Green Building Council Australia

greenstar

A practical guide to upfront carbon reductions

For new buildings and major refurbishments

lendlease

NSW GOVERNMENT

Sustainability Victoria

Building a sustainable future

Established in 2002, Green Building Council of Australia (GBCA) is the nation's authority on sustainable buildings, communities and cities. Our vision is for healthy, resilient and positive places for people. Our purpose is to lead the sustainable transformation of the built environment. GBCA represents more than 550 individual companies with a combined annual turnover of more than $46 billion.

Principal partner

Lendlease is proud to be principal partner of the Practical guide to upfront carbon reductions. As a global integrated real estate group, we draw on decades of experience and the latest thinking in development, design, placemaking, construction and investments to deliver iconic and inclusive places for everyone. We're a 1.5 degree aligned company and aim to create $250 million of social value by 2025. We have clear decarbonisation plans in place and we measure the positive impact we are making in communities around the world.

GBCA thanks Lendlease for their contributions in this guide, and for allowing the use of their "Low Embodied Carbon Guideline" which has informed various sections.

Funding partners

The National Australian Built Environment Rating Scheme (NABERS) is a world-leading national government program that provides simple, reliable and comparable sustainability measurements across multiple building sectors like offices, hotels, shopping centres and more. NABERS provides an annual rating for a building's efficiency in energy, water, waste or indoor environment quality. Over the last 20 years NABERS has proven that measurement leads to better management. Buildings that have obtained NABERS ratings for a decade achieve energy savings of 30-40% on average.

Sustainability Victoria's purpose is to transition Victoria to a circular, climate-resilient economy. Sustainability Victoria does this by contributing to achieving the Government's targets for 2025 and 2030 in recycling and net-zero emissions. We work together in partnership with our stakeholders in industry, business, entrepreneurs, research institutions, schools, households, individuals, community groups and governments within Victoria and across Australia. To achieve our goals, SV will lead and support industries on how we design, make, and use the products and materials in our economy.

Technical partner

Mott MacDonald has been delivering projects in Australia for over 40 years and focuses on creating sustainable social outcomes across the Transport, Advisory, Built Environment, Water and Energy sectors. As a leading multidisciplinary buildings consultant in Australia, we specialise in developing sustainable solutions in building structures, services, and engineering sciences.

We bring the advanced digital systems and infrastructure that you would expect from a 18,000 strong global organisation, with over 1,200 staff across Australia.

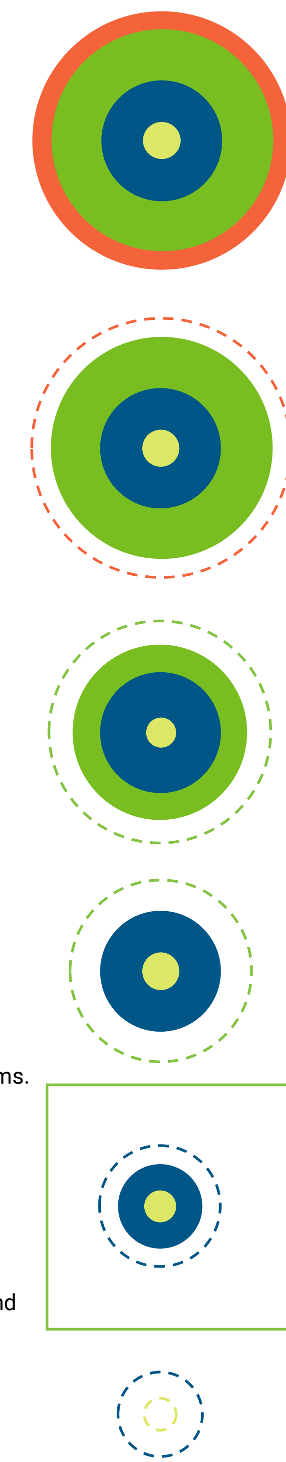
The information provided in this guide is for illustrative purposes only. In all cases, building owners are encouraged to consult with dedicated professionals to assist them in reducing upfront carbon emissions.

How to use this guide

This guide provides information on reducing upfront carbon emissions in new buildings and major refurbishments. The guide outlines steps to be taken during the design and construction process and offers solutions for common challenges. It is intended to be used alongside a calculation guide[1] that was released in December 2022.

Delivering Climate Positive Buildings

The diagram shows typical steps to decarbonise buildings in line with our Climate Positive Roadmap[2]. This guide covers how to reduce upfront carbon emissions. It addresses absolute reductions of carbon in the material production and construction processes. Separate guides[3] exist on making new and existing buildings fossil fuel free. We encourage you to apply these steps throughout your portfolio.



Standard building

Measure typical greenhouse gas (GHG) emissions due to energy use and construction, repair, maintenance & refurbishment and end of life.

Fossil fuel free

Eliminate natural gas for space heating, domestic hot water and cooking, both base building and tenants.

Highly efficient

Manage peak and reduce net building energy consumption through energy efficiency measures and effective demand management controls.

Powered by renewables

Provide all electricity from 100% renewable sources – on-site and/or off-site.

Built with lower upfront carbon

Significantly reduce upfront carbon through material/product selection during design and construction.

This guide

Offset with nature[4]

After reducing all other GHG emissions as much as possible, procure credible nature based offsets.

Legend

GHG EMISSIONS	USED FOR
Natural gas	Space heating, domestic hot water and cooking.
Electricity	Ventilation, cooling, lighting, pumps, small power, lifts, security, controls, and IT systems.
Other	Emergency (backup) power, and refrigerants.
Materials	Emissions from products, materials and activities for repair, maintenance and refurbishment.

Everything you wanted to know about upfront carbon (but were afraid to ask).

There are several terms and concepts that you should know about upfront carbon, including its definition, calculation, and significance.

What are upfront carbon emissions?

Upfront carbon emissions are produced during a building's material production and construction activities before its use.

Is it different to embodied carbon?

Embodied carbon includes upfront carbon, as well as modelled assumptions for future potential carbon. Upfront carbon is a tangible part of a building's embodied carbon, reflecting past actions rather than future projections. There is higher certainty when it comes to upfront carbon reductions than future potential carbon reductions, hence the need to focus on it during construction.

What defines embodied carbon?

Embodied carbon includes upfront carbon (A1 to A5) and emissions from the use and end-of-life stages of a building (B1 to B5 and C1 to C4, respectively). It is defined in the EN 15978 Standard[5].

How much of a problem is it?

Today, at least 25% of a typical building's emissions occur during the upfront carbon stage[6] which cannot be changed once the building is constructed as these emissions are already spent. This percentage will increase as the grid decarbonises.

What can I do about it?

To tackle upfront carbon, we need to build with less, reduce and optimise virgin material usage, and use low-carbon materials and construction technologies.

How hard is it to reduce it?

Reducing upfront carbon is easiest during planning and early-stage design are where the largest reductions can be achieved with the least effort. As construction begins, options become more limited, and there is much less that can be done to reduce upfront carbon once the building is operational apart from upgrade or re-fit of elements.

How do I calculate it?

Calculating upfront carbon involves determining the amount of each material used in a building and multiplying it by the carbon content per unit of use. Material databases provide generic carbon information, whilst a product's Environmental Product Declaration (EPD) can offer product specific carbon emissions.

Two main methods of calculation are comparison against a fixed benchmark or a reference project. Calculating against a reference requires defining both the reference and actual buildings.

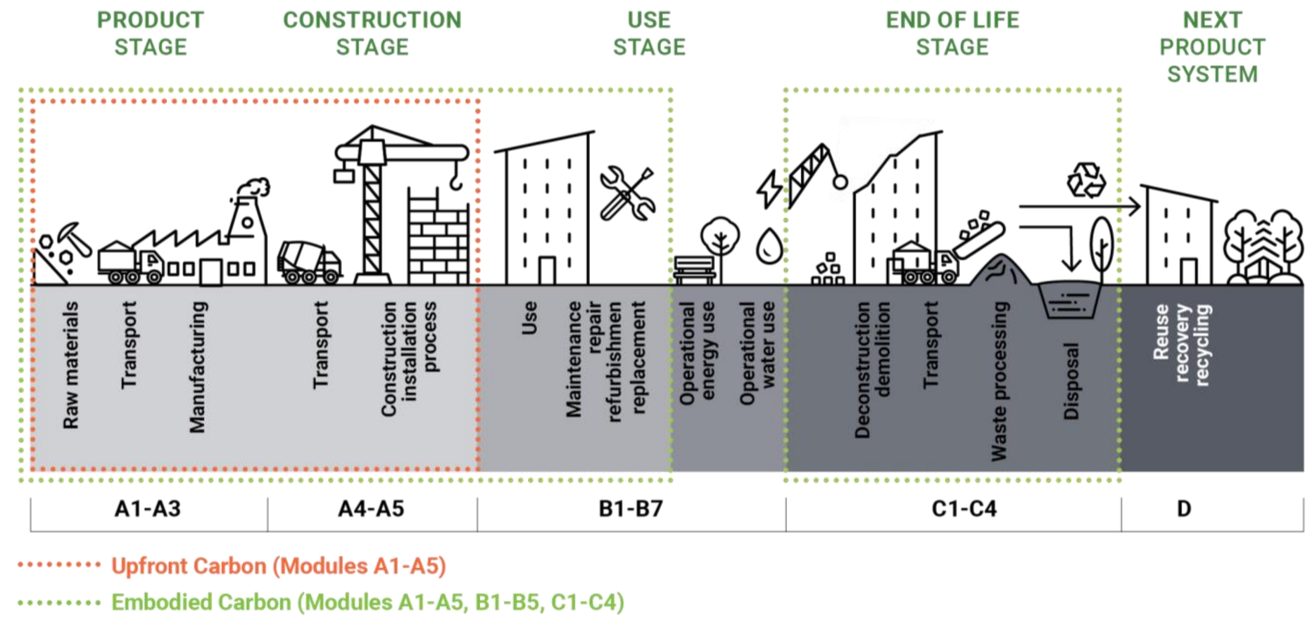


Figure 1. Embodied Carbon over the life of an asset adapted from Embodied Carbon and Embodied Energy in Australia's Buildings (thinkstep-anz 2021)

I heard that you can't trust calculations or compare buildings?

Assumptions in upfront carbon calculations can vary in scope, input data, and more. However, assuming the same conditions and if reviewed by a third party, reduction calculations are relevant. Documents such as GBCA's Upfront Carbon Emissions Calculation Guide help reduce variability in assumptions and increase confidence in the calculation. Comparisons between buildings are more difficult, but the guide above, and the upcoming NABERS tool will make those more relevant.

Why not focus on whole life carbon or operating emissions?

Historically, industry has focused on operational emissions. As we decarbonise the grid, upfront carbon emissions during design and construction become more impactful and cannot be reduced post building completion. Early design also offers the opportunity to maximise energy efficiency and reduce operating emissions.

Although it's essential to consider other emissions, doing so should not come at the expense of upfront carbon or operations, which are more easily influenced early on. Reducing other embodied carbon emissions is also vital, but reducing upfront emissions has a greater impact on a building's carbon footprint today.

How is upfront carbon addressed by Green Star?

Green Star already has requirements for all projects to reduce their upfront carbon to obtain a rating. Green Star uses a reference building comparison for now but will switch to the NABERS benchmarks once released.

The case for reducing upfront carbon

Climate change, health and wellbeing, natural resource depletion, consumer preferences, investor demand - these are key issues that are impacting how we develop or refurbish buildings in our cities. Key to these challenges is how we transform our methods of construction to reduce and eliminate our upfront carbon.

The built environment represents about 40% of all emissions worldwide. Of those emissions[7], 10% comes from construction activities. In Australia[8], that proportion is higher, with approximately 16% of all emissions generated from the built environment come from product and materials used in the construction and refurbishments of buildings, fitouts, and precincts.

At a building level, upfront carbon emissions[6] from materials and construction activities are around a quarter of a building's lifetime emissions. While currently a smaller proportion than a building's operating emissions, upfront emissions are spent on the day the building opens – they can never be changed.

As we move into a decarbonised world, buildings with lower upfront emissions are key to reducing our sector's emissions. These buildings are more attractive to investors as they demonstrate the developer and builder are responsible entities. Upfront carbon emissions are also being highlighted in sustainability reporting frameworks and initiatives, as they are considered part of an entities scope 3 emissions.

