Australian Government | Infrastructure Australia

Embodied Carbon Projections for Australian Infrastructure and Buildings

2024

Acknowledgement of Country

Infrastructure Australia proudly acknowledges the Traditional Owners and Custodians of Australia, and their continuing connections to the land, waters, and communities. We pay our respects to them and to their Elders past and present. In preparing for the future of our infrastructure, we acknowledge the importance of looking beyond the immediate past to learn from Aboriginal and Torres Strait Islander peoples' unique history of land management and settlement, art, culture, and society that began over 65,000 years ago.

As part of Infrastructure Australia's commitment to reconciliation, we will continue to develop strong, mutually beneficial relationships with Aboriginal and Torres Strait Islander partners who can help us to innovate and deliver better outcomes for Aboriginal and Torres Strait Islander communities, recognising their expertise in improving quality of life in their communities.

A note from the artist:

"Through sharing culture, we can create a sense of belonging, by connecting to the land we stand on. This connection of people and our communities is shown through connecting campfires. These being places we sit, yarn, and share knowledge.

The Infrastructure Australia values - expressed by the colours blue, green, orange, purple and teal - weave through the artwork to represent the opportunities and benefits for our communities.

Under this sits our rivers, lakes, oceans, and waterways. Water being the giver and supporter of life and flows through us all. I see the reconciliation journey as the water along the path to benefiting our people.

Around our waterways I've shown our traditional infrastructure. Our connections and songlines. The systems set up by the First Peoples of this place that we aim to weave into the modern landscape."

Nani, by Kevin Wilson (Maduwongga, Wongutha).

Acknowledgement

Infrastructure Australia would like to acknowledge project sponsor the Department of Climate Change, Energy, Environment and Water (DCCEEW), as well as project partner the Department of Infrastructure, Transport, Regional Development, Communications, and the Arts (DITRDCA).

We also acknowledge and thank the dedicated work of the project consultants thinkstep-anz, supported by Slattery. Critically, the report would not have been possible without the generous contributions from the Technical Reference Group (Infrastructure NSW; Australasian Procurement and Construction Council; Infrastructure Sustainability Council; NABERS; Green Building Council of Australia; CSIRO; Development Victoria; Australian Constructors Association; Consult Australia; Engineers Australia; Australian Institute of Quantity Surveyors; MECLA; DITRDCA; DCCEEW) and over 200 individuals representing businesses, industry and governments across the infrastructure and building sectors who participated in the workshops and interviews. Finally, we thank the extensive involvement and inputs from John Holland, Lendlease, Infrabuild, BlueScope, Transurban and H1 Holdings to support our analysis through the provision of data.

Contents

Foreword

It is with pleasure that I present this *Embodied Carbon Projections for Australian Infrastructure and Buildings* report, which, for the first time, uses our Market Capacity Program data to measure the embodied carbon intensity of forward-looking infrastructure and buildings pipelines across a five year period.

This report identifies that, in the near term, the biggest immediate opportunity for lowering embodied carbon emissions lies in upfront emissions from the manufacture and supply of materials. These easy-to-abate emissions represent almost 2% of the yearly national total, and are addressable via low-cost and practical decarbonisation strategies explored in this report.

In the long-term however, the decarbonisation of Australia relies on us cultivating the optimum conditions for success, today. This means developing an informed market that values carbon in policy, and consistently measures and reports embodied emissions.

To this effect, we have included six recommendations for governments to consider in the development of sectoral decarbonisation plans that will inform the Australian Government's Net Zero 2050 plan and 2035 carbon reduction targets.

I would like to extend my thanks to the project team whose efforts culminated in this insightful research, and also express gratitude to all those involved across the jurisdictions and industry for their invaluable contribution which have enriched the depth and breadth of our findings.

Gabrielle Trainor AO

Interim Chief Commissioner

Executive summary

This *Embodied Carbon Projections for Australian Infrastructure and Buildings* report establishes a baseline for upfront embodied carbon in Australia's built environment. It does this by estimating the carbon impact of the forward-looking construction pipeline for building and infrastructure from 2022–23 to 2026–27.

It finds that the built environment is directly responsible for nearly one third of Australia's total emissions and contributes to over half of all emissions. Over the next five years, construction activity from the pipeline will be responsible for producing between 37 to 64 Mt CO_2e per year. Almost a quarter of upfront emissions from construction activity over the next five years (or 2% of Australia's total emissions in 2022–23 can be abated at no additional cost by employing practical decarbonisation strategies, such as material substitution. Targeted engagement with industry and government stakeholders indicated that this will require an informed market which values carbon in policy and consistently measures and reports embodied emissions.

The carbon impact of the forward looking construction pipeline is based on Infrastructure Australia's National Infrastructure Project Database, which aggregates project level data for buildings, transport, and utilities projects valued over $100 million in New South Wales, Victoria, Queensland and Western Australia, and over $50 million in South Australia, the Australian Capital Territory, the Northern Territory and Tasmania, in addition to private building projects with a capital value of over $25 million. To account for the effect of project unknowns on construction material quantities and address gaps in smaller residential projects, an additional forecast of embodied carbon emissions was also conducted which aligns material demand quantities with estimates of national supply levels (See *Section 5: Accounting for Uncertainty: Hybrid Analysis*)

The report highlights key areas of opportunity for governments to consider in the development of sectoral decarbonisation plans that will inform the Australian Government's Net Zero 2050 plan and 2035 carbon reduction targets.

Key findings

1. **Currently, buildings and infrastructure are directly responsible for almost one third of Australia's total carbon emissions,** and indirectly responsible for over half of all emissions. See **Figure 1**.

2. **Embodied carbon from building activity contributed 10% of national carbon emissions in 2023**, with upfront carbon contributing 7%. Unlike operational emissions, which can be reduced by decarbonising the grid using efficient equipment and continuous commissioning, embodied carbon emissions are locked in once the asset is complete. Reducing embodied carbon emissions generates significant and immediate abatement.

3. **The largest sources of embodied carbon in 2022–23 was calculated to be buildings (21 Mt CO_2e)**, followed by transport infrastructure (10 Mt CO_2e) and then utilities (5 Mt CO_2e).

4. **The upfront embodied carbon in Australia's pipeline of infrastructure and buildings is forecast to be between 37 Mt CO_2e and 64 Mt CO_2e per year for the next 5 years, equating to 247 Mt CO_2e** unless deliberate action is taken to reduce this.

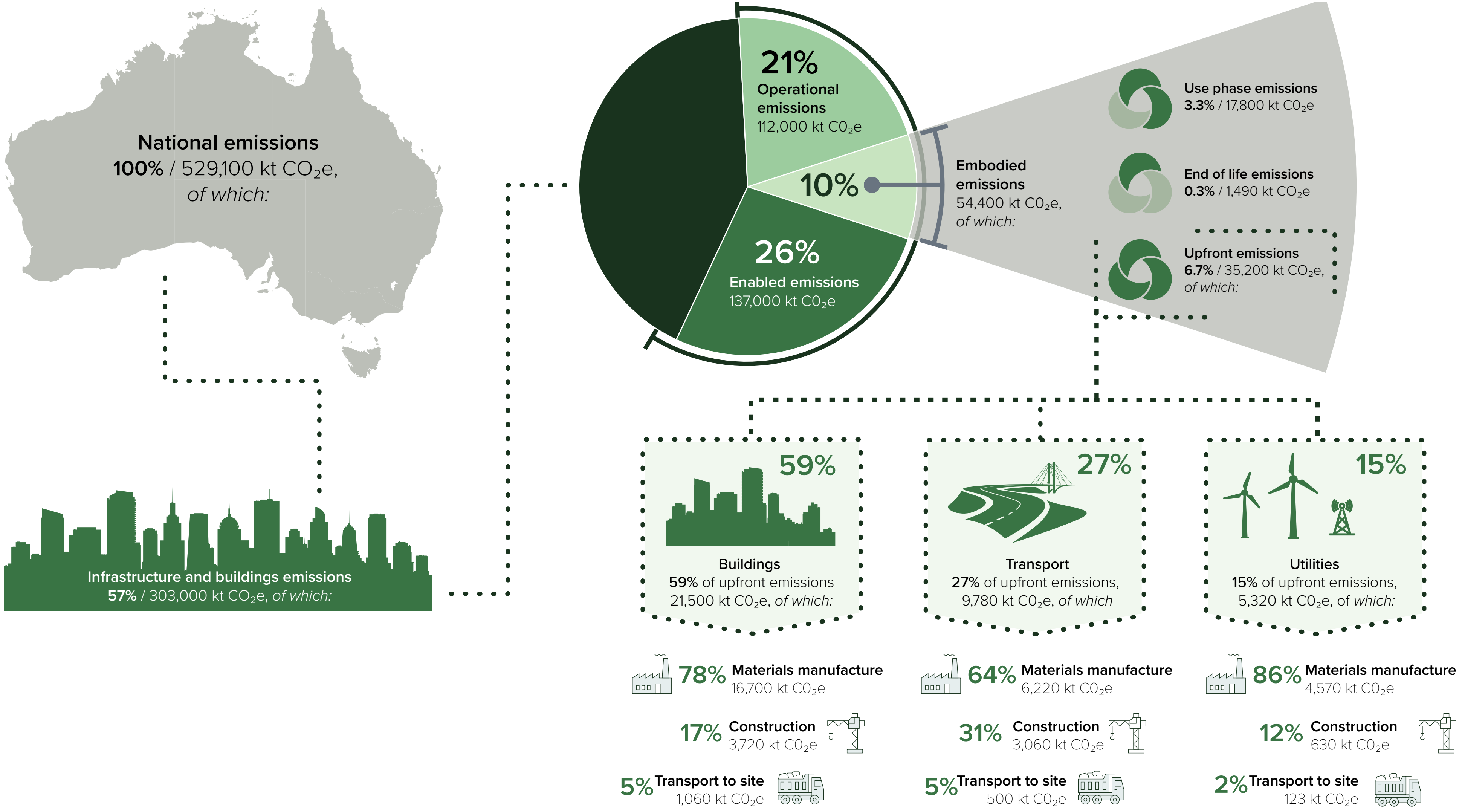
5. **Upfront emissions occur during and/or prior to construction and account for 7% of Australia's national emissions in 2022–23**, with most of these emissions originating from the manufacture of construction materials.

6. **A 23% reduction in upfront carbon emissions is possible by 2026–27** by applying like-for-like decarbonisation strategies that that can be achieved by industry and government actively working together. This is equivalent to a reduction of 9 Mt CO_2e, roughly 2% of Australia's gross national GHG emissions of 529 Mt CO_2e in 2022–23.

7. **In addition to like-for-like decarbonisation strategies, further significant emissions reductions would be achievable** through design optimisation and less-build strategies.

Figure 1: Carbon emission projections for Australian infrastructure and buildings, 2023

Source: Infrastructure Australia (2023).
Enabled emissions have been defined in this study to exclude primary industry (mining, agriculture, and forestry).



Recommendations

This report offers the following **six recommendations** aimed at supporting the development of Australian Government decarbonisation policies for infrastructure and the built environment.

Table 1: Recommendations for knowledge and systems

	Report finding	Opportunities	Recommendations
1	The decarbonisation of the built environment suffers from industry silos and a lack of collective ambition. While governments and industry are working hard to manage their emissions, efforts often focus on individual assets, overlooking interconnected networks and systems. Moreover, project-level decarbonisation initiatives often commence late in the planning stages, risking the discretionary nature of carbon reduction goals and potential compromises through value engineering.	To decarbonise the built environment at scale, it is essential to take a comprehensive approach and work together across the value chain. This means seeing assets as part of a larger interconnected system, breaking down barriers across sectors, markets and jurisdictions and developing a unified strategy. By applying decarbonisation principles early on and considering the entire lifespan of buildings and infrastructure, it is possible to maximise opportunities to reduce embodied carbon and minimise trade-offs.	The Australian Government, working with state and territory governments, should develop a comprehensive national plan to actively promote the decarbonisation of emissions embodied in Australia's built environment, in particular by: • linking new construction decisions to Net Zero 2050 and 2035 reduction targets • using the decarbonisation hierarchy to drive a clear strategy for reducing whole-life carbon from a project's 'needs' stage to lock in the greatest opportunity to influence carbon reductions • using lifecycle thinking to manage environmental and social impacts, minimise carbon footprints and avoid trade-offs.
2	Limited understanding of decarbonisation and climate related issues across industry along with a lack of confidence in using lower carbon materials are obstacles to moving towards low carbon solutions. While individual projects may see success, there is a lack of collective data to support widespread adoption of innovative approaches. The Austroads Environment and Sustainability Taskforce, along with the Australian Government, state and territory governments, and New Zealand, are actively working together to fill knowledge gaps and promote new methods for reducing carbon in road-related infrastructure. At the same time, the Australian Government's investment in the Infrastructure Net Zero Initiative aims to unite industry and government stakeholders to drive ongoing policy changes and innovation in cutting carbon emissions from infrastructure.	Decarbonisation at scale requires education and training for professionals, trades and consumers. Training should focus on addressing carbon literacy, specification of low-carbon products, and construction techniques with low-carbon materials. Sharing proven methods and project learnings can support broader knowledge uplift across industry.	The Australian Government, with state and territory governments should build carbon confidence and literacy for professionals, trades and consumers by: • complementing the ongoing efforts of the Austroads Environment and Sustainability Taskforce and the Infrastructure Net Zero Initiative to develop education programs for professionals, trades and consumers which target carbon literacy and low carbon product specifications and construction • developing a national sharing platform for industry practitioners to showcase learnings from projects, pilots, concessions, model contracts and specifications for low carbon solutions • piloting projects to trial new solutions and produce data about new products and construction techniques.

Table 2: Recommendations for **collaboration**

	Report finding	Opportunities	Recommendations
3	Industry currently lacks a nationally accepted way of measuring embodied carbon. Different methods are used to calculate and claim carbon reductions and there is no single, trusted dataset for all construction material emissions factors. Without this, it is hard to access and compare the emissions of different products. Across Australia there is no uniform mandates to measure and report embodied carbon. There is work being progressed by National Australian Built Environment Rating System and the Infrastructure and Transport Ministers' Meeting to produce consistent methodologies to calculate upfront carbon for buildings and transport projects, respectively.	Decarbonisation should be based on a nationally accepted way of measuring embodied carbon, which is supported by a national database of emissions factors for construction materials to ensure consistency in measurement. Policy support for measuring and disclosing upfront carbon can help industry understand the true impact of new construction and stimulate the market for low carbon solutions.	The Australian Government, with state and territory governments, should develop a nationally standardised embodied carbon measurement system, which allows for consistent methods to collect, measure, and assess data about embodied carbon. This could involve: • establishing a national database of default emissions factors and environmental product declarations to support embodied carbon measurement, and be a single source of truth for practitioners in the built environment • setting requirements to measure and disclose upfront carbon on projects over a threshold value and set best practice targets informed by benchmarks for different asset classes • investigating ways to drive national alignment on data to support carbon calculations, including standardising the collection of construction and commissioning data.

	Report finding	Opportunities	Recommendations
4	A lack of consistent and continuous demand for low carbon products creates difficulties for the development of low carbon solutions that are commercially viable. Companies seeking to develop lower carbon products face cost premiums, and some domestic manufacturers have expressed concerns with carbon leakage from high-carbon, low-cost imports. The lack of valuation for carbon impacts in many projects results in cost-driven decision-making during procurement, often favouring low-cost options over initially specified low-carbon alternatives. In December 2023, the Infrastructure and Transport Ministers' Meeting approved a nationally consistent set of carbon values for use in transport infrastructure projects. As of March 2024, Infrastructure Australia requires the use of these values in infrastructure proposal submissions. The Infrastructure Decarbonisation Working Group, led by the NSW Government and the Australian Government, is also developing policies to reduce embodied emissions in transport infrastructure. This includes the creation of a 'carbon in procurement and contracts' guideline to support the implementation of measures promoting transport decarbonisation.	A nationally agreed approach for stimulating demand for low carbon solutions would help to demonstrate consistency and reliability for the supply chain. Funding support for the development of low carbon materials will also help to speed up their adoption into Australia's built environment.	The Australian Government, working with state and territory governments, should agree a common national approach to drive market demand for low carbon solutions. This could involve: • developing nationally consistent procurement guidance through the Infrastructure Decarbonisation Working Group focused on enabling low carbon solutions in transport project requirements • addressing cross-border carbon leakage and ensuring a means of fair carbon accounting between domestic and imported products, through the Australian Government's ongoing work to investigate a domestic Carbon Border Adjustment Mechanism • exploring funding or grants models to reduce the cost burden for projects to adopt lower carbon products and technologies • investing in sustainable finance instruments to incentivise the adoption of low carbon materials and technologies on projects, by working with concessional finance providers • investigating incentives for low carbon construction with planning authorities.

	Report finding	Opportunities	Recommendations
5	The unwillingness of the industry to embrace new project delivery approaches due to fear of risk exposure is impeding progress in decarbonisation The incremental effort involved in identifying risks associated with new delivery approaches and then allocating risk to the party best placed to manage is substantial, leading project teams to opt for traditional solutions and conservative procurement practices.	Asset owners and contractors need to share risks and rewards to encourage the adoption of lower-carbon solutions on projects. This could involve prioritising decarbonisation as a metric for project success, offering shared reward incentives through contracts, and developing new models for project delivery. Government funded projects that support trials and pilots of new solutions would provide data and insights to support investment decisions and increase industry confidence.	The Australian Government, working with state and territory governments, should develop new methods for project delivery which share risks and rewards for innovative approaches. This could involve: • specifying outcomes and expectations of project delivery that embed specific requirements for decarbonisation • developing performance-based, collaborative contract models and business cases, which assume the use of low carbon materials, early contractor involvement on projects, embodied carbon analysis in pre-tender processes, and clear direction for decarbonisation in tender documentation • exploring opportunities to include trials of new materials in flagship projects, and sharing learnings.

Table 3: Recommendations for the operating environment

	Report finding	Opportunities	Recommendations
6	Supplier investment in low-carbon solutions is hampered by overly prescriptive product specifications on projects, which specify that materials must meet a certain prescriptive characteristic rather than performance outcomes. This inhibits the entry of new materials and solutions. Slow updates to industry standards and project specifications also mean that the pace of development will outstrip a standard or specification's ability to keep up with the latest options available.	Governments and private entities should transition to performance-based specifications on projects, which focus on desired outcomes rather than specific product characteristics. This would allow for innovative approaches that deviate from traditional specifications and support the uptake of lower carbon solutions on projects. Faster, more agile processes should be introduced to ensure that standards and specifications can be updated in a timely way.	The Australian Government, with state and territory governments, should work with industry to drive national alignment on low-carbon expectations through performance-based standards and specifications. This could involve: • establishing unified specifications and guidelines that promote the adoption of lower-carbon products more consistently across all jurisdictions, which should be incorporated into widely accessible model specification clauses to enable standardised practices • procuring using performance-based specifications, that allow for materials and solutions to be judged on meeting performance criteria, rather than specifying that they must be of a certain characteristic • leading efforts to expedite the updating of standards and specifications, developing a more efficient system and providing funding for critical updates to keep pace with evolving options.

Current embodied carbon initiatives

We note the following efforts of governments to lower embodied carbon in infrastructure and buildings:

The Australian Government

- Work is underway to develop nationally consistent frameworks for decarbonising infrastructure. Under the auspices of the Infrastructure and Transport Ministers' Meeting, three workstreams have been established to:
  - develop a nationally consistent approach to measure embodied carbon for infrastructure, which will support industry action to reduce emissions and facilitate future benchmarking and target setting (led by Infrastructure NSW)
  - develop a nationally consistent approach to valuing carbon for economic appraisal and policy evaluation (led by Infrastructure Australia)
  - explore policy levers available to governments to reduce embodied emissions, including principles to support the identification of opportunities for the national harmonisation of policies to reduce embodied emissions, as well as inform governments' selection of these policies (led by Transport for NSW with the Australian Government).
- The National Australian Built Environment Rating System is developing a national framework for measuring, benchmarking and certifying emissions from construction and building materials. This will allow building owners to set robust and measurable targets for reducing embodied carbon in buildings.

State and territory governments

- NSW Government, through Infrastructure NSW, has published a Decarbonising Infrastructure Delivery Policy which sets expectations for NSW Government infrastructure delivery agencies on managing carbon in public infrastructure projects. This is supported by Measurement Guidance. In partnership with the Environment Protection Authority, Infrastructure NSW is also developing a monitoring framework to require infrastructure projects to report embodied carbon and maximise the use of recycled materials.
- Infrastructure Victoria has released advice on opportunities for the Victorian Government to reduce emissions of future public infrastructure investments. This advice focuses on policy and guidance to address emissions at all stages of development.

