emission factors for - Aluminium billet (domestic): 12.71 t CO2e/t as per the Australian Aluminium Council https://aluminium.org.au/sustainability/ - Aluminium billet (imported): 16.9 t CO2e/t as per International Aluminium Institute LCI 2019: https://international-aluminium.org/resource/2019-life-cycle-inventory-lci-data-and-environmental-metrics/ - Extrusion + powder coating: 2.44 t CO2e/t as per https://aec.org/sites/default/files/2022-11/102.1-EPD-AEC-2022-Al-Ext-Mill-Paint-Anod.pdf Assume 50% domestic billet and 50% imported billet as no other data were available.
Asphalt (Urban)	6.05E-05	Yes	Based on DG14 https://epd-australasia.com/epd/boral-national-asphalt-epd/ - see "Asphalt (U)_RAP replacement" sheet for calculations
Asphalt (Highway)	7.34E-05	Yes	Based on DG14 HD A15E HFA https://epd-australasia.com/epd/boral-national-asphalt-epd/ - see "Asphalt (H)_RAP replacement" sheet for calculations
Bathroom Fitout	1.32E-03	No	Average of emission factors for - Basins: 8.8 kg CO2e/unit / 9kg/unit = 0.98 kgCO2e/kg as per BRANZ CO_2NSTRUCT Database for "Ceramic basins sanitary ware (ceramic vitreous china) (basin - mass = 9 kg), imported" - Electrical equipment: 9.33 kgCO2e/unit / 2.14 kg/unit = 4.36 kgCO2e/kg as per BRANZ CO_2NSTRUCT Database for "Lighting (indoor), batten LED luminaire, Thorn Lighting, POPPACK LED 4500-840 HFI L1200, 35.6 W, (4650 lumens, 131 lumens/W), (product number: 96631544), imported (Europe)" - Mirror: 3 kgCO2e/m2 / 2.5 kg/m2 = 1.2 kg CO2e/kg - Mirrored cabinet: assumed as shower cubicle - Shower cubicle: ((0.9x1.5x2)+(0.75x1.5x2)) m2 x 3 kgCO2e/m2 / 40 kg = 0.37 kg CO2e/kg as per https://www.henrybrooks.co.nz/product/shower-cubicle-900x750-3-sided-alcove/ - Toilet: 17.6 kgCO2e/unit / 18 kg/unit = 0.98 kgCO2e/kg as per BRANZ CO_2NSTRUCT Database - Vanity with basin: 8.8 kgCO2e/unit / 9 kg/unit - 0.98 kg CO2e/kg as per BRANZ CO_2NSTRUCT Database for "Ceramic basins sanitary ware (ceramic vitreous china) (basin - mass = 9 kg), imported"
Bitumen Binders	3.81E-04	No	"Bitumen, at refinery" as per AusLCI v1.42 https://www.auslci.com.au/index.php/EmissionFactors
Bricks	2.17E-04	No	"Brick, at plant" as per AusLCI v1.42 Construction https://www.auslci.com.au/index.php/EmissionFactors
Building Services	3.16E-03	No	Calculation based on mechanical, electrical and plumbing services in office buildings from https://www.sciencedirect.com/science/article/abs/pii/S0378778819340071: - Average mass of building services: 19 kg/m2 - Average carbon footprint of building services: 60 kgCO2e/m2

Material	Emission factor (kt CO_2e/t)	Affected by replacement strategy	Notes
Carpet	8.33E-03	No	"Carpet - tile, tufted (pile material 1000 - 1100 g/m² recycled polyamide 6, heavy bitumen base with fibre glass reinforcement) (total recycled content = 23.4%)" from BRANZ CO_2NSTRUCT Database
Cement	8.31E-04	Yes	EF calculated using material flow analysis of cement in Australia; see "Cement_MFA" sheet for calculations
Ceramic Tiles	4.50E-04	No	Based on "porcelain stoneware tiles" from Saloni EPD S-P-01155 v2.0 https://api.environdec.com/api/v1/EPDLibrary/Files/08e8581b-33e7-4738-566c-08da12da9675/Data
Copper	4.39E-03	No	Primary cathode @ 4.1 kgCO2e/kg from ICA (2021) "Copper Environmental Profile" + extrusion @ 0.29 kg CO2e/kg from "Genius Copper Wire Rod" EPD #S-P-02032.
Electrical Bulk	3.83E-03	No	Assume 50% copper + 50% plastics/polymeric
Fiberglass	1.72E-03	No	Based on "mats" from Glass Fibre Europe (2023) - "Life cycle assessment of CFGF – Continuous Filament Glass Fibre Products"
Girders	3.09E-03	No	Assumed same as "Steel - Structural Elements"
Glass	1.97E-03	No	"Pilkington Insulight™ 4/16/6.8 Double IGU with Offline Coated Laminated Glass" as per EPD S-P-02492 https://www.environdec.com/library/epd2492
Glass (HV Insulators)	1.08E-03	No	"Flat glass, coated, at plant" as per AusLCI v1.42 Construction https://www.auslci.com.au/index.php/EmissionFactors
Insulation	1.56E-03	No	Based on "Mineral Plus, Mineral Wool Products λ 0.037 W/mK" (Turkey & Czech Republic) EPD S-P-04571 as per https://www.knaufinsulation.com/download-epd-glass-mineral-wool
Kitchen Fitout	2.66E-03	No	Weighted average based on cost breakdown (scaled to 100%) from https://sydneyhomecentre.com.au/blogs/resources/the-real-cost-of-a-kitchen-renovation - Cabinets (25% of cost): 1.21 kg CO2e/kg = 15.7 kg CO2e/m2 / 13kg/m2 as per "18 mm E0 & E1 moisture resistant (MR) melamine coated MDF" from https://epd-australasia.com/wp-content/uploads/2018/04/EDP-4-MDF-Dec-2020-1.pdf - Appliances (15% of cost): 4.34 kgCO2e/kg = 51 kgCO2e/cooktop / 11.75 kg/cooktop as per Pop 600 from https://api.environdec.com/api/v1/EPDLibrary/Files/23e4d76a-a55b-45cb-c722-08da1b891163/Data - Kitchen bench & splashbacks (12% of cost): assume 1/3 MDF, 1/3 glass, 1/3 stainless steel (with EFs as per this table)
Linemarking & Road Furnitures	3.17E-03	No	Based on GALVABOND® steel with a zinc coating class of Z100 in 0.40mm base metal thickness (BMT) as per https://epd-australasia.com/wp-content/uploads/2023/08/SP09342-Bluescope-EPD-GALVABOND_Jul23.pdf
Paint	2.29E-03	No	Average of 4 Dulux paints as per https://epd-australasia.com/wp-content/uploads/2021/12/Dulux-UltraAir-EPD-Brochure_V4.pdf
Plasterboard	2.29E-04	No	Based on average of Mastashield 10mm and Mastashield 13 mm as per https://epd-australasia.com/wp-content/uploads/2023/06/SP07445-Etex-Siniat-Plasterboard-280623.pdf
Plastics and Polymeric Materials	3.26E-03	No	Based on "PVC non-pressure pipe solid wall" as per https://epd-australasia.com/wp-content/uploads/2018/04/SP00716-Vinidex-EPD-Non-Pressure-Pipes_v2-Sep22.pdf
Plywood	1.02E-03	No	Based on "formply, A-bond, 17 mm (formwork)" from FWPA EPD for plywood (S-P-00564 v1.2)
PV Panels	7.64E-03	No	Photovoltaic solar panel SPICN6(LAR)-66-(420-440) as per https://api.environdec.com/api/v1/EPDLibrary/Files/8f4fff54-c918-401d-f983-08db99345335/Data