Lower upfront carbon emissions are also in the spotlight, as local, state, and federal governments set targets to decarbonise the sector. The NSW Government is introducing upfront carbon disclosure requirements for residential and non-residential buildings as part of their Sustainable Buildings SEPP[9]. Nationally, NABERS, in partnership with GBCA, is developing a rating tool to benchmark and measure upfront carbon in buildings[10].

In the business case for lowering upfront carbon emissions, the following factors can be considered:

- **Climate change**: Reducing the impacts of the built environment through decarbonising the sector. As operational carbon is reduced through renewable electricity and energy efficiency measures, embodied carbon emissions become the focus, representing a larger proportion of total emissions[11].
- **Investor benefits: I**nvestors are looking for assets with a clear decarbonisation pathway. Lower upfront carbon buildings will have access to sustainable finance (Green Bonds and Loans), potentially at lower interest rates[12]. The rise of scope 3 reporting and its inclusion in corporate net zero targets means that upfront carbon is no longer an optional consideration[13].
- **Tenant and consumer preferences**: Many organisations have set goals for decarbonising assets that they own or lease. By reporting on upfront emission reductions, organisations will be better informed about the spaces they occupy.

International and domestic policies driving upfront carbon action

IEA's zero carbon ready definition

In May 2021, the International Energy Agency released 'Net Zero by 2050: A roadmap for the energy sector'[14]. Within this report, the IEA set out its path for the building sector - Zero-carbon-ready buildings. In addition to zero-carbon-ready buildings being highly energy efficient sourcing renewable energy using an energy supply that will be fully decarbonised by 2050, the IEA recognises Scope 3 emissions, those in modules A1-A5 (the modules this guide addresses).

The IEA recommends buildings codes be adjusted to target net-zero emissions from material use in buildings.

NSW Sustainable Buildings SEPP

In August 2022, the NSW Government announced the Sustainable Buildings SEPP[9]. Taking effect from October 2023, the new policy introduces sustainability measures for non-residential buildings and improves the standards for residential buildings under BASIX.

The policy requires calculation and reporting of embodied emissions to set market signals and future targets. The new SEPP adds a material index to the current BASIX tool, building current data on materials and, in the future, will move to rewarding homes that use materials with lower embodied emissions.

City of Melbourne's Zero Carbon Buildings Plan

In October 2022, the City of Melbourne released its Zero Carbon Buildings Plan[15] aiming to drive policies to deliver on their 2040 commitment. The plan defines zero carbon buildings as buildings in which no additional carbon is emitted into the environment through the construction, operations and whole of life of the building. It specifically calls out embodied energy reductions within its goals. The final plan is expected to be launched in the middle of 2023.

The investor case for reducing upfront carbon

Net zero asset owners alliance

Made up of institutional investors, the UN's Net Zero Asset Owner Alliance (NZAOA) is committed to transition their investment portfolios to net-zero by 2050 (or consistent with a 1.5C maximum temperature rise).

Specifically, members are tasked with engaging in financial services regulation and economic policy through climate policy engagement. Additionally, members pledge to steward the assets they control within their portfolio through corporate alignment due to the perceived "obstructive climate policy engagement" by investees which "can slow sectoral ……decarbonisation and the transition to net zero". The net zero asset owners alliance has called for scope 3 emissions to be considered[16].

Taskforce for climate related financial disclosure (TCFD)

Created by the Financial Stability Board, the TCFD has been charged with recommending the information companies disclose to investors, insurance underwriters and lenders to help them assess and price climate related risks. TCFD guidance is now commonly used by boards of real estate companies, and guidance is expanding to note that scope 3 emissions are a key material risk that needs to be addressed[17].

Clean Energy Finance Corporation

As a major investor in Australia's built environment, the CEFC released "Opportunities for cutting embodied carbon"[18] in buildings and infrastructure.

The paper lays out investors' roles in decarbonisation, including the importance of holding company directors to account on their fiduciary requirements with regards to climate change associated risks and to support efforts in the decarbonisation of the supply and value chain.

Market solutions driving change

Upfront carbon requirements in Green Star

The Green Star Buildings tool (v1) has a dedicated Upfront Carbon Emissions credit. The Reference Project method is used to calculate reductions of the building design. Any remaining upfront carbon emissions can be compensated through nature-based offsets under the 'Other Carbon Emission' credit.

Projects seeking a rating under Green Star Buildings must reduce upfront carbon by at least 10% (Minimum Expectation). Those seeking higher ratings must achieve at least a 20% reduction (Credit Achievement worth 3 points). Requirements will increase in the future to meet a 40% reduction (Exceptional Performance worth an additional 3 points).

To help with the reference carbon calculations, GBCA released an interim upfront carbon calculation guide[1].

More information can be found in Green Star Buildings Submission Guidelines.

Climate Active Carbon Neutral

In 2022, Climate Active expanded its "Carbon Neutral Standard for Products and Services" to provide certification for reducing and offsetting the upfront carbon emissions in new buildings and major refurbishments[19]. The guideline covers the construction stage, up to the point of delivery. Since its release, groups like GPT have certified developments alongside their Green Star ratings[20].

NABERS Embodied Emissions

In partnership with the GBCA, NABERS is developing a tool to measure, verify and compare upfront carbon in new buildings[10]. This national tool will allow for the creation of robust and measurable targets, increasing the reliability of upfront carbon emissions reductions in buildings. Doing so will enhance reporting to investors, increase demand for low-carbon design practices and construction materials, and create a common language for embodied carbon emissions in Australia.

What is a typical building's upfront carbon?

The upfront carbon of a building per square metre can vary greatly depending on several factors, such as the building materials used, the size and complexity of the building, and the location and climate. There are several studies that point to a range of expected emissions per square meter for multiple building types. These studies have been made across various countries, including Australia, and all point to similar numbers. The table below synthesizes them and aims to provide a reference.

	$kgCO_2e/m^2$ GFA	
	Low	**High**
Commercial	500	1000
Education (primary and secondary)	200	500
Education (tertiary)	750	1000
Health	700	900
Industrial	350	500
Multi-unit residential	600	800
Public building	500	800

Table 1: The estimates developed for this table should be considered indicative. The values vary based on data sources, boundaries, scale, location and other factors. To arrive at these figures, we considered the following studies:

- Slattery (2022)[6]
- ISTRUCTE (2022)[21]
- CLF (2017)[22]
- ARUP (2021)[23]
- Built (2021)[24]

It's important to note that these estimates are just a rough guide, and that the actual upfront carbon of a building will depend on a range of factors that are specific to the project. These numbers cannot be used to define reductions but can be used to test calculations against.

These estimates also do not account for any biogenic carbon, storage, or offsets.

Where is the upfront carbon?

In general, most of the building's upfront carbon is in the superstructure (suspended floors, structural walls, columns and beams), substructure (foundations, basement retaining walls and ground slabs) and envelope.

Prioritising these elements during design and material choice yields the highest opportunity to reduce upfront carbon.

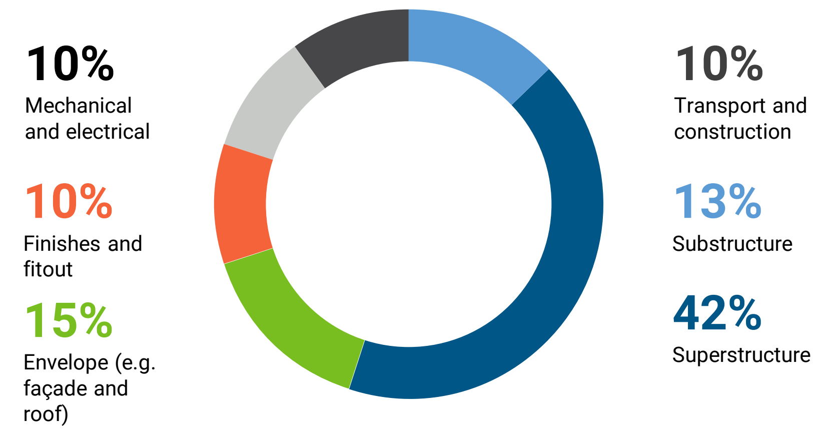


Figure 2: Typical breakdown of construction upfront carbon in a new office building[6]

The lifespan of different building elements also vary with the superstructure and substructure being able to last the longest. By maximising the lifespan of the most carbon intensive elements, this reduces the need for replacement and additional upfront carbon emissions associated with new construction.

Transportation of Products and Materials

Heavy transport vehicles have proven difficult to decarbonise to date. However, the automotive industry has broadly started to electrify heavy commercial vehicles that will assist the built environment reducing the A4 module emissions for their projects. In addition to reduced carbon emissions, there are obvious benefits for developers and society with reduced air and noise pollution from these vehicles[25].

Construction equipment emissions

Construction machinery and equipment, typically fueled by fossil fuels[5] are also a source of upfront carbon in construction. Fossil Free Construction requires the reduction of fossil fuels such as diesel, petrol and LPG to power site office, construction machinery and equipment. Electric Vehicles, and renewable fuels such as diesel and biofuels are options currently accessible to the sector as we move towards electrification.

Published last year, Lendlease and University of Queensland's report *Stepping Up the Pace: Fossil Fuel Free Construction* outlined a roadmap for removing fossil fuels from construction sites[26].

How to measure upfront carbon?

Upfront carbon for a building can be calculated by multiplying the quantity of a specific product and its specific product emissions, adding all product emissions together (modules A1 to A3), plus the associated construction emissions (modules A4 to A5). The calculation is not complex, once all information is available.

A more comprehensive calculation can be done through a life cycle analysis (LCA) calculation. An LCA will provide more information than just upfront carbon and may yield valuable insights and potential opportunities for improving a building beyond upfront carbon reductions.

For projects that use building information modelling (BIM) tools, plug-ins allow live assessment of design changes on upfront carbon results. BIM can also be used to create 'digital twins' of buildings that provide a repository or bank of materials data, including material specification and emissions content.

Multiple data sources exist, and they can be divided into process-based LCA, top-down LCA, or hybrid LCA.

Process-based (LCA) evaluates products by analysing all aspects of the manufacturing, as far as practicable – it is specific, and targeted, but can have data limitations. Top-down LCA estimates impacts by allocating the total environmental burden of a product class (e.g. concrete) – it is comprehensive, but conservative and broad. Hybrid LCA combines both to give more targeted information, but still delivers generic information (e.g. specific concrete grades).

There are many databases where you can find this information[5]. When doing calculations, it is important to use aligned data sources to ensure comparability between results.

Measuring reductions in upfront carbon

The two accepted methods to calculate upfront carbon are:

- Comparison against a Fixed Benchmark
- Comparison against a Reference Project

The fixed benchmark approach uses a direct comparison of a Proposed Project's upfront carbon rate against a benchmark relevant to the building's scale and function.

Under the Reference Project method, two upfront carbon calculations are compared; a Reference Project and a Proposed Project. The Proposed Project represents the current building design while the Reference Project is a hypothetical project that is similar in shape, scale, function and location but based on standard construction practices without attention to upfront carbon reduction.

GBCA, with assistance from NABERS, has released a guide for calculating upfront carbon emissions reductions against a reference building. This guide:

- Outlines the scope of inclusions and exclusions in an upfront carbon calculation
- Provides options for reducing upfront carbon emissions
- Defines default Reference Project's materials

Although there is no industry-agreed fixed benchmark available in Australia – only a potential range of emissions as noted on the previous page -- the NABERS Embodied Emissions project is expected to provide them. Until then, the interim guide provides the best guidance available for Australia for comparing reductions against a Reference Project.

The typical sources of information are:

Process	**Product specific EPD**	A verified and standardised document, compliant with ISO14025, that provides transparent information on a product's lifecycle carbon footprint, water consumption, energy use, and other relevant impacts. Appendix C provides more information.
Process	**Industry specific EPD**	As above, but for a class of products from multiple manufacturers. It should be noted that this EPD only applies to the products and participants listed within. Because it is for multiple manufacturers, it reflects an average, so some products may have higher emissions.
Top-down	**Generic material data**	Delivered from process-based or hybrid-LCA studies, this dataset provides generic information on products such as generic concrete mixes. Australia's EPIC Database is an example of one.
Top-down	**Literature data**	Derived from information from top-down LCA studies, this provides information on the product class, which might be useful when the product selection is unknown.