SECTION 1

Introduction

A report on embodied carbon in Australia's infrastructure and buildings

This report offers a combination of quantitative and qualitative analysis to assist governments in understanding the potential for decarbonising infrastructure and buildings, as well as the increased usage of low embodied carbon materials in construction. These are key focus areas identified in the Australian Government's most recent Infrastructure Policy Statement (November 2023).[1]

By presenting data and insights, it seeks to inform the development of policies aimed at reducing embodied carbon in the built environment. It also aims to initiate discussions on potential policy levers that align with this goal, such as the ongoing development of sector-specific plans by the Australian Government for the decarbonisation of buildings and transport infrastructure.

It responds to three pieces of legislation:

- *The Climate Change Act 2022 (Cth)*, which legislates a 43% reduction in 2005 national greenhouse gas (GHG) emissions by 2030, and a net zero reduction by 2050.
- *The Climate Change (Consequential Amendments) 2022 Act*, which legislates for government institutions to focus on achieving emissions targets.
- *The Infrastructure Australia Act 2008* which requires Infrastructure Australia to consider the impact of infrastructure proposals on Australia's net greenhouse gas emissions, the achievement of Australia's GHG emissions reduction targets and any policy issues arising from climate change that Infrastructure Australia considers relevant to the proposal.

Baseline measures of carbon emissions for Australia's infrastructure and buildings

This report leverages Infrastructure Australia data to analyse the embodied carbon emissions of Australia's infrastructure and buildings pipeline. This includes estimating the embodied carbon that will be produced in the next five years if no action is taken, evaluating the potential emissions and costs associated with using low-carbon building materials and construction methods, and identifying barriers and government interventions that could increase the adoption of these solutions.

Section 2: Baseline Measures of Embodied Carbon presents baseline measures of carbon emissions produced by Australia's infrastructure (listed below and depicted in **Figure 1**):

- Emission type (embodied, operational, enabled)
- Embodied emission type (upfront, use phase, end-of-life)
- Upfront carbon (materials manufacture, transport to site, construction process)

Also in *Section 2: Baseline Measures of Embodied Carbon* are the carbon and cost impacts of using like-for-like material substitutions in government infrastructure projects for two decarbonisation scenarios.

Projections based on forward-looking government construction pipelines

Embodied carbon projections in this report are based on the quantities of construction materials demanded by the forward-looking infrastructure pipelines of the Australian Government, and state and territory governments. These quantities have been determined using the analytical tools of Infrastructure Australia's Market Capacity Program - an assumptions-based methodology that identifies market capacity risks by analysing infrastructure project data provided by governments, which, combined with private investment data provided by GlobalData, reflects around 75% of market demand in the forward estimates period.

Working towards Net Zero 2050

This report offers high-level recommendations for the Australian Government to work towards the reduction of embodied carbon from infrastructure and buildings in support of Net Zero 2050. These recommendations aim to initiate investigations and identification of policy levers that are best placed to achieve this objective, and were developed following extensive consultations with government stakeholders, industry members, and technical experts - see *Appendix* for a summary of our stakeholder consultation insights.

A summary of opportunities and recommendations is included in the *Executive Summary* of this report.

Embodied carbon policy: current state

Throughout Australia, governments are taking steps to design and implement policies targeting the reduction to embodied carbon in the built environment.

The Australian Government

The Australian Government is actively working to create consistent frameworks for decarbonising infrastructure and buildings. Three key workstreams have been established under the auspices of the Infrastructure and Transport Ministers' Meeting[2]:

- **Measuring embodied carbon:** The focus is on developing a nationally consistent approach to measure embodied carbon in infrastructure. This will aid in reducing emissions, supporting industry action, and enabling benchmarking and target setting.
- **Valuing carbon:** Infrastructure Australia is leading the effort to develop a nationally consistent approach to valuing carbon for economic appraisal and policy evaluation.
- **Policy levers and harmonisation:** Transport for NSW, in collaboration with the Australian Government, is exploring policy levers to reduce embodied emissions. This includes developing principles to harmonize national policies aimed at reducing embodied emissions and guiding governments in policy selection.

The National Australian Built Environment Rating System is working on a national framework to measure, benchmark, and certify emissions from construction and building materials. This framework aims to help building owners establish measurable targets for reducing embodied carbon in buildings.

State and territory governments

NSW Government, through Infrastructure NSW, has published a Decarbonising Infrastructure Delivery Policy which sets expectations for NSW Government infrastructure delivery agencies on managing carbon in public infrastructure projects. This is supported by Measurement Guidance. In partnership with the Environment Protection Authority, Infrastructure NSW is also developing a monitoring framework to require infrastructure projects to report embodied carbon and maximise the use of recycled materials

Infrastructure Victoria has released advice on opportunities for the Victorian Government to reduce emissions of future public infrastructure investments. This advice focuses on policy and guidance to address emissions at all stages of development.

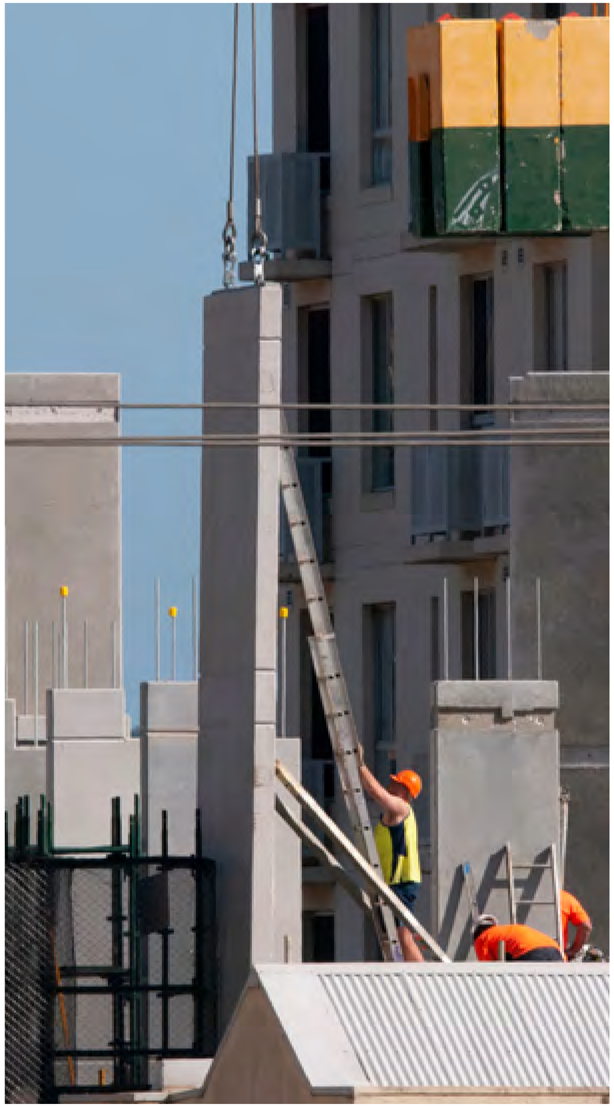
Overview of the Market Capacity Program

This research is underpinned by Infrastructure Australia's Market Capacity Program, a data-driven research initiative designed to help stakeholders understand the national infrastructure pipeline. By continuously monitoring market conditions and capacity to deliver infrastructure, the Market Capacity Program provides insights to inform government policies and management of infrastructure pipelines. The Market Capacity Program was set up in response to a request by Ministers at the Council of Australian Governments meeting of 13 March 2020.

The Market Capacity Program is underpinned by a National Infrastructure Project Database, a central database that brings together and organises project data. State and territory governments contribute to the database by providing regular, comprehensive, up-to-date information. A Market Capacity Intelligence System complements the database. This is an extensive set of analytical tools to examine and visualise capacity across different sectors, project types and resources. Together, this suite of tools, data and reports provide up-to-date evidence to better understand Australia's infrastructure pipeline and the market's capacity to deliver in the coming years.

Accounting for uncertainty

Given that Market Capacity Program analysis cannot account for future changes in cost, schedule, or scope, *Section 5: Accounting for Uncertainty: Hybrid Analysis* offers an alternate forecast of embodied carbon emissions, which considers the effect of project unknowns on construction material quantities - for example, resource shortages and typical project slippage. In addition, these alternative projections address gaps in smaller residential projects, expand material categories, and align calculated material demand quantities with estimates of national supply levels.



SECTION 2

Baseline measures of embodied carbon

Key findings

Embodied carbon from construction activity in 2023 contributed 10% of Australia's total carbon emissions, with upfront carbon contributing 7%.

A steady reduction of upfront carbon is achievable by applying like for like decarbonisation strategies, with potential for 23% reduction on the baseline by 2027. This roughly equates to a reduction of 9 Mt CO_2e, or 2% of Australia's national greenhouse gas (GHG) emissions in 2023.

The reduction of upfront carbon in the manufacturing of construction materials and the construction process provides a short-term opportunity for policymakers to consider in working towards Net Zero 2050.

To support decarbonisation policy design and implementation, this section provides baseline measures of embodied carbon in infrastructure, and estimated emissions and costs from the use of like for like material substitutions in government infrastructure.

Embodied carbon accounts for 10% of national emissions

Australian infrastructure and buildings were projected to contribute 57% of national carbon emissions in 2023. Of this, embodied carbon from construction activity in the built environment represents 10% of national emissions, as shown in **Table 4**.

Embodied carbon represents the sum of the GHG emissions associated with materials and construction processes throughout the whole lifecycle of an infrastructure or building asset, including material extraction, transportation, manufacturing, construction, use, replacement, demolition and end of life. These emissions are 'locked in' by the decisions made during the planning, design, procurement, delivery and maintenance of new construction projects.

As Australia strives towards net zero, it is crucial to address embodied carbon, which reflect the climate consequences of today's construction decisions, and embed emissions for the lifetime of the asset.

Table 4: Breakdown of carbon emission projections for infrastructure and buildings, 2023

Emission	Definition	2023 emissions (kt CO_2e)	Share of national emissions
Embodied	Emissions associated with materials and construction processes used over an asset's life.	54,400	10%
Operational	Emissions from asset use: mainly electricity and on-site combustion of diesel and natural gas.	112,000	21%
Enabled	Emissions made possible by an asset's existence, such as diesel emissions made possible by the presence of highways.	137,000	26%

The importance of addressing embodied carbon

While operational and enabled emissions represent a larger proportion of the total compared to embodied carbon, there are already many initiatives targeting them, and they can be reduced by decarbonising the electricity grid or using green hydrogen.

Embodied carbon is much harder to abate. While some embodied carbon will reduce as the grid decarbonises, others will not. This is because the carbon footprint of many building products (such as steel, cement, bitumen, glass, plasterboard, bricks and aggregates) comes from process heat and chemical emissions rather than from electricity.

As the grid decarbonises and progress is made on reducing the operational energy use of Australia's buildings and infrastructure, embodied emissions are expected to account for a greater share of an asset's carbon footprint over its lifecycle.

There is an opportunity for governments to increase their range of embodied carbon reduction policies as part of efforts to decarbonise the built environment, which have to date focused extensively on addressing operational emissions.

Focusing on upfront carbon

Embodied carbon can be divided into the different stages of an asset's life at which they occur. These include:

- **Upfront** embodied carbon emissions, which occur at the start of an asset's life, up to practical completion. They include emissions from materials production, transport, construction waste and the construction process.
- **Use phase** embodied carbon emissions, which occur during an asset's life when it is maintained, repaired, replaced and renovated. Examples include regular fitouts of buildings, recladding of buildings and maintaining/replacing road pavements.
- **End of life** embodied emissions, which occur at the end of an asset's life. This includes emissions from deconstruction, demolition, transportation and waste management after the asset is no longer in use.

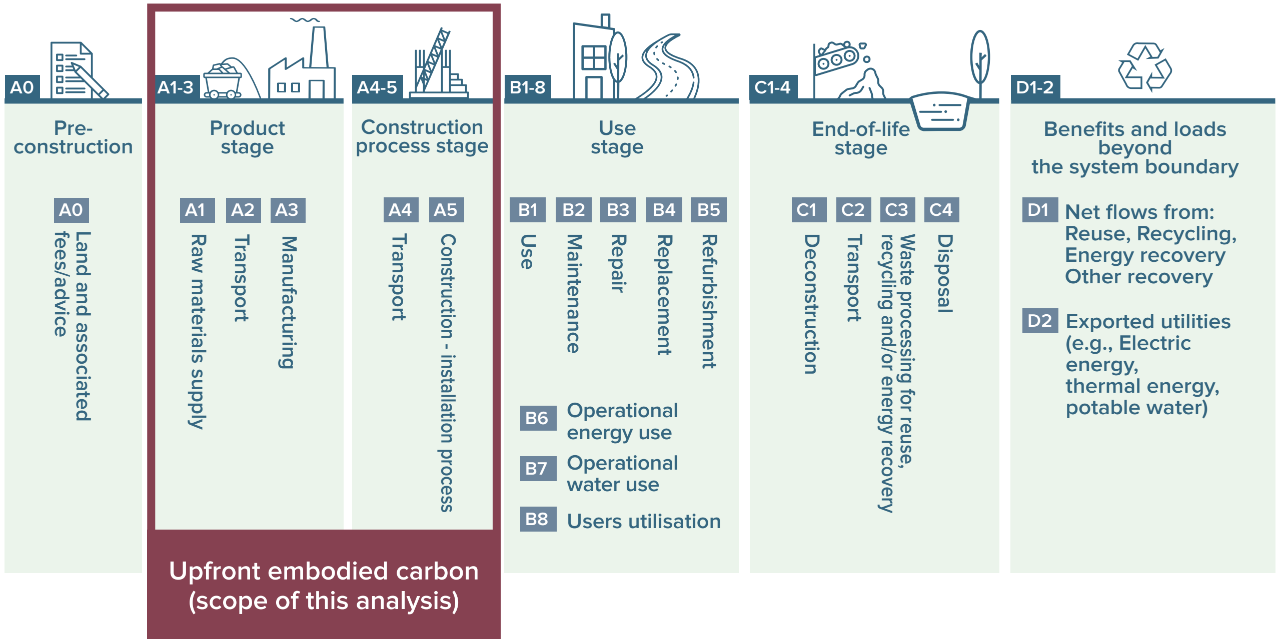
The analysis in this report focuses on upfront embodied carbon, defined here as the greenhouse gas emissions and removals associated with the creation of an asset, network or system up to practical completion.[3]

Figure 2 illustrates the activities underlying the infrastructure and buildings lifecycle modules as defined by international and European standards for lifecycle assessment of buildings and infrastructure assets.[4,5,6,7,8]

Activities factored into upfront carbon calculations include:

- Modules A1-A3: Manufacture of building products
- Module A4: Transport of building products to site.
- Module A5: Construction, which includes:
  - land use change from land clearing
  - construction waste
  - construction energy
  - commissioning energy.

Figure 2: Infrastructure and buildings lifecycle modules, highlighting upfront carbon



Based on data from Infrastructure Australia's Market Capacity Program (2023), Australia's construction pipeline is projected to produce between 37 Mt CO_2e and 64 Mt CO_2e of upfront carbon each year, between 2022–23 and 2026–27. Of this, buildings represent the largest share of the total upfront carbon, accounting for approximately half of total forecast emissions in most years. This is followed by utilities, which have the greatest variability, accounting for 14% of forecast upfront emissions in 2022–23 and 41% in 2026–27. Finally transport infrastructure accounts for approximately one-fifth to one-quarter of upfront emissions in most years. In 2023, upfront carbon from building activity is estimated to produce approximately 7% of Australia's national emissions (see **Table 5**).

Table 5: Embodied carbon emission projections by lifecycle module, 2023

Embodied carbon emissions	Definition	2023 emissions (kt CO_2e)	Share of national emissions
Upfront	Emissions from the creation of an asset, network, or system, up to the point of practical completion.	35,200	6.6%
Use phase	Emissions from maintaining and/or refurbishing an asset.	17,800	3.4%
End-of-life	Emissions from asset demolition and/or deconstruction.	1,490	0.3%

Materials manufacturing produces the most upfront carbon

Of the activities responsible for upfront carbon emissions, the manufacturing of construction materials (modules A1—A3 in **Figure 2**) account for most upfront carbon. These activities are described in **Table 6**.

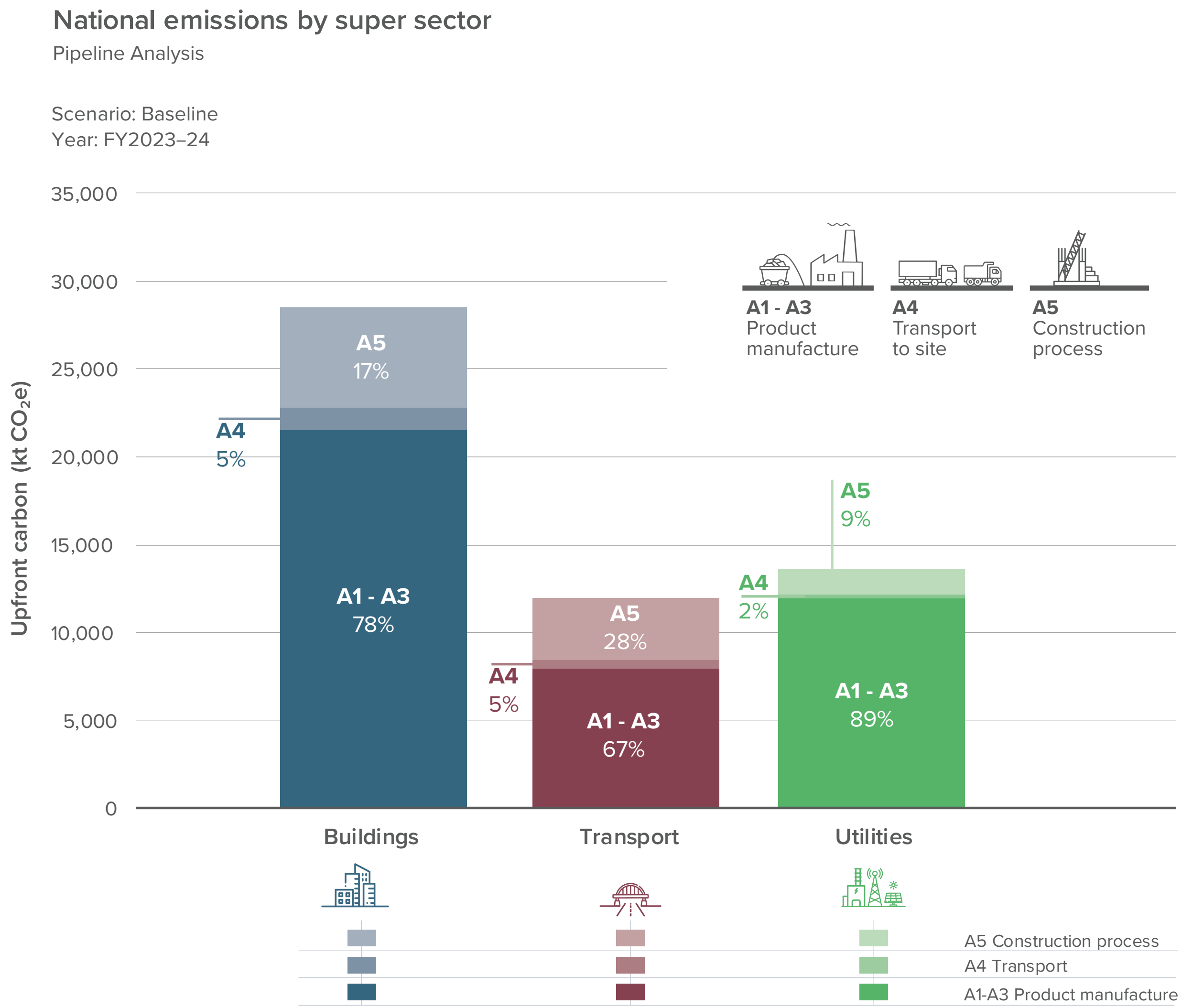
Table 6: Upfront carbon projections for lifecycle modules A1—A3, A4 and A5, 2023

Upfront carbon emissions	Description	2023 emissions (kt CO_2e)	Share of upfront carbon emissions from infrastructure and buildings
Materials manufacture (A1-A3)	Emissions from the manufacture of construction products, from extracting, harvesting, or recovering raw materials, through to the manufacturer's outbound factory gate.	27,500	75%
Transport to site (A4)	Transport of building products to site.	1,680	5%
Construction (A5)	Emissions from asset construction including land use change/clearing, waste, and energy (including commissioning).	7,400	20%

Across all sectors, materials manufacturing dominates upfront carbon emissions

Materials manufacturing (modules A1—A3 in **Figure 2**) represents the highest proportion of upfront carbon emissions across all sectors. This can be seen in **Figure 3**, which shows a breakdown of emissions by lifecycle module for 2023–24.