Material	Emission factor (kt CO_2e/t)	Affected by replacement strategy	Notes
Rail Track	3.32E-03	No	Based on "rail products" in Liberty EPD S-P-01547 v1.2 as per https://www.infrabuild.com/wp-content/uploads/sites/8/2020/10/Hot-Rolled-Structural-and-Rail-Products-EPD-Liberty-Primary-Steel_2022.pdf
Rock/Bluestone	8.70E-06	No	Assumed same as "Aggregates"
Sand	3.59E-06	No	"Sand, at mine" as per AusLCI v1.42 Construction https://www.auslci.com.au/index.php/EmissionFactors
Stainless Steel	8.53E-03	No	"China(Ave)" scenario from Gyllenram & Wei (2022) "304 grade Stainless Steel Carbon Footprint Comparison: EU, Indonesia and China"
Steel - Structural Elements	3.09E-03	Yes	Unweighted average (as no market share data available) of: - 3.32 kg CO2e/kg for "structural sections" from Liberty Whyalla EPD S-P-01547 v1.2 as per https://epd-australasia.com/epd/hot-rolled-structural-and-rail-2/ - 2.86 kg CO2e/kg for "steel welded beams and columns" from BlueScope Port Kembla EPD S-P-00559 https://epd-australasia.com/epd/steel-welded-beams-and-columns/
Steel - Transmission Cable	1.58E-03	Yes	Assumed same as "Steel Re-inforcement"
Steel Re-inforcement	1.58E-03	Yes	Based on "Reinforcing bar" in "Reinforcing Rod, Bar & Wire by InfraBuild Steel" EPD No. S-P-00855 v1.2. There was insufficient data on imported products to be able to calculate a national average and so InfraBuild's product is considered to be the market average.
Timber	2.85E-04	No	Based on "Dressed, kiln-dried softwood" as per https://epd-australasia.com/epd/softwood-timber/

G-1-2 Construction energy

Table 62: Emission factors for construction energy

Energy source	Emission factor	Unit	Source
Diesel	3.38E-03	kt CO2e/kL	Australian National Greenhouse Accounts Factors - February 2023, Table 7; https://www.dcceew.gov.au/sites/default/files/documents/national-greenhouse-accounts-factors-2022.pdf
Biodiesel	1.32E-03	kt CO2e/kL	Carbon Estimate Reporting Tool; https://www.transport.nsw.gov.au/industry/doing-business-transport/sustainability-at-transport
Electricity	7.70E-07	kt CO2e/kWh	Australian National Greenhouse Accounts Factors - February 2023, Table 1; https://www.dcceew.gov.au/sites/default/files/documents/national-greenhouse-accounts-factors-2022.pdf
GreenPower	9.00E-08	kt CO2e/kWh	Australian National Greenhouse Accounts Factors - February 2023, Table 1; https://www.dcceew.gov.au/sites/default/files/documents/national-greenhouse-accounts-factors-2022.pdf

G-1-3 Construction waste

Table 63: Emission factors for construction waste

Material	EF landfill (kg CO_2e/kg)	EF recycling (kg CO_2e/kg)	EF incineration (kg CO_2e/kg)	Source landfill	Source recycling	Source incineration
Aggregate	1.13E-02	5.14E-03	0.00E+00	AusLCI "waste treatment, inert waste, at landfill" including infrastructure	AusLCI "recycled aggregate, at plant" including infrastructure	n/a
Asphalt	1.13E-02	0.00E+00	0.00E+00	AusLCI "waste treatment, inert waste, at landfill" including infrastructure	AusLCI "asphalt, Recycled Asphalt Product (RAP), at point of origin"	n/a
Cement	1.13E-02	5.14E-03	0.00E+00	AusLCI "waste treatment, inert waste, at landfill" including infrastructure	AusLCI "recycled aggregate, at plant" including infrastructure	n/a
Rock/Bluestone	1.13E-02	5.14E-03	0.00E+00	AusLCI "waste treatment, inert waste, at landfill" including infrastructure	AusLCI "recycled aggregate, at plant" including infrastructure	n/a
Sand	1.13E-02	5.14E-03	0.00E+00	AusLCI "waste treatment, inert waste, at landfill" including infrastructure	AusLCI "recycled aggregate, at plant" including infrastructure	n/a
Steel - Structural Elements	1.13E-02	0.00E+00	0.00E+00	AusLCI "waste treatment, inert waste, at landfill" including infrastructure	Structural steel reaches its end-of-waste state as soon as it is put in a skip	n/a
Electrical Bulk	1.13E-02	5.14E-03	0.00E+00	AusLCI "waste treatment, inert waste, at landfill" including infrastructure	AusLCI "recycled aggregate, at plant" including infrastructure	n/a
Timber	1.05E-01	1.01E-02	1.01E-02	GWP for "Landfill (typical)" from FWPA (2022), "Environmental Product Declaration: Softwood Timber", EPD # S-P-00560, Version 2.0.	GWPF for "Recycling" from FWPA (2022), "Environmental Product Declaration: Softwood Timber", EPD # S-P-00560, Version 2.0.	GWPF for "Energy recovery" from FWPA (2022), "Environmental Product Declaration: Softwood Timber", EPD # S-P-00560, Version 2.0.
Bricks	1.13E-02	5.14E-03	0.00E+00	AusLCI "waste treatment, inert waste, at landfill" including infrastructure	AusLCI "recycled aggregate, at plant" including infrastructure	n/a
Plasterboard	1.13E-02	5.14E-03	0.00E+00	AusLCI "waste treatment, inert waste, at landfill" including infrastructure	AusLCI "recycled aggregate, at plant" including infrastructure	n/a
Bitumen Binders	1.13E-02	0.00E+00	0.00E+00	AusLCI "waste treatment, inert waste, at landfill" including infrastructure	AusLCI "asphalt, Recycled Asphalt Product (RAP), at point of origin"	n/a
Steel Re-inforcement	1.13E-02	0.00E+00	0.00E+00	AusLCI "waste treatment, inert waste, at landfill" including infrastructure	Steel reinforcement reaches its end-of-waste state as soon as it is put in a skip	n/a