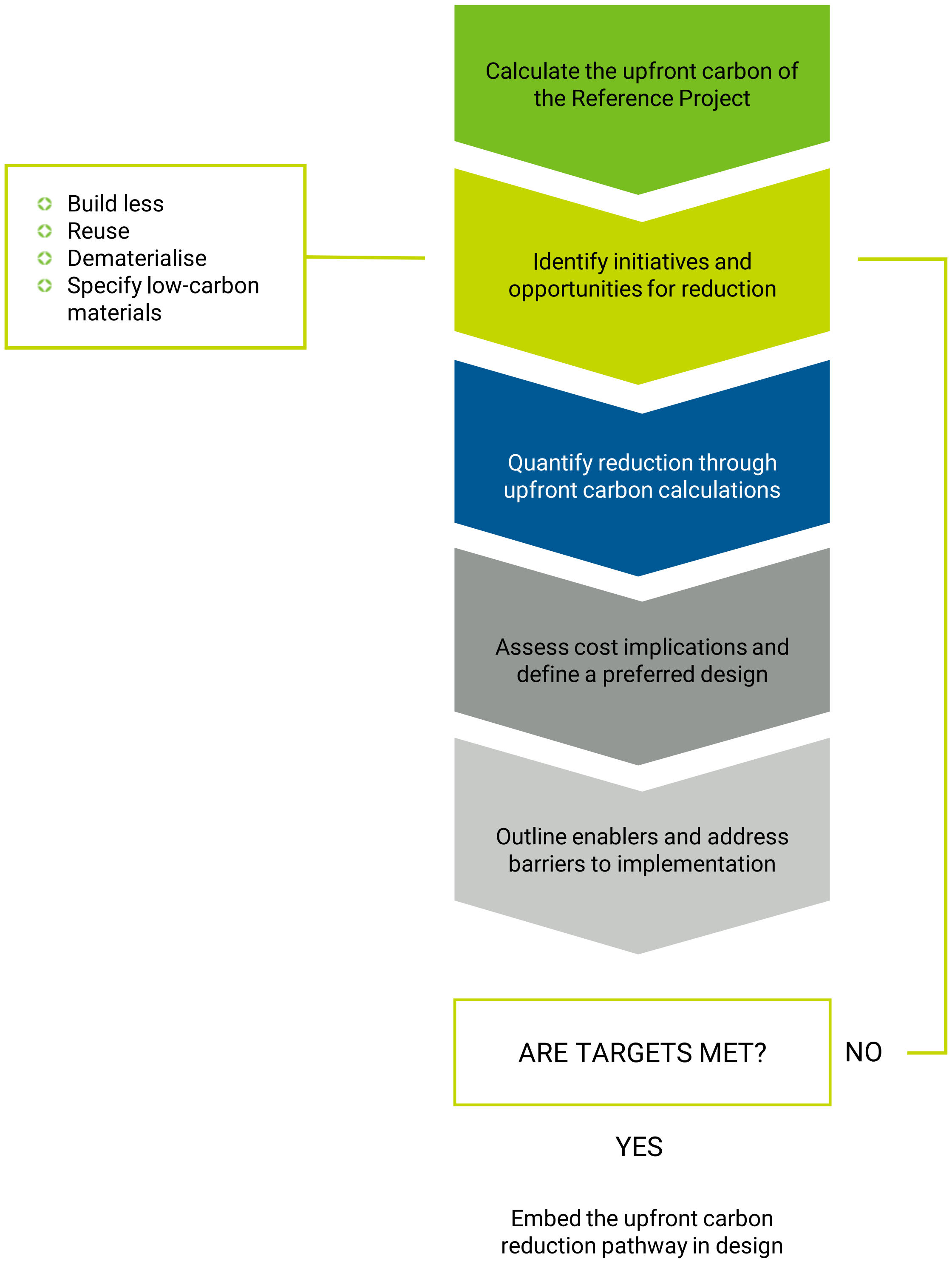
Reducing carbon at each stage of the process

Addressing upfront carbon emissions from the earliest stages of a project allows for the implementation of effective strategies that reduce the overall environmental impact. Calculating upfront carbon is something that should be done multiple times during the development of the project. Doing so allows progress to be compared against targets.

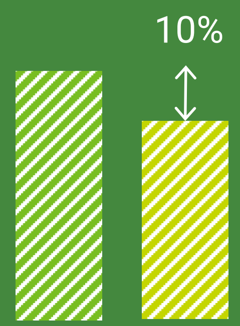
Stage	Potential reduction	Calculation certainty	Options available	Things to consider	Data used
Feasibility & Brief	100%	Lowest	Re-use an existing building, or maximise the reuse of existing building components, with a focus on retaining structure and envelopes. For new buildings, adopt low-carbon design approaches in material selection and design options.	Identify components with the highest carbon contribution, likely in the substructure, superstructure and envelope and major services. Answer the key question: How much new space is needed?	Calculations are likely to use more generic material data, as specific materials will not be selected yet. Future calculations can be compared against this stage, but be careful that the emissions reductions aren't occurring due to changing data sources.
Design			Optimise the shape and design of the building, reduce the quantity of materials, and increase modularity and future adaptability.	This stage offers an opportunity to reduce complexity in the design and save carbon. Consider the shape and volume of the new building, and specify low carbon materials.	As the design is refined, calculations should be updated regularly to reflect changes.
Tender			Look for opportunities to reduce the carbon in the structure and envelope. Seek innovative solutions in the tender with a focus on low-carbon materials. Ask specifically for the tender response to calculate carbon alongside the price. Collaborate with suppliers and contractors to further reduce the project's carbon footprint throughout the supply chain.	Set out clear guidelines for contractors to respond to in the calculations, as depending on how the calculate, they may get a lower result without providing a benefit. There are still opportunities to reduce carbon in materials, future construction practices, and options for suppliers and contractors to offer innovative solutions.	The calculations should require product-specific EPDs where known, with industry-wide EPDs or robust general databases to supplement them. Where possible this information should be included within the BIM model for the project.
Construction			The implementation of efficient construction practices, such as just-in-time delivery, use of low-carbon construction equipment and renewable fuels, contributes to lowering the project's carbon emissions. This is also a key time to ensure transport and construction process emissions are monitored and reduced. The construction stage offers the opportunity to reduce fossil fuel use on-site.	With targets set, continue reviewing during construction. As suppliers are selected and product-specific EPDs are sourced (where available), update the calculation. This process should be repeated when any changes occur to monitor and confirm alignment with reduction targets.	There should be bills of quantities for all materials at this stage and a robust upfront carbon calculation that should be able to be confirmed against targets. The BIM model should continue to be updated.
Handover	0%	Highest	Whilst handover marks the end of the project, strategies such as design for disassembly or reuse will help reduce the upfront carbon of future refurbishment or maintenance projects.	The builder should collect all final quantities and EPD information and make them available for final documentation.	At this point, a final calculation is done, and reviewed against targets.

Developing upfront carbon targets

The first step is for you to set out your targets. This is an iterative process, and the earlier you start, the higher the potential for reductions.

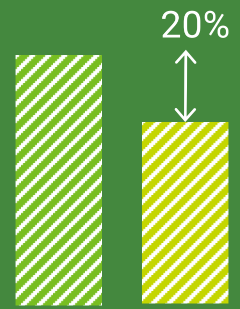


What reduction targets should you aim for?



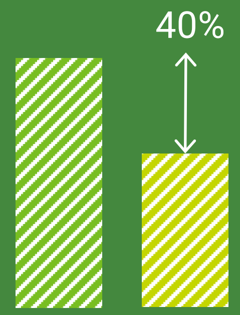
A 10% reduction is generally achievable with the use of low carbon materials and is minimal to cost neutral.

This level of reduction is the minimum reduction that must be achieved be all projects targeting Green Star Buildings certification[27].



A 20% reduction will require most than just substituting materials for a low carbon option. More collaboration is needed between stakeholders to dematerialise the building through design optimisation and the reuse of existing buildings will be needed.

From 2026 onwards, all buildings that target Green Star Buildings will be required to reach this reduction target.



A 40% reduction is ambitious but achievable. Building on the above, this reduction can be achieved by reusing existing buildings or by using reused components or low carbon materials are part of all new building elements.

By 2030, all Green Star buildings should demonstrate this reduction, making high upfront carbon reductions standard practice in the built environment.

Legend

Standard building | **Proposed**

Getting to zero upfront carbon today

Decarbonising the built environment requires reducing upfront carbon and compensating for any remaining emissions.

Reduce as far as practicable, then compensate

According to the Intergovernmental Panel on Climate Change (IPCC), limiting global warming to 1.5°C requires rapid and far-reaching reductions in emissions, while at the same time, noting the importance of addressing remaining emissions through carbon-removal activities[28].

The Science Based Targets Initiative (SBTi) emphasizes the reduction aspect as well prior to compensation activities. The Corporate Net-Zero Standard[29] emphasises that companies must prioritise reducing emissions within their own operations and value chains. Offsetting and compensation activities, such as carbon offsets and biogenic carbon, can be used to address residual emissions, but these must be separated from reduction efforts.

At this point, it is not likely that a building can reduce its upfront carbon emissions to zero without compensation activities like biogenic carbon and carbon offsets.

The role of biogenic carbon and offsetting

Biogenic carbon refers to the carbon absorbed and released by living organisms, such as trees. For products like timber, this carbon can be considered stored on site, in the building. Carbon offsetting is a method of compensating for emissions by funding projects that remove emissions from the atmosphere [A].

Biogenic carbon and carbon offsets are related in that they both contribute to the overall balance of carbon in the atmosphere. They can be considered a form of compensation for upfront emissions.

Keeping track of your emissions

According to the Royal Institution of Chartered Surveyors (RICS) Whole of Life Carbon Standard[30], it is best practice to keep reduction calculations separate from compensation calculations. This approach ensures that efforts to reduce emissions are not conflated – while the carbon balance account is maintained, both actions serve distinct purposes.

Both reduction and compensation strategies are essential in addressing upfront carbon emissions in buildings. While reduction is the primary objective, compensation through biogenic carbon and carbon offsets plays a vital role in taking responsibility for remaining emissions. It is crucial to keep these strategies separate in order to accurately track progress and maintain transparency.

A. Carbon offsets for abatement activities are not advised; instead, it is recommended to use high-quality carbon removal offsets, with a preference for nature-based solutions. GBCA published guidance on why nature-based offsets, and the Property Council of Australia further released an assurance framework to guarantee the delivery of high-quality offsets.

Roles in the project lifecycle

The below stakeholders have important roles to play in reducing upfront carbon through the lifecycle of a project. The graphic on the next page outlines these roles in more detail.

Investors – Invest in buildings with improved lifespans through refurbishment and reuse, and that deliver credible reductions in upfront carbon.

Developers – Increase utilisation of existing buildings through refurbishment and reuse, avoiding demolition. Rethink the size and shape of new buildings. Promote the use of different materials.

Authorities – Require all developments subject to planning approval to measure and report upfront carbon. Adopt recognised performance standards to set reduction targets. Ensure standard specifications feature low carbon options.

Professional Services – Help define the brief to deliver upfront carbon reductions. Work collaboratively to design and specify low upfront carbon buildings. Advocate for net zero buildings.