Figure 3: Upfront carbon projections for lifecycle modules A1—A3, A4 and A5 by sector, FY 2023–24

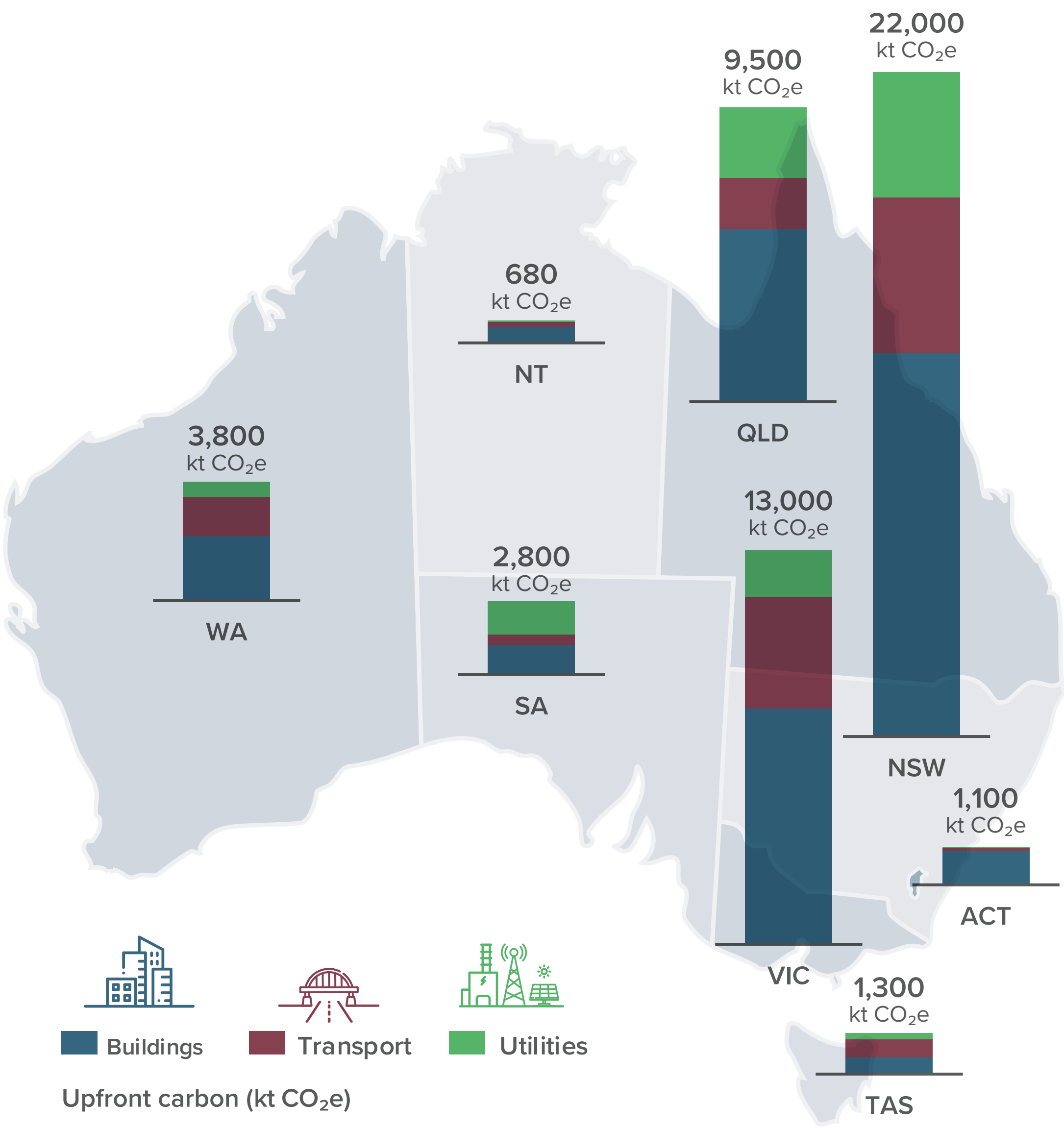


The dominance of materials manufacturing in upfront carbon is most pronounced in the buildings sector in terms of volume (21 Mt CO_2e) and in the utilities sector in terms of share (89%). Construction is the second most significant lifecycle stage, accounting for 9% to 28% of total emissions. The key contributors to construction emissions vary between asset types. Some are due to construction or commissioning energy, while others are the result of land use change. Transport of building products to site is the least significant lifecycle module relatively, accounting for only 2–5% of total emissions.

Emissions broadly follow population, but priorities differ between regions

Carbon emissions shown in **Figure 4** reflect the five-year infrastructure ambitions of each state and territory. The largest share of emissions is forecast to come from New South Wales, followed by Victoria, Queensland, Western Australia, South Australia, Tasmania, the Australian Capital Territory and the Northern Territory. While these emissions broadly follow differences in population, there are major differences in how they are made up. South Australia, Queensland and New South Wales plan to invest heavily in utilities, particularly utility solar. Tasmania, Western Australia and Victoria plan to invest in transport infrastructure. The Australian Capital Territory and the Northern Territory are focused on buildings.

Figure 4: Upfront carbon emissions of states and territories, FY 2024



The potential for low-carbon building materials and construction methods

This research also investigated the carbon and cost impact of using like-for-like, decarbonisation strategies in forthcoming public infrastructure projects found in Infrastructure Australia's Market Capacity Program database.

The adoption rates for decarbonisation strategies were calculated under two scenarios, reflecting a mid-level and maximum rate of adoption The Maximum Decarbonisation Scenario represents the highest level of ambition that industry stakeholders felt were achievable by 2026–27, assuming that cost was not a barrier. The Mid-level Decarbonisation Scenario uses lower uptake rates and reduces the use of decarbonisation strategies that are particularly expensive.

Table 7 presents a summary of the different uptake rates per scenario. *Section 4: Cost and Carbon Abatement Potential* examines cost and carbon abatement potential of each strategy.

Table 7: Uptake rates per decarbonisation scenario

Decarbonisation strategy	Baseline*	Mid-Level Decarbonisation by 2026–27*	Maximum Decarbonisation by 2026–27*
Supplementary cementitious materials replace cement	0–35%	40%	50%
Reclaimed asphalt pavement replaces asphalt in: • wearing course • base course	0–10% 5–20%	0–25% 10–40%	15–25% 20–40%
Recycled crushed concrete replaces aggregates in: • pavement subbase • concrete	0–5% 0%	5–20% 5%	10–30% 10%
Structural steel lightweighting	0%	50%	100%
Reinforcing steel lightweighting	0%	50%	100%
Fibre reinforcing replaces mesh/bar	30%	60%	100%
Steel made in electric arc furnace with 100% renewable electricity	Grid average	50%	100%
Hydrated lime replaced in asphalt	0%	100%	100%
Aluminium made with 100% renewable electricity	Grid average	25%	50%
Biodiesel in construction	5%	10%	20%
Renewable electricity in construction	Grid average	30%	100%

* A range indicates that uptake rates vary by state and typecast.

23% of upfront carbon from public infrastructure could be abated by 2026–27

Our analysis concludes that under the Maximum Decarbonisation Scenario, the upfront carbon emissions from public infrastructure could be 23% lower in 2026–27 with the use of like-for-like decarbonisation strategies considered in this report – see **Table 8**.

Table 8: Carbon impact from Maximum Decarbonisation Scenario and reduction against Baseline Scenario

	2022–23		2023–24		2024–25		2025–26		2026–27	
	kt CO_2e	Change	kt CO_2e	Change	kt CO_2e	Change	kt CO_2e	Change	kt CO_2e	Change
Buildings	21,000	0%	27,000	-5%	30,000	-9%	21,000	-19%	9,900	-31%
Transport	9,800	0%	11,000	-4%	10,000	-7%	8,300	-16%	6,900	-25%
Utilities	5,300	0%	13,000	-2%	19,000	-4%	15,000	-8%	14,000	-16%
Total	**37,000**	**0%**	**52,000**	**-4%**	**59,000**	**-7%**	**45,000**	**-15%**	**30,000**	**-23%**

A 23% reduction in upfront carbon emissions from public infrastructure is equivalent to a reduction of 9 Mt CO_2e, roughly 2% of Australia's gross national greenhouse gas emissions of 529 Mt CO_2e in FY 2023.[9]

This scenario would lead to a cost saving of $160 million (see **Table 9**), which is equal to 0.14% of the total value in Infrastructure Australia's Market Capacity Program pipeline.

Table 9: Carbon and cost changes for the three decarbonisation scenarios in 2026–27

Scenario	Carbon abatement	Cost
Baseline	No change	No change
Mid-level decarbonisation	13% reduction (5.0 Mt CO_2e)	0.24% cost saving ($280 million)
Maximum decarbonisation	23% reduction (9.2 Mt CO_2e)	0.14% cost saving ($160 million)

A breakdown of the costs of the Maximum Decarbonisation Scenario is shown in **Table 10**. Replacing materials with lower-carbon alternatives results in an overall saving in material spend as cost-saving strategies more than compensate for those with a cost uplift. Increases in construction and commissioning costs are due to the use of biodiesel and renewable electricity. The increase in labour cost is due to an estimated increase in structural engineering fees to optimise structural steel (i.e., to reduce the amount of structural steel needed to achieve the desired level of performance).

Table 10: Cost impact from the like-for-like use of replacement materials, by input (Maximum Decarbonisation Scenario)

Cost	Original cost ($million)	Additional cost ($million)	Change
Materials	$36,000	$-690	-1.9%
Construction	$8,300	$240	2.9%
Commissioning	$680	$85	13%
Labour	$45,000	$200	0.44%
Unaffected	$26,000	$0	0%
Total costs	$116,000	-	0.14%

Under the Mid-level Decarbonisation Scenario, a 13% reduction in upfront carbon emissions is achievable with a larger cost saving of $280 million – or 0.24% of the total project value in Infrastructure Australia's Market Capacity Program pipeline.

These scenarios show the significant potential for replacement materials in lowering embodied carbon emissions in infrastructure. However, it is worth noting that emission projections may not be realised exactly as presented as they are subject to government ambitions, market conditions, and emissions that occur beyond Australia's territorial boundaries, which that may or may not change over time.

While a 23% saving in upfront carbon would be a significant contribution to Australia's decarbonisation agenda, eliminating the other three quarters of upfront carbon emissions from the construction pipeline will need a different approach. It will need building products to be decarbonised from the supply side, and changes in how Australia plans, designs and procures assets so that embodied carbon is considered early. The only way to effectively reduce embodied carbon at scale is to start early and coordinate through the value chain.

SECTION 3

Barriers and opportunities

A conscious and concerted national effort is going to be crucial in meeting Australia's net zero commitments. Successful decarbonisation of the built environment will require coordinating across the whole infrastructure planning, delivery and operation system, and a step change in how infrastructure and building assets are planned, built, operated, maintained and reviewed. This also involves overcoming a series of obstacles to change.

Taking insights from our consultation with industry and government stakeholders, this section explores obstacles to reducing embodied carbon in the built environment and provides recommendations for the Australian Government as it designs and implements targeted decarbonisation policies.

RECOMMENDATION 1

The Australian Government, working with state and territory governments, should develop a comprehensive national plan to actively promote the decarbonisation of emissions embodied in Australia's built environment, in particular by:

- linking new construction decisions to Net Zero 2050 and 2035 reduction targets
- using the decarbonisation hierarchy to drive a clear strategy for reducing whole-life carbon from a project's 'needs' stage to lock in the greatest opportunity to influence carbon reductions

Using lifecycle thinking to manage environmental and social impacts, minimise carbon footprints and avoid trade-offs

Disjointed operating environments are not conducive for achieving net zero targets

The individual carbon-reduction efforts of governments are a welcome first step on the path to national decarbonisation.

While many individual initiatives are underway, there is no overarching plan for targeting embodied carbon in the built environment. This limits the scope for collaboration across the built environment and linking new construction with Australia's ambition for a net zero transition.

At the individual asset level, decarbonising a building or infrastructure asset is often considered without studying the implications for carbon on the wider system that the asset belongs to. Disconnected operations or any form of tunnel vision in decision making is a barrier to just transition, and can result in unforeseen trade-offs or unintended social, environment and/or economic impacts.

To address this, decarbonisation of the built environment should be addressed using a systems-based approach and through close collaboration across the value chain.

Using lifecycle thinking, which considers the impacts that asset owners and managers can control and influence when assets are created, operated and used ensures that multiple environmental and social impacts are considered across an asset's whole lifespan.

Asset owners should also collaborate with other members of the value chain to speed up decarbonisation through the project delivery process. Early engagement and collaboration among value chain members such as owners and managers, designers, constructors, procurers and product/material suppliers is needed at all levels, from system to asset in order to effectively reduce carbon emissions.

Applying the decarbonisation hierarchy

To maximise whole-life carbon reduction and scale up the individual efforts of individual project teams, stakeholders should use the decarbonisation hierarchy (see **Figure 5**) to evaluate need, assess alternatives, adopt low carbon solutions, and improve. The greatest opportunity to avoid or reduce emissions occurs at the 'need' stage, and gradually decreases through the design, materials selection, construction, and operation stages. Whole-life carbon can be influenced again at the end of an asset's first life, if/when it can be refurbished, repurposed, deconstructed and/or decommissioned.

Figure 5: The decarbonisation hierarchy adopted from PAS 2080 (2023) [10]

AVOID

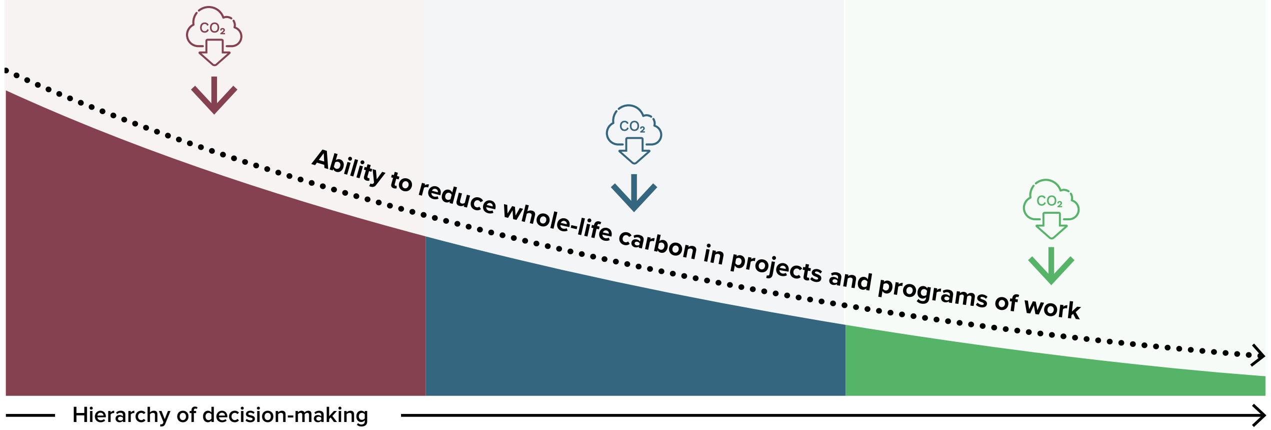
- Link the project / program to the national net zero target at the system level
- Evaluate the need at the asset/network level and explore other ways of satisfying it, e.g., building nothing, or building less by reusing/retrofitting/repurposing existing assets

SWITCH

- Assess alternatives, and make the design as effective as possible to reduce whole-life emissions
- Choose low-carbon solutions, e.g., materials and technologies that reduce operational carbon

IMPROVE

- Adopt solutions to improve the use of resources and design life of an asset, e.g., circular economy principles, construction sequencing
- Use assets more efficiently



RECOMMENDATION 2

The Australian Government, with state and territory governments, should build carbon confidence and literacy in buildings and infrastructure by:

- complementing the ongoing efforts of the Austroads Environment and Sustainability Taskforce and the Infrastructure Net Zero Initiative to develop education programs for professionals, trades and consumers which target carbon literacy and low carbon product specifications and construction
- developing a national sharing platform for industry practitioners to showcase learnings from projects, pilots, concessions, model contracts and specifications for low carbon solutions

Piloting projects to trial new solutions and produce data about new products and construction techniques.

Widespread climate illiteracy and a lack of knowledge sharing can delay uptake of lower carbon materials

Australia's decarbonisation efforts are detrimentally impacted by a general lack of understanding among industry professionals, trades, and consumers of climate and carbon issues (climate literacy), myths concerning low carbon materials and an absence of detailed and actionable learnings.

As assets are built or renewed, product choices are made based on current knowledge and perceptions developed over time. Myths about the difficulties and impracticality of using lower-carbon materials are common, and influence project decisions at both design and procurement stages. Where the availability, quality and performance of low-carbon construction materials are not well understood, hesitancy in their adoption is to be expected.

Knowledge about characteristics of low carbon products needs to be supplemented with practical awareness and know-how on their use for a project. Lack of confidence about specification and use results in low and fragmented demand for low-carbon products, which slows supply chain development due to insufficient demand, and less product availability.

Use of low-carbon products on projects often rely on substantial trials and testing, which are essential to ensure that alternative products are fit for purpose for their intended applications. Without evidence of multiple prior successes, project teams may be unwilling to use lower carbon alternatives which is problematic as test results are rarely published and case studies lack the detail required to replicate results.

One example of efforts to address these gaps in the industry and promote innovative building techniques in the transport infrastructure sector can be seen in the Austroads Environment and Sustainability Taskforce, comprising the Australian Government, state and territory governments, and New Zealand Government. Together, they are developing guidance, conducting research, and updating Austroads standards.

Additionally, the Australian Government has invested in the Infrastructure Net Zero Initiative, which brings together industry and government stakeholders to achieve the shared goal of decarbonising infrastructure. This collaboration recognises the shared responsibility of decarbonisation and the opportunity to create an aligned and effective use of collective time, resources, and expertise to accelerate the highest-priority initiatives to drive lasting policy change and industry innovation.

RECOMMENDATION 3

The Australian Government, with state and territory governments, should develop a nationally standardised embodied carbon measurement system, which allows for consistent methods to collect, measure and assess data about embodied carbon.

This could involve:

- Establishing a national database of default emissions factors and EPDs to support embodied carbon measurement, and be a single source of truth for practitioners in the built environment.
- Setting requirements to measure and disclose upfront carbon on projects over a threshold value and set best practice targets informed by benchmarks for different asset classes.
- Investigating ways to drive national alignment on data to support carbon calculations, including standardising the collection of construction and commissioning data.

An absence of standard measures and tools obstructs meaningful progress

Reducing carbon emissions at scale is only possible with reliable and consistent measurement tools. Currently, the lack of a standard methodology and data system at a national level poses a significant challenge.

There is no common method for measuring embodied carbon in Australia's buildings and infrastructure. Various methods are used to calculated and claim carbon reductions on projects, leading to a lack of consistency and credibility in measurement, with inconsistent and non-comparable results. This makes it difficult for stakeholders to accurately calculate and track carbon emissions. Additionally, there is no comprehensive dataset for process-based lifecycle analysis emissions factors, which makes it difficult to access and compare the emissions of different building products. Furthermore, a shortage of compliant product data, such as third party verified EPDs, which limits the ability for decision makers to make informed low carbon choices when selecting building materials.

Recognising the imperative to consistently measure, compare and set reduction targets for embodied carbon in buildings, the National Australian Built Environment Rating System (NABERS) is working to create an embodied carbon rating tool for buildings, which would allow building owners to set robust and measurable targets for reducing embodied carbon in buildings. In concurrence, the Infrastructure and Transport Ministers' Meeting (ITMM) has agreed to develop a nationally consistent approach for measuring embodied carbon in infrastructure projects and consider further policy levers available to reduce emissions.[11] This includes consideration of developing and maintaining a national emissions factor library and nationally consistent data reporting and collection.

RECOMMENDATION 4

The Australian Government, working with state and territory governments, should agree a common national approach to drive market demand for low carbon solutions.

This could involve:

- developing nationally consistent procurement guidance through the Infrastructure Decarbonisation Working Group focused on enabling low carbon solutions in project requirements
- addressing cross-border carbon leakage and ensuring a means of fair carbon accounting between domestic and imported products, through the Australian Government's ongoing work to investigate a domestic Carbon Border Adjustment Mechanism
- exploring funding or grants models to reduce the cost burden for projects to adopt lower carbon products and technologies
- investing in sustainable finance instruments to incentivise the adoption of low carbon materials and technologies on projects, by working with concessional finance providers
- investigating incentives for low carbon construction with planning authorities.