Material	EF landfill (kg CO_2e/kg)	EF recycling (kg CO_2e/kg)	EF incineration (kg CO_2e/kg)	Source landfill	Source recycling	Source incineration
Rail Track	1.13E-02	0.00E+00	0.00E+00	AusLCI "waste treatment, inert waste, at landfill" including infrastructure	Structural steel reaches its end-of-waste state as soon as it is put in a skip	n/a
Linemarking & Road Furnitures	1.13E-02	5.14E-03	0.00E+00	AusLCI "waste treatment, inert waste, at landfill" including infrastructure	AusLCI "recycled aggregate, at plant" including infrastructure	n/a
Girders	1.13E-02	0.00E+00	0.00E+00	AusLCI "waste treatment, inert waste, at landfill" including infrastructure	Structural steel reaches its end-of-waste state as soon as it is put in a skip	n/a
Copper	1.13E-02	0.00E+00	0.00E+00	AusLCI "waste treatment, inert waste, at landfill" including infrastructure	Copper reaches its end-of-waste state as soon as it is put in a skip	n/a
Aluminium	1.13E-02	0.00E+00	0.00E+00	AusLCI "waste treatment, inert waste, at landfill" including infrastructure	Aluminium reaches its end-of-waste state as soon as it is put in a skip	n/a
Steel - Transmission Cable	1.13E-02	0.00E+00	0.00E+00	AusLCI "waste treatment, inert waste, at landfill" including infrastructure	Steel reaches its end-of-waste state as soon as it is put in a skip	n/a
Glass (HV Insulators)	1.13E-02	5.14E-03	0.00E+00	AusLCI "waste treatment, inert waste, at landfill" including infrastructure	AusLCI "recycled aggregate, at plant" including infrastructure	n/a
PV Panels	1.13E-02	5.14E-03	0.00E+00	AusLCI "waste treatment, inert waste, at landfill" including infrastructure	AusLCI "recycled aggregate, at plant" including infrastructure	n/a
Plastics and Polymeric materials	1.13E-02	0.00E+00	3.14E+00	AusLCI "waste treatment, inert waste, at landfill" including infrastructure	Cut-off assuming plastic has value if separately collected	Assume plastic is LDPE and all stored carbon is released as CO2
Fiberglass	1.13E-02	5.14E-03	0.00E+00	AusLCI "waste treatment, inert waste, at landfill" including infrastructure	AusLCI "recycled aggregate, at plant" including infrastructure	n/a
Bathroom Fitout	1.13E-02	5.14E-03	0.00E+00	AusLCI "waste treatment, inert waste, at landfill" including infrastructure	AusLCI "recycled aggregate, at plant" including infrastructure	n/a
Building Services	1.13E-02	5.14E-03	0.00E+00	AusLCI "waste treatment, inert waste, at landfill" including infrastructure	AusLCI "recycled aggregate, at plant" including infrastructure	n/a
Ceramic Tiles	1.13E-02	5.14E-03	0.00E+00	AusLCI "waste treatment, inert waste, at landfill" including infrastructure	AusLCI "recycled aggregate, at plant" including infrastructure	n/a
Carpet	8.77E-01	5.77E-03	1.76E+00	GUT (2016). "Tufted carpet tiles - luxury class LC1-LC5 - with 1200 g/m² maximum surface pile weight - pile	GUT (2016). "Tufted carpet tiles - luxury class LC1-LC5 - with 1200 g/m² maximum surface pile weight - pile	GUT (2016). "Tufted carpet tiles - luxury class LC1-LC5 - with 1200 g/m² maximum surface pile weight - pile

Material	EF landfill (kg CO_2e/kg)	EF recycling (kg CO_2e/kg)	EF incineration (kg CO_2e/kg)	Source landfill	Source recycling	Source incineration
				material made of polyamide 6.6, bitumen based heavy backing". EPD-GUT-20160019-CCA1-EN. Version of 11 March 2016. Institut Bauen und Umwelt e.V. (IBU).	material made of polyamide 6.6, bitumen based heavy backing". EPD-GUT-20160019-CCA1-EN. Version of 11 March 2016. Institut Bauen und Umwelt e.V. (IBU).	material made of polyamide 6.6, bitumen based heavy backing". EPD-GUT-20160019-CCA1-EN. Version of 11 March 2016. Institut Bauen und Umwelt e.V. (IBU).
Glass	1.13E-02	5.14E-03	0.00E+00	AusLCI "waste treatment, inert waste, at landfill" including infrastructure	AusLCI "recycled aggregate, at plant" including infrastructure	n/a
Insulation	1.13E-02	5.14E-03	0.00E+00	AusLCI "waste treatment, inert waste, at landfill" including infrastructure	AusLCI "recycled aggregate, at plant" including infrastructure	n/a
Kitchen Fitout	1.13E-02	5.14E-03	0.00E+00	AusLCI "waste treatment, inert waste, at landfill" including infrastructure	AusLCI "recycled aggregate, at plant" including infrastructure	n/a
Paint	1.13E-02	5.14E-03	0.00E+00	AusLCI "waste treatment, inert waste, at landfill" including infrastructure	AusLCI "recycled aggregate, at plant" including infrastructure	n/a
Plywood	1.93E-01	1.63E-01	1.63E-01	GWP for "Landfill (typical)" from FWPA (2017), "Environmental Product Declaration: Plywood", EPD # S-P-00564, Version 1.2.	GWPF for "Recycling" from FWPA (2017), "Environmental Product Declaration: Plywood", EPD # S-P-00564, Version 1.2.	GWPF for "Energy recovery" from FWPA (2017), "Environmental Product Declaration: Plywood", EPD # S-P-00564, Version 1.2.
Stainless Steel	1.13E-02	0.00E+00	0.00E+00	AusLCI "waste treatment, inert waste, at landfill" including infrastructure	Stainless steel reaches its end-of-waste state as soon as it is put in a skip	n/a

G-2 Transportation

G-2-1 Transport modes

Table 64: Emission factors for transportation

Transport mode	Emission factor (kt CO_2e/t.km)	Reference/notes
Articulated truck	7.20E-08	TfNSW CERT / Carbon Tool (used for material transport)
Rail, bulk transport	2.43E-08	TfNSW CERT / Carbon Tool
Shipping	1.32E-08	TfNSW CERT / Carbon Tool
Rigid truck	2.16E-07	TfNSW CERT / Carbon Tool (used for transport to end-of-life only)

G-2-2 Transport distances

The transport distances in Table 65 were calculated specifically for this project. These distances:

- Are designed to represent a market-weighted average product in each state.
- Start from the primary producer and include all downstream manufacturing stages to get the product to the local market. Examples:
    - 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.
- Are weighted to account for imports. This means that long-distance 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 for the following material types:

- Asphalt
- Bitumen
- Cement
- Concrete
- Gravel
- Rock
- Sand
- Steel, rail
- Steel, reinforcement
- Steel, structural
- Timber, hardwood
- Timber, softwood
- Timber, unclassified

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 this study.
- Focuses primarily on transport from the manufacturer, but does not necessarily include transport from the primary producer (e.g., for steel).