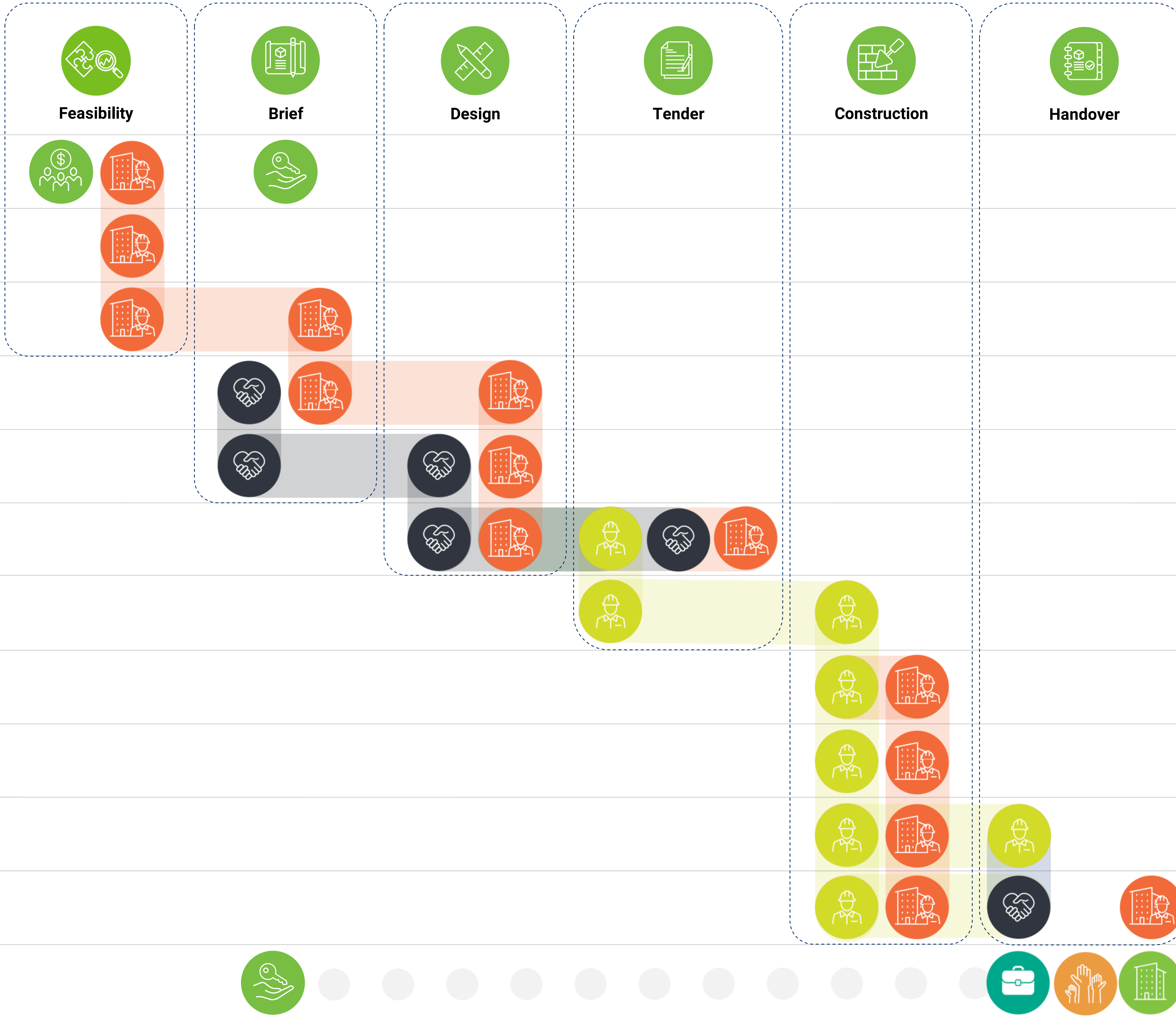
Builders & Trades – Facilitate supply chain transformation in collaboration with trades. Track and report upfront carbon. Have an action plan to reduce upfront carbon.

Leasing Agents – Advocate for low upfront carbon buildings with the developer, prospective tenants and occupants, and purchasers. Demonstrate benefits.

Tenants & Occupants – Choose to lease or occupy refurbished and reused buildings, and buildings that demonstrate a credible reduction in upfront carbon.

Owners – Promote benefits of low upfront carbon buildings and seek to own buildings that have been refurbished and reused, and are low upfront carbon buildings.

The lifecycle of the project in one page



Prevent	Set a vision for upfront carbon reduction for your organisation
Prevent	Introduce upfront carbon targets into your site feasibility studies
Prevent	Where possible, select sites with suitable ground conditions that require no/minimal demolition or can reuse existing buildings, avoiding new construction
Reduce & Optimise	Develop a brief with clear targets and expectations for your development and site
Reduce & Optimise	Develop design options against targets, and quantify potential further reductions
Reduce & Optimise	Select a preferred option seeking further analysis to look for more reductions
Reduce & Optimise	Optimise further by streamlining components and using low carbon materials
Deliver	Deliver a plan for lean construction and deconstruction, rules for substitutions and waste reduction
Deliver	Electrify site construction vehicles and offices. Utilise Heavy Duty EVs for transport of products and materials to site
Deliver	Record materials, transportation, on-site energy, water, waste, and collect EPDs
Deliver	Complete the construction stage calculations to confirm performance
Encourage	Require low upfront carbon buildings and fitouts in your leasing practices

Feasibility

Feasibility is critical as the decisions and targets related to upfront carbon are decided here.

Stakeholders

Questions

- Can the project be avoided?
- Can the project reuse any or all of an existing building?
- What are the project's targets for upfront carbon reduction?
- What can be done to get there?

Opportunities

- Eliminate the need for development
- Prefer sites with buildings that can be reused to avoid demolition and new construction
- Avoid sites with complex ground conditions

Deliverables

- A Vision Statement for the project, highlighting ambitions including upfront carbon
- A performance brief with measurable upfront carbon reduction targets for the project
- Identification of options to retain or reuse existing assets
- Feasibility recommendations with measurable upfront carbon reduction targets (against a Reference Project or similar), recommendations for reuse (where possible)
- Ambition for a performance based brief to enable substitutions for products or materials that have the same outcomes
- Communication strategy to ensure these ambitions are shared throughout the project lifecycle
- Budget for the inclusion of low embodied carbon materials and products
- Identity innovation opportunities

Before the next stage you should:

- Complete a 'hot spot' upfront carbon analysis for the design brief. This will assist in identifying where initiatives will realise the most valuable reductions in upfront carbon and underpin preparation of an upfront carbon reduction pathway.

Brief

A finalised brief sets the objectives for the project's deliverables and clarifies the roles of the project team. This is a vital for setting clear goals through to construction.

Stakeholders

Questions

- How to ensure practices to reuse building elements?
- How to identify further opportunities through the lifecycle?
- How does the team manage change as more details become clear through the project?

Opportunities

- Challenge the brief: are there any further opportunities for reducing carbon?
- Does the brief encourage innovation? Invite recommendations for practices or technology from the team's experience.

Deliverables

- A design brief with a whole of building, measurable upfront carbon target that includes:
  - The boundary or scope of the target
  - What is included and what is excluded
  - The data and/or methodology used to establish the target
  - A description of the main assumptions used to establish the Reference Project
- Schedule of pre-approved materials, products, and assemblies
- Budget for processes, products and materials
- Where demolition can't be avoided, develop a circular deconstruction strategy that identifies options for material recovery and reuse in the project or for use off site.

Before the next stage you should:

- Complete a whole building life cycle assessment.

Comparing strategies to reduce and compensate upfront carbon emissions

From retaining an asset to building a new one, the opportunities to reduce upfront carbon emissions vary based on your chosen strategy. To the right is an indicative comparison available per strategy chosen. In all cases, specific site conditions will vary, and consultant advice should be sought.

In general, the best strategies for eliminating or reducing upfront carbon emissions will prefer the retention or reuse of existing assets. Reusing a building instead of demolishing and replacing it offers the maximum guaranteed emissions savings. Refurbishment is also typically quicker than new construction so there are financial savings from this strategy as well.

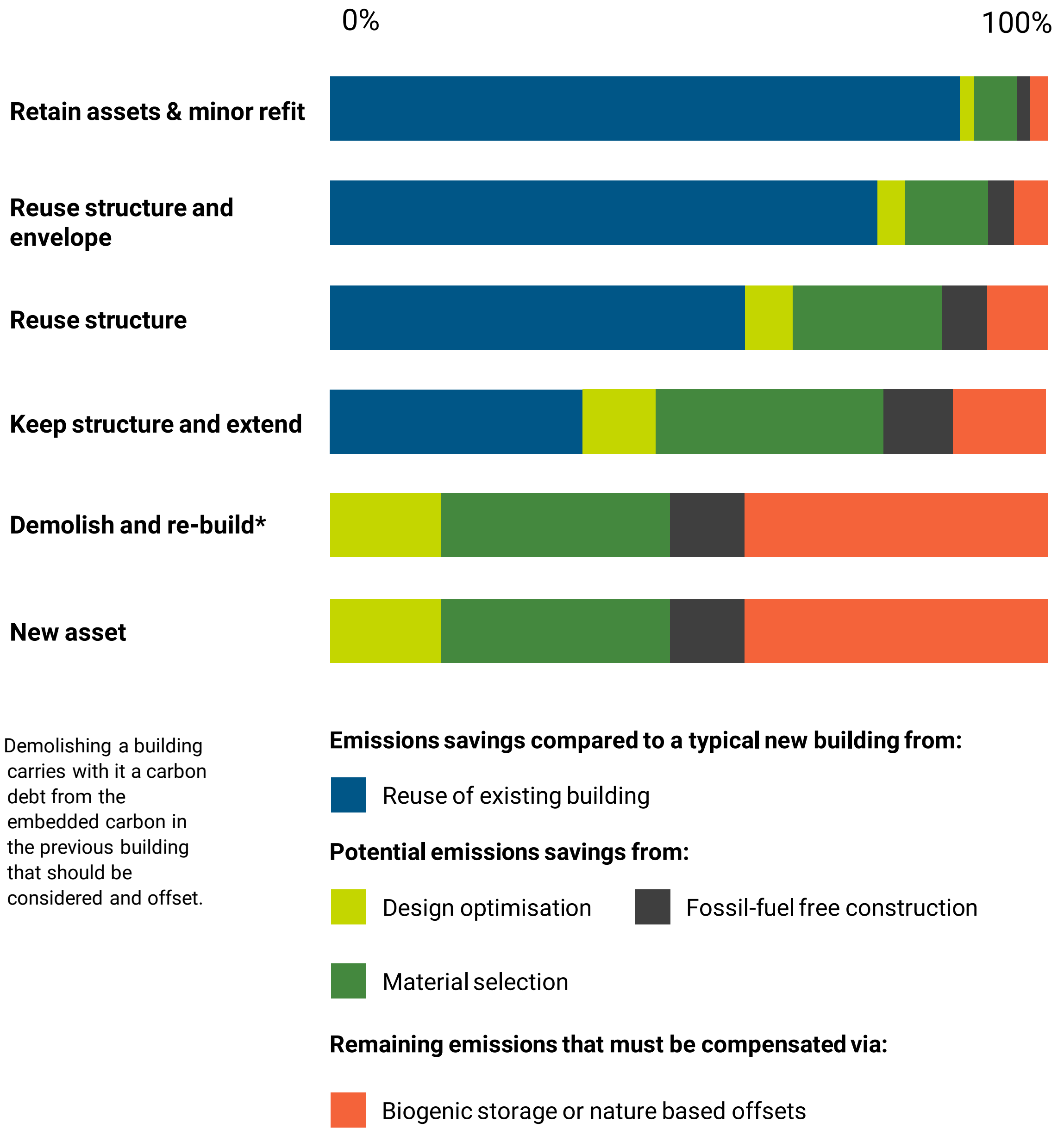
For new buildings, and all other options, design optimisation strategies and material selection will yield a 40% to 75% reduction of whatever remaining carbon exists (depending which building components are reused or refurbished). The remaining emissions will need to be compensated. As yet, it is not possible to have a new zero upfront emissions building.

Rewarding reuse strategies in Green Star Buildings

Green Star Buildings was redesigned to better reward reusing buildings, reused building components, and reused products, particularly when the building is fully electric and powered by renewables.

For example, assets where the structure and envelope are retained, and where they are refurbished to be all-electric can achieve enough points to get to a 5-star rating, provided they meet the other minimum expectations.

Potential impact of upfront carbon emissions strategies



* Demolishing a building carries with it a carbon debt from the embedded carbon in the previous building that should be considered and offset.

Concept Design

The early design stage allows assumptions to be tested and options to be worked through. The preferred concept will be one that meets the brief requirements and upfront carbon targets the best.

Stakeholders

Questions

Rationalise the design:

- Where in the build are opportunities for dematerialisation?

Optimise the design:

- How can we integrate reused or standardised elements?
- How can low carbon design initiatives be integrated into the concept?
- What are opportunities to design for disassembly?

Opportunities

- Integrate existing buildings / elements into the design
- Align load bearing structural elements
- Reduce and/or even eliminate transfer structures
- Optimise the structural grid for low carbon materials
- Minimise substructure
- Challenge design margins

Deliverables

- Reference Project
- Alternative design options with measured upfront carbon impacts
- Upfront carbon roadmap
- Design stage upfront carbon calculation

Before the next stage you should:

- Identify if there is a possibility to standardise building elements, and design for disassembly.
- Identify material banks for components which could be reused as part of the deconstruction strategy.

Detailed Design

At this stage, there is a greater amount of information available about the design, enabling more accurate modelling and testing of assumptions from earlier stages.