Industry needs a steadier flow of demand to justify decarbonisation investment

Industry is less willing to create more products and solutions that have low carbon impact, because the demand for them is not dependable. This hinders the advancement of the sector and the country as a whole.

Stakeholders identify several causes of demand dependability:

- The lack of common targets or incentives to drive demand for lower carbon solutions across jurisdictions.
- A focus on upfront cost that leads to low-carbon products being descoped in favour of lower-cost yet higher-carbon alternatives. A contributing factor is that carbon is not currently valued in the decision-making process for many projects.
- Suppliers not being engaged early enough in the project, limiting their ability to provide innovative solutions that meet design requirements as well a lower-carbon alternative. Once designs are finalised, the options for low carbon products become more limited.
- The high cost of product trials that reduce the pool of projects willing to undertake them.
- Leakage of carbon into Australia through higher-carbon, low-cost imports, which deters local, low carbon product development.

Many stakeholders interviewed for this report called for fairer carbon accounting, including the Building Products Industry Council and representatives of the steel industry, for who carbon leakage was regarded as an item of importance for government intervention.

In March 2023, the Australian Government announced it would undertake a review of carbon leakage as part of the Safeguard Mechanism reforms. The review will assess carbon leakage risks and policy options to address them, including the feasibility of an Australian Carbon Border Adjustment Mechanism. The review will focus on trade-exposed goods under the Safeguard Mechanism, particularly steel and cement which are key inputs for many types of infrastructure. The review's first consultation paper was released on 13 November 2023 and closed on 12 December 2023. A second round of consultation will be undertaken in mid-2024. This review is expected to be completed by 30 September 2024.

The delivery of major infrastructure projects presents a unique opportunity for the Australian Government to drive decarbonisation outcomes. For instance, the Infrastructure Policy Statement, released in November 2023 notes that as emissions reduction techniques emerge, the Australian Government expects them to be factored into project delivery. This lays a clear foundation on which project selection funding decisions could be made in future.

There is also work underway to drive a more consistent approach to procurement. Through the ITMM, the Infrastructure and Transport Ministers' Meeting, the Infrastructure Decarbonisation Working Group, chaired by NSW and the Commonwealth, is developing a 'carbon in procurement and contracts' guideline to inform the implementation of measures to ensure transport infrastructure projects support decarbonisation goals.

To elevate the consideration of carbon in project decision making, ITMM approved a nationally consistent set of values for use in transport infrastructure projects. Infrastructure Australia has introduced a requirement that infrastructure proposals submitted to Infrastructure Australia must use the nationally consistent set of carbon values in their submissions from July 2024.

RECOMMENDATION 5

The Australian Government, working with state and territory governments, should develop new methods for project delivery which share risks and rewards for innovative approaches.

This could involve:

- specifying outcomes and expectations of project delivery that embeds specific requirements for decarbonisation
- developing performance based, collaborative contract models and business cases, which assume the use of low carbon materials, early contractor involvement on projects, embodied carbon analysis in pre-tender processes, and clear direction for decarbonisation in tender documentation
- exploring opportunities to include trials of new materials in flagship projects and sharing learnings.

Industry confidence to invest in decarbonisation is low, for fears that risks may not be rewarded

Stakeholders identified fear of risk exposure as one of the major barriers hindering effective decarbonisation efforts. This reluctance stems from industry inertia, where trying new approaches or technologies to reduce carbon emissions is often seen as risky. Hesitance is further compounded by industry's limited bandwidth, as it contends with numerous commercial and workforce challenges alongside the complexity of the bidding process. Government procurement practices were reported to be conservative, undermining the imperative to tackle climate change and adopt progressive policies.

This inherent reluctance to take risks has also led to a resistance to pilot new projects as well as a preference to pass on risks to other parties. This is particularly evident in traditional contract models, where risk is typically shifted to the constructor in post-tender D&C (design and construct) contracts. Unfortunately, by this stage, the opportunity for significant decarbonisation in the project has often passed, leaving the constructor with limited options for reducing carbon.

Moreover, the aversion to risk has also hindered the willingness to try new and innovative approaches. Many stakeholders reported that there is a preference for familiar and low-risk solutions, instead of considering effective or innovative alternatives. As a result, even when new and well-tested solutions are available in other countries, there is a reluctance to adopt them in Australian projects. This is exemplified by the use of general purpose limestone cement, which is commonly used overseas by not yet embraced in Australia. Overall, the apprehension towards risk and change in the industry is seen as a barrier to decarbonisation efforts.

RECOMMENDATION 6

The Australian Government, with state and territory governments, should work with industry to drive greater national alignment on low-carbon expectations through performance-based standards and specifications.

This could involve:

- establishing unified specifications and guidelines that promote the adoption of lower-carbon products more consistently across all jurisdictions. This should be incorporated into widely accessible model specification clauses to enable standardised practices
- procuring using performance-based specifications, that allow for materials and solutions to be judged on meeting performance criteria, rather than specifying that they must be of a certain characteristic.

Leading efforts to expedite the updating of standards and specifications, developing a more efficient system and providing funding for critical updates to keep pace with evolving options.

Product development is hindered by traditional standards and specifications

During consultation, industry stakeholders were frustrated by existing specifications, which prescribed specific characteristics for products rather than performance outcomes. This can limit the entry of new and innovative materials into the market.

Existing construction bias and out-dated material standards and specifications often preclude the use of lower-carbon materials, mixes and processes. Traditionally, specifications prescribe characteristics of a compliant product, such as a minimum required composition. These are typically narrow, focusing on known solutions.

Another barrier to progress is fragmentation in product specifications across jurisdictions, which discourages investment by diluting market demand. This is further compounded by Australia's inherent challenges of low population and geographical spread, making it difficult to justify product changes due to inconsistent demand for specific requirements.

The low pace of updates to standards and specifications is another significant barrier. Stakeholders expressed frustration at the lag in updating these standards, which makes it difficult for the industry to keep up with the latest low carbon materials. According to some stakeholders, slow progress in the update of existing stipulations mean that new solutions are judged on their adherence to narrow and prescriptive specifications rather than their performance.

As innovation in low carbon materials continues to advance, it is imperative that measures are taken to speed up the process of updating standards and specifications.

To overcome these barriers, it is necessary to address the issue of consistency in product specifications at a national level. There is also a need to transition to performance-based specifications and ensure that standards and industry specifications are updated in a timely manner.

SECTION 4

Cost and abatement potential

Analysis presented in Section 2: Baseline Measures of Embodied Carbon showed that Australia can reduce upfront carbon emissions from its pipeline of infrastructure and buildings by up to 23% in 2026–27 by applying like-for-like decarbonisation strategies considered in this report.

The cost and carbon abatement potential of each decarbonisation strategy is shown in **Figure 6**. Four of the 11 groups of strategies considered in this report lead to a cost saving at the project level – recycled crushed concrete replaces aggregates in concrete and pavement sub-base; reclaimed asphalt pavement replaces asphalt in base course and wearing course; structural steel lightweighting and hydrated lime replaced in asphalt - and one is cost neutral – reinforcing steel lightweighting. The following remaining strategies incur a cost, shown in red, however most costs are small compared to the value of assets in the pipeline:

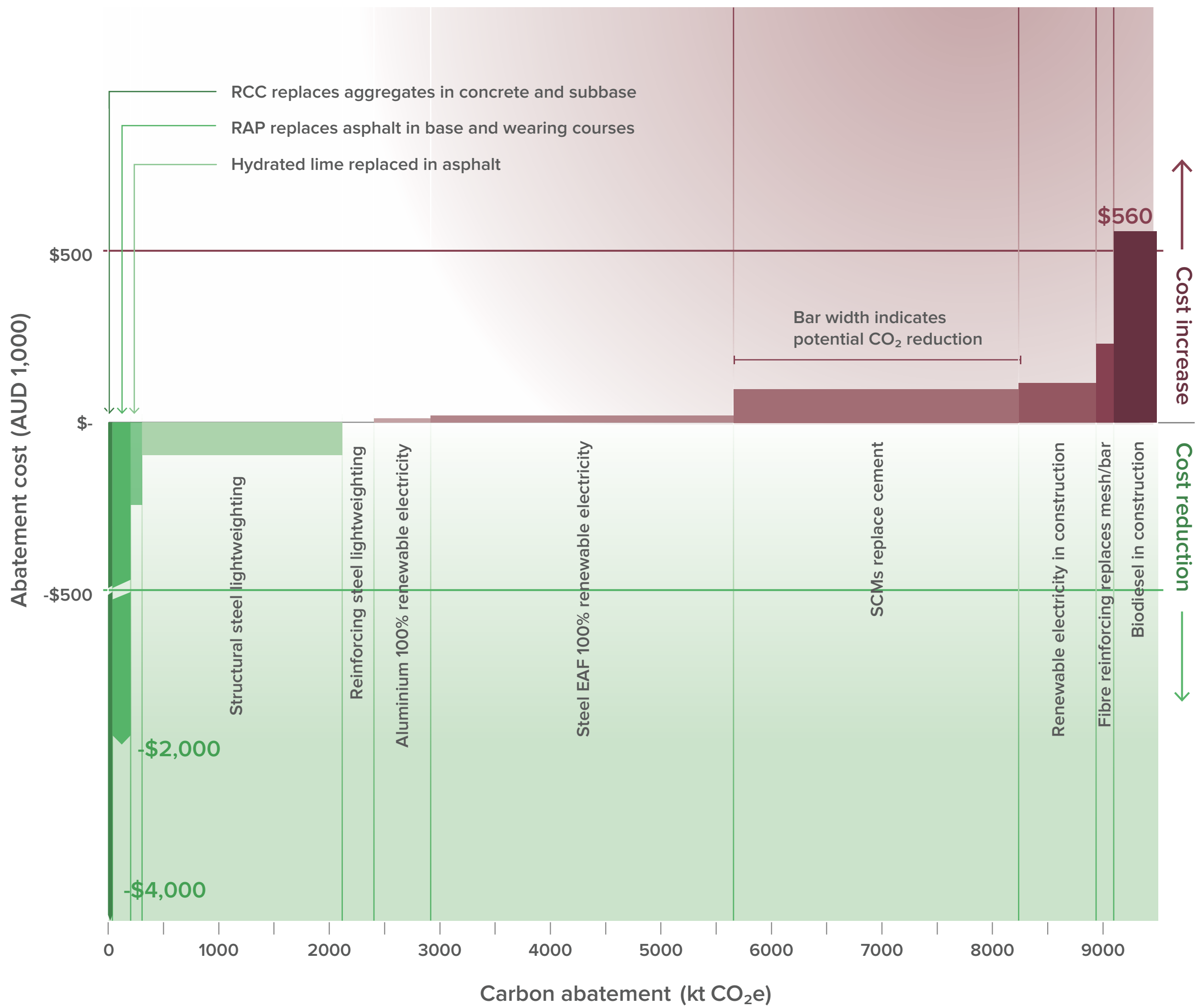
- Aluminium made with 100% renewable electricity.
- Steel made in an electric arc furnace with 100% renewable electricity.
- Supplementary cementitious materials that replace cement.
- Renewable electricity in construction.
- Steel fibre reinforcing that replaces steel mesh/ bar reinforcing.
- Biodiesel in construction.

Of the strategies, biodiesel uptake is by far the most expensive, with relatively small benefit to reducing greenhouse gas (GHG) emissions. The Maximum Decarbonisation Scenario assumes that usage increases from 1% in 2022–23 to 20% by 2026–27 (i.e., nationwide adoption of a B20 blend across the construction sector. However, with current pricing, this strategy becomes expensive at the national level. As such, the Mid-Level Decarbonisation Strategy assumes a moderate uptake of biodiesel beyond current levels.

The strategies with the greatest influence on upfront carbon are:

- steel made from electric arc furnace with 100% renewable electricity
- reinforcing steel lightweighting
- structural steeling lightweighting
- supplementary cementitious materials replace cement
- renewable electricity in construction and commissioning.

Figure 6: Marginal abatement cost curve, 2026–27



SECTION 5

Accounting for uncertainty: hybrid analysis

The analysis in this report is based on Infrastructure Australia's Market Capacity Project Database. This system aggregates project-level data to create a comprehensive overview of Australia's infrastructure and building investment pipeline. This data is informed by budget processes and forward projections derived from budget estimate periods.

However, the landscape for project delivery has become progressively challenging, with constraints of available skilled labour and resources, market fluctuations, and inconsistencies in project and portfolio planning standards. Consequently, delays due to slippage are now widespread, which can lead to over-estimation of material demand.

Further, Infrastructure Australia's Market Capacity project database focuses on major projects per state.

Major projects are defined as:

- infrastructure projects with a capital value of $100 million or more in New South Wales, Victoria, Queensland, and Western Australia
- infrastructure projects with a capital value of $50 million or more in South Australia, Tasmania, the Australian Capital Territory, and the Northern Territory
- private building projects with a capital value of $25 million or more
- all energy projects, regardless of capital value.

The forecast may overestimate spend - and therefore upfront carbon - in some areas as a result of project slippage and threshold values, while underestimating it in others.

This project applies two scenarios to manage uncertainty:

- **Pipeline Analysis:** Calculations are based solely on the pipeline of infrastructure and building projects from Infrastructure Australia's National Infrastructure Project Database, without any scaling. Projects below the thresholds above are excluded. Projects are reported in the year they are forecast, without accounting for potential slippage. In practice, this means that most of the residential housing market is excluded and that the pipeline is too full, particularly for the next 2—3 years (meaning it cannot all be delivered within the planned time horizon).
- **Hybrid Analysis:** This analysis is designed to achieve a more realistic forecast of future embodied emissions, and represents a more comprehensive dataset for buildings. This is done in four steps:

    1. **Fill gaps for buildings under $25 million**
    Data from the Australian Bureau of Statistics (ABS) is used to account for construction of all buildings, regardless of their capital value.[12,13] Forecasts from Master Builders Australia were used to project the ABS data into the future.[14]
    2. **Expand the material categories for buildings**
    Additional materials (e.g., aluminium, glass and building services) is added to Infrastructure Australia's materials classification to capture more embodied emissions from buildings.
    3. **Account for project slippag**
    Historic building approvals data from Australian Bureau of Statistics was used to account for project slippage and project cancellations. Construction rates for transport and utilities were not adjusted.
    4. **Reconcile quantities of calculated material with the market's ability to supply these materials**
    Material quantities were summed to determine the deviation from total material supply at the national level. These comparisons were only made for a small number of materials where data was available or could be calculated, namely asphalt, total cementitious materials, reinforcing steel and structural steel. Where there were significant deviations (>±10%), project volumes were scaled to match total material demand. A rate of 5% year-on-year growth was allowed for per material category. (The reason for applying slippage factors first was to try to get a better balance across the project types before scaling up/down.)

Hybrid analysis findings

Upfront carbon emissions from construction activity in Australia's buildings and infrastructure under the Hybrid analysis was calculated as 38 Mt CO_2e in 2022–23, the baseline for this study. This is equivalent to 7% of Australia's total greenhouse gas (GHG) emissions in 2022–23. Use phase embodied carbon was estimated to be 18 Mt CO_2e, and end-of-life embodied carbon was estimated to be 1.5 Mt CO_2e (**Table 11**).

For detailed results of the hybrid analysis please refer to the report *Supporting Appendices: Embodied Carbon Projections for Australian Infrastructure and Buildings*.

Table 11: Embodied carbon emissions by lifecycle module, hybrid analysis (2022–23).

Embodied carbon emissions	Definition	Emissions (kt CO_2e)	Share of national emissions
Upfront	Emissions from the creation of an asset, network, or system, up to the point of practical completion	38,200	7.2%
Use phase	Emissions from maintaining and/or refurbishing an asset	17,800	3.4%
End-of-life	Emissions from asset demolition and/or deconstruction	1,480	0.3%

Most upfront carbon emission come from manufacturing construction products. **Figure 7** provides a breakdown of upfront carbon emissions by lifecycle module. Construction products make up 73% of upfront emissions (modules A1 to A3 in carbon footprint standards). The remaining 27% comes from transport (module A4, 4%) and construction (module A5, 23%). In the construction phase, emissions come from four main sources: land use change for greenfield sites, construction waste, construction machinery and commissioning.

Figure 7: Breakdown of upfront carbon emissions by lifecycle stage using the hybrid method

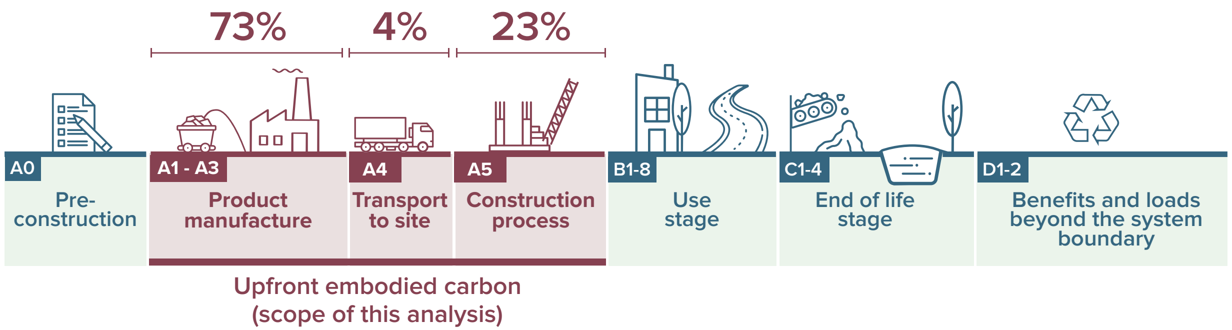


Figure 8 presents a 5-year view of upfront carbon emissions from the infrastructure and buildings construction pipeline. Under the hybrid analysis, the upfront embodied carbon in Australia's pipeline of infrastructure and buildings is forecast to be between 40 Mt CO_2e and 56 Mt CO_2e each year for the next 5 years, equating to 256 Mt CO_2e. Buildings represent the largest share, accounting for approximately half of the total forecast carbon emission (133 Mt CO_2e). This is followed by Utilities, which accounts for approximately 28% of the total emissions (71 Mt CO_2e). Transport infrastructure accounts for approximately a fifth of the total (52 Mt CO_2e).

Figure 8: National emissions over 5 years (hybrid analysis).

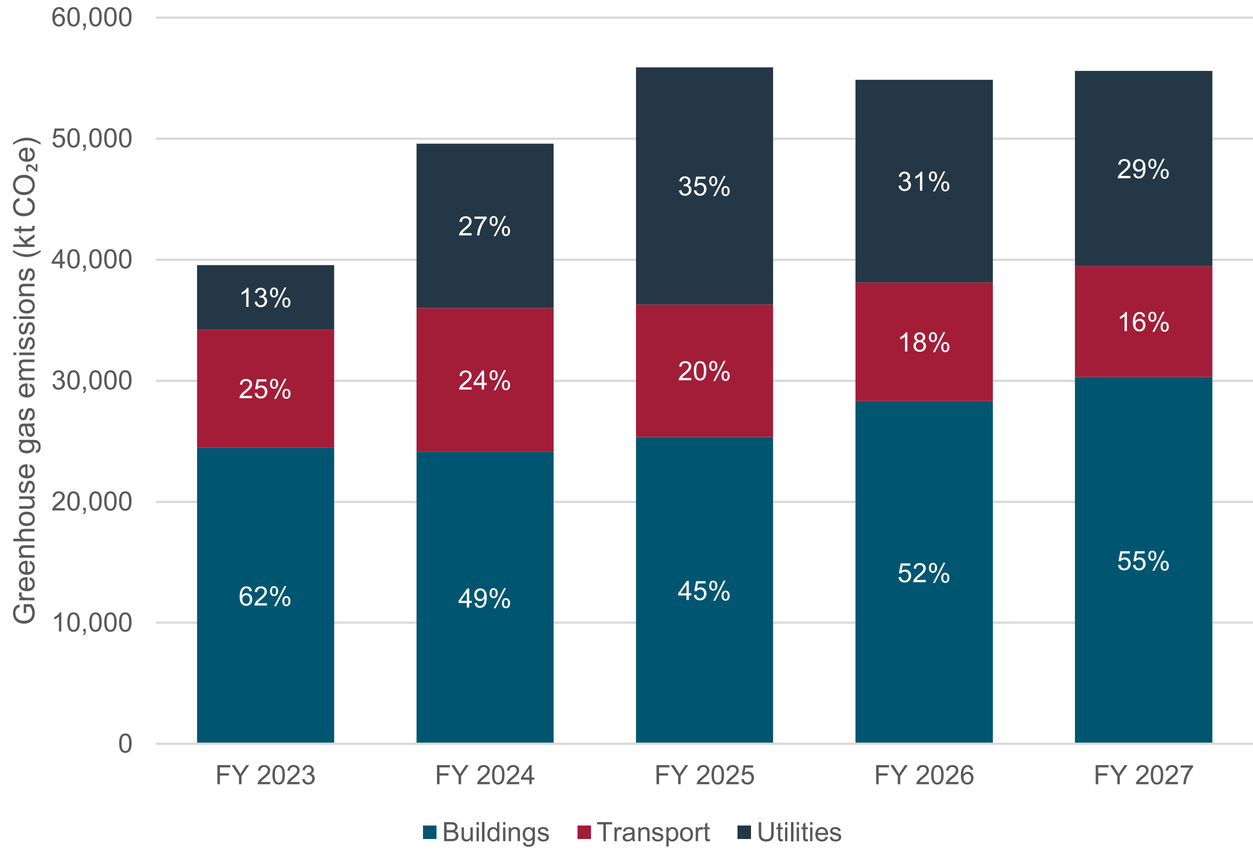


Figure 9 presents forecast upfront carbon using both the hybrid analysis (lighter filled stacked bars) and the pipeline analysis (darker filled stacked bars). The pipeline analysis shows dramatic growth in upfront carbon (high ambition in the short-term) and then decline (projects later in the time horizon not yet identified and committed). The hybrid analysis attempts to correct for this variability and therefore shows steady growth over the 5-year period between 2022–23 and 2026–27. It shows a steady increase until FY 2025, followed by a levelling out in 2025–26 and 2026–27.