As such, thinkstep-anz supplemented the CSIRO TraNSIT data to include:

- Weighted average product on the market, accounting for transport of imported products.
- Sea freight and coastal shipping.
- Additional materials that were not in the TraNSIT dataset.
- Upstream transport from the primary producer to the secondary producer / manufacturer.

Table 65: Transport distance per material and mode (module A4)

Material	State	Truck (km)	Rail (km)	Sea (km)
Aggregate	ACT	90	0	0
Aggregate	NSW	62	0	0
Aggregate	NT	450	0	0
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
Bitumen Binders	SA	252	18	6,000
Bitumen Binders	TAS	111	18	6,000
Bitumen Binders	VIC	124	18	6,000

Material	State	Truck (km)	Rail (km)	Sea (km)
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
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

Material	State	Truck (km)	Rail (km)	Sea (km)
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
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

Material	State	Truck (km)	Rail (km)	Sea (km)
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
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

Material	State	Truck (km)	Rail (km)	Sea (km)
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
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

Material	State	Truck (km)	Rail (km)	Sea (km)
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
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

G-3 Construction waste and refurbishment

The amount of waste and fate of waste for the materials in this study are given in Table 66. This table also includes replacement cycles for assessing the impacts of replacement in module B. The primary source for construction waste rates was RICS' "Whole life carbon assessment for the built environment" (RICS, 2023). The primary sources for waste fates were DCCEEW's National Waste Database 2022 (DCCEEW, 2023f), Victoria's waste projection model dashboard (Recycling Victoria, 2023), direct data collection with construction waste processors, EPDs and industry estimates. All replacement cycles (in years) are estimates by thinkstep-anz.

Table 66: Construction waste rates, replacement cycles, and construction/renovation waste fates per construction material

Material	Construction waste	Replacement cycle (years)	To landfill	To recycling	To incineration	Source for construction waste	Source for fate
Aggregate	5%	Never	10%	90%	0%	Concrete from RICS WLCA 2nd Ed. (2023)	Industry estimates. Aggregates are concrete aggregates.
Aluminium	1%	30*	50%	50%	0%	RICS WLCA 2nd Ed. (2023)	Estimate
Asphalt	6%	n/a (accounted for already)	0%	100%	0%	RICS WLCA 2nd Ed. (2023)	All recycled as RAP or used for other purposes
Bathroom Fitout	6%	20**	100%	0%	0%	Estimate based on RICS WLCA 2nd Ed. (2023)	Estimate
Bitumen Binders	6%	n/a (accounted for already)	0%	100%	0%	RICS WLCA 2nd Ed. (2023)	All left in-place
Bricks	6%	Never	10%	90%	0%	RICS WLCA 2nd Ed. (2023)	Industry estimates
Building Services	1%	20	60%	40%	0%	Estimate based on RICS WLCA 2nd Ed. (2023)	Ventilation systems from RICS WLCA 2nd Ed. (2023)

Material	Construction waste	Replacement cycle (years)	To landfill	To recycling	To incineration	Source for construction waste	Source for fate
Carpet	6%	10**	80%	20%	0%	RICS WLCA 2nd Ed. (2023)	Estimate
Cement	5%	Never	10%	90%	0%	Concrete from RICS WLCA 2nd Ed. (2023)	Industry estimates. Cement is cement in concrete.
Ceramic Tiles	6%	50**	100%	0%	0%	RICS WLCA 2nd Ed. (2023)	Estimate
Copper	1%	30	50%	50%	0%	Estimate based on RICS WLCA 2nd Ed. (2023)	Wire cables from RICS WLCA 2nd Ed. (2023)
Electrical Bulk	1%	50	60%	40%	0%	Estimate based on RICS WLCA 2nd Ed. (2023)	Ventilation systems from RICS WLCA 2nd Ed. (2023)
Fiberglass	1%	25	100%	0%	0%	Estimate based on RICS WLCA 2nd Ed. (2023)	Estimate
Girders	1%	Never	10%	90%	0%	RICS WLCA 2nd Ed. (2023)	BlueScope EPDs
Glass	1%	30*	80%	20%	0%	RICS WLCA 2nd Ed. (2023)	Estimate
Glass (HV Insulators)	1%	30	100%	0%	0%	Estimate based on RICS WLCA 2nd Ed. (2023)	Estimate
Insulation	7%	50	100%	0%	0%	RICS WLCA 2nd Ed. (2023)	Adapted to AU conditions from RICS WLCA 2nd Ed. (2023)
Kitchen Fitout	6%	20**	100%	0%	0%	Estimate based on RICS WLCA 2nd Ed. (2023)	Estimate

Material	Construction waste	Replacement cycle (years)	To landfill	To recycling	To incineration	Source for construction waste	Source for fate
Linemarking & Road Furnitures	6%	30	100%	0%	0%	Estimate based on RICS WLCA 2nd Ed. (2023)	Estimate
Paint	6%	8**	100%	0%	0%	RICS WLCA 2nd Ed. (2023)	All lost as surface coating
Plasterboard	15%	30*	83%	17%	0%	Etex EPD	RICS WLCA 2nd Ed. (2023)
Plastics and Polymeric materials	6%	Never***	100%	0%	0%	Estimate based on RICS WLCA 2nd Ed. (2023)	Estimate
Plywood	10%	Never***	70%	25%	5%	RICS WLCA 2nd Ed. (2023)	DCCEEW National Waste Database 2022
PV Panels	1%	25	100%	0%	0%	Estimate based on RICS WLCA 2nd Ed. (2023)	Estimate
Rail Track	1%	50	10%	90%	0%	RICS WLCA 2nd Ed. (2023)	InfraBuild EPDs
Rock/Bluestone	5%	Never	10%	90%	0%	RICS WLCA 2nd Ed. (2023)	Industry estimates
Sand	5%	Never	10%	90%	0%	Concrete from RICS WLCA 2nd Ed. (2023)	Industry estimates. Sand is sand in concrete.
Stainless Steel	1%	80	50%	50%	0%	Estimate based on RICS WLCA 2nd Ed. (2023)	Estimate
Steel - Structural Elements	1%	Never	10%	90%	0%	RICS WLCA 2nd Ed. (2023)	BlueScope EPDs
Steel - Transmission Cable	1%	80	10%	90%	0%	Estimate based on RICS WLCA 2nd Ed. (2023)	InfraBuild EPDs

Material	Construction waste	Replacement cycle (years)	To landfill	To recycling	To incineration	Source for construction waste	Source for fate
Steel Re-inforcement	5%	Never	10%	90%	0%	RICS WLCA 2nd Ed. (2023)	InfraBuild EPDs
Timber	2%	Never***	70%	25%	5%	RICS WLCA 2nd Ed. (2023)	DCCEEW National Waste Database 2022

* Aluminium and glass in this study are for windows, doors and curtain walls. This study assumes a significant portion of insulated glazing units (primarily double glazing). Insulated glazing units will eventually mist/fog and need to be replaced. Further, commercial facades may be replaced for aesthetic and/or thermal performance reasons.