Stakeholders

Questions

- Where in the build are opportunities for dematerialisation?
- How can we integrate reused or standardised elements?
- What are opportunities to design for disassembly?
- Where are opportunities for low carbon finishes, fittings and furniture?

Opportunities

- Fine tuning of carbon reduction with more finalised information
- Alignment with the project team with targets communicated and monitored
- More detailed understanding of opportunities for innovation within the build
- Focus on material selection and specify low carbon. (See Appendix B)

Deliverables

- Updated carbon reduction pathway
- Confirmed targets are deliverable
- Finalised scheme assessed, with upfront carbon calculated
- Collaborated with consultants and contractors to ensure bill of quantities are accurate and contingency ordering is minimised

Before the next stage you should:

- Finalise bill of quantities including performance specifications and reduced contingencies for materials

Design considerations in reducing a project's upfront carbon

Stage	Initiative	Consideration	Cost impact	Potential upfront carbon reduction
Feasibility	**Retain existing building**	Temporary support and/or structural strengthening may be needed during repair work adding some upfront carbon.	V	+++
Brief	**Reduce number of floors whilst maintaining the building's height**	Fewer floors may result in less material quantity however taller structures can require larger vertical support elements. Larger mullions and wall studs and thicker panels may be needed to cover the larger vertical spans.	$$	++
Concept design	**Reduce structural grid**	Larger amount of columns may impact a floor's spatial flow. Important to optimise columns, beams, and floor sizes to ensure total upfront carbon is lower	$	++
Concept design	**Reconsider basement levels**	Impacts to lettable area may occur as services and amenities may need to be relocated.	$$	++
Detailed design	**Use a braced steel frame rather than a moment frame**	A braced steel frame may impact on views and daylight if not considered in the design.	$	+
Detailed design	**Consider timber for the superstructure. Where timber is used, ensure it carries a certified chain of custody.**	Use of timber may result in reduced floor to ceiling height and/or number of storeys, as well as reduced floor space due to larger columns being needed.	$$	++
Detailed design	**Switch to higher grade strength steel to reduce steel quantity**	Higher strength steel does not always lead to smaller member sizes therefore the total upfront carbon may not be reduced – make sure to optimise.	$$	+
Detailed design	**Switch to lower grade strength concrete to reduce Portland cement**	Larger volumes of concrete may be required with a lower grade mix for structural strength and durability purposes and may result in larger supporting structural elements and higher upfront carbon overall.	$	+
Detailed design	**Increase percentage of Substitute Cementitious Materials in concrete**	The concrete may take longer to cure impacting construction timelines. The concrete colour may be different.	$$	+++
Detailed design	**Increase wall to window ratio to reduce aluminium framing**	If the aluminium has recycled content, smaller glazing panels may yield less upfront carbon. Improved thermal performance and lower operational energy demand. Reduced views and daylight.	$$	+
Detailed design	**Increase recycled content in glazing**	Potential for lower aesthetic quality.	$$	++

Legend

$ (green)	< 5% in savings	+	Low impact
$ (orange)	< 5% in cost	++	Medium impact
$$	5% to 15% in cost	+++	High impact
V	Depends on circumstance		

Tender

The tender, and its return, are the point where all requirements are finalised and communicated prior to being costed for construction

Stakeholders

Questions

DEVELOPER:

- How can we embed the carbon reduction requirements for the project?
- How can we evaluate tenders i.e.. weighting for carbon reduction?

BUILDER:

- Can further reductions be made?
- Are there other materials or processes to assist?
- Can the brief be challenged further?

Opportunities

- At this stage, project teams should challenge the brief for any further opportunities to reduce carbon
- Does the brief encourage innovation? Invite recommendations for practices or technology from the team's experience

Deliverables

- Finalised documentation
- Detailed performance specifications including metrics and obligations for reporting
- Specified carbon metrics for products
- Expand the digital BIM environment to access material banks and map components for reuse
- Allow for seamless iterations with tendering builders to test and evaluate further optimisations
- Builder to develop a Construction Sustainability Report

Before the next stage you should:

- Align project team with the vision for the project
- Set out which metrics will be monitored and tracked, and how

Specifications

Specifications should include language that requires the builder to submit EPDs for all components considered and tracked for upfront carbon reduction. The EPDs should cover, at a minimum, the life cycle product stage, or modules A1-A3. Specifications should also call for the Contractor to submit a bill of quantities (BOQ) that provides products/materials itemised by application and type. The global warming potential (GWP), or carbon content, for each item, based on EPDs, should also be included.

Digital Solutions

Underpinning the specifications, an advanced building information model (BIM) should be provided. To support an effective knowledge transfer to the builder, it should:

- Label all new components and all relevant components that will be reused from an existing asset
- Facilitate BOQ extraction in a range of formats
- Detail GWP targets or ranges for all component types

Tender Evaluations

The tendering builders should understand the established brief requirements, i.e., the functional brief requirements of the project and its upfront carbon reduction target. The specifications should provide room for the builders to innovate but be clearly performance based so that tenderers can make changes to materials or processes if the agreed metrics are met or exceeded. Builders work extensively with the trades and supply chain, are in a unique position to further optimise for upfront carbon reductions. The tender process should be designed to facilitate this interaction and incentivise improvement performance.

Construction

Once on site, it is important to ensure that monitoring and measurement is in place and that any variations to the design are checked with the principal for performance before substitutions are made.

Stakeholders

Questions

- How to track, monitor and report on agreed metrics?
- What is the process for product substitution to ensure targets are met?
- Can I reduce the carbon emissions from all construction activities by switching to renewables or fossil-fuel-free equipment?

Opportunities

- Access material banks for disassembled components for reuse and deposit into these banks with any resources that are surplus to requirements
- Use fossil-fuel free equipment, and renewable energy on-site[26]

Deliverables

- Construction Sustainability Report
- Induction workshop to align key suppliers/contractors with the roles, objectives and targets to reduce upfront carbon.
- Record of materials and transportation
- On-site energy consumption reporting
- EPDs for all relevant products
- Develop a detailed and comprehensive repository of data across the trades and supply chain that offers advanced reduction strategies
- Put forward advanced strategies that significantly improve reductions, and qualify the triple bottom line business case for their adoption
- Access material banks for disassembled components for reuse and deposit into these banks any resources that are surplus to requirements

Builder Responsibilities

At this stage, the builder has the responsibility to deliver on the upfront carbon targets set by the principal. To deliver reductions, the builder must:

- Demonstrate capabilities, experience and strategies related to upfront carbon reporting and reduction and provide input on cost and program.
- Reconcile upfront carbon reduction performance against the upfront carbon roadmap - review and compare BOQs, EPDs, etc.
- Demand detailed environmental information from suppliers as standard to support comparative evaluation and selection, perform due diligence to ensure final products are as ordered or have the same properties, especially in respect to their embodied carbon.
- Procure renewable energy for site offices, and use low-carbon fuels or all electric equipment to reduce upfront carbon during construction activities. Also work with suppliers to reduce emissions from transport (See Appendix B).

Construction Sustainability Report

- The construction sustainability report covers construction to handover. The plan should be used as a measuring and management tool to ensure lean construction, material reuse, and waste reduction management.
- Estimation of the embodied carbon should be on a regular basis in order to understand how design and material selection affect the ultimate outcome. The number and timing of iterations must be agreed upon with the embodied carbon assessor.
- Construction-related upfront carbon reporting for the plan should be in appropriate units (e.g., kgCO_2e) and be reported regularly, with a final summary document provided at handover. Regular reporting is often important for Construction (A5) emissions so consider frequent, or monthly reporting, as needed.
- The construction sustainability report should include the upfront carbon estimates for any temporary works materials, on-site construction emissions, and materials waste. It should promote the integration of temporary works materials into permanent works or demonstrate reuse strategies to extend the life of these materials.

Handover

Once on site, it is important to ensure that monitoring and measurement is in place and that any variations to the design are checked with the principal for performance before substitutions are made.

Stakeholders

Questions

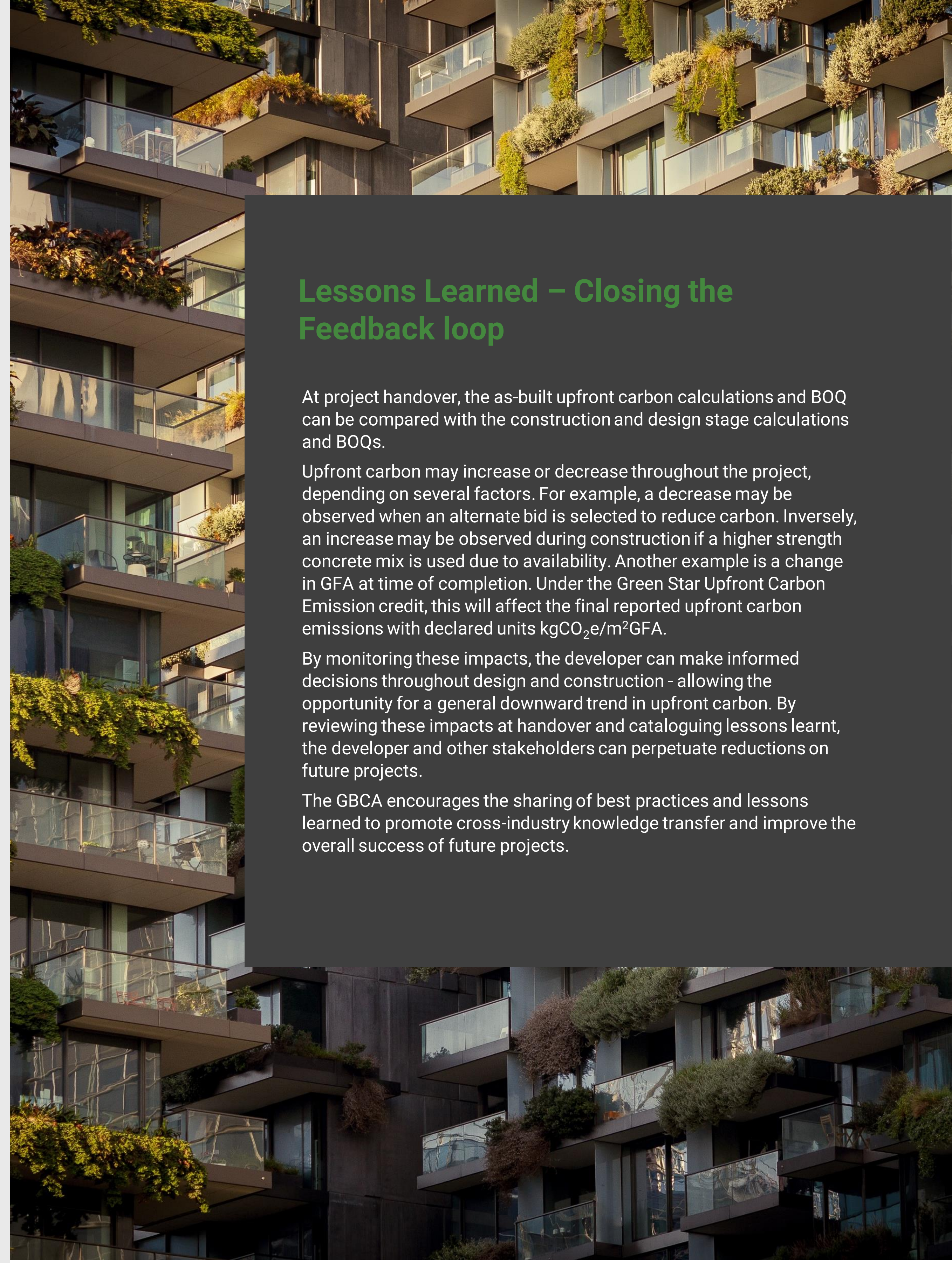
- How to capture outcomes?
- How to improve performance in future?

Opportunities

- Lessons learned
- Set standard upfront carbon reduction targets/benchmarks and identify opportunities for more ambitious reductions
- Demonstrate a strong correlation in design, construction and as-built performance

Deliverables

- Finalised construction carbon plan
- Final As-Built BOQ and compiled EPDs
- As-built upfront carbon calculations
- Building User's Guide and Building Logbook with upfront carbon targets and reduction strategies



Lessons Learned – Closing the Feedback loop

At project handover, the as-built upfront carbon calculations and BOQ can be compared with the construction and design stage calculations and BOQs.