Comparing the two analyses:

The total results are similar for the years 2022–23 to 2025–26. However, the make-up of these results is quite different. For buildings, the pipeline analysis is skewed towards larger projects, many of which will not be built in the forecast year. The hybrid analysis is influenced by many smaller projects, particularly residential building construction.

The pipeline analysis shows a rapid rise in construction, followed by a decline. The hybrid analysis is more stable over time. This is due to the difference in underlying approach for forecasting building construction, in which the pipeline analysis relies on self-reporting, and the hybrid analysis forecasts future building construction activity based on past construction activity.

Figure 9: A comparison of national emissions over five years using the hybrid analysis and pipeline analysis

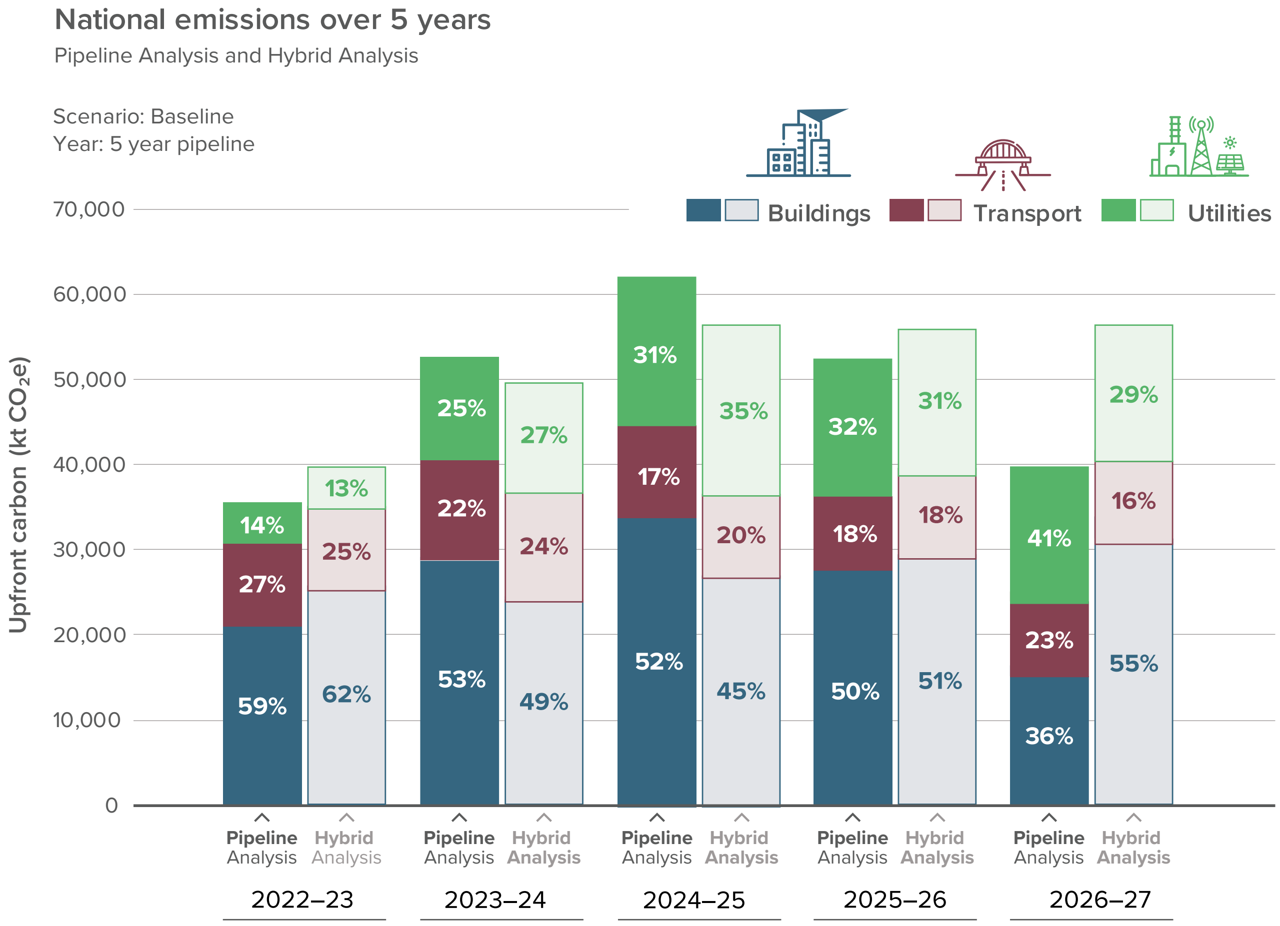
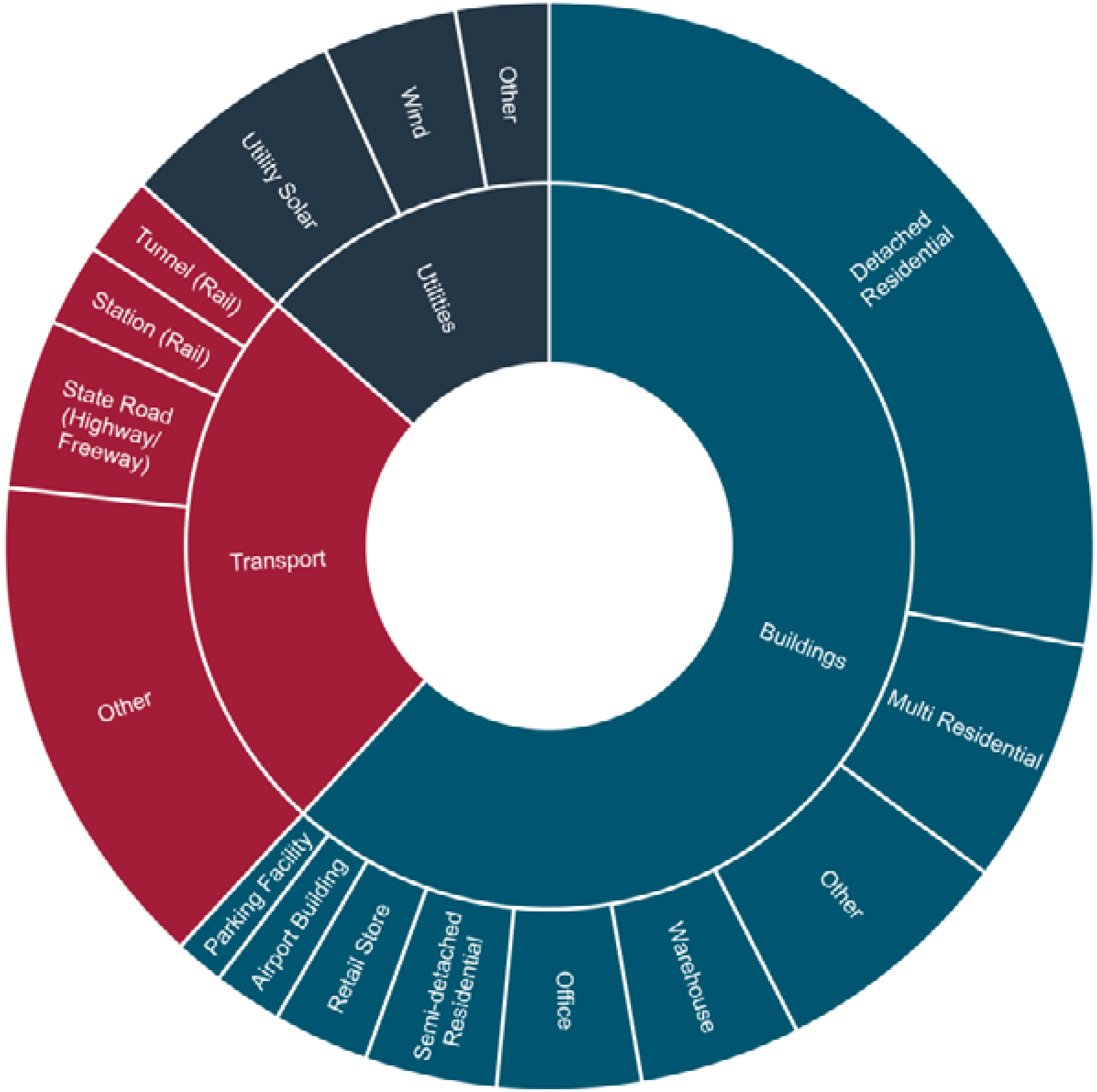


Figure 10 shows a breakdown of the emissions by project type using the hybrid analysis for 2022–23. Detached residential buildings, multi-unit residential buildings and utility solar are forecast to have the highest upfront carbon footprint at the national level, with detached residential buildings in first place, due to the sheer number constructed. The next group of project types is state roads (Freeway/Highway), warehouse and office buildings – with state roads and warehouses having a relatively similar forecast upfront carbon footprint in 2022–23. Wind utilities, semi-detached residential buildings, retail stores and railway stations round out the top 10.

Figure 10: Embodied carbon for the 10 highest contributing typecasts in baseline year 2022–23 (hybrid analysis)



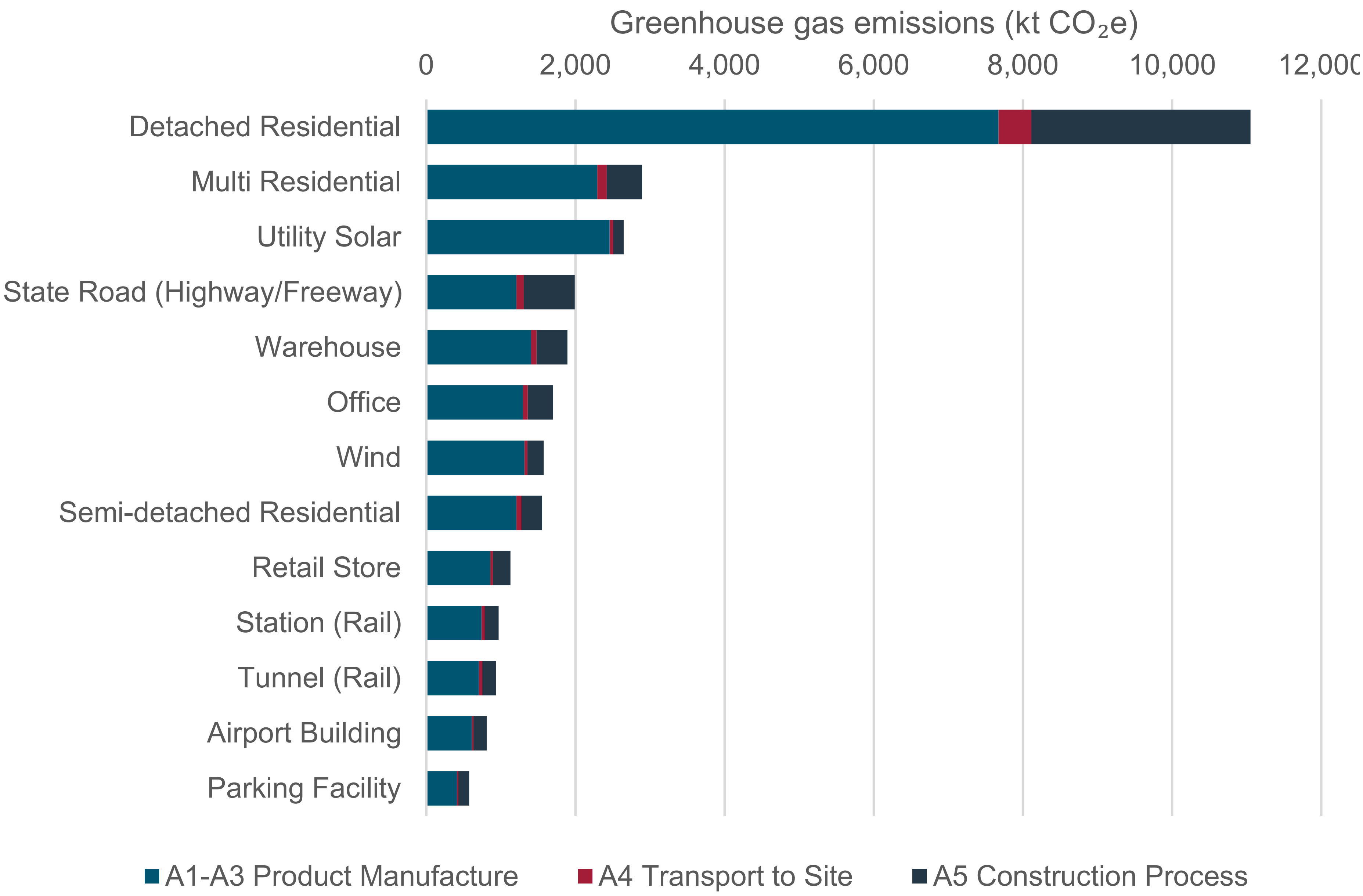

Greenhouse gas emissions (kt CO_2e)
0
2,000
4,000
6,000
8,000
10,000
12,000
Detached Residential
Multi Residential
Utility Solar
State Road (Highway/Freeway)
Warehouse
Office
Wind
Semi-detached Residential
Retail Store
Station (Rail)
Tunnel (Rail)
Airport Building
Parking Facility
A1-A3 Product Manufacture
A4 Transport to Site
A5 Construction Process

Figure 11 shows the carbon and cost changes for both the hybrid and pipeline Analysis, under the Mid-Level Decarbonisation Scenario and Maximum Decarbonisation Scenario. According to the hybrid analysis, the Maximum Decarbonisation Scenario is able to achieve a 21% carbon reduction on the pipeline by 2026–27, with a cost uplift of $37 million. The more moderate Mid-Level Decarbonisation Scenario can achieve a 12% carbon reduction on the pipeline for a saving of $200 million.

Figure 11: Carbon and cost changes from decarbonisation scenarios in FY 2027

Scenario	Carbon abatement		Cost	
	Pipeline	**Hybrid**	**Pipeline**	**Hybrid**
Mid-Level Decarbonisation	13% reduction (5.0 Mt CO_2e ↓)	12% reduction (6.7 Mt CO_2e ↓)	0.24% saving ($280M ↓)	0.08% saving ($200M ↓)
Maximum Decarbonisation	23% reduction (9.2 Mt CO_2e ↓)	21% reduction (12 Mt CO_2e ↓)	0.14% saving ($160M ↓)	0.02% uplift ($37M ↑)

SECTION 6

Methodology and Assumptions

Methodology overview

This report calculates:

1. **A baseline carbon footprint for infrastructure and buildings.** The baseline carbon footprint represents the upfront carbon that is expected to result from Australia's construction pipeline of buildings and infrastructure between the financial years 2022–23 and 2026–27, if no action is taken. It assumes that the adoption of low-carbon technologies remains at 2022–23 levels.
2. **The potential to reduce this baseline carbon footprint by substituting materials and energy with low-carbon alternatives, under two decarbonisation scenarios.** Two decarbonisation scenarios are used to represent two technically achievable, levels of ambition for uptake of decarbonisation strategies.
   a. **The mid-level decarbonisation scenario** includes low-carbon technologies that are available on the market today, have proven technological viability, are cost competitive, and can be scaled up to the national level by 2026–27.
   b. **The maximum decarbonisation scenario** is designed to be an achievable best case. It assumes that barriers in standards, procurement and cost can be overcome. Achieving it would require strong alignment between government and industry on low-carbon outcomes.

Scope

The analysis in this report is based on Infrastructure Australia's Market Capacity Project Database, including major projects per state, defined as:

- infrastructure projects with a capital value of $100 million or more in New South Wales, Victoria, Queensland, and Western Australia
- infrastructure projects with a capital value of $50 million or more in South Australia, Tasmania, the Australian Capital Territory, and the Northern Territory
- private building projects with a capital value of $25 million or more
- all energy projects, regardless of capital value.

Material quantities

Material quantities were determined from this system, which combines forecast capital expenditure with an overlay of the typical spend on plant, labour, equipment and materials (PLEM) per asset type.

For this report:

- Materials data were the primary source and the basis for calculations in modules A1-A3 and construction waste in module A5.
- Plant data were the basis for construction energy in module A5.
- Labour data were used for construction costs in module A5, where strategies had an influence on labour costs.
- Equipment data were not used.

Emission factor selection and calculation

Emission factors were calculated to represent national or state averages wherever possible. Emission factors were weighted using apparent consumption, as below:

$$Apparent\ consumption = Domestic\ production + Imports - Exports$$

Where there were multiple domestic manufacturers or multiple import countries, emissions were weighted by market share wherever possible. Where this information was not publicly available, plant manufacturing capacity was used as a proxy for market share for domestic manufacture.

Upfront carbon

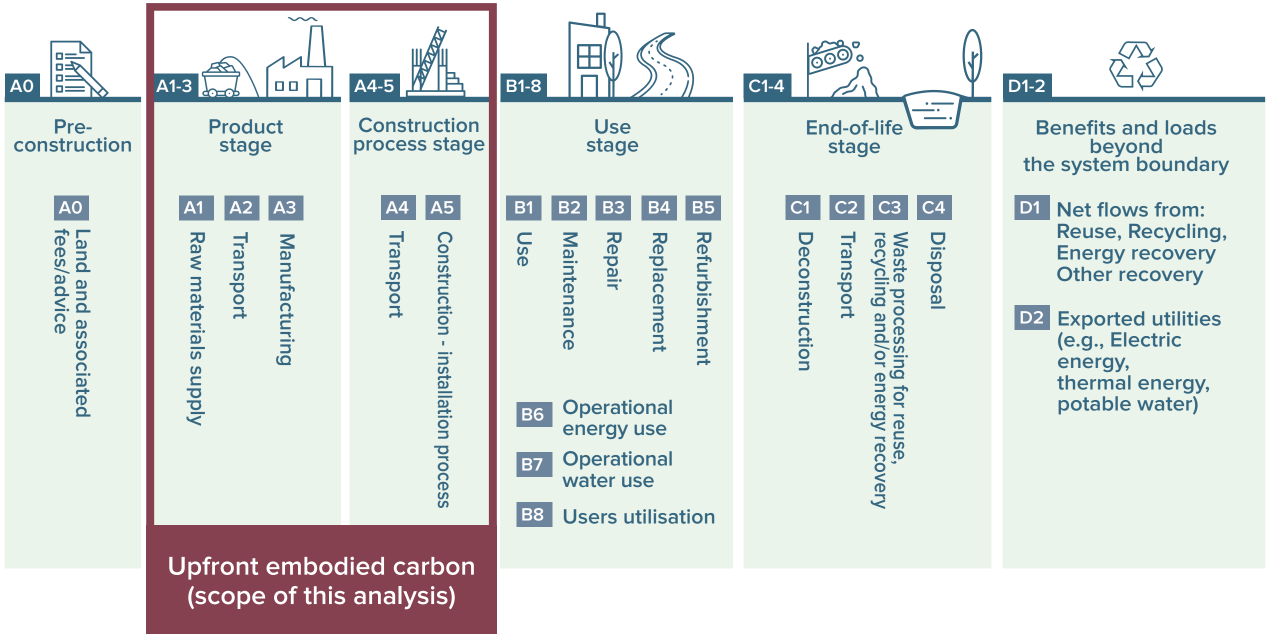
The analysis in this report focuses on upfront carbon defined here as the greenhouse gas emissions and removals associated with the creation of an asset, network or system up to practical completion. This definition is based on that for 'capital carbon' from PAS 2080:2023 (BSI Australia, 2023).