** Replacement rates were estimated based on market replacement rates and were not based on material wear-out. Fit-out materials such as bathroom fixtures, kitchen fit-out, carpet, tiles, paint and plasterboard are often replaced for aesthetic reasons, not because of physical failure.

*** "Timber", "Plywood" and "Plastic and polymeric materials" are primarily materials used in the structure of the building in this study, making them less likely to be replaced.

G-4 Hybrid Analysis

Infrastructure Australia's Market Capacity Intelligence System has historically focused on linear infrastructure. While it does contain plant, labour, equipment and materials data for buildings, this data was at a relatively high level, particularly for materials. The Hybrid Analysis used materials data collected specifically for this project for buildings. Data for commercial buildings were supplied by Slattery. Data for residential buildings were supplied by Chatham Homes.

Because Infrastructure Australia's Market Capacity Intelligence System contains approximately 30 types of building, it was not feasible to collect detailed materials data for all of them. Instead, five archetypal buildings were chosen to represent the market and then scaled up to the total market by gross floor area. Details of these buildings are supplied in Table 67.

Table 67: Details of buildings used for material data in the Hybrid Analysis

Parameter	Building, high-rise, non-residential	Building, low-rise, warehouse-type	Building, low-rise, civic/commercial	Building, high-rise, non-residential	Building, low-rise, residential, detached
Floor area (average) (gross floor area) (m²)	51,666	12,550	2,575	22,999	313
Floorplate area (m²)	1,193	3,232	1,091	927	313
Façade area (m²)	31,790	4,688	2,326	10,116	Unspecified

Parameter	Building, high-rise, non-residential	Building, low-rise, warehouse-type	Building, low-rise, civic/commercial	Building, high-rise, non-residential	Building, low-rise, residential, detached
Number of floors above grade	39	3	2	23	1
Number of floors below grade	4	0	0	3	0
Number of buildings included in average	3	3	3	3	1
Year construction commenced	2020 to 2024	2022 to 2023	2019 to 2021	2022 to 2023	2023

* For building services, it can be difficult to separate material costs from labour and other costs. This report assumes 40% of total cost is material-related for mechanical, vertical transportation and plumbing/hydraulic services, with 20% of the cost as material-related for electrical, fire and other services.

Because individual typecasts can contain a mix of different building types, a ratio between two different building archetypes was used as shown in Table 68. The same bill of quantities was used for "Building, low-rise, residential, attached" and "Building, low-rise, residential, detached".

Table 68: Asset classifications per typecast

Project type (typecast)	Asset class 1	Class 1 Share	Asset class 2	Class 2 Share
Airport Building	Building, low-rise, civic/commercial	70%	Building, high-rise, non-residential	30%
Higher Education (Addon/Brownfield)	Building, low-rise, civic/commercial	50%	Building, high-rise, non-residential	50%
Higher Education (Brownfield)	Building, low-rise, civic/commercial	50%	Building, high-rise, non-residential	50%
Higher Education (Greenfield)	Building, low-rise, civic/commercial	50%	Building, high-rise, non-residential	50%
School (Brownfield)	Building, low-rise, civic/commercial	90%	Building, high-rise, non-residential	10%
School (Greenfield)	Building, low-rise, civic/commercial	90%	Building, high-rise, non-residential	10%
Aged Care Facility (Addon/Brownfield)	Building, low-rise, residential, attached	80%	Building, high-rise, residential	20%
Aged Care Facility (Brownfield)	Building, low-rise, residential, attached	80%	Building, high-rise, residential	20%
Aged Care Facility (Greenfield)	Building, low-rise, residential, attached	80%	Building, high-rise, residential	20%
Health Facility (Addon/Brownfield)	Building, low-rise, civic/commercial	80%	Building, high-rise, non-residential	20%
Health Facility (Brownfield)	Building, low-rise, civic/commercial	80%	Building, high-rise, non-residential	20%
Health Facility (Greenfield)	Building, low-rise, civic/commercial	80%	Building, high-rise, non-residential	20%
Hospital (Addon/Brownfield)	Building, high-rise, non-residential	50%	Building, low-rise, civic/commercial	50%
Hospital (Greenfield)	Building, high-rise, non-residential	50%	Building, low-rise, civic/commercial	50%
Correctional Centre	Building, low-rise, civic/commercial	90%	Building, high-rise, residential	10%

Project type (typecast)	Asset class 1	Class 1 Share	Asset class 2	Class 2 Share
Courthouse	Building, low-rise, civic/commercial	100%		0%
Fire and Emergency Facility	Building, low-rise, civic/commercial	100%		0%
Police Facility	Building, low-rise, civic/commercial	100%		0%
Arts Facility	Building, low-rise, civic/commercial	100%		0%
Civic/Convention Centre	Building, low-rise, civic/commercial	60%	Building, high-rise, non-residential	40%
Laboratory	Building, low-rise, civic/commercial	60%	Building, high-rise, non-residential	40%
Office	Building, high-rise, non-residential	80%	Building, high-rise, non-residential	20%
Accommodation	Building, high-rise, residential	70%	Building, low-rise, residential, attached	30%
Detached Residential	Building, low-rise, residential, detached	100%		0%
Multi Residential	Building, high-rise, residential	100%		0%
Semi-detached Residential	Building, low-rise, residential, attached	100%		0%
Retail Store	Building, low-rise, civic/commercial	80%	Building, high-rise, non-residential	20%
Arena/Sporting Facility	Building, low-rise, civic/commercial	100%		0%
Data Centre	Building, low-rise, warehouse-type	100%		0%
Parking Facility	Building, high-rise, non-residential	100%		0%
Warehouse	Building, low-rise, warehouse-type	100%		0%

Table 80 to Table 83 compare calculated material consumption in both the Pipeline Analysis and Hybrid Analysis to thinkstep-anz's estimates of total market capacity. These estimates were compiled through a combination of calculations based on publicly available data from industry associations (e.g., the Cement Industry Federation, the Australian Steel Institute and the World Steel Association) and public industry estimates.