Upfront carbon may increase or decrease throughout the project, depending on several factors. For example, a decrease may be observed when an alternate bid is selected to reduce carbon. Inversely, an increase may be observed during construction if a higher strength concrete mix is used due to availability. Another example is a change in GFA at time of completion. Under the Green Star Upfront Carbon Emission credit, this will affect the final reported upfront carbon emissions with declared units $kgCO_2e/m^2GFA$.

By monitoring these impacts, the developer can make informed decisions throughout design and construction - allowing the opportunity for a general downward trend in upfront carbon. By reviewing these impacts at handover and cataloguing lessons learnt, the developer and other stakeholders can perpetuate reductions on future projects.

The GBCA encourages the sharing of best practices and lessons learned to promote cross-industry knowledge transfer and improve the overall success of future projects.

Case Study: 25 King Street

Building typology
High-rise, multi-storey

Location
Brisbane, QLD

Sector
Commercial

Developer
Lendlease

Builder
Lendlease

Procurement
Design & Construct

Key Influences

Key outcomes

CLT and Glulam structure and finishes

Average 40% Portland cement reduction

At 52 metres tall and 14,965 m^2 of office NLA spread across 10 floors, 25 King Street is Australia's largest commercial office building constructed with Cross Laminated Timber (CLT) and glue laminated timber (Glulam). As part of the $2.9 billion renewal of the Brisbane Showgrounds in Bowen Hills QLD, the project sits within one of Australia's biggest urban renewal initiatives. Now home to its engineering team Aurecon, it holds many sustainability ratings including a 6 star Green Star Design and As-Built rating, NABERS 6 star office energy, 4.5 star water and 3.5 waste ratings and Carbon Neutral certification for base building and a Platinum WELL Shell and Core rating.

The project team wanted a building that would visibly express sustainability and engineering. Since concept stage, upfront carbon emissions and decision to build with timber was established.

25 King Street reduced upfront carbon within Modules A1 –A3 by 38.7% when compared to a reference building

The key upfront carbon reduction design initiatives at 25 King Street included:

- Engineered timber was used in lieu of carbon intensive concrete and steel for structural columns and beams
- Minimalist internal finishes with CLT cladding and flooring with no suspended ceilings systems throughout
- 40% reduction in overall Portland Cement use

A Life Cycle Inventory was established from the building cost plan, preliminary bill of quantities and site construction bill of materials, as well as drawings, specifications, environmental product declarations and the like, using the GaBi Professional + Extension Database. The scope for upfront carbon was Modules A1 to A3.

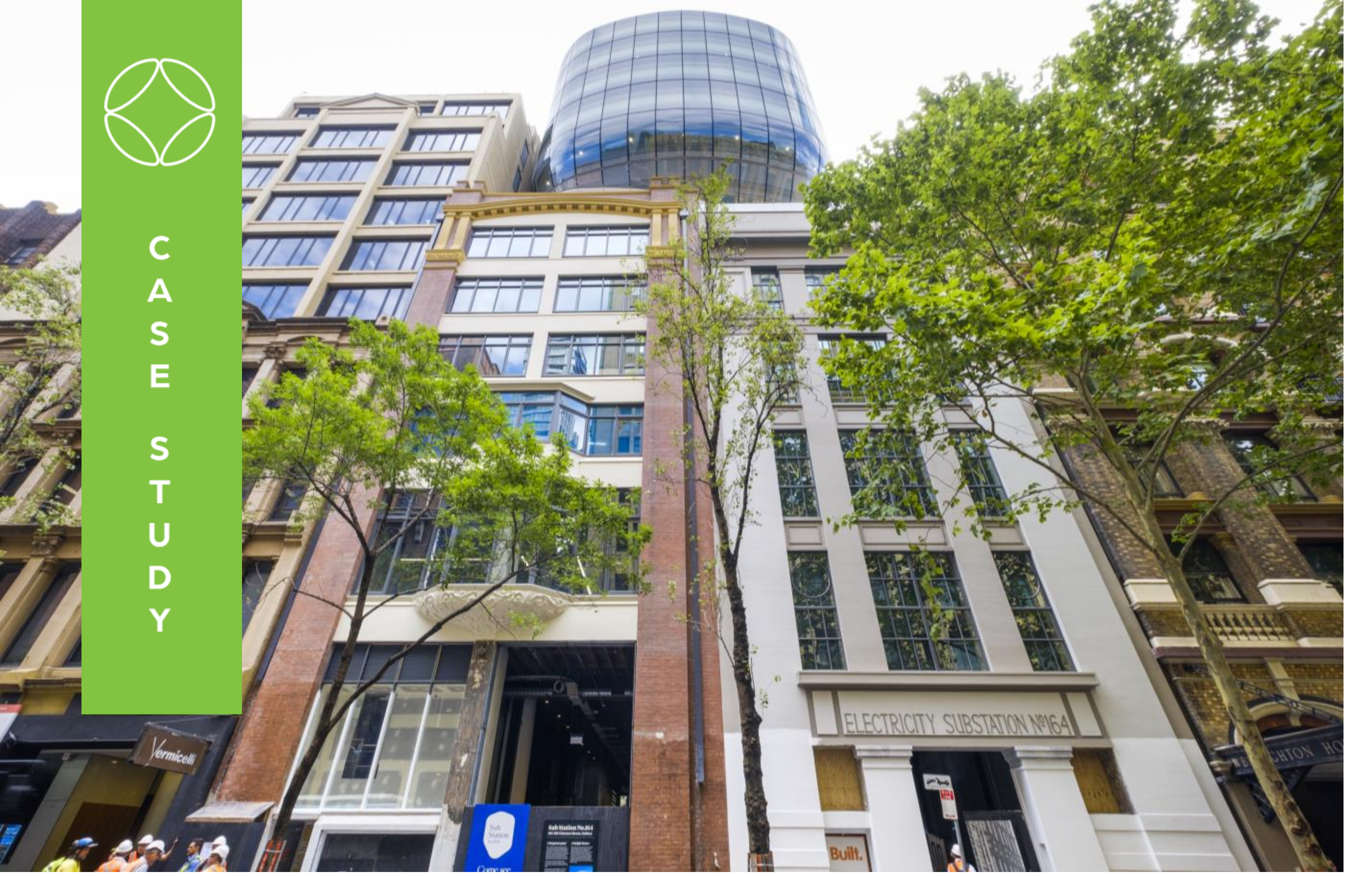
The Reference Project comprised of a standard concrete/steel construction, while the Proposed Project was of a Cross Laminated Timber (CLT) and Glulam structure. The structural design of the two cases is consistent, using a post and beam construction, however the physical quantities of structural materials (concrete and steel compared with CLT and Glulam) vary between the Reference Project and the Design Case. These quantities of structural materials have been determined for both the Reference and Design Cases by engineering and cost planning experts and the bill of quantities. Where data was unavailable, the study uses estimated inputs based on similar projects.

The focus on sustainability within design attracts more and higher quality tenants and lower vacancy risk. 25 King Street offers high-end office space with strong lease covenants. Its tenants, as reported by IIG, have been attracted by 25 King's amenity, innovation and overall quality, including the extensive use of engineered timber to drive environmental performance.

Image credit: Lendlease

> 25 King has set a new benchmark for sustainability, occupant wellbeing and building performance. A low carbon, low waste and highly energy efficient building that also puts health and wellbeing at the heart of its design.
>
> ANN AUSTIN | Head of Sustainability – Australia, Lendlease

CASE STUDY



Case Study: Substation No. 164

Building typology
High-rise, multi-storey

Location
Sydney, NSW

Sector
Commercial

Developer
Built and Nuveen

Builder
Built

Procurement
Early Contractor Involvement/ Design & Construct

Sub Station No.164 featured the adaptive reuse of two heritage buildings, incorporating a striking steel and glass 'bubble' structure which appears to float above. The building offers 7,867 m^2 of A-grade office space.

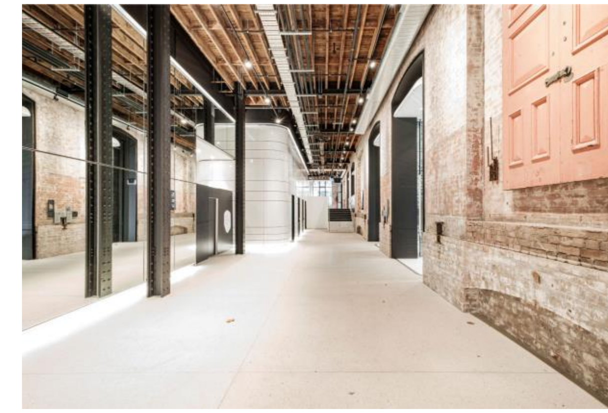
The heritage part of the building was a 110-year-old timber and brick structure had been occupied by the Norman Shelley Spirit Warehouse and a DC Electrical Substation, built in 1909 and 1930 respectively. Built took on the challenge of upgrading and retaining and reusing as much of the buildings' original material as possible. As a result, the project's upfront carbon footprint reduced by 21%.

Many of the original heritage components, such as brick and timber, were retained and incorporated into the final design. Applying the concept of dematerialisation by using the existing building fabric such as exposed concrete, bricks and up-cycling timber flooring reclaimed from the site as key design aesthetics conserved resources by minimising use of virgin materials.

During construction, the site used 100% GreenPower onsite, processes which further improved the carbon outcomes of the project.

Reference Project Definition

A reference case was based on the initial measurement of the project that was developed for a cost plan, and additional measurements taken by the engineers to calculate the materials that would be required if a new structure were built rather than retaining the existing heritage buildings.



> "By retaining as much of the building's heritage as we could, and by using low carbon materials, we created an iconic building, restored a part of Sydney's history, and drove significant upfront carbon savings - a win for everyone."
>
> Brett Mason, Managing Director & CEO, Built

Key Influences

Key Outcomes
Retained structure and materials.
Average 44% Portland cement reduction

The key innovations allowing such a substantial upfront carbon reduction included:

- Substantial retention of the existing brick façades, walls, floors and columns. The reuse of existing timber floors in the warehouse as formwork for the concrete floor slabs required to meet current fire codes, contributed not only to structural efficiency, it also significantly improved upfront carbon efficiency.
- Existing timber flooring removed to make space for the new lift core was retained and repurposed as wall paneling in Built's head office, reinforcing the qualities of the existing heritage building fabric and finding a new use for existing materials.
- An integrated design process between the design team and Built's design managers and structural engineer consultant.
- Structural efficiencies were found that enabled the deletion of a main column and reductions in structural walls – reducing concrete and steel quantities in the build.
- Concrete mixes with an average 44% cement replacement were used.

CASE STUDY

Case Study: Burwood Brickworks

Building typology
Low-rise

Location
Burwood, VIC

Sector
Retail

Developer
Frasers Property

Builder
Hacer Group

Procurement
Design & Construct

The project team improved upfront carbon outcomes through use of lower-strength concrete where feasible, limiting carbon-intensive materials, opting for carbon sequestering materials, reviewing EPDs, incorporating a significant number of salvaged materials, using high-recycled content materials, using structural materials as the final finish, and minimising waste.

In the design phase, the project adopted the mindset of "adaptive reuse and appropriate durability". Given the retail typology, the project team focused on both the potential flexibility and disassembly of the base building, and guided tenants to undertake their fitout designs with regard to material/product selection, and accessible installation approaches to allow easier maintenance and deconstruction.

Additional systems and services were reduced in the first instance through passive design, e.g. maintaining daylight via the layout, and prioritising modular components across standard structural grids. High-traffic components were clearly designated from others and this differential wear and tear was considered in the design.

Clear spans in the supermarket, mall, cinema, and regularly spaced structural elements across the structural grid allow for multiple alternate uses of the interior in the future without costly structural alterations. Generous floor-to-floor heights are to be allowed throughout the mall and the tenancies on both levels, helpful for daylighting, natural ventilation, and adding or upgrading building services.

In total, more than half the construction material budget was for materials manufactured and / or assembled in Victoria. More than two-thirds of the materials budget was spent in Australia.

In the design phase, the project adopted the mindset of "adaptive reuse and appropriate durability"

Key Influences

Key Outcomes
Reduced Portland cement mixes, low carbon materials, recycled and repurposed materials

Flat floors with very few transitions from one floor height to another were ensured throughout, to allow more flexibility when renovating or change of use. Structural layouts across shopfronts allow flexibility across the interior openings, and intertenancy walls can be readily moved without heavily wasteful demolition.