Carbon emissions are calculated as the "sum of greenhouse gas emissions and greenhouse gas removals in a product system, expressed as CO_2-equivalent (CO_2e) and based on a life cycle assessment using the single impact category of climate change" (ISO, 2018). Where the term carbon is used in this report, it refers to the carbon dioxide equivalent (CO_2e) of all greenhouse gases.

Upfront carbon includes the following life cycle modules:

- Modules A1—A3: Manufacture of building products.
- Module A4: Transport of building products to site.
- Module A5: Construction, which includes:
  - land use change from land clearing
  - construction waste
  - construction energy
  - commissioning energy.

Figure 12: Lifecycle modules according to ISO 21931-1:2022, highlighting upfront carbon



These lifecycle module codes (i.e., A1-A3, A4 and A5) derive from international and European standards for lifecycle assessment of buildings and infrastructure assets. It is worth noting that many building/infrastructure asset carbon footprint studies do not include commissioning energy. This is an item that emerged as being relevant for some asset types during the stakeholder consultation process for this project. Further, land use change is often excluded due to a lack of good data on its potential impacts. Both are included within this study.

Two analyses for two purposes

This report employs two different calculation approaches for two different purposes:

1. The **pipeline analysis** calculates the emissions embodied in Australia's pipeline of infrastructure and buildings, as forecast. Calculations are based solely on Infrastructure Australia's National Infrastructure Project Database, without any scaling. Projects that fall below the thresholds are excluded. Projects are reported in the year they are forecast, without accounting for slippage.
2. The **hybrid analysis** aims to calculate the embodied emissions that occur in a specific year. This is done by filling gaps for building projects under $25 million, by accounting for project slippage where possible and by including a wider range of construction products.

The purpose of the Hybrid Analysis is to demonstrate the significance of embodied carbon relative to Australia's total national greenhouse gas (GHG) emissions. Its figures are presented as percentages of emissions as well as absolute emissions. By contrast, the Pipeline Analysis is not presented relative to national emissions because the forecast emissions may be spread across more than one year.

Calculation method

Calculating the baseline carbon footprint

The baseline carbon footprint was calculated by summing several elements:

- **Manufacture of building products** = amount of construction (in $) × material intensity (typically kg per $) × emission factor (typically kg CO_2e per kg).
- **Transport of building products to site** = amount of construction (in $) × material intensity (typically kg per $) × typical transport distance (in km) × emission factor (typically kg CO_2e per kg·km).
- **Land use change from land clearing** = total land use change from construction (in kg CO_2e) × construction per typecast (in $) / total amount of construction (in $)
- **Construction energy** = operation of plant (in $ per type of plant/machine) × energy intensity (e.g., MJ per $) × emission factor (e.g., kg CO_2e per MJ)
- **Construction waste** = amount of construction (in $) × material intensity (typically kg per $) × waste factor (%) × emission factor (typically kg CO_2e per kg).
- **Commissioning energy** = amount of energy used for commissioning (in $) × energy intensity (e.g., MJ per $) × emission factor (e.g., kg CO_2e per MJ)

The amount of construction is total dollars per asset type (of which there are 63 types) and per state/territory. In the base analysis for the report (the Pipeline Analysis), the amount of construction comes solely from Infrastructure Australia's National Infrastructure Project Database. The Hybrid Analysis uses the same data for transport infrastructure and utilities, but bases its buildings data on statistics from the *Australian Bureau of Statistics and the Department of Climate Change, Energy, the Environment and Water.*

Forecasting emission savings

Identifying decarbonisation strategies

The materials available within Infrastructure Australia's database were used as the basis for developing an initial longlist of decarbonisation strategies. Strategies were divided into those that affect materials/products (modules A1-A3) and those that affect construction (module A5).

13 decarbonisation strategies were selected (in 11 groups) with different rates and levels of adoption, from an initial longlist of 25 strategies.

Five criteria were used to select decarbonisation strategies:

- **MTargets upfront carbon**

  Only decarbonisation strategies that had the potential to actively reduce upfront carbon were considered.

- **Like-for-like replacement**

  The analysis in this report focuses on like-for-like material replacement only (i.e., intra-material substitution). It does not consider inter-material substitution (e.g., replacing asphalt with concrete or concrete with timber), changes in project design or changes in project execution. This is because the data available per project type is so highly aggregated that it is not feasible to do anything else credibly.

- **Additionality of emissions savings**

  Emissions reductions must go beyond savings that would occur anyway due to other existing policies or activities. Perhaps the most obvious example is decarbonisation of the electricity grid. This analysis only considers electricity decarbonisation that is significantly above decarbonisation of the grid.

- **Already available on the Australian market**

  Decarbonisation strategies either had to already be available on the Australian market in the base year (2022–23) or to represent a change to a product already available on the market (e.g., supply-side decarbonisation of the energy mix for a product already on the market).

- **Strong potential for decarbonisation.**

  The intent of this project was to identify significant opportunities for decarbonisation nationally. As such, strategies had to have strong potential to reduce upfront carbon and be available at scale across Australia.

For each of the 13 strategies, we consider:

- Level of uptake by 2026–27 The Maximum Decarbonisation Scenario always assumes a level of uptake that is the same or greater than the Mid-Level Decarbonisation Scenario.
- Change in amount of material used per asset (for efficiency strategies).
- Change in carbon intensity per unit of material (for material emission factor strategies).
- Change in material, energy and labour costs (as relevant).
- Change in carbon intensity per unit of construction energy.

Uptake scenarios

This analysis applies three scenarios for uptake rates of the decarbonisation strategies. The uptake rates for the Baseline Scenario, and the maximum uptake rate by 2026–27. under the Mid-level Decarbonisation Scenario and the Maximum Decarbonisation Scenario can be found in **Table 7** in *Section 2: Baseline Measures of Embodied Carbon*. Current and future uptake rates were determined through workshops with industry, supplemented with research by the authors. Detailed analysis of the decarbonisation strategies can be found in the report *Supporting Appendices: Embodied Carbon Projections for Australian Infrastructure and Buildings*.

Baseline Scenario

This is the base case for this report. The project team has endeavoured to determine actual adoption rates for all decarbonisation strategies as of the base year 2022–23. These baseline rates are then assumed for all future years through to the final year for this analysis 2026–27. No further uptake beyond the current rate is considered within this scenario. Emission factors are also assumed to hold stable for each material. This means that the amount of product forecast to be used is the only variable between years.

Maximum Decarbonisation Scenario

This scenario represents the highest practical level of ambition by 2026–27.. It is designed to be an achievable best case. It assumes that barriers in standards, procurement and cost can be overcome. The main limitations on uptake rates in this scenario are:

- **Physical impossibility**
  There would not be enough of the material physically available. Examples include eclaimed asphalt pavement (RAP), recycled, content in steel and recycled content in aluminium. There will never be enough material available for 100% recycling rates while material demand is growing globally.
- **Deterioration in performance meaning replacement is no longer like-for-like**
  Stakeholders commented that while it is physically possible to achieve 100% replacement rates, this can lead to deteriorations in physical properties for some materials, meaning that the replacement material would no longer be functionally equivalent to original, virgin material. Examples mentioned during consultation include SCMs in concrete at replacement rates over 60–70%, high use of RAP in pavement wearing courses, and high use of recycled aggregates in concrete.
- **Growth that outstrips capacity to supply within the next 4 years**
  Given the relatively short time horizon for this analysis, we also assume that the sector cannot go from very low levels of replacement to extremely high levels overnight because supply would be unlikely to be able to grow fast enough.

Mid-Level Decarbonisation Scenario

This scenario represents an intermediate level of ambition that is part way between the Baseline Scenario and the Maximum Decarbonisation Scenario. Adoption rates are defined by a combination of three factors:

- **Moderate price**
  All strategies that either paid for themselves or could be achieved for a moderate price increase were implemented. Highly expensive strategies were eliminated (or taken up at a much lower rate to reduce cost), regardless of their decarbonisation potential.
- **Technical and regulatory feasibility**
  Strategies with high perceived barriers in technology and/or regulation/standards were eliminated. So too were those with high perceived risk.
- **'Trickle down' approach**
  Performance rates already achieved by the best-performing sectors and/or best-performing states/territories in 2022-23 were rolled out to the worst-performing sectors/states by 2026–27, while the best performers were assumed to push ahead even further.

Costing replacement options

The costing of decarbonisation strategies was conducted by Slattery. Slattery contacted suppliers and contractors to obtain baseline material costs and how these costs would change if the material was substituted. Each supplier or contractor's information was recorded in an Excel spreadsheet with material type and price per tonne impact. The percentage of cost increases for materials per state was obtained when available.

For low-carbon concrete, prices per tonne / cubic metre were not obtained. Rather, suppliers estimated how cost would increase for a variety of concrete products incorporating supplementary cementitious materials (SCMs) compared to standard cement blend products. Pricing data obtained from the market was sense-checked against Slattery's own internal pricing data.

Once market research was completed, estimated percentage price changes were provided for each material substitution. Where a variation in price difference was obtained for the same material substitution, the middle value of the range was used.

Definitions

Manufacture of building products (modules A1-A3)

Emissions from manufacturing building products are calculated from extracting, harvesting, or recovering raw materials through to the manufacturer's outbound factory gate.

For recycled and reused products, the boundary between asset life cycles has been set by applying the "end-of-waste state" defined by European standard EN 15804+A2 *Sustainability of construction works - Environmental product declarations - Core rules for the product category of construction products*.[15] The end-of-waste state is the point at which material stops being counted as waste and starts being counted as a product. This boundary is important because it defines the point at which greenhouse gas emissions from recovery and recycling stop being counted as waste disposal in the previous asset's lifecycle (i.e., zero emissions in the current asset's lifecycle) and start being counted as the emissions of manufacture in the current asset's life cycle.

Following EN 15804+A2, the end-of-waste state for a recovered material is reached when it meets four criteria: [16]

- It is commonly used for specific purposes.
- There is market demand (i.e., someone will pay for the recovered material).
- It meets relevant technical or legal requirements, e.g., relevant standards.
- It is not classified as hazardous by relevant legislation.

In practice, this definition means that the greenhouse gas emissions from many types of recycling will be classified as waste treatment operations at the end of the previous asset's life cycle (and therefore not at the start of the current asset's lifecycle). Exceptions include metals – particularly steel and aluminium – where the end-of-waste state is reached as soon as the metals are put into a (source- separated) skip on the construction site.

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. A consumption-based approach is applied, meaning that all freight is included, including freight that occurs overseas.

Land use change (module A5)

Land use change includes the greenhouse gas 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).

Construction waste (module A5)

Construction waste emissions are calculated as the sum of four components:

- Emissions from manufacturing wasted materials. The same emission factors are used as for modules A1-A3.
- Emissions from transporting wasted materials to site. The same emission factors are used as for module A4.
- Emissions from transporting wasted materials to waste treatment. A default assumption of 50 km transport in a rigid truck is applied. The same emission factors are used as for module A4.
- Emissions from end-of-life treatment of waste, e.g., landfill or recycling up to the end-of- waste state (see definition of the end-of-waste state earlier in this section).

Construction energy (module A5)

Construction energy is all energy (diesel, electricity, etc.) associated with constructing an asset. This includes land clearing, excavation, laying materials, erecting structures, etc. Only energy used on-site – including site offices – is within the scope of this analysis. Activities that occur off-site are not considered. This means that corporate offices and design offices are excluded, as is transport of staff to and from the jobsite.

Commissioning energy (module A5)

Commissioning is the stage in the project where an asset is tested – in whole or in part – before being handed over to the client. It takes place between construction completion and practical completion, though it often occurs in stages for larger projects. Commissioning may continue following handover to the asset owner, however the commissioning energy included in module A5 contains only the work completed under the control of the constructor.

Typically, commissioning includes the testing of critical systems, such as back-up electricity generators, security systems, fire systems, extractor fans and plant rooms. Commissioning energy is typically electricity, though significant amounts of diesel can often be used, particularly to test back-up generators or in cases where commissioning is done when the project is still off-grid.

Greenhouse gas emissions

"Greenhouse gas emissions", "GHG emissions", "carbon footprint" and "carbon emissions" are used interchangeably in this report. They are defined as the "sum of greenhouse gas emissions and greenhouse gas removals in a product system, expressed as CO_2-equivalent (CO_2e) and based on a life cycle assessment using the single impact category of climate change" (ISO, 2018). Where the term "carbon" is used in this report, it refers to the carbon dioxide equivalent (CO_2e) of all greenhouse gases and not to elemental carbon.

GHG emissions have been calculated using Global Warming Potential over 100-year time horizon (GWP100). GWP100 is defined by the Intergovernmental Panel on Climate Change (IPCC). Where possible the IPCC's latest report – the Sixth Assessment Report (AR6) – was used.[17] However, given that this report relies on many different sources, many emission factors follow earlier reports, primarily AR4 and AR5.[18 19] This is expected to have little relevance to the results as nearly all upfront carbon emissions associated with buildings and infrastructure assets are carbon dioxide (CO_2) and 1 kilogram of CO_2 is characterised as 1 kilogram of CO_2-equivalent (CO_2e) across all versions of the GWP100 indicator.

GHG emissions and removals are reported separately for the Pipeline Analysis and Hybrid Analysis in the *Supporting Appendices: Embodied Carbon Projections for Australian Infrastructure and Buildings* in line with ISO 14067:2018 Greenhouse gases - Carbon footprint of products - Requirements and guidelines for quantification and PAS 2080:2023.[20,21] The main results in the body of the report focus on greenhouse gas emissions only.

Assumptions

Emissions are calculated from the bottom up

This report aggregates information from the bottom up and then validates it against top-down data. The approach was chosen to improve the granularity of the results. More specifically:

- All construction activity data is an aggregation of project-level data.
- All carbon footprint data is based on bottom-up process-based lifecycle assessment rather than top-down input-output life cycle assessment.

Exceptions have been made where no bottom-up data were available, notably for land use change.

Calculations focus on consumption, not production

This report applies a consumption-based approach. This approach includes the greenhouse gas emissions associated with materials and energy consumed within Australia and excludes the greenhouse gas emissions from domestically produced products that are exported.

The use of a consumption-based approach means that only a portion of the upfront carbon reported in this study occurs within Australia's territorial boundaries. This is more important for some materials than others. For some products (e.g., photovoltaic panels), 100% of what is consumed domestically has been produced overseas. For others (e.g., aggregates and electricity), 100% of what is consumed here, has also been produced in Australia. For most products, there is a mix of domestic supply and imports.

A consumption-based approach was considered appropriate for this study because all countries share the same atmosphere, meaning that it doesn't matter in which country greenhouse gas emissions are released. However, it is important to recognise that the Paris Agreement applies a production-based approach and only considers greenhouse gas emissions from within a country's territory.

How significant is the difference between the two approaches for this analysis? Australia's consumption-based emissions are typically 10-15% lower than our production-based emissions, according to work by the Department of Climate Change, Energy, the Environment and Water.[22] These figures are net emissions, including the effects of Land Use, Land Use Change and Forestry. Previous analyses that have considered gross emissions – excluding Land Use, Land Use Change and Forestry – have shown similar emissions when applying production-based and consumption-based approaches.[23]

The differences between consumption-based and production-based approaches are not likely to be significant for this analysis. Some of the forecast savings will fall outside Australia's territorial boundaries, however many of the decarbonisation strategies considered will also apply to products that are manufactured in Australia for export, helping to balance the books.

Process-based life cycle assessment

There are three main ways to calculate emission factors:

1. Process-based lifecycle assessment (process-based LCA)
2. Input-output lifecycle assessment (IO-LCA)
3. Hybrid lifecycle assessment (Hybrid LCA)

Process-based life cycle assessment (process-based LCA) is a bottom-up approach that starts from the many individual process steps required to make something and adds them all up to calculate total emissions. Because of its detail, process-based LCA can be used to differentiate between many different product variants. So, for example, it is possible to distinguish between a concrete mix with 10% fly ash and another with 20% ground granulated blast furnace slag. However, to make the method practical, cut-off rules and/or proxies are used to represent parts of the supply chain that are less environmentally relevant. This leads to truncation error, meaning that not all environmental emissions are captured.

An alternative approach is input-output lifecycle assessment (IO-LCA). IO-LCA is a top-down approach that uses economic input-output tables to consider trade between sectors of the economy. Each economic sector is assigned a direct emission per dollar and the trade between sectors allows indirect emissions to be calculated. IO-LCA is complete by definition (i.e., no truncation error) provided that national inventories capture all direct emissions per sector. However, it has very low resolution – at the level of market sectors only – which means that it cannot distinguish between products from the same sector.

Hybrid lifecycle assessment (Hybrid LCA) seeks to combine the two methods and achieve the best of both worlds. There are two Hybrid LCA databases for construction products in Australia:

1. The Environmental Performance in Construction (EPiC) Database, published by the University of Melbourne.[24]
2. The Integrated Carbon Metrics (ICM) Embodied Carbon Life Cycle Inventory Database, published by the University of New South Wales.[25]

This report uses process-based LCA as its primary method for four main reasons:

- **Granularity:** This report includes two decarbonisation scenarios which are based on like-for- like replacement. As such, the analysis in this project requires a method that can distinguish between products in the same market sector. This requirement rules out IO-LCA.
- **Data availability:** Process-based LCA is the method used to calculate the results in an Environmental Product Declaration and the method underpinning product carbon neutral declarations. As such, most of the product-specific data available in Australia (and worldwide) is process-based LCA data.
- **Industry support:** Consultation through this process and through related projects (e.g., National Australian Built Environment Rating System Embodied Carbon) have shown overwhelming support for process-based LCA through the entire building and construction supply chain.
- **Global standardisation:** International standards for LCA and product carbon footprinting typically rely on process-based LCA data wherever it is available.

The body of this report applies process-based LCA for all core calculations. For comparison purposes, upfront embodied carbon emissions for 2022–23 were also calculated using an economy-wide input-output LCA (IO-LCA) approach. This can be found in the report *Supporting Appendices: Embodied Carbon Projections for Australian Infrastructure and Buildings*.

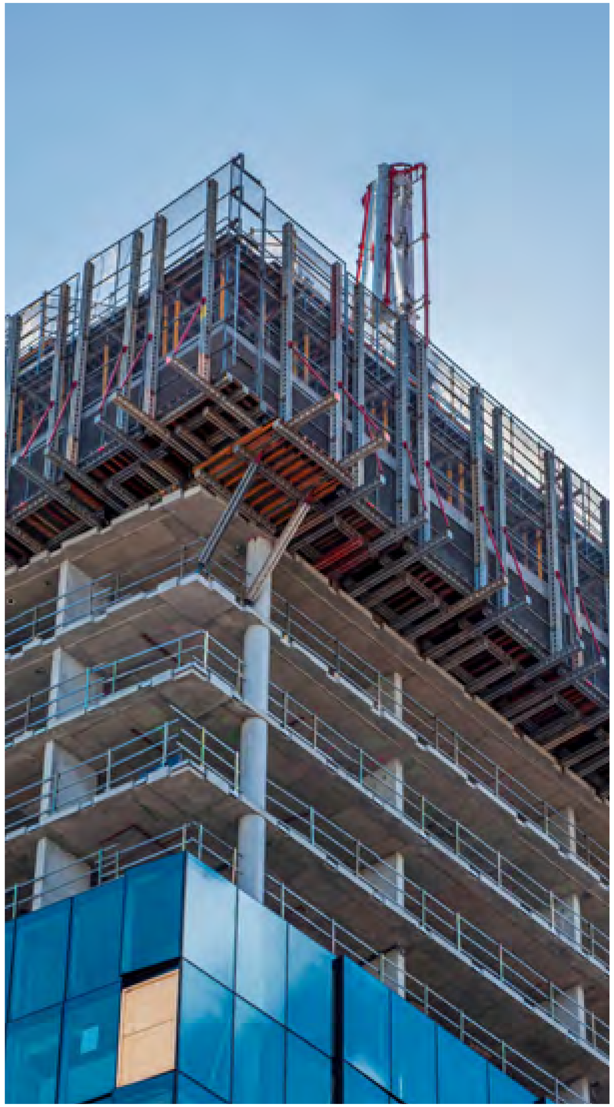
Limitations

This analysis is limited primarily by its own scope. It does not consider:

- No-build or build-less solutions.
- Optimised design solutions.
- Inter-material substitution, e.g., concrete for asphalt, or timber for reinforced concrete.
- Life cycle stages beyond upfront carbon, including maintenance/replacement, end of life and emissions from users' utilisation of the asset. The durability of materials has only been considered insofar as to eliminate strategies (or to lower uptake rates) to try to ensure that replacements are like-for-like and will not comprise performance.
- Environmental impacts other than carbon footprint.