In this analysis:

- Market totals for "Aggregate" and "Asphalt" are constant across all years as there is no available data.
- Market totals for "Cement", "Steel - Structural Elements", "Steel Re-inforcement" have been projected for future years.
- Market totals for all materials also include materials used in module B (renovations and maintenance).
- The totals for the Pipeline Analysis and Hybrid Analysis also include construction waste.
- "Cement" is all cementitious materials, including SCMs.

Looking across the tables, the calculated quantities are…

- at or below estimated market capacity for cementitious materials. This was one of the main checks completed.
- much above estimated market capacity for "Steel - Structural Elements". However, the additional steel is primarily structural steel for wind turbines and solar photovoltaic installations – two areas that are commonly met through imported products. As such, this is an area that should be able to respond quickly to increased demand.

- often above 100% for "Steel Re-inforcement". However, these quantities fall into more acceptable ranges through lightweighting in the Mid-Level Decarbonisation Scenario and Maximum Decarbonisation Scenario. Increased demand for steel reinforcement can also be met through increased imports if there is insufficient local supply.
- often above 100% for "Asphalt". The reason for this was thought to be overly ambitious forecasting for new road construction; however, there was no alternative dataset available to forecast new road construction and so Infrastructure Australia's core forecast is used for both the Pipeline Analysis and the Hybrid Analysis. (Some buildings also use small amounts of asphalt leading to different quantities.)
- much below estimated market capacity for "Aggregates". This is likely because bills of quantities used in this study do not contain all fill materials, all temporary works, etc. Aggregates are a small contributor to the carbon footprint of the built environment and so this was considered of low importance.
- much below estimated market capacity for "PV Panels". The reason for this could not be identified. If PV panels are undercounted, this could be a significant source of additional (imported) embodied carbon as PV panels have a high carbon footprint per unit.

Table 80: Validation of materials flows against market totals for Baseline Scenario in FY 2023

Material	Market total	Pipeline total	Pipeline comparison	Hybrid total	Hybrid comparison
Aggregate	200,000,000	68,968,082	34%	51,848,242	26%
Asphalt	10,000,000	15,007,270	150%	13,671,870	137%
Cement	15,600,000	12,628,327	81%	13,540,881	87%
Residential	5,630,000	2,579,286	46%	7,012,610	125%
Detached and semi-detached dwellings	-	282,945	Unavailable	5,758,046	Unavailable
Apartments	-	1,897,203	Unavailable	1,104,968	Unavailable
Accommodation	-	399,139	Unavailable	149,595	Unavailable
Non-Residential	7,460,000	6,046,948	81%	2,526,178	34%
Non-dwellings	-	8,343,289	Unavailable	3,780,741	Unavailable
Civil	2,510,000	4,002,093	159%	4,002,093	159%
Transport	-	3,549,601	Unavailable	3,549,601	Unavailable
Utilities	-	452,493	Unavailable	452,493	Unavailable
PV Panels	463,357	129,513	28%	141,518	31%
Buildings	139,007	0	0%	12,006	9%
Utilities	324,350	129,513	40%	129,513	40%
Steel - Structural Elements	2,280,000	2,853,228	125%	1,630,862	72%
Residential	1,060,000	509,814	48%	187,841	18%

Material	Market total	Pipeline total	Pipeline comparison	Hybrid total	Hybrid comparison
Detached and semi-detached dwellings	-	68,041	Unavailable	144,465	Unavailable
Apartments	-	364,986	Unavailable	38,591	Unavailable
Accommodation	-	76,787	Unavailable	4,785	Unavailable
Non-Residential	930,000	1,410,309	152%	509,916	55%
Non-dwellings	-	1,852,081	Unavailable	553,292	Unavailable
Civil	290,000	933,105	322%	933,105	322%
Transport	-	331,915	Unavailable	331,915	Unavailable
Utilities	-	601,191	Unavailable	601,191	Unavailable
Steel Re-inforcement	2,010,000	3,458,005	172%	1,988,618	99%
Residential	920,000	885,229	96%	646,143	70%
Detached and semi-detached dwellings	-	153,599	Unavailable	376,469	Unavailable
Apartments	-	514,955	Unavailable	243,628	Unavailable
Accommodation	-	216,675	Unavailable	26,046	Unavailable
Non-Residential	520,000	1,860,380	358%	630,078	121%
Non-dwellings	-	2,592,010	Unavailable	899,753	Unavailable
Civil	570,000	712,396	125%	712,396	125%
Transport	-	672,452	Unavailable	672,452	Unavailable
Utilities	-	39,944	Unavailable	39,944	Unavailable

Table 81: Validation of materials flows against market totals for Baseline Scenario in FY 2027

Material	Market total	Pipeline total	Pipeline comparison	Hybrid total	Hybrid comparison
Aggregate	200,000,000	60,078,270	30%	63,081,127	32%
Asphalt	10,000,000	14,196,747	142%	13,397,993	134%
Cement	16,370,000	10,539,093	64%	17,025,782	104%
Residential	5,910,000	1,988,941	34%	9,411,618	159%
Detached and semi-detached dwellings	-	293,271	Unavailable	7,486,113	Unavailable
Apartments	-	1,540,238	Unavailable	1,767,120	Unavailable
Accommodation	-	155,432	Unavailable	158,385	Unavailable
Non-Residential	7,830,000	3,621,521	46%	2,685,533	34%

Material	Market total	Pipeline total	Pipeline comparison	Hybrid total	Hybrid comparison
Non-dwellings	-	5,317,190	Unavailable	4,611,038	Unavailable
Civil	2,630,000	4,928,631	187%	4,928,631	187%
Transport	-	3,412,166	Unavailable	3,412,166	Unavailable
Utilities	-	1,516,465	Unavailable	1,516,465	Unavailable
PV Panels	1,131,243	183,156	16%	198,721	18%
Buildings	339,373	0	0%	15,565	5%
Utilities	791,870	183,156	23%	183,156	23%
Steel - Structural Elements	2,410,000	4,091,689	170%	3,668,497	152%
Residential	1,120,000	396,739	35%	254,603	23%
Detached and semi-detached dwellings	-	70,525	Unavailable	187,821	Unavailable
Apartments	-	296,312	Unavailable	61,716	Unavailable
Accommodation	-	29,902	Unavailable	5,066	Unavailable
Non-Residential	980,000	822,629	84%	541,574	55%
Non-dwellings	-	1,148,844	Unavailable	608,355	Unavailable
Civil	310,000	2,872,320	927%	2,872,320	927%
Transport	-	345,679	Unavailable	345,679	Unavailable
Utilities	-	2,526,641	Unavailable	2,526,641	Unavailable
Steel Re-inforcement	2,120,000	2,532,006	119%	2,258,033	107%
Residential	970,000	661,646	68%	906,651	93%
Detached and semi-detached dwellings	-	159,204	Unavailable	489,452	Unavailable
Apartments	-	418,065	Unavailable	389,622	Unavailable
Accommodation	-	84,377	Unavailable	27,577	Unavailable
Non-Residential	550,000	1,189,223	216%	670,245	122%
Non-dwellings	-	1,691,665	Unavailable	1,087,444	Unavailable
Civil	600,000	681,136	114%	681,136	114%
Transport	-	603,489	Unavailable	603,489	Unavailable
Utilities	-	77,647	Unavailable	77,647	Unavailable