Natural "honest" finishes were prioritised, which helped to avoid superfluous coatings that make items more bespoke and less likely to be salvageable in the future. In turn, these materials can better retain value, making them more feasible for reuse and recycling. In electrical items, plug-in devices were preferred over hardwiring to avoid re-engineering controls and entire systems for small future changes.

Through the construction phase of the project, the contractors had to commit to reducing environmental burdens from the extraction, processing, and disposal of materials. Subcontractors were encouraged to remove excessive packaging from products, where possible, prior to arrival on site.

Over-ordering was utilised as spare product were retained by the subcontractor for use on future projects. In the installation methodology repeatable mechanical (rather than toxic chemical) connections were made, which allows easier maintenance as well as deconstruction, and leaves labelling in place for easier reassembly in the components' next life.

Considering the end-of-life phase, the project team focused on adaptability and deconstruction to allow for multiple alternate uses of the interior in the future designing flexible building services, whilst providing equity of access without costly structural alteration.

Case Study: Quay Quarter Tower

Building typology
High-rise, multi-storey

Location
Sydney, NSW

Sector
Commercial Office

Developer
AMP Capital

Builder
Multiplex

Procurement
Design & Construct

Key Influences

Key outcomes
Reuse of existing structure

The 46-storey, 188m tall AMP Centre was originally designed by Peddle Thorp & Walker and constructed in 1972. It is fronted by the AMP building featuring the American-inspired curved glass curtain wall- "Sydney's front door" providing a landmark entry to the city from the north and from the Harbour. The site is of historical and aesthetic significance as the first "skyscraper" in Sydney.

Due to aging and inefficient mechanical services and leaking façade, the site underwent master planning in 2013 with options to redevelop this building with the agenda of adaptive reuse being key to its success. A key strategy arising from AMP Capital and the design team's feasibility studies was the retention of 65% of the existing structure (existing columns, beams and slabs) and 95% of its original core.

To enable the twisting angular design by 3XN – a series of stacked 'vertical villages' designed around atria – floorplates were extended in different directions to create large open-plan spaces. The façade engineers in conjunction with the architects devised the facade shading strategy which folds and tapers following the sun as it moves from east to west minimising glare to support the twisting aesthetic while enhancing views towards the Opera House and the harbour.

The Life Cycle Assessment conducted by the team demonstrated a saving of over 12,000 tonnes of CO_2e- of upfront carbon emissions from the reuse of concrete alone compared to a Reference Project. The structural carbon footprint of the building was estimated at 247 Kg CO_2/m^2 gross internal area. This is in contrast to 600 - 700 Kg CO_2/m^2 for a new building with full demolition of an existing building.

The new building structure is a bespoke addition to the existing building, with minimum demolition to stitch the extension to double its size. The slab extensions were designed as composite steel frames with a high strength-to-weight ratio to reduce gravity-induced overturning forces, hence reducing the embodied emissions of the new structure.

Structural frames and materials were chosen to efficiently conserve and maximise the reuse of the existing building with minimum retrofit and strengthening.

The Reference Project was defined as a new building with the reused concrete elements assuming new construction with the concrete strength and volume reflecting the existing structure and modern emissions factors.

The focus on upfront carbon provided for a safer planning approval pathway by retaining a substantial part of the existing frame and retaining the over-shadowing footprint in the botanic gardens to build within. Cost benefits also resulted. Apart from the savings on new build material costs, more than 12 months of construction time was saved in avoiding demolition of existing structure and parallel construction of new structure.

CASE STUDY

> To re-use and leverage a 46 year old tower structure to double the size of the original building and save over 12,000 tonnes of embedded carbon, has produced an extraordinary outcome in terms of environmental sustainability, planning and commercial benefit to our investors.
>
> MURRAY MIDDLETON | Head of Development, Real Estate at AMP Capital

What's next?

Upfront carbon is one of the critical challenges of our time. As the market matures, benchmarks are refined, and low carbon materials and processes enter the market, this guide will continue to be updated.

Where can I get more information?

The following organisations are working to drive reductions in upfront carbon emissions in Australia.

- **Green Building Council of Australia** (GBCA), which represents 600+ members, including individual companies with a collective annual turnover of more than $46 billion. The GBCA has defined a Climate Positive Pathway for buildings and collaborates with industry to drive whole life carbon reductions and net zero outcomes through Green Star and the 'Interim upfront carbon modelling guide'.
- **NABERS**, is a national initiative that provides distinct ratings from one to six stars for buildings across energy, water, waste and indoor environment. In 2021, in partnership with GBCA, NABERS announced the development of a benchmark for embodied carbon. NABERS is managed by the NSW Department of Planning, Industry and Environment on behalf of the Federal, State and Territory governments of Australia.
- **World Green Building Council** (WorldGBC), the largest local-regional-global action network accelerating sustainability in the built environment. The WorldGBC offers embodied carbon resources and primers to assist in driving reductions.
- **Australian Institute of Architects** (AIA), established a Climate Action Sustainability Taskforce (CAST),. This taskforce is supporting the architectural profession in taking a decisive and active stance about the twin crises of climate change and biodiversity loss.
- **Clean Energy Finance Corporation** (CEFC), a specialist investor at the centre of efforts to help deliver on Australia's ambitions for a thriving, low emissions future. The CEFC collaborated with GBCA and ISC to release a guide identifying opportunities to reduce upfront carbon in buildings and infrastructure.
- **Climate Active**, Climate Active is program by the Australian Government to drive efforts in measuring, reducing, and offsetting carbon emissions. It recently released a guideline for awarding a climate active rating to new buildings that reduce and compensate all upfront carbon emissions.
- **CRC for Low Carbon Living**, Australia's leading research and innovation hub dedicated to driving the nation's built environment sector towards a globally competitive low carbon future. Offering guides to low carbon commercial buildings – new build and retrofit.
- **Engineers Australia (EA),** collaborating with industry, EA is defining practical solutions and driving innovative engineering to transform systems, technologies and infrastructure.

- **Materials and Embodied Carbon Leadership Alliance,** The Materials & Embodied Carbon Leaders' Alliance (MECLA) is an alliance that brings together the drive to reduce embodied carbon in the building and construction industry, MECLA is determined to transform the building and construction sector to reach Net-Zero emissions.
- **Royal Institution of Chartered Surveyors** (RICS), a professional body based in the UK with standards in the land, property and construction sectors worldwide. RICS has developed the Whole Life Carbon Assessment for the Built Environment 1st Edition (November 2017). It provides a framework for assessing the carbon emissions of a building over its lifecycle.

Information for product manufacturers

Information on product-level emissions can be found in the following. These resources can also help product manufacturers on their journey to understand and disclose their emissions.

- **Australian Life Cycle Assessment Society (ALCAS)**, delivered the Australian National Life Cycle Inventory Database (AusLCI). AusLCI is a national, publicly-accessible database for transparent environmental information on a wide range of Australian products and services over their entire life cycle.
- **Chartered Institution of Building Services Engineers (CIBSE),** has produced TM65 guide, Embodied carbon in building services: A calculation methodology (2021), providing guidance on how to use environmental product declarations (EPDs) to assess the embodied carbon of building services equipment; and where not available, it provides guidance on how to estimate embodied carbon.
- **EC3** is an American free and easy-to-use database of digital, third-party verified Environmental Product Declarations (EPDs). EC3 includes EPDs for Australian and international products. It focuses on the upfront supply chain emissions of construction materials.
- **EPD Australasia** is a regional partner of the International EPD® System with over 1,800 EPDs now published from businesses in 37 countries. EPD Australasia registers and publishes Environmental Product Declarations (EPDs) and Climate Declarations.
- **EPIC Database** is a comprehensive and consistent open-access Life Cycle Inventory of environmental flow coefficients for construction materials. The database contains over 850 coefficients that can be incorporated into existing Life Cycle Assessment workflows and processes. The Database was developed by the University of Melbourne School of Design.

Appendix A: Valuable terminology

Biogenic carbon emissions	Biogenic carbon emissions originate from biological sources such as trees and soil.
Carbon dioxide equivalent	Carbon dioxide equivalent (CO2e) is a unit of measurement that is used to standardise the climate effects of various greenhouse gases.
Carbon footprint	A carbon footprint is the total greenhouse gas (GHG) emissions caused by an individual, event, organisation, service, place or product, expressed as carbon dioxide equivalent (CO2e).
Carbon neutral	Climate neutrality refers to the concept of an individual or organisation achieving a balance between the emissions of greenhouse gases and the absorption of these gases by natural processes, resulting in net zero emissions. This can be achieved by reducing carbon emissions, carbon offsetting, or a combination of both. In Australia, carbon neutrality is defined by the Australian Government through Climate Active.
Carbon sequestration	Capturing and storing carbon dioxide from the atmosphere, for example by establishing forests. The long-term effect of a forest as an ecosystem will make a much larger impact than planting individual trees. GBCA released "Climate Positive Buildings and our Net Zero Ambitions" which provides more information on this topic.
Cradle to cradle	Describes a material or product that is recycled into a new product at the end of its life, so that ultimately there is no waste.
Cradle to gate	Describes a material or product from resource extraction to the factory gate, before it is transported to the next step in the construction process stage.
Cradle to grave	Describes a material or product from raw materials extracted and processing, through each stage of manufacturing, transport, product use, and ultimately, disposal.
Embodied carbon	Emissions associated with building construction, including those from extraction, transport, manufacture and install of materials and products, as well as the use and end-of-life emissions associated.
Environmental product declaration (EPD)	A certified public summary of a product's environmental impact over its life cycle. Based on international standards and independently verified, it is widely recognised by industry and governments.
Environmental, Social and Governance (ESG)	A set of standards for measuring a business' or organisation's sustainability and ethical impact. ESG criteria are increasingly popular as a way for consumers and investors to evaluate companies they want to engage with.
Gate to practice completion	A term used in life cycle assessments to describe a material or product being transported from the factory gate to the construction site and being installed through the building's construction.

Global Warming Potential (GWP)	GWP is used in the life cycle assessment to quantify the climate impact in GHG emissions of materials and products. It is useful in defining performance targets or ranges in CO2e for materials and products.
Global Warming Potential Total (GWPT)	The sum of GWP from fossil fuels (GWPF), biogenic sources (GWPB) and land use and land use change (GWPL) as defined in EN 15804:2012+A2:2019
Green finance	Loans and other financial products and services that encourage industries and organisations to adopt sustainable practices, both environmental and social.
Greenhouse gases	Gases that trap heat in the atmosphere.
ISO (International Organisation for Standardization)	An independent, non-governmental, international organisation that develops standards to ensure quality, safety, and efficiency of products, services, and systems.
Life cycle assessment (LCA)	Measurement method that quantifies the environmental impacts of a product, service, or organisation over its life cycle and value chain. It is a science-based, whole-systems approach to understand and address environmental issues.
Net zero emissions	Reducing direct (scope 1) and indirect emissions (scope 2) of a business or organisation's activities, and its value chain emissions (scope 3) to zero or to a residual level that is consistent with a 1.5°C-aligned pathway (see Paris Agreement). Residual emissions must compensated for.
Paris Agreement	A legally-binding international treaty on climate change adopted by more than 190 countries in 2015. Its goal is to limit global warming to well below 2°C, preferably to 1.5°C, compared to pre-industrial levels.
Emissions scope	Scope 1 emissions are direct emissions that occur from sources that are controlled or owned by an organisation. Scope 2 emissions are indirect emissions associated with buying electricity or thermal energy. Scope 3 includes all other emissions that occur in a company's value chain.
Taskforce for Climate-related Financial Disclosures (TCFD)	An international organisation created in 2015 to develop consistent climate-related financial risk disclosures for use by companies, banks, and investors in providing information to stakeholders.
Triple bottom line	Evaluation of a business, organisation or investment across social, environmental and financial performance. This economic analysis method considers direct and indirect benefits of decisions and investments.
Value chain	A business model that describes the full range of activities needed to create a product or service.

Appendix B: Carbon in materials

The high emitting elements in a building are the superstructure, substructure and envelope, due to the carbon intensive materials used. Figure 2 highlights the main building elements and the common materials that are used. A higher variety of materials are used in services and finishes however both elements have less information readily available.