Other limitations include:

- There is limited data on project rework (i.e., where something must be ripped out and replaced because it is out of specification). This is excluded from the current analysis.
- There is currently no simple way to split between rural versus urban projects. The location affects the availability of recycled bulk materials and transport distances. In this study, the split of rural/urban population has been used to adjust transport distances (module A4) and uptake rates try to reflect a mix of rural and urban projects.
- Not considering cost escalation over the five-year time horizon.
- Not considering decarbonisation of the business-as-usual case over the five-year time horizon.



Appendix – Consultation insights

Overview of stakeholder consultations

Engaging government and industry stakeholders was an important part of this project. The engagement ensured stakeholders:

- understood the project and what it meant for them (e.g., its aim, methods, planned outcomes and progress) and could update their own stakeholders
- could contribute to the project (e.g., explain decarbonisation activities and challenges for their sector, provide feedback on issues identified, provide data, suggest areas to explore further).

Figure 13: Extent of stakeholder engagement in the project

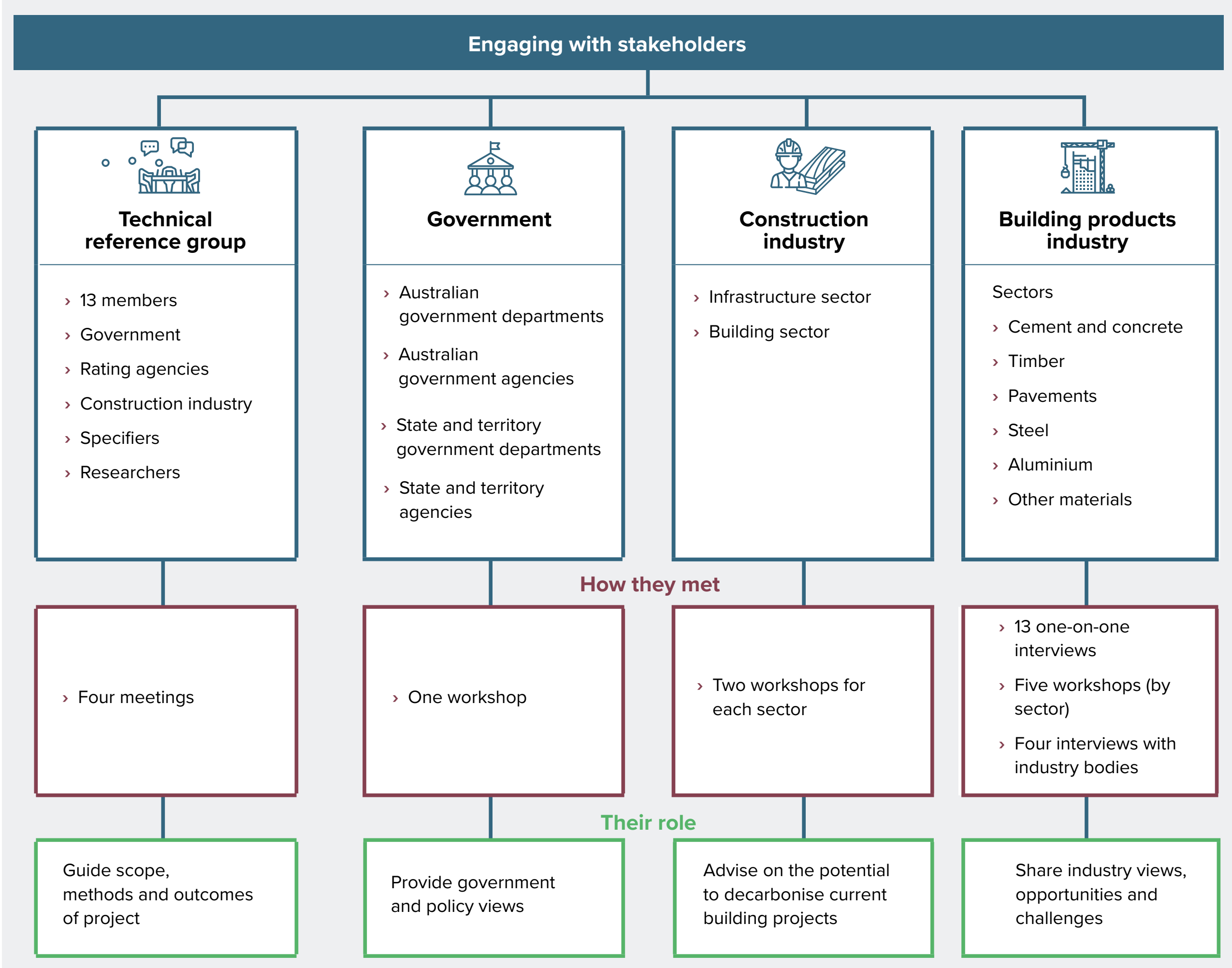


Figure 14: Key messages from stakeholders

1. **Think in systems to influence whole-life outcomes**
   Decarbonisation of the built environment should be addressed at a systems level, and through close collaboration across the value chain.
2. **Follow the decarbonisation hierarchy**
   Applying the decarbonisation hierarchy to all emissions, right from the 'need' stage, provides the greatest opportunity to influence whole-life carbon reduction.
3. **Agree common tools and measures**
   To be credible, decarbonisation should be based on a nationally accepted way of measuring embodied carbon and agreed emission factors.
4. **Collaborate strategically**
   To speed up decarbonisation, government and industry bodies all need to work together strategically
5. **Share the risk**
   To encourage industry to develop innovative lower-carbon solutions, the asset owner and contractor need to share the risks and rewards.
6. **Prioritise changes to standards, specifications and codes**
   Rapidly adopting a consistent, performance-based approach will increase the uptake of innovative lower-carbon solutions.
7. **Focus on leadership**
   Government and large private organisations need to take the lead in lower-carbon purchasing
8. **Support the transition**
   Targeted incentives are needed to encourage industry to decarbonise
9. **Build and share knowledge**
   Knowledege gaps and perception barriers need to be addressed to increase the uptake of innovative lower-carbon solutions.

Supply chain insights

Stakeholders consulted during the project provided insights into the many constraints across the supply chain for low-carbon materials. They highlighted the need to innovate, coordinate and break down silos. The most common supply chain frustrations stem from:

- the absence of a national built environment net zero pathway,
- poor planning and coordination,
- pervasive inertia and conservatism, and
- lack of certainty and incentives to innovate.

These challenges are also present in the larger value-chain, within which the supply chain operates. *Section 3: Barriers and Opportunities* examines the barriers to and enablers of decarbonising the value- chain. This section provides examples to illustrate the most common supply chain constraints identified by the industry stakeholders who produce, supply, procure and install low-carbon materials.

The constraints to using low-carbon products identified through consultation can be grouped into six broad categories: geography, resource availability, availability of low-emissions power, technical constraints, economic barriers, and regulations.

Geography

Infrastructure Australia's *Replacement Materials* report shows that geographical limitations hinder the use of lower-carbon replacement materials, such as recycled crushed glass, recycled crushed concrete, and supplementary cementitious materials. [26] These materials are not widely available due to logistical reasons, resulting in difficulty for stakeholders in accessing them. The high costs and associated transport emissions also counteract the potential carbon reduction. Availability of resources varies between states and between metropolitan and regional areas within the same state. The pavement industry reports that there is a lack of clean and suitable volumes of reclaimed asphalt pavement near to manufacturing facilities, and there is limited plant capacity to process in many locations.

Constructors too reported logistical challenges and cost impacts of sourcing lower-carbon 'waste' materials, because it is difficult to access these materials near new construction sites.

Resource availability

Limited supply of recyclate

Limited availability of recyclate hinders production of lower carbon building products, as many stakeholders reported. Reasons for this scarcity varied among industries.

The plastic pipe industry said that despite being able to incorporate recyclate into non-pressure pipes, there is a low volume of waste pipe available for recycling. Since plastic pipes are long-lived (up to 100 years), post-consumer recyclate is scarce, which limits production of lower-carbon plastic pipe and conduit.

Similarly, steel and aluminium producers struggle with limited recyclate availability, with much of Australia's aluminium recyclate being sent offshore. This impacts their competitiveness in terms of both price and lower-carbon production. The recycled content in Australian aluminium is predicted to remain at less than 5% for the next five years, so Australian producers will continue to rely on imports to manufacture high recycled content building materials.[27]

Despite having the capability to process recycled steel, Australian steel manufacturers face insufficient steel scrap on the global market to meet demand.

The concrete and pavement industries also struggle with sourcing quality recyclate, with shortages reported by asphalt producers for materials such as recycled crushed glass and crushed and screened reclaimed asphalt pavement. The concrete industry said that growing demand for supplementary cementitious materials threatened the future supply of lower carbon concrete mixes, unless grinding capability increased in line with that demand.

Limited supply of biobased alternatives

Bio-based alternatives are available to replace many fossil-based materials and processes, but using them on a large scale for low carbon building products remains challenging.

The plastic pipe industry reports that the available volume of alternative raw material sources is limited and costly, even though bio and circular resins that may be 'dropped into' existing production processes are commercially available.

The steel industry is also exploring biochar as an alternative to coke in steel making, but sourcing sufficient quantities to meet industry demand is difficult. Additionally, combining bio-based and fossil-derived materials in production systems may not produce a clearly recognisable bio-based product, making it necessary to declare the entire product mix as one in Environmental Product Declarations.

Native forest timber

The timber industry expressed concern that the negative narrative around forest management may lead to reduced supply of responsibly sourced low-carbon timber products. Logging in native forests is set to be banned in Victoria and Western Australia in 2024, and a court action to halt logging is currently underway in Tasmania and New South Wales. Hardwood from Australia's native forests is typically made into flooring, decking, window frames, beams and joists.

Availability of low-emissions energy

A decarbonised supply chain is reliant on low-emissions power generation to manufacture and transport low carbon materials. Until a spread of cost-competitive, low-emissions electricity is available, with capacity to support 24-hour operations, high-emitter industries will struggle to produce low-emissions solutions.

The supply of low-emissions power generation extends to capital investment decisions too. For example, the aluminium industry said that the single biggest factor in developing future refining, smelting and manufacturing locations is reliable, internationally competitive, low emissions energy.

Constructors face similar challenges in decarbonising on-site operations. Biodiesel blends can be used to help power site generators and diesel machinery, but constructors said that supply is limited. In some cases it made more sense (commercially) to offset construction emissions with carbon credits. The ability to use 'sustainable' biodiesel to decarbonise construction activities is constrained by the lack of local commercial production facilities, as Australian feedstocks are exported. Imported biodiesel is subject to the full fuel excise and therefore uncompetitive with standard diesel.

Technical constraints

Existing construction biases and conservative materials standards often limit new and innovative materials, mixes, and processes. For example, although hydrated lime can reduce the carbon footprint of asphalt, it is only permitted for Northern Territory roads. Asphalt suppliers felt that the cost of additional testing required for reclaimed asphalt pavement mixes was 'a tax on choosing the right mix' which can limit uptake of a market-ready low-carbon solution.

The concrete industry faces frustration with overly restrictive standards for supplementary cementitious materials and conservative engineering specifications that lead to higher emission outcomes. Suggestions for harmonised national standards have been made, allowing for the uptake of alternative materials at scale. For example, state specifications permit different rates of fly ash; Western Australia specifies the recovery rate of generated fly ash at 72%, compared to 18% in Queensland and 10% in New South Wales.

Despite successes with buried thermoplastic pipes in other countries and a trial in Australia, the plastic pipe industry has faced difficulties negotiating with Australian road authorities and traditional higher carbon products are still favored. Furthermore, the timber industry has concerns about the current treatment of biogenic carbon at end of life reported in Environmental Product Declarations (EPD), following an update to EN15804+A2.28 They question the factual accuracy of the standard, and perceive that it limits the selection of low-carbon timber solutions due to the way the standard requires its carbon footprint to be expressed.

Economic barriers

Stakeholders highlighted commercial constraints to supplying low carbon products, citing examples such as steel manufacturers needing funding for plant upgrades and research initiatives to produce higher grade steels by 2026–27.

Producers struggle to justify capital investment due to limited or inconsistent demand, hindering the implementation of processes for producing lower-carbon products. For example, the concrete industry said that they could implement processes to produce lower-carbon products now if there was enough demand to justify the investment. Likewise, the pavement industry said that capital costs to upgrade asphalt plants to provide lower-carbon asphalt would need to be justified commercially before a commitment could be made to invest.

With no strong market driver for low carbon products, national net zero targets must be embedded in the built environment for innovative solutions to thrive.

The market's reluctance to pay a premium for some low carbon products is also a major disincentive, stifling innovation and limiting uptake.

Constructors noted that many start-ups struggle to introduce their products to the construction industry, due to a lack of carbon literacy and understanding of testing and quality assurance requirements. This can result in failure to penetrate the market, even with good, low-carbon products. Additionally, obtaining EPDs can be prohibitively expensive for small to medium enterprises and start-ups, further constraining the introduction of viable low-carbon products to the market.

Regulations

Industry stakeholders stressed that requirements for regulatory licensing of recycling infrastructure limits their ability to receive, store and process 'waste' materials. The ability to store 'waste' on site depends on approvals at significant cost and often the storage volumes and timeframes are inadequate. For example, asphalt suppliers said that the Environmental Protection Authority (EPA) will not allow on-site storage of replacement materials for use in products.

Producers said that when they are classified as a waste receiver, there are regulatory barriers to the use of the recycled or waste content in their products. Regulatory reform is needed to re-classify resources that are currently classified as 'waste' so that they can be used as a feedstock.

A producer of non-cementitious building products said that the EPA could do more to pressure the waste industry to clean up waste streams destined for the building products sector. Access to more clean 'waste' can help increase the supply of these low-carbon products.

The pavement industry is frustrated at the lack of alignment in regulatory requirements and standards among state and territory roading authorities and the reluctance to adopt technologies and practices that have been proven elsewhere in the world. Stakeholders feel that statutory authorities are reluctant to listen to them, which prevents them from sharing their local expertise, and promoting the uptake of viable low-carbon innovations.

The pavement industry is frustrated that state and territory roading authorities will not align regulatory requirements and standards where practical or adopt technologies and practices that have been proven elsewhere in the world. Stakeholders feel their local expertise regarding viable low-carbon innovations is overlooked by statutory authorities.

The aluminium industry argues that Australia's Critical Minerals List should be changed to include bauxite, alumina, and aluminium. The industry says this would stimulate investment in refining, smelting and processing these critical minerals in Australia, and support clean energy technologies and electricity network infrastructure. The Australian aluminium industry is not at capacity, and as noted above, most of Australia's scrap aluminium is shipped offshore at a time when there is an increasing demand for recycled aluminium and low-carbon aluminium products.

Appendix – Policy levers

Levers available to governments to address upfront carbon at the project level

Australia will rely on every sector to decarbonise at scale to support the net zero transformation. The built environment is directly responsible for one-third of Australia's total carbon emissions, and indirectly responsible for over half of all emissions. Policies that help the built environment to address upfront carbon at the project level will contribute to the national Net Zero 2050 goal.

The analysis in this report shows that national, state and territory governments can make decisions to drive down Australia's carbon emissions today. Policy-makers and teams delivering construction projects have effective interventions that will change how Australia constructs its built environment.

Identifying realistic and important government levers

Industry and government have identified many areas for the government to act on upfront carbon in infrastructure and buildings.

Assessment criteria and process

A two-step process based on two criteria led to the recommended areas of focus:

1. **Criterion 1 (ability)**: how well the action can reasonably be adopted in policy or practice

   At step one of the process, representatives from government departments and agencies refined proposed lists of policy interventions and non-policy levers. These were then ranked based on how challenging they would be to implement successfully. They also identified interventions that lacked agreement.

2. **Criterion 2 (effectiveness)**: how well the action will help decarbonise the built environment at both pace and scale.

   At step two of the process, the Technical Reference Group reviewed the grouped lists and voted on how important or significant the actions are to decarbonisation. Their votes were translated into high, medium and low importance.

Dealing with 'additional' topics

Further engagement with stakeholders later in the project saw other opportunities emerge. This report includes the opportunities that more than one stakeholder raised. 'High importance' means several stakeholders raised the opportunity. The additional opportunities are classified as 'not rated', meaning they have not been assigned a difficulty or importance.

Figure 15 summarises the most promising opportunities identified for government intervention, based on importance and agreement on options as a possible government priority.

Figure 15: Most promising opportunities identified for government intervention in consultation workshop

Standards and specifications

Opportunity	Importance	Level of difficulty
National policy, standards and specification alignment / consistency	high	not rated
Update specifications and standards to support low-carbon materials	medium	low
Mandatory EPDs for manufacturers of prescribed (emissions-intensive) materials	not rated	not rated
Materials passports for all new buildings and infrastructure projects	not rated	not rated

Target setting and baselines

Opportunity	Importance	Level of difficulty
Carbon and energy management plans for all big build projects	high	low
Set upfront carbon targets for all buildings and infrastructure	high	low
Carbon budgets for projects	medium	low

Funding and incentives

Opportunity	Importance	Level of difficulty
National carbon price	high	high
Commonwealth Treasury sustainable finance instruments for infrastructure	medium	low
R&D funding for developing and improving low-carbon materials	medium	low
Support for R&D for age testing of newer products	medium	not rated
Subsidise cost premium	medium	not rated
Incentives to help drive better decisions for individual homeowner	not rated	not rated

Monitoring and reporting

Opportunity	Importance	Level of difficulty
Reporting of scope 3 emissions for all major entities	high	low
Measure and disclose embodied carbon in NCC	high	not rated

Education and awareness

Opportunity	Importance	Level of difficulty
Fund education and training programmes for industry and consumers	not rated	not rated
Provide funding for a guide based on this data with the 'how' to decarbonise infrastructure and buildings	not rated	not rated

Government procurement

Opportunity	Importance	Level of difficulty
Minimum standards for government buildings / leases	high	high
Use government projects as the exemplar for low-carbon construction	high	not rated
Government procurement signalling change in practices	medium	not rated

Assessing emissions

Opportunity	Importance	Level of difficulty
Nationally harmonised approach for principles, definitions, methodology, database: a national framework	high	low
Measure and disclose upfront carbon for all buildings and infrastructure	high	low

Supply chain support

Opportunity	Importance	Level of difficulty
Facilitate waste (resource) on-site storage and processing to reduce carbon impacts	high	not rated
Amend waste regulations to allow simpler avenues to use 'waste' resources, waste industries to provide cleaner waste streams	not rated	not rated
Carbon Border Adjustment Mechanism (CBAM) to address carbon leakage	not rated	not rated

Carbon in decision-making

Opportunity	Importance	Level of difficulty
Recognise end-of-life value of products	high	not rated
Willingness to pay for lower-carbon products	high	not rated
Incentivise adaptive reuse	medium	low
Retrofit first policy (like London)	medium	low
Include whole-life embodied carbon to factor in durability and lifespan	medium	low
Levy or ban on high carbon products	high	high
Social value of carbon in cost benefit analysis	medium	high
Weighting of embodied carbon targets in business cases and tender evaluations	not rated	not rated

Importance:
- high
- medium
- not rated

Level of difficulty:
- low
- high
- not rated

Figure 16 includes full results from analysing possible government interventions. It includes all the information from **Figure 15**, plus other measures, and recommended timeframes for action. The importance (1), level of difficulty (2), and recommended timeframes (3) are noted for each opportunity.

Timeframes

The recommended timeframes for action are all relatively short. This is because urgent action is needed to reach Australia's decarbonisation target.