Table 82: Validation of materials flows against market totals for Mid-level Decarbonisation Scenario in FY 2027

Material	Market total	Pipeline total	Pipeline comparison	Hybrid total	Hybrid comparison
Aggregate	200,000,000	60,078,270	30%	63,081,127	32%
Asphalt	10,000,000	14,196,747	142%	13,397,993	134%
Cement	16,370,000	10,539,093	64%	17,025,782	104%
Residential	5,910,000	1,988,941	34%	9,411,618	159%
Detached and semi-detached dwellings	-	293,271	Unavailable	7,486,113	Unavailable
Apartments	-	1,540,238	Unavailable	1,767,120	Unavailable
Accommodation	-	155,432	Unavailable	158,385	Unavailable
Non-Residential	7,830,000	3,621,521	46%	2,685,533	34%
Non-dwellings	-	5,317,190	Unavailable	4,611,038	Unavailable
Civil	2,630,000	4,928,631	187%	4,928,631	187%
Transport	-	3,412,166	Unavailable	3,412,166	Unavailable
Utilities	-	1,516,465	Unavailable	1,516,465	Unavailable
PV Panels	1,131,243	183,156	16%	198,721	18%
Buildings	339,373	0	0%	15,565	5%
Utilities	791,870	183,156	23%	183,156	23%
Steel - Structural Elements	2,410,000	3,814,811	158%	3,426,564	142%
Residential	1,120,000	369,505	33%	242,165	22%
Detached and semi-detached dwellings	-	67,757	Unavailable	180,392	Unavailable
Apartments	-	274,089	Unavailable	57,087	Unavailable
Accommodation	-	27,659	Unavailable	4,686	Unavailable
Non-Residential	980,000	771,017	79%	510,109	52%
Non-dwellings	-	1,072,765	Unavailable	571,883	Unavailable
Civil	310,000	2,674,289	863%	2,674,289	863%
Transport	-	335,888	Unavailable	335,888	Unavailable
Utilities	-	2,338,401	Unavailable	2,338,401	Unavailable
Steel Re-inforcement	2,120,000	2,428,142	115%	2,158,050	102%
Residential	970,000	637,191	66%	878,456	91%
Detached and semi-detached dwellings	-	155,726	Unavailable	478,675	Unavailable

Material	Market total	Pipeline total	Pipeline comparison	Hybrid total	Hybrid comparison
Apartments	-	400,610	Unavailable	373,356	Unavailable
Accommodation	-	80,854	Unavailable	26,425	Unavailable
Non-Residential	550,000	1,121,731	204%	610,374	111%
Non-dwellings	-	1,603,196	Unavailable	1,010,155	Unavailable
Civil	600,000	669,220	112%	669,220	112%
Transport	-	591,573	Unavailable	591,573	Unavailable
Utilities	-	77,647	Unavailable	77,647	Unavailable

Table 83: Validation of materials flows against market totals for Maximum Decarbonisation Scenario in FY 2027

Material	Market total	Pipeline total	Pipeline comparison	Hybrid total	Hybrid comparison
Aggregate	200,000,000	60,078,270	30%	63,081,127	32%
Asphalt	10,000,000	14,196,747	142%	13,397,993	134%
Cement	16,370,000	10,539,093	64%	17,025,782	104%
Residential	5,910,000	1,988,941	34%	9,411,618	159%
Detached and semi-detached dwellings	-	293,271	Unavailable	7,486,113	Unavailable
Apartments	-	1,540,238	Unavailable	1,767,120	Unavailable
Accommodation	-	155,432	Unavailable	158,385	Unavailable
Non-Residential	7,830,000	3,621,521	46%	2,685,533	34%
Non-dwellings	-	5,317,190	Unavailable	4,611,038	Unavailable
Civil	2,630,000	4,928,631	187%	4,928,631	187%
Transport	-	3,412,166	Unavailable	3,412,166	Unavailable
Utilities	-	1,516,465	Unavailable	1,516,465	Unavailable
PV Panels	1,131,243	183,156	16%	198,721	18%
Buildings	339,373	0	0%	15,565	5%
Utilities	791,870	183,156	23%	183,156	23%
Steel - Structural Elements	2,410,000	3,537,934	147%	3,184,632	132%
Residential	1,120,000	342,271	31%	229,728	21%
Detached and semi-detached dwellings	-	64,988	Unavailable	172,963	Unavailable
Apartments	-	251,866	Unavailable	52,459	Unavailable

Material	Market total	Pipeline total	Pipeline comparison	Hybrid total	Hybrid comparison
Accommodation	-	25,417	Unavailable	4,306	Unavailable
Non-Residential	980,000	719,405	73%	478,645	49%
Non-dwellings	-	996,687	Unavailable	535,410	Unavailable
Civil	310,000	2,476,259	799%	2,476,259	799%
Transport	-	326,097	Unavailable	326,097	Unavailable
Utilities	-	2,150,162	Unavailable	2,150,162	Unavailable
Steel Re-inforcement	2,120,000	2,316,433	109%	2,047,003	97%
Residential	970,000	612,735	63%	850,261	88%
Detached and semi-detached dwellings	-	152,247	Unavailable	467,898	Unavailable
Apartments	-	383,156	Unavailable	357,089	Unavailable
Accommodation	-	77,332	Unavailable	25,274	Unavailable
Non-Residential	550,000	1,046,394	190%	539,437	98%
Non-dwellings	-	1,506,882	Unavailable	921,800	Unavailable
Civil	600,000	657,304	110%	657,304	110%
Transport	-	579,657	Unavailable	579,657	Unavailable
Utilities	-	77,647	Unavailable	77,647	Unavailable

Table 84: National construction forecast for the 5-year pipeline

Project type (typecast)	Total GFA (m²)
Accommodation	3,811,457
Aged Care Facility (Addon/Brownfield)	458,721
Aged Care Facility (Brownfield)	458,721
Aged Care Facility (Greenfield)	458,721
Airport Building	4,374,919
Arena/Sporting Facility	1,884,497
Arts Facility	1,884,497
Civic/Convention Centre	2,947,071
Correctional Centre	411,476
Courthouse	411,476
Data Centre	1,010,338
Detached Residential	132,409,455
Fire and Emergency Facility	411,476
Health Facility (Addon/Brownfield)	194,602
Health Facility (Brownfield)	194,602
Health Facility (Greenfield)	194,602
Higher Education (Addon/Brownfield)	490,200
Higher Education (Brownfield)	490,200
Higher Education (Greenfield)	490,200
Hospital (Addon/Brownfield)	194,602
Hospital (Greenfield)	194,602
Laboratory	411,476
Multi Residential	33,860,966
Office	13,853,114
Parking Facility	4,374,919
Police Facility	411,476
Retail Store	5,855,507
School (Brownfield)	490,200
School (Greenfield)	490,200
Semi-detached Residential	23,839,793
Warehouse	20,817,429

References

AAC. (2023, February 3). Australian Aluminium Council Response to Australia's Critical Minerals Strategy: Discussion Paper. Canberra, ACT: Australian Aluminium Council.