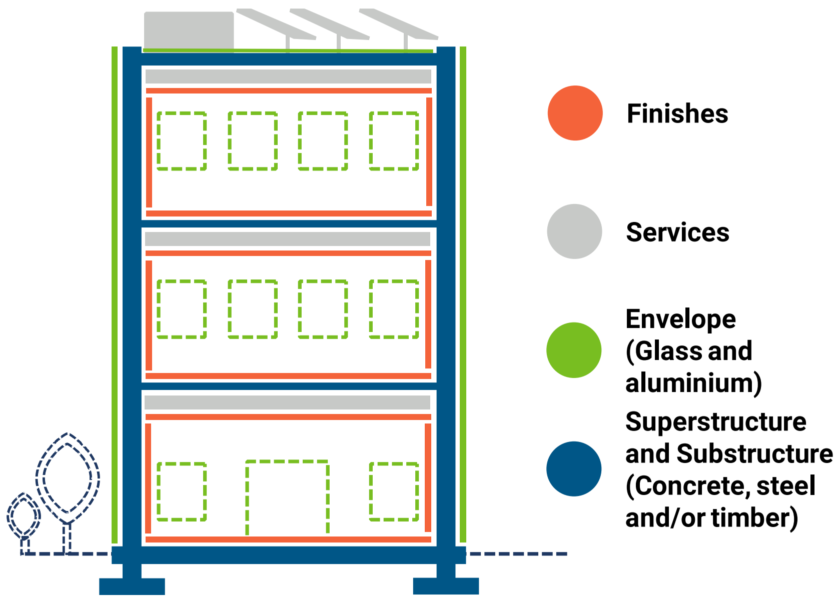


Figure 2: Typical materiality of building elements

STEEL

Traditional Steel is produced in a blast furnace using coke and is a major contributor to upfront carbon. Recycled steel is now often processed within an Electric Arc Furnace (EAF) but this makes up a small percentage of total steel used in the built environment. When specifying steel, consider:

- Sourcing steel from ResponsibleSteel certified sites or at least from ResponsibleSteel members or members of similar schemes.
- Specifying high strength steel – this may enable reductions in the quantity of steel and the project's upfront carbon.
- Focusing on incorporating re-used members.
- Where relevant, specifying steel produced using low carbon emissions-intensive processes or renewable energy.

CONCRETE

Traditional concrete often contains Portland Cement which is the greatest contributor to its carbon emissions. Portland cement can be replaced by supplementary cementitious materials (SCMs):

- Fly ash, a coal combustion product. This is a good alternative however as coal power generation decreases, so will availability.
- Ground granulated blast furnace slag (GGBS or GGBFS) is obtained by quenching molten iron slag (a by-product of iron and steel-making) from a blast furnace in water or steam. GGBFS production is also decreasing as the industry moves towards electric arc furnaces.

How to reduce the upfront carbon in concrete?

1. Define the correct strength and performance – When comparing design options, consider reduced concrete strength. To support Portland Cement reduction, engage with concrete suppliers to evaluate their standard mix options against performance requirements.
2. Specify low carbon concrete – Low carbon concrete mixes are vital to most reduction pathways. All specifications should require the builder to submit EPDs for all components. Specifications should also call for the builder to submit a BOQ that provides the projected concrete volumes, recycled content and GWP itemised by application and type.
3. Reduce and eliminate excess orders on site. This can be achieved through careful measurement of structure (or formwork) to minimise wastage.
4. Deliver the specified grade and no higher. Concrete strengths have diverse applications and costs; using higher strength concrete for low-grade applications compromises material efficiency and raises the carbon intensity of the project.

Action:

- Specify alternative binders and admixture.
- Put demand side pressure on suppliers to capture and sequester emissions from productions.

TIMBER

Timber buildings offer a range of advantages. Not only is it a bio-based carbon sequestering material, but they offer benefits of increased on-site safety and potentially shorter construction time. Building occupants benefit from improved air quality, reduced stress levels due to timber's biophilic attributes, and improved thermal performance.

Unlike most steel or concrete, timber has substantially lower levels of upfront carbon associated with the manufacturing process.

How do you account for the biogenic benefits of timber?

As a bio-based material, timber can remove CO_2 from the atmosphere and store it. This is called carbon sequestration. Engage with LCA practitioners and evaluate related guidance to correctly account for this in your project.

Specifying timber:

- Source timber from sustainably managed forests. The Programme for the Endorsement of Forest Certification (PEFC) and The Forest Stewardship Council (FSC) are both international, non-profit, non-governmental organisations that promote sustainable forest management. While these schemes may prevent illegal timber from being used in a project, it would be prudent for project teams to do their own due diligence.
- Explore opportunities with local structural timber suppliers wherever possible to reduce transportation impacts
- Design for deconstruction to maximise reuse
- Design for transportation to reduce the need for complex structural connections
- Design for efficient grid, loading and dematerialisation

How should you use timber?

- Utilise timber as the primary construction material where possible
- Fully reuse timber products and limit requirement for raw materials where possible
- For low to mid-rise:
  - Grid size – optimise to provide the most efficient span distances and loading distributions
  - Floor type – optimise thickness of the flooring to reduce material use
  - Fire rating and weather proofing – determine whether additional materials are required to ensure the timber structure meets these requirements
- For high-rise: whole mass timber is not been seen as a practical alternative at this stage. Hybrid-timber construction systems that combine timber with different materials (e.g., steel and concrete) and Cross Laminated Timber can deliver a wide range of structural solutions. This should be weighed up with options for deconstruction and reuse or recycling at end of use.

ALUMINIUM

Per kilogram of material, aluminium is a major contributor to upfront carbon. This is primarily due to the large amount of electricity used during the smelting process.

How do you reduce the upfront carbon in aluminium?

Two main types of low carbon aluminium products exist that reduce emissions in the smelting phase:

- Aluminium produced with renewable electricity
- Aluminium produced with a high recycled content (~75%)

Early engagement with suppliers to explore low carbon solutions that exist in their supply chain is key.

Action:

Adopt a circular economy approach to façade systems (where aluminium is most often found in buildings) with refurbishment and reuse, or renting façade modules from suppliers as part of a materials bank.

GLASS

Glass is a heavy carbon contributor for the envelope. Similar to aluminium, it also requires a high input of industrial heat in its manufacture.

How do you reduce upfront carbon in glass?

In the Australian market, low carbon glass options are still emerging. However, European technology is developing solutions for the industry. In the short term, plans to incorporate glass with a 40% recycled content are being pursued. Long term solutions include electrifying manufacturing equipment and switching energy sources to renewable electricity and green hydrogen.

Action:

- Procure glass manufactured using renewable electricity and green hydrogen
- Specify high recycled content
- Adopt a circular economy approach to façade systems with refurbishment and reuse, or renting façade modules from suppliers as part of a materials bank

FINISHES

Finishes make up a smaller portion of upfront carbon; however they are the most often replaced through the building life-cycle and make up a large portion of module B4. Finishes provide a good opportunity for upfront carbon reductions with a wide range of product choices compared with other building elements.

Emissions are likely to be driven by two key aspects:

- Presence of high embodied carbon materials
- Volume of the finishes product (e.g. high volume products such as decorative ceilings and carpets are likely to contribute a greater portion of upfront carbon)

How do you reduce the upfront carbon in finishes?

It is recommended that the following principles are applied:

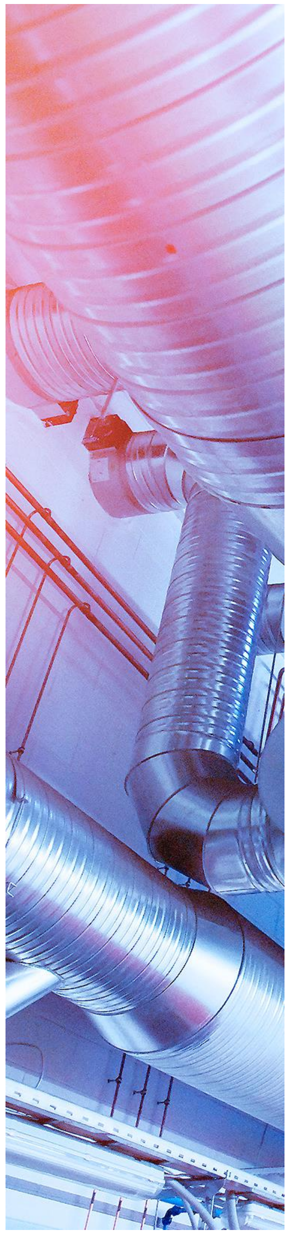
1. Where options exist, use less applied finishes or utilise the raw finish of the envelope or structure
2. Undertake an integrated fitout to minimise waste material
3. Ask suppliers for EPDs to make like for like comparisons between different products
4. Consider the longevity of the finish when specifying
5. Specify products with a high recycled content
6. Identify and preference suppliers that are using renewable energy sources in the manufacture of their products
7. Identify and preference suppliers with product stewardship or take back schemes. This acts to extend the life of products and keeps materials in use at a higher value for a longer time.

Action:

Reduce the use of finishes where possible.

Specify products made by renewable energy and with suppliers that offer product stewardship schemes.

BUILDING SERVICES



Any decision made to reduce upfront carbon needs to ensure that the operational energy performance is not impacted. The diversity of materials in building services, as well as the complexity of its supply chain, means that engagement with suppliers should be early to ensure building services equipment is both operationally efficient and low carbon.

Approximately half of the upfront carbon of mechanical and fire protection services can be attributed to steel. For electrical services, polyvinyl chloride (PVC) (~40%) and aluminium (~30%) make up the main portion. Hydraulic services are dominated by copper and polyethylene (each contributing ~35-40%).

How do you reduce the upfront carbon in building services?

Low carbon alternatives will generally rely on technologies and processes such as electric arc furnace produced steel, and high recycled content in aluminium and PVC. When and where the majority of the emissions occur (e.g., at a steel mill or aluminium smelter) are often not in the direct control of suppliers but sit further back in the supply chain. Because of this, it may be more efficient to signal demand and collaborate with suppliers. These changes will take time, so we need to start this conversation now.

The building services industry is relatively new to the upfront carbon conversation as, historically, building services focused on operational efficiency. However, as more buildings are electrified and the structure of buildings is decarbonised, the upfront carbon of building services will become increasingly important.

Action:

- Compare and specify building services products based on product-specific EPDs
- Preference suppliers that are working within their own supply chain to drive low carbon materials and increase recycled content
- Specify low GWP or natural refrigerant plant and equipment only
- Embed sensors in components that retain as-built data and support resource-rich material banks

Appendix C: Environmental Product Declarations

ENVIRONMENTAL PRODUCT DECLARATIONS

To measure the embodied carbon of a material or product, the standard reporting mechanism is an Environmental Product Declaration (EPD). An EPD is a report that describes a material or product's environmental impact. It is analogous to a nutrition label, reporting a variety of health information. In this case, one of the important tracked "nutrients" is the product's GWP. EPDs are governed by industry-established Product Category Rules (PCRs) that document the reporting requirements and guidelines for a specific material or product type. They are typically updated every five years following a series of ISO standards. EPDs are commissioned by manufacturers or vendors to report their environmental impacts. The most credible EPDs are third-party verified, with a number of organisations providing this service to the industry. For vendors that have not yet created EPDs for their products, several trade organisations have created industry-average EPDs based on the average national data for those materials.

What is the best source of EPDs in Australia?

The GBCA recognises EPDs that are compliant with EN15804, EPD Australasia and the International EPD system.

Types of EPDs	PCR is third-party reviewed?	EPD is third-party reviewed	Specific to a single product from a single supplier?	Standards followed?
Product-Specific Declaration	–	–	✓	• ISO 14044
Product-Specific Type III **PREFERRED**	✓	✓	✓	• ISO 14025 • ISO 14040 • ISO 14044 • ISO 21930 / EN 15804
Industry-Wide	✓	✓	–	• ISO 14025 • ISO 14040 • ISO 14044 • ISO 21930 / EN 15804

How do you compare EPDs?

Currently, EPD comparisons are not straightforward between different materials and products (e.g., concrete to steel to timber) because EPDs for specific materials are governed by different PCRs. While PCRs primarily focus on the product life cycle stage, they each make different assumptions, and in turn make it difficult to compare the data.

EPDs of the same material or product, however, are generally comparable when following the same PCR. It is these "apples-to-apples" conditions that result in the most accurate comparison of carbon emissions.

Overall, while inconsistency and uncertainty exist with EPD data, it is the most accurate information available for measuring carbon emissions of materials and products. This data will be refined and improved over time with industry adoption.

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