1. <2025 – before 2025
2. 2025–2028 – from 2025 to fully implemented by 2028
3. 2028–2030 – final actions completed by 2030

These three factors have determined timeframes:

1. How important the action is
2. How difficult it is to implement in policy
3. How difficult it is to implement (technically and practically)

Figure 16: Potential government levers to accelerate built environment decarbonisation

	Policy proposal	1	2	3
Carbon in decision making	Recognise end-of-life value of products	high	not rated	<2025
	Willingness to pay for lower-carbon products	high	not rated	<2025
	Incentivise adaptive reuse	medium	low	<2025
	Retrofit first policy (like London)	medium	low	<2025
	Include whole-life embodied carbon to factor in durability and lifespan	medium	low	<2025
	Levy or ban on high carbon products	high	high	2025-2028
	Social value of carbon in cost benefit analysis	medium	high	2025-2028
	Weighting of embodied carbon targets in business cases and tender evaluations	not rated	not rated	<2025
	Stored biogenic carbon in a building becomes a valuable building asset	low	not rated	2028-2030
Standards and specifications	National policy, standards and specification alignment / consistency	high	not rated	<2025
	Update specifications and standards to support low-carbon materials	medium	low	<2025
	Mandatory EPDs for manufacturers of prescribed (emissions-intensive) materials	not rated	not rated	<2025
	Materials passports for all new buildings and infrastructure projects	not rated	not rated	2025-2028
Assessing emissions	Nationally harmonised approach for principles, definitions, methodology, database: a national framework	high	low	<2025
	Measure and disclose upfront carbon for all buildings and infrastructure	high	low	<2025
Target setting and baselines	Carbon and energy management plans for all big build projects	high	low	<2025
	Set upfront carbon targets for all buildings and infrastructure	high	low	2025-2028
	Carbon budgets for projects	medium	low	2025-2028
	Carbon caps for projects	high	lacking agreement	2025-2028
	Requiring Green Star or IS ratings	medium	lacking agreement	2025-2028
	Requirements for prescribed high-emissions materials	low	low	2028-2030
Monitoring and reporting	Reporting of scope 3 emissions for all major entities	high	low	<2025
	Measure and disclose embodied carbon in NCC	high	not rated	2025-2028
	Link to TCFD reporting	low	low	2028-2030
Government procurement	Minimum standards for government buildings / leases	high	high	2025-2028
	Use government projects as the exemplar for low-carbon construction	high	not rated	<2025
	Government procurement signalling change in practices	medium	not rated	<2025
Supply chain support	Facilitate waste (resource) on-site storage and processing to reduce carbon impacts	high	not rated	<2025
	Amend waste regulations to allow simpler avenues to use 'waste' resources, waste industries to provide cleaner waste streams	not rated	not rated	<2025
	Consider opportunities for sovereign manufacture of alternative materials	medium	lacking agreement	2025-2028
	Carbon Border Adjustment Mechanism (CBAM) to address carbon leakage	not rated	not rated	2025-2028
	Positive new plantation investment policies for sourcing renewable fibre	low	not rated	2028-2030
	Prevent carbon leakage to support major capital investments by manufacturers	low	not rated	2028-2030
	Mandate larger percentage of domestic industry to support their transformation	low	lacking agreement	2028-2030
Funding and incentives	National carbon price	high	high	<2025
	Commonwealth Treasury sustainable finance instruments for infrastructure	medium	low	<2025
	R&D funding for developing and improving low-carbon materials	medium	low	<2025
	Support for R&D for age testing of newer products	medium	not rated	<2025
	Subsidise cost premium	medium	not rated	2025-2028
	Incentives to help drive better decisions for individual homeowner	not rated	not rated	2025-2028
	Use of planning incentives for exemplar projects	medium	lacking agreement	2028-2030
	Support to develop Carbon Capture, Use and Storage (CCUS)	low	not rated	2025-2028
	Financial incentives, e.g., tax breaks for companies addressing embodied carbon	low	not rated	2025-2028
	Resource this project to complete a fuller analysis of decarbonisation methods	low	not rated	<2025
Education and awareness	Fund education and training programmes for industry and consumers	not rated	not rated	<2025
	Provide funding for a guide based on this data with the 'how' to decarbonise infrastructure and buildings	not rated	not rated	<2025

1. Importance:
- high
- medium
- low
- not rated

2. Level of difficulty
- low
- high
- not rated
- lacking agreement

3. Recommended timeframes
- **<2025** – before 2025
- **2025-2028** – from 2025 to fully implemented by 2028
- **2028-2030** – final actions to be completed by 2030

How policy can support decarbonisation of the built environment

The opportunities for government action fit broadly into nine categories:

Carbon in decision-making

Upfront carbon must be assigned value in the decision-making process for projects, such as in tender evaluations. Valuing reductions in carbon means it can be weighted against other criteria such as price, quality and delivery.

A major barrier to using low-carbon products, or reusing existing buildings or materials, is a perception of unreasonable cost. However, if there is a clear priority to reduce carbon in all projects, this becomes another 'necessary cost', much like buying products that comply with codes and standards.

Creating a perceived value for low-carbon commodities can encourage more reuse and retrofits. It can also promote taking a whole-life carbon view for an asset, which protects against possible trade-offs.

Standards and specifications

Industry often cites the content of existing standards and specifications as a major factor that inhibits using low-carbon products. They raise two challenges: a lack of national agreement and consistency, and the need to update standards and specifications to support low-carbon purchasing.

National agreements and consistency

The best way to support low-carbon construction is by setting consistent requirements that are included in all similar standards and specifications. Performance-based specifications allow for more innovative and flexible approaches. Confirming common expectations across national and sub-national jurisdictions helps create the consistent demand and volume that supply chains need to change.

Updating standards and specifications

The process for updating standards and specifications needs a systemic overhaul. Updates are often slow and arduous and create a barrier to innovation and change. New, more agile approaches to updates will encourage using lower-carbon solutions on construction projects.
A more open approach to other forms of compliance, which include identifying and managing risks, can encourage industry to trial newer solutions more quickly. Government should also consider more requirements to disclose high-emissions products through EPDs and material passports.

Assessing emissions

A national approach to measuring upfront carbon involves adopting common principles, methodologies, emission factors and reporting mechanisms nationally and across all states and territories. This approach will create a consistent, credible way to decarbonise the built environment nationally over time and make it possible to compare different projects.

Disclosures

A national methodology would enable the disclosure of upfront carbon for infrastructure and building projects. This will make it easier to understand the impacts of construction and continue to investigate the best levers to reduce it. Disclosure using agreed methods to measure the upfront carbon in construction, will help everyone understand what is possible and encourage a 'race' to reduce emissions which can be publicly monitored and measured. Disclosure will also show the progress being made and make it possible to refine actions to help achieve national and sub-national goals.

Setting targets and baselines

To help Australia reach its decarbonisation targets, managing and reducing the upfront carbon in infrastructure and buildings must be planned and deliberate. Carbon and energy management plans for construction projects are an important part of the carbon reduction toolkit. Requiring these plans for all government-funded projects and assets will ensure better decisions and action early in projects.

Consistent ways of measuring lead to baselines people trust. Setting targets for upfront carbon in construction will increase the potential for change in the built environment's footprint. Targets are a better option than a carbon 'cap'. Firstly, they are not seen as a 'cap'. This is because some stakeholders view caps as unnecessary constraints where site conditions and other factors may make it hard or impossible to reach targets.

Carbon 'budgets', based on targets, can be allocated for projects or even parts of the pipeline. This makes it easier to take an holistic view about what is possible within the constraints of decarbonising.

Monitoring and reporting

Upfront carbon for developing assets should be seen as part of a wider Scope 3 emissions picture. Stakeholders wanted to see larger entities reporting their Scope 3 emissions. This would put more focus on upfront carbon and all the other carbon emissions that a company can influence.

Many stakeholders also wanted the National Construction Code (NCC) to include reporting of upfront carbon.

Government procurement

The Australian Government, and state and territory governments have the largest buying power in the built environment, and the greatest commercial influence for change. Government policies and agencies need to lead changes in low-carbon procurement and leaders in the private sector need to support this. National, state and territory procurement strategies must be set to match net-zero policies, and support decarbonisation to achieve agreed targets.

Industry reported that government projects typically avoid risk and lack ambition. A systemic change would see making decarbonising a national priority. It also means seeing the work involved in leading low-carbon construction and setting minimum standards for government-leased buildings as a necessary investment.

Support for supply chains

Supporting manufacturers in hard-to-abate sectors with both incentives and disincentives for change is a cornerstone of government policy. This is important and must be continued and strengthened. Manufacturers also raised reducing carbon leakage as an opportunity.

Industries experiencing challenges with technological constraints are seeking new ways to lower their carbon emissions. Several stakeholders suggested that using 'waste' streams as raw material resources could be a promising way to decarbonise. However, regulatory constraints on how waste is classified, processed, and stored and how end-of-life products (resources) classified as 'waste' can be used has delayed developing lower-carbon products by years.

Stakeholders also identified opportunities to provide cleaner, more consistent recyclate, such as recycled crushed glass. This would allow more processing of reused materials to make construction products instead of using new raw materials.

Funding and incentives

The Technical Reference Group saw introducing a national value for carbon as an important impetus for decarbonisation. Some stakeholders said that it was not a 'price' as a tradeable commodity that was needed. Rather, it was an agreed value for carbon to use in business cases and decisions to prioritise decarbonisation.

Industry calls for government funding to support decarbonisation reflected the challenges of price premiums for low-carbon products and the possible benefits of offering incentives to decarbonise. Stakeholders raised the expense of research and development to create new products as a barrier, together with the rigorous testing needed to prove they are fit for purpose. A further suggestion was the development of sustainable finance instruments to support infrastructure projects.

Education and awareness

Government and the private sector, large and small entities, commercial and consumer, do not understand decarbonisation as well as they need to. Education is one of the greatest missing links. It should cover simple fundamentals and case studies that highlight best practice, and help people develop the techniques they need to design, specify and install for low-carbon construction.

Industry identified an opportunity to partner with government to develop urgent solutions to this issue.

Industry also requested a guide which combines the findings of this project with information about how to build low-carbon infrastructure and buildings.

Acting faster offers the greatest potential for decarbonisation

Governments across Australia are already acting on many of the issues raised in this report, to varying extent. However, more progress is needed.

The most urgent actions identified by the consultation, that should be acted on before 2025, include:

Decarbonisation measures in policy

- Align national policy and make it consistent.
- Confirm a nationally harmonised approach for principles, definitions, methodology, database (a national framework).
- Measure and disclose upfront carbon for all buildings and infrastructure.
- Require carbon and energy management plans for all big build projects.
- Require reporting of Scope 3 emissions for all major entities.
- Facilitate on-site waste (resource) storage and processing.
- Amend waste regulations to allow simpler ways to use 'waste' resources.

Requirements for government assets and government-funded projects

- Include weighted embodied carbon targets in business cases and tender evaluations.
- Align national standards and specifications and make them consistent.
- Use government projects as the exemplar for low-carbon construction.
- Use government procurement to signal a change in practices.
- Recognise the end-of-life value of products.
- Offer incentives for adaptive reuse and retrofitting.
- Be willingness to pay for lower-carbon products.
- Include whole-life carbon to factor in durability and lifespan.
- Require mandatory Environmental Product Declarations for emissions-intensive products.

Providing government support to promote and influence change in industry

- Fund education and training programs.
- Create a national carbon price.
- Create Commonwealth Treasury sustainable finance instruments for infrastructure.
- Fund R&D to develop, improve and age-test low-carbon products.
- Complete a fuller analysis of decarbonisation methods not included in this report.
- Develop a guide on how to build low-carbon infrastructure and buildings.
- Require waste industries to provide cleaner waste streams.

Glossary

Term	Definition
Aggregates	Aggregates for concrete comprising small stones, gravel and sand.
Asset	Physical entity forming part of a network and/or system that has potential or actual value to an organisation and its stakeholders.
Asset owner/manager	Organisation that manages and is responsible for providing, operating and maintaining a buildings and infrastructure network or asset(s).
Attributable emissions	Greenhouse gas emissions from services, materials and energy flows that become the product, make the product and carry the product or service through its life cycle.
Baseline	Scenario for what carbon emissions and removals would have been in the absence of planned measures aiming to reduce emissions
Biodiesel	A liquid fuel derived from vegetable oils or animal fats. Biodiesel can be blended and used in many different concentrations, from B5, which is 95% petroleum diesel and 5% biodiesel, all the way up to B100, which is pure biodiesel.
Biofuel	An alternative fuel that is developed from biological, natural, and renewable sources. Biofuels are an attractive option due to their high energy density and convenient handling and storage properties. Biofuels can be used on their own (with some precautions or restrictions) or blended with petroleum fuels.

Term	Definition
Biogenic carbon	Carbon removals associated with Carbon Sequestration into biomass, including natural building materials (e.g. timber) as well as any emissions associated with this Carbon Sequestration.
Brownfield site	An industrial or commercial site that is idle or underused because of real or perceived environmental pollution.
Built environment	Collection of human-made or induced physical objects located in a particular area or region.
Capital carbon	Greenhouse gas emissions and removals associated with the creation and end-of-life treatment of an asset, network or system, and optionally with its maintenance and refurbishment.
Carbon Border Adjustment Mechanism	An emerging set of trade policy tools that aim to prevent carbon-intensive economic activity from moving out of jurisdictions with relatively stringent climate policies and into those with relatively less stringent policies.
Carbon budget	Estimated amount of whole-life carbon a system can emit.
Carbon dioxide equivalents (CO_2-e)	A measure that quantifies the global warming effect of different greenhouse gases in terms of the amount of carbon dioxide that would deliver the same global warming effect.
Carbon intensity	The amount of CO_2e emitted as a unit of production or output e.g., per $ revenue, full-time equivalent or m2 floor area.

Term	Definition
Carbon leakage	A loss of competitiveness and/or relocation of trade-exposed, emissions-intensive industries as a result of carbon penalties applying in some countries but not others. Carbon leakage includes potential increases in global emissions due to import substitution and lost future investment in existing or new businesses.
Carbon management	Assessment, reduction and removal of greenhouse gas emissions during the planning, optioneering, design, delivery, operation, use, end of life (and beyond) of new, or the management of existing, assets, networks and/or systems.
Carbon offsets	An action intended to compensate for the emission of CO_2e into the atmosphere as a result of industrial or other human activity, especially when quantified and traded as part of a commercial scheme.
Carbon uptake **(Recarbonation/ Carbonation)**	Cement recarbonation or concrete carbonation refers to the process where CO_2 is absorbed by concrete during its use and end-of-life phase. The amount absorbed is significant but less than the total emitted in cement production.
Carbon capture use and storage	Carbon capture, utilisation and storage – also referred to as carbon capture, utilisation and sequestration – describes processes that capture CO_2 emissions from industrial sources and either reuses or stores it, so it will not enter the atmosphere.
CO_2	CO_2 stands for carbon dioxide. It is a colourless, odourless, and non-combustible gas. It is a greenhouse gas that contributes to global warming. Formed by complete combustion of fossil fuels (coal, charcoal, natural gas, petroleum) and CO_2-containing products (such as limestone).
Electric arc furnace	A furnace that heats materials using electricity.

Term	Definition
Embodied carbon	Greenhouse gas emissions associated with materials and construction processes throughout the whole life cycle of a building or infrastructure being the sum of upfront carbon, in-use embodied carbon, and end-of-life embodied carbon, measured by CO_2e.
Embodied energy	The total energy necessary for an entire product life cycle including raw material extraction, transport, manufacture, assembly, installation, maintenance, repair, disassembly, replacement, deconstruction and/or decomposition. This includes renewable and non-renewable energy. Embodied energy does not correlate to embodied carbon.
Emissions factor	Amount of greenhouse gases emitted, expressed as carbon dioxide equivalent (CO_2e) and relative to a unit of activity.
Emissions reduction	Quantified decrease in greenhouse gas emissions specifically related to or arising from an activity between two points in time or relative to a baseline.
Enabled emissions	The emissions generated from third parties using infrastructure. Examples include vehicles driving over roads and chemical processes occurring in factories. In practice, it is difficult to set a boundary on what is enabled by the built environment and what is not. This analysis assumes that primary industries (e.g., mining, agriculture and forestry) and solid waste treatment (e.g., landfills) are not significantly enabled by the built environment.
End of life	Stage which begins when the asset has reached the end of its design life and is ready for refurbishment, retrofit, disposal, dismantling, etc., and ends when the asset is recycled, reused, recovered or returned to nature (combustion, deterioration).

Term	Definition
Environmental Product Declaration	An independently verified and registered document that communicates transparent and comparable information about the life-cycle environmental impact of products and services in a credible way. An Environmental Product Declaration is compliant with the standard ISO 14025 and is known as a Type III environmental declaration.
Decarbonisation hierarchy	A decision-making hierarchy which identifies potential opportunities for managing and reducing whole life emissions for projects and programmes of work in the built environment. Value chain members are required to demonstrate that they have taken into account actions which 'avoid', 'switch' and 'improve'.
Global Warming Potential (GWP)	Global Warming Potential is a measure of how much heat a greenhouse gas traps in the atmosphere relative to carbon dioxide (CO_2). It has been developed to compare the global warming impact of different gases. The Global Warming Potential depends on how effective the gas is at trapping heat and how long it stays in the atmosphere before it breaks down.
Greenfield site	An area of land that has never previously had buildings on it or been used for industry
Greenhouse gas intensity	For a product, the total GHG emissions released in energy consumption for production and overhead, GHG emissions released by transport used for business travel and additional GHG emissions from the production process divided by the value of the product (i.e., the total factory gate price). Refer also to Carbon Intensity.
Greenhouse gases	Greenhouse gases are those gaseous constituents of the atmosphere, from both natural and anthropogenic sources, which contribute to the greenhouse effect, as detailed in the Intergovernmental Panel for Climate Change Glossary. Greenhouse gas emissions are often referred to as 'carbon emissions' in general usage.

Term	Definition
Life Cycle Assessment	An analysis of the environmental and/or social impacts of a product, process or a service for its entire life cycle. It looks at the raw material extraction, production, manufacture, distribution, use and disposal of a product.
Life cycle stages	Defined stages throughout the life cycle of a building or infrastructure including the product stage, construction process stage, use stage, end of life stage and benefits and loads beyond the building or infrastructure life cycle, as outlined in EN 15978.
Nature-based solutions	Actions to protect, sustainably manage and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits.
Net zero	Reduction of anthropogenic greenhouse gas emissions to zero or to a residual level that is consistent with reaching net zero emissions in eligible 1.5 °C pathways (hence time-bound) and neutralizing the impact of residual emissions (if any) by removing an equivalent volume of carbon.
Network	Combination of interconnected assets (buildings and infrastructure) that provide services (e.g., water, power, transport) to society as part of a wider system.
Net zero carbon	Net-zero is used throughout this document with respect to the industry and its products and relates to the reduction of CO_2 emissions, across the whole life cycle, to zero. Carbon capture by industry at industrial plants is included in actions to reduce carbon emissions to zero. Offsetting measures such as planting trees or other nature-based solutions are not included in the calculations to get to net-zero.
Operational carbon	The emissions associated with energy used to operate the building or in the operation of infrastructure.

Term	Definition
Programme of works	Defined set of projects related to the construction, maintenance, operation and/or end of life of an asset, network or system.
Reclaimed asphalt pavement (RAP)	Removed and/or reprocessed pavement materials containing asphalt and aggregates. RAP does not contain a detectable quantity of coal tar or asbestos.
Recycled crushed concrete	Concrete composed of rock fragments coated with cement with or without sands and/or filler, produced in a controlled manner to close tolerances of grading and minimum foreign material content.
Renewable energy	Renewable energy is energy that is produced from renewable sources such as energy from wind, hydro, solar, geothermal, tide, waves and biomass.
Scope 1 emissions	GHG emissions released to the atmosphere as a direct result of an activity, or series of activities at a facility level. Scope 1 emissions are sometimes referred to as direct emissions. Examples are: • emissions produced from manufacturing processes; • emissions from the burning of diesel fuel in trucks; • fugitive emissions, such as methane emissions from coal mines • production of electricity by burning coal.
Scope 2 emissions	Greenhouse gas emissions released to the atmosphere from the indirect consumption of an energy commodity. For example, 'indirect emissions' come from the use of electricity produced by the burning of coal in another facility. Scope 2 Emissions from one facility are part of the Scope 1 Emissions from another facility.

Term	Definition
Scope 3 emissions	Indirect GHG emissions other than Scope 2 Emissions that are generated in the wider economy. They occur as a consequence of the activities of a facility, but from sources not owned or controlled by that facility's business. Some examples are extraction and production of purchased materials, transportation of purchased fuels, use of sold products and services, and flying on a commercial airline by a person from another business. Also referred to as supply chain emissions.
Supplementary cementitious material (SCM)	Supplementary cementitious material, or clinker substitutes, are a wide range of materials that can be used to replace part of the clinker in cement. They can either be blended with cement or used directly in concrete batching. They can be naturally occurring materials, industrial byproducts, or manufactured products. Examples include ground granulated blast furnace slag, fly ash, silica fume, calcined clays (metakaolin) and natural pozzolans (high-silica volcanic ash and pumice).
System	Collection and interconnection of all physical facilities and human interactions that are operated in a coordinated way to provide a particular service.
Upfront carbon	Upfront carbon: the greenhouse gas emissions and removals associated with the creation of an asset, network or system up to practical completion.
Value chain	Organisations and stakeholders involved in creating, operating and managing assets and/or networks.
Whole-life carbon	The total of all Greenhouse gas emissions and removals, both operational and embodied, over the lifecycle of an asset, including its disposal. Potential benefits or loads from future energy recovery, reuse and recycling are reported separately.

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Online ISBN: 978-1-925352-77-1