AAC. (2023). *Sustainability Data Tables 2000 to 2022*. Retrieved from The Australian Aluminium Council: https://aluminium.org.au/sustainability/

ABS. (2023). *Australian National Accounts: Input-Output Tables methodology.* Retrieved from https://www.abs.gov.au/methodologies/australian-national-accounts-input-output-tables-methodology/2020-21

ABS. (2023b). *Building Approvals, Australia (July 2023).* Canberra, Australia: Australian Bureau of Statistics.

ABS. (2023b). *Energy Account, Australia, 2020-21.* Canberra, Australia: Australian Bureau of Statistics.

ABS. (2023c). *Customised Report for DCCEEW: Building Approvals [Non-residential Buildings].* Canberra, Australia: Australian Bureau of Statistics.

AEC. (2022). *Environmental Product Declaration for Aluminium Extrusions: Mill Finished, Painted, and Anodized. Declaration 4790414446.102.1.* Marietta, GA, USA: UL Environment and the Aluminium Extruders Council (AEC).

ALCAS. (2023). *AusLCI Emissions Factors, v1.42*. Retrieved from Australian Life Cycle Assessment Society: https://www.auslci.com.au/index.php/EmissionFactors

BRANZ. (2023). *CO_2NSTRUCT Database.* Porirua, New Zealand: Building Research Association of New Zealand.

Crawford, R. H., Stephan, A., & Prideaux, F. (2019). *Environmental Performance in Construction (EPiC) Database.* Melbourne: The University of Melbourne.

DCCEEW. (2022). *Annual Climate Change Statement.* Canberra: Australian Government.

DCCEEW. (2022). *Quarterly Update of Australia's National Greenhouse Gas Inventory: March 2022. Incorporating preliminary emissions up to June 2022.* Canberra: DCCEEW.

DCCEEW. (2023a). *Quarterly Update of Australia's National Greenhouse Gas Inventory: June 2022.* Canberra, Australia: Department of Climate Change, Energy, the Environment and Water.

DCCEEW. (2023b, September 6). *Australia's carbon leakage review*. Retrieved from Department of Climate Change, Energy, the Environment and Water: https://www.dcceew.gov.au/climate-change/emissions-reduction/review-carbon-leakage

DCCEEW. (2023c). *Australian National Greenhouse Accounts Factors: 2022.* Canberra, Australia: Department of Climate Change, Energy, the Environment and Water.

DCCEEW. (2023c). *National Inventory Report 2021.* Canberra, Australia: Department of Climate Change, Energy, the Environment and Water.

DCCEEW. (2023d). *Australia. 2023 Common Reporting Table (CRT).* Retrieved from United Nations Framework Convention on Climate Change: https://unfccc.int/documents/627766

DCCEEW. (2023d). *Powering Australia*. Retrieved from Energy.gov.au: https://www.energy.gov.au/government-priorities/australias-energy-strategies-and-frameworks/powering-australia

DCCEEW. (2023e). *National Inventory by Economic Sector 2021 - Data Tables (Excel).* Canberra, Australia: Department of Climate Change, Energy, the Environment and Water.

DCCEEW. (2023f). *National Waste Report 2022.* Canberra, Australia: Department of Climate Change, Energy, the Environment and Water.

Distin, T. (2023). Improving the sustainability of asphalt by using repurposed waste materials. Presentation to Port Stephens Council. Winston Hills NSW: COLAS.

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

GFG. (2020). *GFG Announces Updated Plan To Transform Whyalla Steel Into A World Leading "GREENSTEEL" Facility.* London, UK: GFG Alliance.

GFG. (2023). *New Electric Arc Furnace And Direct Reduction Plant For Whyalla.* London, UK: GFG Alliance.

Harrington. (2021). *Glazing for non-residential buildings under NCC2019 – products, costs, and market insights.* Canberra, Australia: Department of Climate Change, Energy, the Environment and Water (DCCEEW).

IAI. (2022). *Life Cycle Inventory: 2019 Data.* International Aluminium Institute (World Aluminium).

InfraBuild. (2023b). *SENSE 600 Australian Made certified sustainable steel.* Sydney NSW: InfraBuild.

Liersch, T. (2022, 2022). *Embodied Emissions in Industry.* Canberra: DCCEEW.

MPP. (2022). *Making Net-Zero Steel Possible.* Washington DC, USA: Mission Possible Partnership.

NAPA. (2021). *Asphalt Pavement Industry Survey on Recycled Materials and Warm-Mix Asphalt Usage. 12th Annual Survey.* Greenbelt, MD, USA: National Asphalt Pavement Association.

Neaylon, K. (2013). Update on the Australian Bitumen Market. *9th Asian Bitumen Conference.* Jakarta, Indonesia.

Recycling Victoria. (2023). *Victoria's waste projection model dashboard*. Retrieved from State Government of Victoria: https://www.vic.gov.au/victorias-waste-projection-model-dashboard

RICS. (2023). Whole life carbon assessment for the built environment, 2nd edition. London, UK: Royal Institution of Chartered Surveyors (RICS).

Tokede, O., & Rouwette, R. (2023). Problematic consequences of the inclusion of capital goods inventory data in Environmental Product Declarations. *International Journal of Life Cycle Assessment*. Retrieved from https://doi.org/10.1007/s11367-023-02231-4

VDZ. (2021). *Decarbonisation Pathways for the Australian Cement and Concrete Sector.* Canberra, Australia: The Cement Industry Federation, Cement Concrete and Aggregates Australia, SmartCrete CRC and RACE for 2030 CRC.

Viva Energy. (2023). *Paving the way for Australia.* Melbourne VIC: Viva Energy.

Wiedmann, T., Teh, S. H., & Yu, M. (2019). *ICM Database - Integrated Carbon Metrics Embodied Carbon Life Cycle Inventory Database.* Sydney: UNSW. Retrieved from https://researchdata.edu.au/icm-database-integrated-inventory-database/1440719

Yu, M., Wiedmann, T., Crawford, R., & Tait, C. (2017). The carbon footprint of Australia's construction sector.Proceedings of the International High-Performance Built Environment Conference - A Sustainable Built Environment Conference 2016 Series (SBE16). *Procedia Engineering*, 211-220.